Performing drip irrigation by the farmer managed *Seguia* Khrichfa irrigation system, Morocco

Saskia van der Kooij

Thesis committee

Promotors

Prof. Dr C.M.S. de Fraiture
Professor of Water Resources Management
UNESCO-IHE, Institute for Water Education, Delft &
Wageningen University

Prof. Dr M.Z. Zwarteveen
Professor of Water Governance
UNESCO-IHE, Institute for Water Education, Delft &
University of Amsterdam

Co-promotor

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Cirad, Montpellier, France

Other members

Prof. Dr A. Hammani, Institute Agronomique Vétérinaire Hassan II, Rabat, Morocco
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Prof. Dr C.J. Perry, Independent Researcher, United Kingdom
Prof. Dr P. van der Zaag, Unesco IHE, Delft

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Chapter 1

General Introduction

1.1 Introduction

In 2006 I participated in a practical course in Southern Spain where I encountered a beautiful small-scale, farmer managed irrigation system, Yunquera. It belonged to a peaceful and quiet village where old farmers seemed to have all the time to wait for their irrigation turn. While we walked through the irrigation system we saw remnants of the Moorish past: the *acequia* irrigation infrastructure, aqueducts, water mills and a tower – the shadow of which used to indicate when a 'water turn' was finished. While admiring the traditional irrigation system, I heard farmers talk about the modernization of Yunquera: they were planning to install drip irrigation. These plans of the Yunquera water users confused me as the combination of modern drip irrigation with a traditional farmer managed irrigation system seemed a contradiction. In conventional irrigation thinking, drip irrigation - and in particular its capacity to apply precise amounts of water to plants, accurately matching water deliveries to crop water requirements and thereby increasing water use efficiencies - is associated with progress and modernity. Converting a traditional farmer managed irrigation system to drip irrigation would therefore imply an irreversible modification of age-old water infrastructures and management systems in favour of supposedly more rational and efficient methods and technologies. It would, in other words, imply the destruction of a beautiful cultural heritage inscribed in landscapes and people. It was because I cherished this cultural heritage that my impulse was to reject the idea of drip irrigation in Yunquera. I returned to Yunquera in 2008 (for my MSc thesis research) to understand why drip irrigation would be installed in Yunquera. I did not only aim to understand the reasons for installing drip irrigation because of my own discomfort with modernizing this traditional irrigation system but also because the most logical reason for installing drip irrigation – increasing irrigation efficiency - was absent. As no-one had complained about the availability of water, there seemed little justification for installing efficient drip irrigation here.

In retrospect, I had a romanticized view of farmer managed irrigation systems (FMIS) and an engineering biased view of drip irrigation. Approaching FMIS as markers of tradition and drip irrigation as an icon of efficiency and modernity indeed implied that the two would never be able to 'marry', as it places them in different worlds. These categories that I used to make sense of drip irrigation and of FMIS mutually excluded each other: choosing one automatically meant rejecting the other. While I was afraid that drip irrigation would destroy a rural ideal, others (aligning with a modernization discourse) would instead see Yunquera's traditionality as a hindrance to the efficient use of the country's scarce water resources. While I felt attracted to the idyll of the past, many irrigation engineers would instead be attracted by the introduction of drip irrigation which would help bring about a modern, entrepreneurial future based on a more efficient use of water.

1.1.1 Modernization thinking in irrigation

Conventional irrigation thinking favours a future in which water is used ever more rationally and efficiently (van Halsema, 2002; Bolding, 2004; Zwarteveen, 2006). Irrigation modernization thinking has "strong positivist beliefs in technology as a motor of progress" and "perceives development as an evolutionary, linear process of change which takes societies from their pre-modern, primitive, phase through a series of stages towards the final destination of modernity" (Zwarteveen, 2006, p.53). In this line of thinking, drip irrigation is favoured over supposedly more wasteful surface methods of irrigation. Its use will help achieving a desired future: "Use of drip irrigation methods in field crops is inevitable in the near future because of the problem caused by crop patterns and traditional irrigation methods." (Topak et al., 2011 p.80). Indeed, in the epistemic communities of irrigation scholars, the term 'modernization' is used to refer to a conversion from supposedly backward and wasteful surface irrigation methods to supposedly more efficient and rational irrigation technologies and modes of management. The latter for instance include canal lining, automatically controlled water distribution methods, water pricing and drip irrigation. In irrigation thinking, modernization thus refers to the "upgrading" (Burt, 1999, p.15) of irrigation systems, aimed at attaining higher water use efficiencies and water productivities through the improved control of water (van Halsema, 2002). As drip irrigation enables full control over water and thus allows applying precisely the right amount of water to crops at the right moment it represents an icon of the engineering ideal to increase irrigation efficiencies.

1.1.2 Efficient drip irrigation?

Drip irrigation can potentially apply water with application efficiencies of 90 % (Brouwer et al., 1989; Skaggs, 2001 and see textbox 1). Because of its renowned efficiency, international donors and countries actively promote the introduction of drip irrigation. Yet, the efficiency of drip irrigation is not uncontested. Field studies of irrigation scholars in farmers' fields indicate varying results (Wolf et al. 1995; Benouniche et al., 2014) indicating that the technology does not necessarily lead to high efficiencies because practices of farmers importantly determine actual uses and abuses of water. In addition, even when high efficiencies would be attained at field level, this says little or nothing about water savings at basin level – a scale relevant for a country's policies. This is why an ongoing debate amongst irrigation scholars discusses the difficulty of scaling up efficiencies: water 'wasted' by one farmer might be the source of water for another user downstream (Molden, 1997; Perry, 2007; Lankford, 2012b). Yet, almost irrespective of the problematic nature of efficiencies, the promise of water savings and higher efficiencies is what importantly contributes to the popularity of drip irrigation in water policy circles.

Drip Irrigation

Drip irrigation is an irrigation technology that allows farmers to apply precise amounts of water to the root zone of plants via plastic pipelines, tubes and emitters. The water flows under pressure towards the emitters which release water with a low flow rate. The emitters are equipped with pressure-regulating devices, allowing for a uniform water distribution within the network. Because of the possibility to precisely apply water according to crop water requirements, losses through evaporation and deep percolation are minimized. The potential field application

Textbox 1. Drip irrigation

1.1.3 Traditional Farmer Managed Irrigation Schemes (FMIS)

At the face of it, drip irrigation's full control over water, and its ability to precisely apply water to crops according to crop water requirements, contradicts with water distribution logics in many FMIS. Here, rules of water distribution (for example a rotational water distribution) tend to restrict the freedom of an individual irrigator to irrigate at the moment of choice, with amounts and timings of water deliveries being determined by fluctuating supplies rather than by crop demands. Burt and Styles (1998) thus argue: "there is absolutely no point in discussing modern irrigation scheduling … with farmers who receive water on a rotation basis" (Burt and Styles, 1998, p.19) as the farmers cannot access water at any moment, and can thus not irrigate precisely according to crop water demands. In addition, open canal infrastructures and offtake structures often also do not allow for precisely dosing water supplies to a calculated crop water requirement. In the irrigation literature 'modern' drip irrigation in a 'traditional' FMIS is rarely discussed (for an exception, Orteiga Reig, 2015)[1] from which I conclude that I was not the only one that did not associate drip irrigation with FMIS: the 'misfit' is experienced within a wider community of irrigation engineers. Rather than thinking about drip irrigation in FMIS, irrigation engineers focus on converting large scale surface irrigation systems (for example in Spain: Lecina et al., 2010; Diaz et al., 2012) and the farms of agricultural entrepreneurs (Skaggs, 2001) to drip irrigation to achieve progress, rationality and modernity.

Without being mentioned explicitly, FMIS thus appear in the drip irrigation literature as the other side of the modernity-tradition binary. By being contrasted to the narratives of agricultural development and modernization, FMIS implicitly become the inefficient, non-rational, backward, sub-ordinate 'other'. Yet, this rather negative view of FMIS which emerges when contrasted to modernisation discourses does not go undisputed, even within engineering circles. In the 1980s and 90s, inspired by social scientists who had studied FMIS (Geertz, 1972; Hunt et al., 1976; Lansing, 1987) as well as by critiques of so-called 'modern' large scale irrigation systems, FMIS also started figuring in irrigation debates as a possible source of inspiration for different ways of thinking about and designing irrigation systems (Coward and Levine, 1987; Adam and Carter, 1987; Kuper, 2011). Studies of FMIS also provided an important impetus for more policy and scholarly attention to questions of water management and the design of irrigation institutions (Coward, 1980; Ostrom, 1990; Ostrom 1992).
Yet, and hugely oversimplifying these often very nuanced and rich debates, one could say that in general both those who view FMIS as something negative as those who see it as something positive remain with the same overall discourse which places FMIS and drip irrigation in two mutually exclusive representational categories. This explains why the preservation of, or some kind of respect for, FMIS is mostly not seen as compatible with drip irrigation. Drip irrigation is seen as risking to destroy cultural heritage (Sese et al., forthcoming), which is for instance why modernizing FMIS calls for respect to local practices and traditions (Plusquellec and Bachri, 2013).

1.1.4 A possible marriage?

The encounter with drip irrigation in the farmer managed Yunquera irrigation system provided the starting point of my attempts, reflected in this thesis, to search for ways of thinking about and representing drip irrigation and FMIS that

1 In this thesis I specifically refer to pressurized drip irrigation. Low-pressure drip irrigation as a pro-poor technology also exists, often specifically designed for farmers working in groups. In such a case, the drip irrigation technology is adapted to (the prototype of) the poor farmers' context to make drip irrigation and the farming community 'fit'.

allowed combining the two. This is not just a personal idiosyncrasy, but a quest with wider relevance as conventional and dominant representational categorisations are not innocent. In assigning higher value to one side of the binary, they have political effects and matter. Categorisations based on the tradition-modern binary for instance importantly co-determine which farmers and which types of irrigation systems are eligible for which forms of public support. Morocco is a case in point: small-scale farmer managed irrigation systems are not expected to apply for drip irrigation subsidies (Ministère de l'Agriculture du Développement Rural et des Pêches Maritimes, 2007). More broadly, searching for ways to make the 'marriage' of drip irrigation and FMIS possible provides a fruitful entry-point to critically engage with discussions about water use efficiencies.

My consecutive visits to Yunquera in the context of my MSc. thesis research provided important first clues for possible ways to explain the combination of drip irrigation with FMIS. I had come back because I continued to be puzzled about the reasons different actors had for wanting to change from the old *acequia* system to drip irrigation. In the course of the research, I discovered that for water users in Yunquera, drip irrigation's technical capacity to bring precise amounts of water to plants was not the only or most important reason for wanting it. Their desire to introduce drip irrigation in their system had more to do with many other things they hoped drip irrigation would help achieve: making agriculture more attractive to youngsters; creating greater credibility for the WUA board in the eyes of the water users; providing a way to combine a job in the coastal cities with living in the rural area; and so on. I thus learned that drip irrigation is and does many different things. While my engineering education had acquainted me with the text-book drip irrigation - a tool to efficiently bring water to plants - I now learned that it also was a labour-scheduler; a modernizer; and an identity builder. Although I still feared that drip would irretrievably alter and even destroy the old *acequia* system, it also became clear to me that many farmers wanted to have drip irrigation precisely because they hoped it could safeguard a future in irrigated farming for the coming generations. I thus also became sensitive to how the mutually exclusive categories of 'traditional' and 'modern' start blurring in the everyday practices of irrigators, so that the combination of drip irrigation with FMIS becomes possible.

That drip irrigation is and does many more things than producing efficiency also alerted me to how 'efficiency' is not something that it intrinsic to the drip irrigation technology. Instead, efficiency is the outcome of how farmers operate and use the system in interaction with each other and the wider watery environment. In this sense, efficiency is something that has to be actively pursued and produced. Drip irrigation is one potentially helpful tool to do this, but the tool by itself does not guarantee that efficiencies will indeed be realized.

1.2 Problem statement, objectives and research question

This PhD study reflects further attempts to solve the puzzle that I described above: finding ways of thinking about and representing drip irrigation and FMIS that reconcile both with each other. My attempts consist of a combination of more theoretical explorations with empirically grounded research of a case study of a FMIS converting to drip irrigation. I have anchored both of these in contemporary debates about water efficiency, debates that have high political urgency because of heightened awareness of the scarcity of water resources. As a device that can potentially help save water, drip irrigation plays a central role in these debates.

The FMIS I chose to study is located in Morocco, a country where the need for smart solutions to tackle water problems is high. Water demand for agriculture is growing, as new lands are taken into production and farmers shift to more water consuming export-oriented crops. Meanwhile, the dams that feed the irrigation systems are only half full as they are silted with erosion or because of the unpredictable rainfall that does not always fill up the dams to the maximum. The speed at which Moroccan agriculture converts to drip irrigation is high. During a first exploration visit to Morocco in 2011, I met with staff of a large scale irrigation system who told me how they worked together with donors to convert surface irrigation systems to drip irrigation; I also met WUA members of a small-scale irrigation system who dreamed to collectively install drip irrigation; I encountered individual farmers who drilled boreholes on rain fed land where they hoped to plant fruit trees irrigated with drip irrigation. The enthusiasm (both with the public administration and with farmers) for drip irrigation seemed even greater in Morocco than what I had noticed in Spain. Also here, drip irrigation seemed to be multiple, able to do different things. Although promoted by the government for its efficiency and productivity, farmers mentioned many other reasons to explain their enthusiasm for drip irrigation.

I conducted most of my field work in the Seguia Khrichfa, a secondary canal of the farmer managed irrigation system Ain Bittit where some farmers had installed drip irrigation and where the WUA was negotiating plans to collectively convert their surface canal system into a drip irrigation system. I was not the only one who was struck by the apparent anomaly of the enthusiast uptake of, and interest in drip irrigation by water users of the Seguia Khrichfa. Irrigation engineers at the Regional Agricultural Department and at the local extension office told me how surprised they were about the 'very advanced' water users association of the Seguia Khrichfa, and explained how they did not expect a FMIS to convert to drip irrigation. In this PhD thesis, I use this surprise as a starting point and source of inspiration to both re-think what drip irrigation does (the performance of drip irrigation) and my conceptualization of FMIS in an attempt to understand how the two can come together.

Conventional approaches to drip irrigation performance and FMIS make it impossible to understand a conversion of a farmer managed irrigation system to drip irrigation without the FMIS, including its cultural heritage, disappearing in the conversion process. The unlikeliness of the combination is the result of approaching the two (FMIS and drip irrigation) as static, non-evolving objects, with each belonging to an opposing category of the modernity – tradition dualism (and its related binaries: efficient – wasteful; rational – non-rational). My aspiration to find a way to understand the combination of drip irrigation with FMIS feeds into wider ambitions to better include and acknowledge FMIS in agricultural policies on the one hand, and to critically rethink debates about the performance and efficiency of (drip-) irrigation on the other. Hence, I use the puzzle of the drip irrigation - FMIS combination as a source of inspiration to rethink both (drip-) irrigation performance and FMIS, as well as the interactions between the two.

I have identified two main steps for realizing these objectives. I first engage in a reflection on ways of understanding the link between drip irrigation and efficiency: how does the irrigation literature construct this link, and what does this link do? Second, I use my empirical findings from Seguia Khrichfa to re-think how drip irrigation performs in a FMIS, feeding into a re-conceptualization of the performance of drip irrigation and of FMIS.

The research problem and objectives lead to the following main research question:

How does drip irrigation perform?

I have divided this main research question into two sub questions. First, I analyse how drip irrigation performance is conceptualized in irrigation engineering literature. Irrigation engineering literature on drip irrigation uses various notions of efficiency, which I aim to 'unpack': what does efficiency mean, and how is it constructed? This will be addressed with the following sub question:

- *How does drip irrigation perform in academic irrigation engineering literature?*

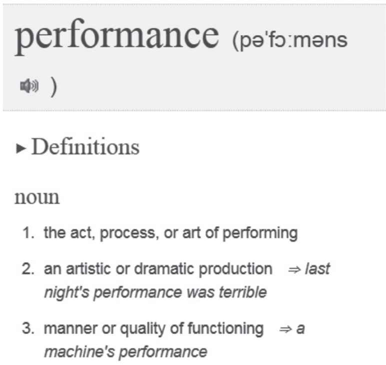
Secondly, I aim to develop alternative approaches to understand the performance of drip irrigation in a way that is meaningful for FMIS. What does drip irrigation do with the FMIS infrastructure, and what does it do for water users engaging with drip irrigation? How does drip irrigation fit in the farming practices and livelihood struggles of water users? The following sub question serves this goal:

- *How does drip irrigation perform in a FMIS?*

1.3 Performance

The questions as formulated above give a key significance to the word 'performance' in my thesis. How to define performance? The Collins dictionary gives seven definitions of performance, of which the first three are: 1) the act, process, or art of performing; 2) an artistic or dramatic production; 3) manner or quality of functioning (Figure 1). In irrigation engineering it is typically the third definition of performance that prevails. The Collins dictionary adds to this definition an example of how the word can be used, and hereby also hints at the third definition being particularly relevant for engineers: "a machine's performance". When studying performance using this definition, a main question becomes how well the machine/technology functions in terms of its pre-defined tasks. Hence, the performance of drip irrigation is usually defined in terms of its efficiency and its uniformity of water application (Burt et al., 1997): drip irrigation is expected to bring about efficiency and uniformity and performance studies measure whether it indeed meets these expectations. Being efficient is thought to be intrinsic to the characteristics of the technology: when used correctly, it will function efficiently.

The first definition in the Collins dictionary: "the act, process, or art of performing" provides a potentially interesting alternative definition of performance. When applied to technology, rather than pre-defining how it should perform, this definition leaves the 'how' questions open. By focussing on the process, this definition of performance is less prescriptive and more descriptive. I also appreciate the second definition, "the art of performing" which hints at creativity, at surprising outcomes. In the following section, I further explain my search for an understanding of performance based on insights from actor network thinking that allows both to understand current performance practices and to develop alternative ways of approaching the performance of drip - one that better acknowledges the multiplicity and contingency of the performance of drip irrigation.


performance (pə'fɔːməns)

▸ Definitions

noun

1. the act, process, or art of performing
2. an artistic or dramatic production ⇒ *last night's performance was terrible*
3. manner or quality of functioning ⇒ *a machine's performance*

Figure 1. screenshot of the online Collins dictionary first three definitions of performance (www.collinsdictionary.com/dictionary/english/performance)

1.3.1 Socio-technical approach to performance

The second and third definitions of performance of the Collins dictionary resonate positively with how actor-network approaches (Callon, 1986; Law, 1992; Akrich et al., 2002) propose conceptualizing technology-society relations. Actor-network thinking pays attention to the mutual shaping and ordering of the material and the social and sees technology as part of socio-technical networks in which objects, people, practices and discourses relate to each other and form each other. Actor network theory treats "…everything in the social and natural worlds as a continuously generated effect of the webs of relations within which they are located." (Law, 2008, p.142). In this approach, the object – in my case drip irrigation – is conceptualized as part of larger socio-technical networks involved in development processes and the modernization of agriculture. Instead of focusing on what drip irrigation should achieve, or on how it should perform, the approach sees performance as the process or production of the interactions between drip irrigation and users. Of particular relevance for this study is that actor-network approaches reject binaries (including the modern-tradition or the efficient-wasteful binary) and object to a linear vision of development, in favour of an open, non-deterministic view of what a technology does in practice (Akrich et al., 2002).

Following actor-network thinking, technologies shape and are shaped by social interactions. The reverse is also true: social interactions with water are mediated by technologies. A technology like drip irrigation (and likewise, a concept like irrigation performance) is embedded in societies, carries with it assumptions about the order of social relations, presumes certain knowledge and favours some uses or users over others. The implication is that changing technologies also implies reconfigurations in people-people relations. Performance in this sense focuses on processes of network ordering and on interactions between heterogeneous elements.

The above theoretical considerations lead to the following definition of performance:

> *Performance is the art of ordering the relations and interactions between people and objects. Performance emerges from practice and results in contingent, surprising outcomes. Technologies do not perform alone, and neither do humans. Rather, technologies and humans perform in interaction with each other and their wider environment.*

1.3.2 Understanding performance - the social construction of knowledge

Performance studies themselves, like for example the assessment of drip irrigation efficiency, can also been seen as performances, as being constructed. Actor-network approaches draw attention to the constructedness of knowledge (Latour, 2005). "Knowledge" may be seen as a product or an effect of a *network of heterogeneous materials*" (Law, 1992, p.381); it is generated through specific practices in which humans and materials (measurement devices and experimental plots, for instance) interact. Knowledge generating practices become embodied and more or less 'fixed' in routines, technologies, procedures, formulas, definitions and conceptual languages. This 'fixedness' is what allows knowledge to travel, and indeed what makes something true or real: truths are performed in practices that consist of reproducing the networks through which they come into being. Approaching the efficiency of drip irrigation as performance thus directs the attention to how efficiencies happen in and through specific networks of people and materials, which form part of broader cultures, disciplines and projects.

The efficiency of drip irrigation has become part of a global policy narrative to address the water crises. This itself influences practices of water re-allocation and use in the field. In professional irrigation communities, efficiency is often proposed to be measured in combination with another performance parameter, uniformity. Uniformity did not travel beyond the engineering domain like efficiency did. The 'travelling' of efficiency into wider debates on solving water problems and modernization of agriculture (for example, Postel 2012 in The National Geographic) makes efficiency particularly important to understand.

1.3.3 The complexity of efficiency

An ongoing debate in irrigation journals discusses the multiple ambiguities related to the use of the term 'efficiency' in irrigation management (Lankford, 2013). Irrigation efficiency is a useful concept in the design of (drip) irrigation systems in order to determine the dimensions of irrigation infrastructure (Keller and Keller, 1995) and to gauge which part of the irrigation water is left unused and thus must be drained (Jensen, 2007). Irrigation efficiency is also an important concept in irrigation management since it can determine the amount of water available to farmers at field level. Several scholars in this debate warn against the erroneous use of irrigation efficiency as a performance indicator or a motivation for implementing water-efficient interventions (Keller et al., 1996; Seckler 1996; Molden 1997).

The concept of 'efficiency' does not tell what happens with the previously 'lost' flows (Keller et al., 1996). Previously 'lost' flows like run-off or drainage might well be used elsewhere in the basin (Molle et al., 2004). Efficiency estimations at local levels thus do not relate to efficiencies at basin scale (Perry et al., 2009). Solutions to avoid erroneous conclusions on the basis of irrigation efficiency are to include re-captured flows in the basin (Jensen, 2007; Keller and Keller, 1995) or to avoid using the notion of efficiency altogether (Seckler et al., 2003; Jensen, 2007).

Other critiques on efficiencies relate to the design and operation of irrigation systems. Horst (1998) argues that when irrigation systems are designed to be too efficient, it would not be possible to operate the system properly: some 'losses' should be allowed to create flexibility for operating the irrigation system. Van Vuren et al., (1992) argues that irrigation efficiencies are usually measured over a timespan of a year, which is logical for irrigation systems fed by reservoirs and dams, but for other systems it is better to differentiate efficiencies for specific periods of the cropping season.

An overall conclusion from this debate is that the notion of irrigation efficiency should be used with care. Its use requires a clear explanation of what is in- or excluded from the calculation and for which contexts the efficiency numbers 'count' and for which situations they can be used. Indeed, efficiency is (spatial- and time-)scale and context specific; it is meaningless beyond specified scales and contexts.

1.3.4 Socio-technical approach to efficiency complexity

The conclusion that performances are scale and context specific resonates well with the practice based approach to performance that I adopt in this study. Interestingly, actor network thinking takes as an entry point of study *network ordering processes*. This means that rather than assuming or prescribing pre-defined boundaries (for example, of the water system) in describing and defining realities, actor network approaches propose making the question of how boundaries and scales come into being central to the analysis. In the words of Latour, 1996: "the metaphor of scales… is replaced by a metaphor of connections." (p.5). A focus on process and connections is thus potentially useful to think differently about the much-discussed question of scale in irrigation efficiency discussions, for instance about basin versus plot. Rather than attempting to delineate at which scale drip irrigation is efficient, an actor network approach would unravel the networks of technologies, water and people through which scales come into being or are contested. The question then becomes *how* scales are used by actors or which scales they apply when making assessments about 'water to be saved'. I make use of this approach to analyse how efficiencies have impact within a wider network of connections which might extend beyond the irrigation system boundaries.

1.4 Farmer Managed Irrigation Systems

Next to re-thinking irrigation performance, I also had to re-think my conceptualisation of FMIS to make these seemingly incompatible concepts go together. When I came to the farmer managed Yunquera irrigation system in Spain for the first time during my studies, I unconsciously aligned with a 'small is beautiful' vision of FMIS which is based on a tradition of farmer managed irrigation research that approaches these systems as traditional technological and managerial entities that function well because they have not yet been 'disturbed' by state interventions, capitalism or other external influences. This approach to FMIS was especially vivid from the 1980 onwards and coincided with a growing interest of sociologists and anthropologists in irrigation (Zwarteveen, 2006).

Scholars like Geertz, 1972; Hunt and Hunt, 1974; Lansing, 1987 described the dynamic character of FMIS and their capability to cope with changes. These ethnographies of irrigation systems were meant to understand social structures and dynamics (such as kinship relations), but they also importantly inspired irrigation thinking (Coward and Levine, 1987). Scholars aimed at deriving lessons from FMIS for best (or most efficiently or effectively) manage resources (Ostrom, 1990; Ostrom 1992). In particular, FMIS studies challenged the view that 'traditional' FMIS were wasteful and in need of modernization. Coward and Levine, 1987 for example called for modifying the trend of “forcing a standard efficiency logic of operations, and the accompanying hardware to operationalise that logic, on these farmer-managed systems.” (Coward and Levine, 1987, p.11). By thus underscoring the incompatibility of FMIS and state-initiated engineering logics, Coward and Levine implicitly invoked the same representational categories as discussed in the first paragraph of the introduction: modernity - tradition, with the former associated with “a standard efficiency logic”. Yet, in their formulation they also hint at the existence of other efficiency logics than the modern engineering one, thereby opening the door for the possibility that traditional FMIS perform efficiently.

In irrigation policies similar binaries figure in the categorization of irrigation systems which are often classified according to scale or management type (farmer managed or state-led). These categorisations, and the policies that are based on them implicitly link up with a modernity-tradition binary and often draw on a rather static notion of FMIS. In line with the anthropological studies that admired traditions while showing their continuous changes, literature on institutions in natural resource management stresses the dynamic character of institutions (Mehta et al, 1999; Shah, 2003; Leach et al., 2010; Cleaver, 2012) and show that it is more interesting to study institutions in “more processual and dynamic terms” (Mehta et al., 1999, p13). This can be a productive approach for the question how drip irrigation performs in a FMIS as it potentially allows seeing drip and FMIS as co-constituting each other in mutually beneficial ways. The introduction of drip irrigation can then be considered as part of the many changes that are part of (and crucial to-) the continuation of FMIS; and their way of adapting to changing conditions.

In this thesis I align with these approaches to study (FMIS) institutions as contingent and continuously evolving, with the nature of changes depending on the complex environment they interact with. This resonates well with the theoretical approach to performance outlined above. Such a process-focussed approach, just as socio-technical approaches, also allows avoiding binaries and static representational categories that place FMIS in a box of tradition - waste and drip in that of modernity - efficiency.

1.5 Irrigation in Morocco

1.5.1 Drip irrigation as a solution

In the last decade, a main trend in Moroccan agriculture is a move towards increasing productivities and competitiveness. Currently the Moroccan State stimulates farmers to shift to export-oriented crops as part of the Green Morocco Plan which was initiated in 2008. Not only do farmers increase the productivity on their fields, they also search for ways to increase the size of their cultivable land. Stimulated by various

State subsidy programs, farmers de-stone unproductive rain-fed land to increase their area under production. In parallel to the focus on entrepreneurial farming, the Green Morocco Plan also entails a 'social' component for small-holders with the aim to support rural livelihoods[2].

While agriculture increases productivity through shifts to new crops and agricultural extensions, it also increases the demand for water. Meanwhile, the dams that provide the large-scale irrigation systems of water do not always completely fill up (due to periods of low rainfall and because the lakes behind the dams are silted through erosion). Both in irrigation systems and in the private irrigation sector, farmers install tube-wells which increase the use of groundwater, causing declining groundwater levels (Bekkar et al., 2009). Groundwater levels drop while the demand for water increases. River basin agencies are concerned about declining groundwater levels and negative water balances (El Haouat, 2012). Also the Ministry of Agriculture is concerned about the negative water balances and the lack of water in the dams which hinders agricultural growth (El Meknassi, 2009). Drip irrigation is the solution proposed by the Moroccan government to tackle both challenges: it saves water and increases production levels.

1.5.2 Drip policy in Morocco

The Moroccan government actively stimulates farmers to install drip irrigation by subsidizing the investment costs with 80 to 100%. Farmers owning more than five hectares can apply for a subsidy of 80%, while farmers with less land and farmers in collectives can apply for subsidies of 100%. These subsidies are part of the National Irrigation Water Saving Plan of 2007 which is encapsulated in the Green Morocco Plan since 2008. The aim of the National Irrigation Water Saving Plan is to counterbalance the water deficits that the country faces. According to the plan, stimulating the conversion of 550,000 hectares of surface irrigated land to drip irrigation in the period from 2007 to 2022 would mean water saving of 826 m^3 per year (Belghiti, 2009). The 'saved' water would partly be used to increase agricultural production in large-scale irrigation systems (which do not perform optimally anymore because of limited water availability) and should be used to replenish aquifers and thus counter dropping groundwater levels. The Basin Agencies align with the PNEEI in the efforts to shift to drip irrigation. They do so by organising training on drip irrigation, providing subsidies and starting pilot sites (El Haouat, 2012).

2 this 'dual' system – of stimulating entrepreneurial farming versus rural development - also relies on the same modernity - tradition binary

1.5.3 Drip in the (Moroccan) field

Drip irrigation is used in many forms in Morocco. On large-scale farms entrepreneurs use high-tech drip irrigation to cultivate cash crops, just as stipulated in the Green Morocco Plan. Small-scale farmers, sometimes with less than a hectare, also use drip irrigation on marginalized plots – mostly also producing cash crops. Local fitters can adapt drip systems to fit other crop choices such as fodder or even cereals. Farmers do not always use State subsidies to install drip irrigation: some consider the subsidy procedures as cumbersome, do not have the required papers or cannot afford to pre-finance a drip system conform the subsidy norms and prefer a cheaper installation (Benouniche et al., 2011). Farmers do not only obtain drip irrigation via official engineering companies and installers but also via informal networks which help 'fit' drip irrigation to local circumstances (Benouniche et al., 2014).

Mostly individual farmers with access to groundwater install drip irrigation (Bekkar et al., 2007). Drip irrigation with access to groundwater is easy as it allows the irrigator to use the water when needed. This accessibility of water fits the high irrigation frequency that is needed for the use of drip irrigation. In addition, access to groundwater assures (to a certain extent) availability of water, avoiding that the drip irrigation system would become useless when water sources dry up. Drip irrigation is also used within surface irrigation systems: either within the command area with a private (tube)well, or with a storage basin to store the surface water from the irrigation system.

Farmers install drip irrigation for various reasons. Drip irrigation is labour-efficient, thus requiring less labourers to irrigate and also less labourers are needed for weed control. It also enables the intensification of farming systems. Drip irrigation is often used for extensions of the irrigated farm area as it allows to irrigate slopes or undulating areas.

While drip irrigation is used in a variety of configurations and for a variety of reasons, one type of irrigation system is not expected to convert to drip irrigation: FMIS.

1.5.4 Drip irrigation in FMIS in Morocco

The water saving program in the Green Morocco Plan focuses mainly on large-scale irrigation schemes and private irrigation. In the new water policy, farmer managed, small scale irrigation systems are considered as "traditional" and rigid, as unable to modernize with drip irrigation, as they are "constrained" by traditional water turns (Ministère de l'Agriculture du Développement Rural et des Pêches Maritimes, 2007):

"The expectations [of the conversion to micro irrigation] have been limited to the large scale irrigation and private irrigation only because of their larger tendency to convert to micro irrigation, as the PMH (small scale irrigation systems) are constrained by the traditional water turn." p.33 Ministère de l'Agriculture du Développement Rural et des Pêches Maritimes, 2007

During the (early) colonial period, from 1920 onwards, the State formalized land and water rights of existing FMIS in order to 'liberate' as much water as possible for State-led irrigation projects, individual settlers, or to drinking water projects which had priority over FMIS. The State diverted water used by FMIS to canals from the State, or to canals with State relations. State officials and colonial farmers moved their intakes further upstream; regulated the off-taking discharge of FMIS; used brutal force or technical means such as canal lining to get control over the water resources (Swearingen, 1987).

After independence in 1956 the Moroccan State focused its attention on the development of large-scale irrigation schemes. The farmer managed irrigation systems were classified as *Petite et Moyenne Hydraulique* (PMH), small and medium sized irrigation systems (see textbox 2). If the State intervened in the PMH the projects were "usually scattered, incomplete, and sometimes incoherent" and focussed on the improvement of the main infrastructure (Abdellaoui, 1989, p.167). It was only in the 1980s that the PMH received some attention from the State again (Plusquellec and Bachri, 2013). This happened because the Moroccan government became inspired by the international (academic) debates advancing FMIS as an attractive alternative irrigation development model, following disappointing results in large-scale irrigation schemes. In practical terms, the State's interest in PMH was also attractive as it allowed for developing rural areas without much financial funds or the need for making water available through large dams. Due to droughts, investments in large dams became less attractive as it was not sure that they would be replenished with rainwater. The question Moroccan scholars became interested in was how to intervene in PMH without changing the farmer managed internal functioning (Bouderbala et al, 1984; Pascon, 1984)). However, interventions that followed this debate often focused on technical measures such as improving infrastructure at sources and lining canals.

Moroccan irrigation categorization

The Moroccan ministry of agriculture classifies the irrigated areas in three categories: large scale irrigation; small- and medium scale irrigation and private irrigation.

- Large scale irrigation

Large scale irrigation (Grande Hydraulique) concerns all the irrigation's surfaces with more than 3,000 ha (Abdellaoui, 1989). The development of large-scale irrigation started in the 1930s, but was accelerated after independence. It includes nine large irrigation systems, covering a total surface of 682.600 hectares (Belghiti, 2010). The large scale irrigation systems are all State interventions and are managed by the State via regional offices for agricultural development (Office Régional de Mise en Valeur Agricole, ORMVA). Within the large scale irrigation systems, the price that farmers pay for the irrigation water is defined by the State.

- Small and medium scale irrigation

The category small and medium scale irrigation (Petite et Moyenne Hydraulique, PMH) includes irrigation systems up to 3000 hectares (Abdellaoui, 1989) and are fed by springs, khettaras, norias, or diversions from rivers (Laith, 2009). All PMH are farmer managed. The total irrigated surface of small scale irrigation in Morocco is estimated at 334.130 hectares (Belghiti, 2010).

Small and medium scale irrigation systems managed by official water users organisations can apply for State support. The main difference between small and medium scale irrigation systems and large scale irrigation systems in State-supported projects is thus that in small and medium scale irrigation systems the farmers (nowadays via Water User Associations) initiate new developments, while in the large-scale irrigation systems the State initiates developments.

- Private irrigation

A part from the above mentioned systems, there are many private irrigation systems that are initiated by individual farmers or organized groups of farmers. These irrigation projects can vary in size – from less than a hectare to several hundreds of hectares (Belghiti, 2005). This category mainly includes farmers accessing groundwater with private wells or tube-wells. Private irrigation is encouraged by the State via financially stimulating the development of agricultural enterprises. The total surface irrigated with private irrigation is estimated at 400.000 hectares (Belghiti, 2005).

Textbox 2. Moroccan irrigation categorization

Later, the international interest in FMIS caused questions about participatory irrigation management and irrigation management transfer. Wouldn't it save public expenditures when farmer groups, which worked so well together in FMIS, would participate in the management of large scale, State controlled irrigation systems? The interest in the management of irrigation by farmers resulted in the decision to create Water Users Associations on State initiative (Herzenni, 2002) – in the large scale irrigation systems but also in the PMH. Although most WUAs only existed on paper, they did become obligatory passage points for State support to FMIS. Farmers generally abandoned WUAs after the specific intervention for which the WUA had been initiated (Lecestre-Rollier, 2002; Riaux, 2011). Interestingly, after a dormant phase, irrigators in some cases appropriated and used these same WUAs to make changes in irrigation management or in the rules governing water distribution (Bekkari and Yepez, 2011), indicating that a processual approach to FMIS is useful, also in the Moroccan setting.

1.5.5 Seguia Khrichfa

As stated by the National Water Saving Plan in Irrigation, FMIS are not expected to convert to drip irrigation. Drip irrigation would not 'fit' with their rotational water distribution. In addition, as a representative from the Regional Agricultural Department of Meknes remarked during an interview, the FMIS have water for free, they do not pay for the water (at least not to the State), so why would they want drip irrigation? (El Mars, 2011, 09-04-2012). Several informants whom I met during my exploratory study nevertheless had noted one particular FMIS in the Saiss area (the agricultural area around Fez and Meknes) that, according to them, was 'very advanced' : Seguia Khrichfa (the Khrichfa Canal). In the Khrichfa region, several farmers had installed drip irrigation on an individual basis; a family cooperative installed drip irrigation on a collective basis outside of the command area; and the WUA had made plans to convert the whole canal to drip irrigation. Here, practices, dreams and project development came together: an ideal place to explore how drip irrigation performs. I also chose the Seguia Khrichfa in Ain Bittit for a practical reason: due to the various interventions that have taken place on the canal in the past, project reports were available, which helped to place current developments in a historic perspective.

The Seguia Khrichfa is a secondary canal that belongs to the Ain Bittit irrigation system in the North of Morocco and falls under the category of small and medium irrigation systems. The Bittit irrigation system covers approximately 5,000 hectares and is fed by springs in a karstic system with a relatively stable discharge of ca. 2,500 litres per second. The spring water is currently shared by the drinking water provider of Meknes (ca. 800 litres per second) and the rural communities Ait Ouallal and Ait Ayach (ca. 1,700 litres per second). The irrigation system named Ain Bittit (*ain* means spring in arab) refers to the irrigation system fed with the share of Ait Ouallal (Abdellaoui, 2009). This thesis focuses on the Khrichfa Canal which belongs to the Ait Ouallal community (see figure 2).

The irrigation infrastructure of Ain Bittit is lined, with only some earthen tertiary canals. The canals seem well-maintained and the irrigation community gets regular State support for reparations. The canals have division boxes which makes a proportional water division possible. The division boxes can be opened and closed with so-called 'Tout-Ou-Rien' (T.O.R.) gates. The Khrichfa Canal has a discharge of ca.100 litres per second and a collective tube-well at the head of the irrigation system can provide an additional 40 litres per second to the Khrichfa Canal during the dry summer months when the demand for water is high. The Khrichfa Canal is seven kilometres long and the total area of Khrichfa that can be irrigated in potential is 400 hectares. Yet, only a quarter of the total command area can be irrigated with the available discharge. The total number of right holders to water in Khrichfa was 309 in 2013. As many right holders rent out their water rights to other water users, the actual number of water users is lower than the number of right holders, and is estimated at ca. hundred 'active' water users by the president of the Water Users Association (WUA).

The WUA of Khrichfa is well-functioning, as State officials that deal with Khrichfa confirm. Their board members are active. Especially the president of the WUA board is very actively involved with the management of the irrigation system. He registers water rights (which change often as right holders can rent out and sell their rights); develops the irrigation calendar; instructs the canal operators and chats with members to monitor what is going on in and beyond the irrigation community. Also the other board members are actively working for the management of the irrigation system: lobbying for the collective drip irrigation project; monitoring maintenance work; bookkeeping the finances and the like. In 2011, when I first arrived in Khrichfa, the main dream of the WUA board members was to arrange drip irrigation for Khrichfa. In 2015, when I made a visit to the area, the drip project seemed to have made way for new plans: installing a solar pump on the collective tube-well or building a WUA office.

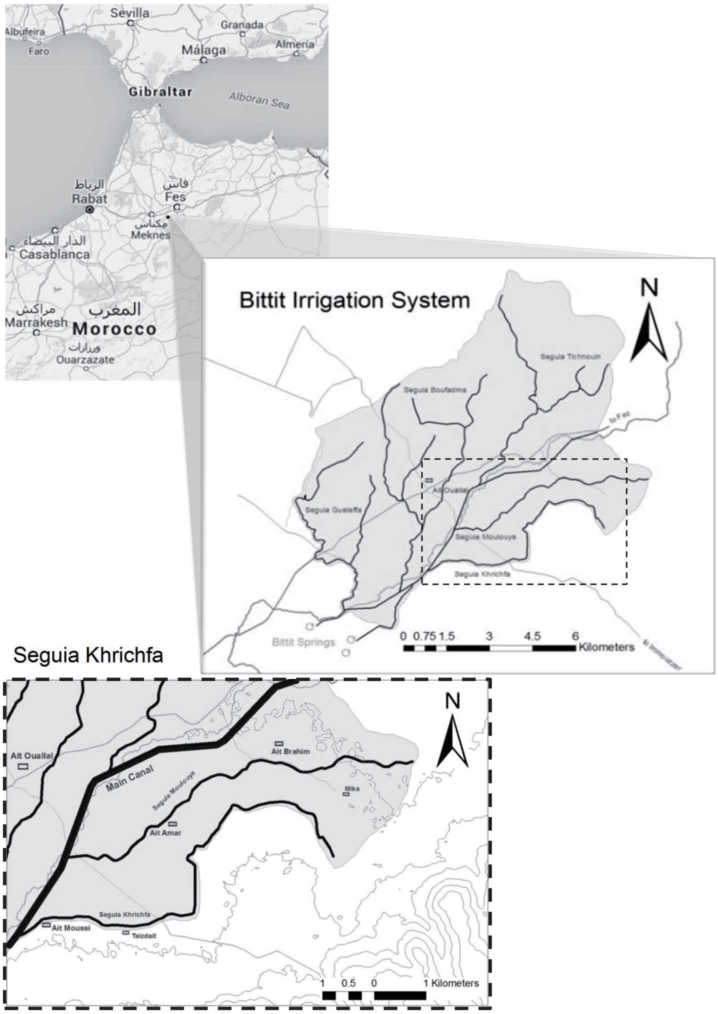


Figure 2. Location of the Seguia Khrichfa (author's elaboration, the map at the upper-left corner is derived from maps.google.com)

1.6 Methodology

Analysing the material and the social on equal terms (Akrich et al., 2002) is an important starting point in this thesis, and works in three ways: in the field, in the analysis, and in the writing. In the field I aimed to understand 'the technical' and 'the social' without on forehand choosing which was most influential. In the analysis I aimed to treat theory and empirical data symmetrically by questioning both, and switching back and forward between the two. Regarding the writing, I aimed to make my work accessible to a broad audience, including engineers and scholars from social sciences.

1.6.1 Three phases of research

The empirical work for this PhD can roughly be divided in three phases. In a first phase (in 2011) I carried out a literature review on drip irrigation and its efficiency. This helped to gain a solid basis for knowing how drip irrigation performs in the engineering literature, and later it helped to see the particularities of drip irrigation in the Khrichfa area. In a second phase (in 2012) I started fieldwork in the Khrichfa area where I first used drip irrigation as the entry-point for interviews and interactions. I visited the drip irrigation projects of Khrichfa water users and farmers in the region, and I discussed the collective drip irrigation project with water users and policy makers. This yielded insights into the motivations people had for installing drip irrigation and revealed all the positive associations that they have with drip. Yet, it was not enough for understanding the relations between irrigators and the rules-in-use that made drip irrigation possible in Khrichfa. In the third phase (in 2013), when the irrigation season started again after a period of inactivity, I returned to Khrichfa and stated explicitly that I came back to understand how the water users' organisation and the rules-in use worked. This created a new entry point that yielded new insights and especially a lot of nuances (also about the technology). However, I am sure that many irrigators in Khrichfa still mainly associate me with drip irrigation, and this will undoubtedly have shaped the interactions that we have had. In this study, I aim to include the reflexivity of my own relation to drip irrigation and how this influenced the interactions I have had with others, and how I came to my conclusions (Coffey, 2002). Parallel to the empirical part of this thesis, I analysed my data by moving back and forwards between theory and the field. This helped to iteratively gain more insights about the performance of drip irrigation.

1.6.2 Methods

Literature review

To understand where efficiency numbers come from, what they mean, and which role they play in international debates, I carried out a literature review of a total of 49 articles which discuss the efficiency of drip irrigation. The articles for this review were selected from the Web of Science database by searching for articles with 'drip irrigation' or a related term ('trickle irrigation' and 'micro irrigation') ànd 'efficiency' or a related term ('productivity' or 'water saving' or 'WUE' or 'IWUE') in the title. I analysed the articles with a qualitative content analysis (Silverman, 2006) for which I used the coding software Atlas.ti to code the used definitions and methods, debates to which the articles related and their description of the technology under study. This literature review formed the basis for understanding drip irrigation performance in scientific literature, and for understanding the constructedness of the efficiency of drip irrigation.

Case study

The case study serves both to understand the use of efficiency in irrigation projects and to explore alternative approaches to drip irrigation performance. I adopted a historical approach (Shah, 2003) which allowed me to see how drip irrigation is part of larger development processes of 'modernizing' Khrichfa through efficiency measures including lining the irrigation infrastructure.

The fieldwork period consisted of semi-structured interviews, observations of irrigation practices and observations of the irrigation management. A typical fieldwork day included some semi-structured interviews with pre-defined informants, tea-drinking, sitting along the irrigation canal while observing water users passing by and making informal chats. However most fieldwork days were a-typical and were equally valuable: invitations to weddings, helping a farmer with a labour intensive job, or taxiing people I met during interviews and who had no transport to places where they needed to be. In other words, I was open for surprises. To keep focussed on my research puzzles I made day-reports of each day, in which I made notes of interviews, observations, meetings, and remaining questions that I could take along to the next day. I triangulated research results with other interviewees, by using mixed methods and by comparing observations with others (Silverman, 1993). I worked with a translator, Rachid, who translated interviews in Darija-French. Besides from being a translator, he also gave feedback on my observations and interpretations and we discussed the working of the irrigation system to understand every detail. I also made field visits with other PhD students to know how others 'see' the field of Khrichfa, and I visited the study sites of them to understand how farmers engage with drip irrigation in other areas – which helped to see the particularity of Khrichfa. This PhD also draws on secondary data obtained from personal archives of some irrigators and the Provincial Department of Agriculture. Unfortunately, due to institutional reforms and migration of departments, many national archives could not be found in public archives.

1.7 Outline of this thesis

Following this introduction chapter I continue with four chapters which are each based on articles. Figure 3 gives a schematic overview of the chapters. In the first two chapters (Chapter 2 and 3) I set out to understand the link between drip irrigation and efficiency: first by understanding how this link is constructed (in other words, 'unpacking' the efficiency of drip) and what this means for drip irrigation in Chapter 2. I then continue with an empirical chapter based on Ain Bittit to understand how efficiencies re-allocate water (Chapter 3). These two chapters together (Chapter 2 and 3) answer the first research sub-question: "*How does drip irrigation perform in academic irrigation engineering literature?*" .

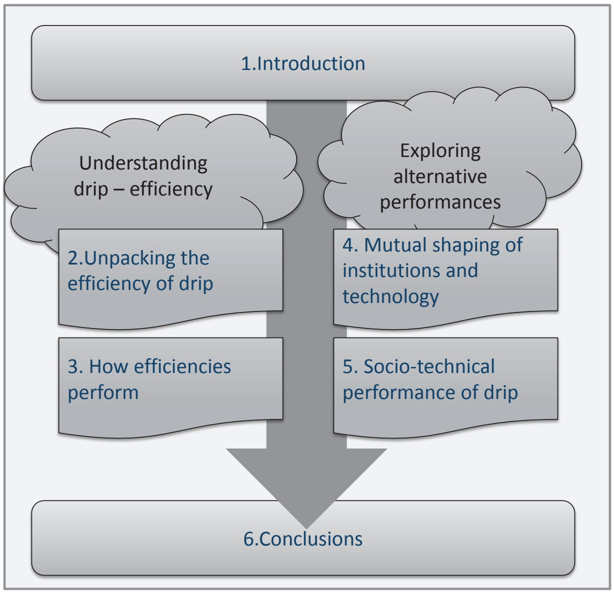


Figure 3. Outline of this thesis

In the second part of this thesis (Chapter 4 and 5) I explore alternative performances of drip irrigation in the farmer managed Seguia Khrichfa. These chapters respond to the second sub-question that I pose in this research: "*How does drip irrigation perform in a FMIS?*". I explore two ways of understanding the performance of drip irrigation in interaction with the Khrichfa FMIS with a socio-technical approach. In Chapter 4 I study the intimate link between material objects and institutions, and how the two mutually shape each other. This chapter shows the 'material' performance of drip irrigation on FMIS institutions. In Chapter 5 I explore more explicitly what a socio-technical approach to drip irrigation performance might look like and focus on the technology-in-use. Chapter 6 is the General Discussion. I answer my research question: *how does drip irrigation perform?* and I end the chapter with a discussion on the implications of this PhD.

Chapter 2

The efficiency of drip irrigation unpacked

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Abstract

Drip irrigation figures prominently in water policy debates as a possible solution to water scarcity problems, based on the assertion that it will improve water use efficiencies. We use this article to carefully trace the scientific basis of this assertion. Through a systematic review of the literature, we show that the term efficiency means different things to different people, and can refer to different elements in the water balance. Most articles claim that drip irrigation is irrigation water use efficient and crop water use efficient, but different studies use different definitions of these terms. In addition, measured efficiency gains not only refer to different capacities of the technology, but are also based on very specific boundary (scale) assumptions. We conclude that efficiency gains from drip irrigation will only be achieved under narrowly defined operational conditions, and just apply to very specific spatial and temporal scales. Hence, and unlike what generalized statements in policy documents and the overall enthusiasm for drip as a water saving tool suggest, expectations of increased water efficiencies associated with drip will only be realized, and are just realizable, in very specific circumstances.

2.1 Introduction

Drip irrigation figures prominently in proposed solutions to the water crisis. In national and international policy documents, it is seen and promoted as a device to use water more efficiently (see for examples: EEA, 2009; CA, 2007; World Bank, 2006). The belief in the water saving potential of drip irrigation is often substantiated with impressive statistics and measurements. Postel (2000) for instance claims that drip irrigation "….has the potential to *at least double crop yield per unit water* in many applications, including irrigation of most vegetables, cotton, sugarcane, and orchard and vineyard crops. A collection of research results from various Indian research institutes indicates *typical water use reductions with drip irrigation of 30-60%* and typical *yield increases of 20-50%* for a variety of crops, including cotton, sugarcane, grapes, tomatoes, and bananas (Indian National Committee, 1994, Sivanappan, 1994). Together, the greater water application efficiency and higher yields produce *a doubling or tripling of water productivity*." (Postel, 2000, p.945, emphasis added). Likewise, in an article in Nature, Gleick 2002 asserts that "Shifting from conventional surface irrigation to drip irrigation in India has increased overall water productivity by 42-255% for crops as diverse as banana, cotton, sugar cane and sweet potato" (Gleick, 2002, p.373). Numbers like those mentioned by Postel and Gleick circulate widely in irrigation and water policy reports, underscoring that drip irrigation is a promising technology to help solve the water crisis. Reports also often contrast drip irrigation with surface irrigation methods, which are presented as inefficient and using excessive amounts of water. A World Bank report for instance states: "Drip irrigation uses 30–50 percent less water than surface irrigation, reduces salinization and waterlogging, and achieves up to 95 percent irrigation efficiency" (World Bank, 2006, p.163).

Where do these numbers come from, and what do they say? In this article we set out to carefully explore the scientific basis of the expectation that drip irrigation will save water, and investigate under which conditions these expectations may be realized. We engage in this exercise because, within irrigation studies, there is much debate and controversy about definitions and (ab-)uses of the term efficiency. In the past, there have been many efforts to come up with one best definition and measurement of efficiency, often as part of attempts to assess and compare the performance of irrigation systems (Israelsen, 1950; Jensen 2007). Burt et al. (1997), for instance, document one such effort, done at the request of the American Society of Civil Engineers (ASCE). Their primary goal was to clarify the terms in use, as too many scholars used the same efficiency terms in different ways. They soon discovered that performance definitions in use needed to be adapted to new technologies and evolving scientific insights. "… in order to avoid confusion and mathematical errors" (p.424), Burt et al. thus proposed changes and improvements to prevailing efficiency definitions. In the 1990s, the efficiency debate received new impetus with a seminal article by Seckler on the (mis) use of efficiency terms (Seckler, 1996). The article focused in particular on the difference between 'dry' and 'wet' water savings to distinguish between re-allocation and resource repletion (also see Molden, 1997; Perry, 1999 and 2007; Jensen, 2007). A recent issue of Agricultural Water Management also engages with this discussion, presenting a collection of papers reviewing and discussing definitions of efficiency in irrigation and water management (Lankford, 2012a).

If there is one thing that the on-going discussion about irrigation efficiency shows, it is that definitions and uses of efficiency terms are not uniform or agreed upon within the community of irrigation scholars (van Halsema and Vincent, 2012; Lankford 2012b) and that claims about efficiency are often inappropriately used outside the contexts to which they apply leading to false estimates of water savings at the basin scale (van Halsema and Vincent, 2012; Perry, 2007). What this means is that any promise of greater efficiency, as for instance made for drip irrigation, needs to be treated with caution. In this article we precisely do that. We engage with the larger debate about irrigation efficiency to present results of a thorough review of the literature about drip irrigation efficiencies. We used the review to identify and categorize the different definitions of efficiency that different authors use, and to trace the debates they engage with so as to understand their concerns and priorities. Our aim with this exercise is not to suggest or propose which definitions are the best. Rather, by carefully mapping and unravelling what different studies and authors say about the efficiency of drip irrigation, we aim to critically examine the origins and validity of the belief that drip irrigation will help minimize water losses and save water.

Two related insights inform our analysis. The first directly stems from the debate about water efficiency and productivity and has to do with the already noted understanding that any assessment of water savings is always scale- and context-sensitive, implying for instance that increases in water use or application efficiencies at the plot or irrigation system level say nothing about how much water is saved at river basin or watershed levels (Seckler 1996; Perry, 2007). Actual water savings depend on where the 'saved' water is going: is it productively used elsewhere or does it flow to the sea? Indeed, and as many scholars have noted, when water saved at plot or system level is recaptured for use within the same plot or system, this may result in reducing downstream water flows, thus causing a re-allocation of water rather than a net saving (Molden, 1997; Sakthivadivel et al., 1999; Seckler et al., 2003; Guillet, 2006; Lankford, 2006; Perry, 2007; van Halsema and Vincent, 2012). Because of this scale- and context sensitivity of water efficiency measures, they are not comparable across locations (van Halsema and Vincent, 2012).

The second important theoretical pillar of our analysis extends this insight, and has to do with the understanding that measuring how much water is used, saved or wasted cannot be done from any neutral or objective perspective, but is always tied to the specific standpoint (and often interests or projects) of the people observing and measuring. van Halsema and Vincent (2012) illustrate this by showing that most measurements of irrigation efficiency are done from what they call a proprietor's perspective, providing an indication of how well the irrigation system uses water without wasting it. From this perspective, the water leaving the system is a loss. Yet, from the perspective of someone responsible for managing and allocating water at the basin level, this same water may be considered as a gain when it can be used for other productive purposes (van Halsema and Vincent, 2012). The acknowledgment that measurements of efficiency are always relative to context (temporal and spatial) scale and perspective thus calls into question the comparability and generalizability of measurements, and brings out the diversity of ways of understanding and looking at water.

In epistemological terms, by bringing out the constructedness of irrigation knowledge, this insight challenges the thesis that there is only one kind of (irrigation) knowledge, only one science, and only one scientific method. For the analysis in this article, we make use of the ideas of Knorr-Cetina about epistemic cultures to express this. The term epistemic culture comes from studying 'science-in-practice'; "investigating scientists at work as opposed to the history of ideas, the structure of scientific theories, or the institutional settings of science" (Knorr-Cetina, 1999, p.9). The reference to culture serves to articulate the idea that science and expert systems are divided by cultures, "as they are pursued by groupings of specialists who are separated from other experts by institutional boundaries deeply entrenched in all levels of education, in most research organizations, in career choices, in our general systems of classification"(Knorr Cetina, 1999, p.2).[3]

3 We ourselves, as the authors of this article, of course also belong to a specific epistemic culture. It can perhaps be characterized as an academic sub-group, the members of which focus on irrigation-related topics from an explicitly interdisciplinary perspective founded on the idea that technology and society are mutually constitutive. This specific article is part of a broader project on drip irrigation, in which we approach technology in terms of what it does (and for whom) in different contexts. Rather than ascribing specific qualities of a technology – such as water saving – to the characteristics of the technology, our approach seeks to understand these as stemming from the interaction between the technology and the context in which it operates (or is invoked).

In what follows, we first discuss our methodology (Section 2) and then go on to characterize drip irrigation efficiency narratives by situating them in broader irrigation efficiency debates and epistemic cultures (Section 3). In section 4, we zoom in on the specific definitions of efficiency used in the drip irrigation debate, examining the assumptions on which these are based and the conditions under which they remain valid. Section 5 presents the conclusions and discussion.

2.2 Methodology

In this article, the scientific literature on drip irrigation constitutes the object of research, rather than being used as a source of reference. We selected the reviewed articles dealing with the efficiency of drip irrigation from the Web of Science database. The first iterative search stage was a broad one, aimed at selecting a wide range of articles. We selected articles with 'drip irrigation' in the title, but also those with 'trickle irrigation' or 'micro irrigation' (but excluding references to other forms of micro irrigation such as micro sprinklers). We combined this with 'efficiency', broadening the search terms for efficiency with: productivity, water saving, WUE and IWUE. We chose for selecting articles with these terms in the title, rather than searching for keywords, as our aim was to find articles that specifically focused on the efficiency of drip irrigation. As we realized the risk of missing important articles with this method, we complemented it with a citation analysis of the selected articles to identify seminal studies in the field. Our initial search yielded 54 articles, of which we excluded six articles as these did not deal with the efficiency of drip irrigation (most of them instead referred to fertilizer use efficiency). For practical reasons, we only included articles available online and written in English. We did not include handbooks and text books on drip irrigation, which have a wider and often more professional audience.

This search strategy resulted in a final list of 49 articles (see the entire list in annex 1), dating from 1974 to 2011, of which most (44) were published in the last decennium. Two of the 49 articles discuss low-cost drip irrigation; seven are on subsurface drip irrigation and the majority, 40, are on standard surface drip irrigation. There is no specific author, research institute or country, which is most prominent in the list of articles. The highest number of articles, 12, was published in Agricultural Water Management. This journal also recently organized a special issue about the question of efficiency.

Final search strategy in Web of Science:

'drip irrigat*' OR 'micro irrigat*' OR 'trickl* irrigat*' in title AND

WUE OR IWUE OR effici* OR productiv* OR 'water sav*' in title

Only English, only Articles

To analyse these articles, we carried out a qualitative content analysis (Silverman, 2006) facilitated by the qualitative data analysis software Atlas.ti. For each article, we coded the quotations of the used definitions of efficiency with the terms used in the text. We noted in which context the terms were used, by coding the debates to which they referred, the justification used for the research and the description of the technology. An attempt to further categorize the efficiency definitions used, on the basis of which flows of water they take into consideration, proved difficult because many articles did not provide the details required to do this. Together, this allowed linking used efficiency terms with concepts and debates. In analogy with suggestions about narrative analysis by Somers and Gibson (1994) and Roe (1991), we used this to re-construct the story line of drip irrigation studies, focusing in particular on how they link discussions and measurement of efficiencies to political and societal concerns over water governance. In addition, we linked our findings to broader discussions and reviews of irrigation scholarship and efficiency studies (including van Halsema, 2002; Seckler, 1996; Zwarteveen, 2006) in an attempt to associate the reviewed drip irrigation studies with specific scholarly communities, traditions and epistemic cultures.

2.3 Narratives and epistemic cultures of drip irrigation studies

Although each of the reviewed articles has its specific interest, they all follow a remarkably similar line of argumentation. They, first, start with some proclamation of a problem or crisis, often related to global environmental concerns. They, secondly, continue by suggesting drip irrigation as a possible (contribution to a) solution to this problem or crisis, referring to its potential to reach high water use efficiencies. To support the claim of high efficiencies, most articles refer to research done by others. Thirdly, authors continue with a description of the area where the study was conducted, which they tend to characterize in terms of cropping patterns, soil types, salinity levels of irrigation water, etc. Fourthly, they present their goal: a search for the circumstances or irrigation conditions (drip or furrow, deficit or full irrigation, etc.) that would yield highest productivities per unit of water for the specific crops and region of interest. The final objective of the reviewed articles, therefore, is to arrive at 'best (irrigation) practices', which are defined as those practices that result in the highest productivities and efficiencies. The emphasis of the articles is on the potential of drip irrigation to precisely adjust water applications to pre-calculated crop water requirements, because drip irrigation allows more regular water applications as compared to surface irrigation and limits the wetted area. The articles mainly focus on agricultural production, and reflect a view of water as a productive good, which constitutes a major limiting factor for food production. An important assumption of the reviewed studies is that both under- and over-irrigation harms yields: "The purpose of irrigation is to keep the water status at a level that maximizes yield within the constraints of available irrigation water supply and growing season weather" (Aujla et al., 2005, p.168).

A main concern of the studies is with how water is distributed within the soil, and with what this means for the root zone of the crop. The underlying rationale of most studies relates to optimizing 'crop per drop', or to maximizing yields per unit of water. This can be achieved by improving the control of water, expressed as the ability to (more) precisely administer water in stipulated quantities and at stipulated times. The studies' concern with controlling water is also shown in frequent references to valves, water metres and other control structures. Seventeen out of 49 studies discuss drip irrigation in combination with deficit irrigation, in which crops purposively get less water than they need with the objective of optimizing the amount of water used per unit of production. When combining drip irrigation with deficit irrigation, it is the reduction in water applications that allows realising efficiency gains rather than the drip irrigation technology itself (which is just the tool enabling deficit irrigation).

With this line of argumentation, perspective and rationale, the reviewed studies can be characterized as belonging to a familiar epistemic tradition in irrigation engineering studies, falling into the broader category of irrigation modernization studies. A general definition of irrigation modernization is given by FAO: "A process of technical and managerial upgrading (...) of irrigation schemes combined with institutional reforms, with the objective to improve resource utilization (labour, water, environment, economy) and water delivery service to farmers" (Burt and Styles, 1998, p.15). Although what 'improvement' entails is not spelled out in this definition, in most studies it refers to an increase in the efficiency with which resources (in particular water and (public) funds) are used. Realizing more outputs with fewer inputs, that is what the irrigation modernization project is about. Avoiding the waste of water and money may be an even more accurate way of summarizing it. For water, this task is seen to consist of better matching water deliveries to crop water requirements, with water delivery conceptualized as a controllable natural-physical process that can be monitored and manipulated with technologies (cf. van Halsema, 2002 p.13). The perspective of these studies most often is that of the irrigation manager or irrigation system operator, implying that the scale at which they apply is that of the irrigation system and that 'waste' is defined as water (or money) leaving the irrigation system without being productively used within the system (cf. Zwarteveen, 2006).

Interestingly, the reviewed studies also belong to this irrigation modernization tradition in yet another sense. The word 'modernization' evokes a notion of progress realized through the use of ever more sophisticated and advanced technologies. As a new and relatively 'modern' technology, drip irrigation assumes an important place in this modernization vision, setting standards of what is achievable and against which current and progressive levels of performance can be measured and assessed. In this way, the adoption or transfer to drip irrigation automatically comes to imply advancement, and is associated both with good water use and management practices as well as with positive development more in general.

Water scarcity is most often mentioned as the problem or crisis, which the reviewed studies aspire to help solving. Twenty-six out of 49 articles explicitly refer to water scarcity to justify their research on drip irrigation. A few examples include: "Water resources are limited worldwide and there is an urgent need to identify and adopt efficient irrigation management strategies since irrigation of agricultural lands accounts for over 85% of worldwide water usage (Zegbe et al., 2006)." (Quezada et al., 2011, p.16), or "The decrease in the availability of water for agriculture, coupled with the requirement for the higher agricultural productivity, means that there is no option but to improve the water use efficiency. This has to include an efficient utilization of available water which otherwise would evaporate or percolate from the root zone of the soil." (Kumar et al., 2009, p.107). Twelve out of the 22 articles not directly naming water scarcity mention a related problem: groundwater depletion (6), competition over natural resources (9) and the high water consumption of agriculture (7). Nine of the remaining studies refer to population growth, and seven state that agricultural development should increase. Six of those do not directly mention limited water availability, but a close reading reveals that they expect to achieve higher levels of agricultural production with the same, or a limited amount of water. In all, our review shows that water scarcity provides the major justification for research on drip irrigation efficiencies. Only the oldest articles (Bucks, et al., 1974; Grieve, 1989) do not link drip irrigation to a societal concern, but discuss drip irrigation as a topic which is interesting of itself, without needing it to be embedded in a wider debate. The appeal to a looming crisis serves to convey a sense of importance, rallying a larger audience around the need for finding credible and relatively quick solutions: "Saving of water is a constant concern and new methods and irrigation strategies are urgent." (Badr et al., 2010, p.69). In this way, the water crisis provides a firm social and environmental mandate for studying drip irrigation. As Quezada et al. (2011, p.17) state: "Drip irrigation is the response to pressure on limited fresh-water resources and plays an important role in the increase of WUE."

Water scarcity figures in the articles as a global environmental challenge, which is not time or location specific. Only in some cases do authors make reference to locations when describing water scarcity such as: "in arid and semi-arid regions" (Al-Mefleh and Tadros, 2010, p.1917), or "in Egyptian agriculture" (Badr et al., 2010, p.64). Also, most articles present water scarcity as a given, rarely specifying its causes. The few articles that do go into possible reasons for scarcity either refer in general terms to an increasing demand for water or point to "abuses in traditional irrigation practices" (Zhai et al., 2010, p.709), using efficiency figures of 40-50% to mark these traditional practices as wasteful. One example: "… field application efficiency in most traditional irrigation methods is still very low, typically less than 50% and often as low as 30%" (El-Hendawy et al., 2008b, p.181). In addition, many articles echo each other in stating that 70 to 80% of the world's fresh water sources are used in agriculture. This statement serves to emphasize the responsibility of the agricultural sector to more efficiently use water. Finally, most articles stress the urgency of the problem of water scarcity. Kumar et al. (2009, p.107) for instance states " there is no option but to ...", Quezada writes "... there is an urgent need" (Quezada et al., 2011, p.16). Other articles use a similar rhetoric: "dramatic shortage of water resources" (Badr et al., 2010, p.69), "the severity of water scarcity" (Karimi and Gomrokchi, 2011, p.36), "the need for water saving in agriculture has never been so great" (Thompson et al., 2009, p.850). Mentioned reasons for this urgency are the increase of the world population, leading to the need to grow more food (water is the "most critical factor in plant growth" (Goodwin, et al., 2003, p.189)) and intensifying competition over water.

This representation of water scarcity as a global and urgent phenomenon is a discursive construction with a clear rhetoric effect: it turns water scarcity into something affecting 'all of us' living on the earth, also making 'all of us' responsible for solving it. This is a distinct de-politicization, since it obscures the fact that a lack of water in most cases has to do with how it is distributed and allocated among competing uses and users, with (more) water for some implying less availability for others. That none of the articles provide details about the specifics of water scarcity (quantifying or qualifying it) for their study areas creates the distinct impression that use of the term merely serves as a legitimation for the research, making it seem (more) acceptable and important, rather than reflecting genuine ambitions to help understanding or solving specific incidences of scarcity. Adding to this impression, and as we further show below, is the fact that none of the studies make explicit how the measured efficiency gains translate into wider water savings, or explain how these will help solving problems of water scarcity.

2.4 Measuring the water use efficiency of drip irrigation: experiments, definitions, equations

Most reviewed articles (44 out of 49) describe experiments with drip irrigation set up at research institutes, one article shows the results of a water distribution model (Barragan et al., 2010) and only 3 articles (Thompson et al., 2009; Kumar et al., 2009 and Maisiri et al., 2005) look at drip irrigation as used by farmers. This is remarkable, as the actual achievement of the measured efficiency gains depends on the behaviour and practices of farmers actually using the technology. Farmer's drip irrigation practices will not just (or sometimes not at all) be determined by a desire to use water more efficiently, but will also be informed by broader objectives of livelihood security or agricultural productivity.

40 articles use the term Water Use Efficiency (WUE). Among these, some explicitly explain that they refer to *crop* Water Use Efficiency (from now onwards referred to WUE_{crop}), while others refer to *Irrigation* Water Use Efficiency (IWUE). A closer examination reveals that 18 of the reviewed articles use WUE_{crop}, which they define as [yield]/ [crop evapotranspiration], whereas 28 use the notion of IWUE. IWUE refers to [yield]/[(irrigation) water applied]. Four articles use the more specific notion of Application Efficiency and three articles use the term Water Productivity[4]. Several articles make reference to more than one efficiency term. We focus on the two most mentioned efficiency terms, WUE_{crop} and IWUE, comparing them with other efficiency terms where relevant.

4 Some scholars propose use of the term water productivity to overcome the lack of clarity associated with the terms water use efficiency. However, few of the reviewed studies use the term water productivity.

Both efficiency concepts – IWUE and WUE- use [yield] in their equation. Yet, what is meant with the notion of yield differs. To name some examples: it can represent dry matter yield of leaves (Al-Mefleh and Tadros, 2010), wet mass basis (Karimi and Gomrokchi, 2011), marketable yield (Bucks et al.,1974) or fresh fruit yield (Cetin and Uygan, 2008). Also in terms of variables, yield can be expressed differently: while Karimi and Gomrokchi (2011) describe yield in gram per m^2, Badr et al. use yield in kilograms per hectare. The denominator of the equation, determining the evapotranspiration (ET), is not straightforward either. ET might be derived from a water balance (leading to actual evapotranspiration, ET_a) or calculated with the Kc values of the specific crop and the specific weather conditions, leading to a calculated ET.

When ET is calculated based on Kc values (in seven out of the 18 WUE_{crop} cases), this is done by making use of weather data from local weather stations. Pan evaporation or local weather data are consequently converted to reference ET (ETo), by making use of the Penman-Monteith method. Reference ETo multiplied by crop specific Kc values leads to the calculated crop ET. These calculations are based on a number of assumptions, which may not directly apply to drip irrigation situations. First, they are made on the basis of surface irrigation methods with relatively long irrigation intervals. With drip irrigation, frequent intervals mean that the soil is wetted more often, thus being exposed to the atmosphere for a longer period of time, which could lead to higher evaporation[5]. At the same time, the wetted area with drip irrigation is smaller, potentially leading to a lower evaporation. In sum, the soil surface will be wet for a longer period over the irrigation season, while the total wetted area will be smaller under drip irrigation and the outcome influences the ET. These differences suggest that there would be merit in adjusting standard Kc values to drip irrigation circumstances, for example as described in the FAO manual 56 (Allen et al., 1998). None of the reviewed articles indicate having done this. Secondly, calculated Kc values are for crops under reference circumstances. Drip irrigation research is often carried out in combination with deficit irrigation methods, leading to water stress and thus a lower evapotranspiration. Thirdly, ET values calculated with this method are based on the evapotranspiration of the soil and the specific crop. Any interferences, such as weeds, are not taken into account. Within our review, it seems that this is done either because of the assumption that drip irrigation will reduce weed growth, or because researchers eliminate all weeds during the experiments.

5 Note, that this argument does not apply for sub-surface drip irrigation, where the soil surface will not be wetted.

The second option to determine ET is to derive the evapotranspiration from the water balance, thus leading to actual evapotranspiration. This is done in 11 out of the 18 WUE_{crop} cases under review. The basic idea behind this method is that all elements in the water balance, except for ET, can be directly measured. In the most elaborated version, this formula looks like: $ET_a = P + I + \Delta S - R - D + C_r$, in which ET_a is the actual evapotranspiration, P is the rainfall, I is the irrigation water, ΔS is the change of water storage in the soil, D is the drainage and C_r is the capillary rise. The eleven studies, which derived ET from a water balance, follow a similar approach. They mention all elements of the water balance as stated above, but in different words or combined in different ways. For example, drainage and capillary rise are taken as one "flux across the lower boundary of the soil profile" in Ibragimov et al., (2007, p115.) However, after mentioning these elements of the water balance, authors continue by arguing that many can be assumed zero or neglected: runoff, drainage, capillary rise and sometimes rain do not have to be taken into consideration, because drip irrigation allows a precise control of water flows: "Surface runoff in this study was negligible because of the control of water application" (Yin et al., 2011, p.41). In addition, the time frame taken for measurements influences the preciseness of the water balance. The element ΔS, change of water storage in the soil, is a good example of this. The change in water storage in the soil is either measured before each irrigation turn (using neutron probes) or measured before planting and after harvest (with gravitary method to measure soil moisture).

For IWUE, calculating the ET (with Kc or water balance) has another function. Rather than assessing the missing factor ET, it is a method to estimate the required irrigation water treatment (which is also sometimes done for WUE_{crop}, to estimate the irrigation water requirements prior to irrigating). The irrigation water use equation is also ambiguous. It does not refer to water used by crops, but to water applied. Different reviewed articles use different ways of defining and calculating the amount of water applied. Some look at the water released by the emitter to the root zone of a crop. An example is Goodwin et al. (2003) who carry out an experiment in containers to make the water balance as exact as possible. Others instead look at amounts of water released by entire irrigation systems. Kumar et al. (2009) take the entire discharge of a particular source to calculate IWUE. In the latter example, the attempt to maximize the efficiency of the involved irrigation system included both the installation of drip irrigation on plots, as well as the lining of the reservoir near the source. The detailed methodological description of Kumar is rare. Most articles do not clearly explain from which point in the system onwards they start intervening and measuring water diversions and applications. Based on the experiments they describe, we deduce that most refer to the water applied to a specific (experimental) plot.

Not only do different articles use different temporal and spatial scales for measuring the amount of water applied, there are also other important differences in how they account for this water. The IWUE experiments are mostly set up to allow expressing water flows as a simple equation. 'Interfering' water flows that would occur under field circumstances – runoff, drainage, capillary rise - are avoided or not mentioned at all. Though some articles clearly specify the parameters used (Yin et al., 2011 and El-Hendawy et al., 2008b), others are less clear about which flows are taken into account. In eight of the 28 articles, for instance, it is unclear whether rainwater (which is water that is used by crops, but not purposively diverted) is included or not. Another important difference is whether or not drainage water is included within the calculations; this is water that is diverted and applied to crops, but that is not beneficially used (by the crop) and can therefore potentially be re-used.

Although the studies make use of the similar term water use efficiency, most do not provide details about their definition of the term and fail to specify what they exactly took into account and what not. In many cases, authors seem to consider their specific definitions and use of the efficiency terms as self-evident. However, our review shows that there is no consensus about which parameters have to be taken into account and that there is a wide variety of different uses of similar efficiency terms. Only one article displays awareness of this ambiguity when arguing why rainfall and water storage in the soil are not accounted for: "Several workers calculated WUE as yield/ irrigation water (either pumped from the water source or received by the crop), ignoring water from other sources which may have contributed to yield" (Hodgson, et al., 1990, p.144).

To conclude, there is huge variation in how different studies define water efficiencies, and which elements they include in efficiency equations. This reflects the fact that studies use IWUE and WUE_{crop} values in accordance with specific contexts and from particular perspectives. Yet, these contexts and perspectives are seldom made explicit; many of the reviewed studies proceed as if their definitions and equations are obvious and generalizable, and do not hesitate to straightforwardly compare their results with results from other studies (which use different definitions and equations). Without specification of the efficiency terms used, and of the specific settings of the experiments, such a comparison is

meaningless.
In addition, most studies assume that reported changes (most often increases) in water efficiencies can be used as measures of water saving or water productivity increases. Even though some of the articles refer to other water uses than irrigation in their introduction, they all assume that water not evapotranspirated by the crop it was assigned to, is lost (or wasted). This assumption is false; measures of WUE_{crop} and IWUE, irrespective of their precise definition, represent the efficiency of water utilization at a specific scale level (plant, plot, farm or system) and thus indicate how well water is handled or used at this scale, without any predictive value for other scales (cf. van Halsema and Vincent, 2012, p.11). Indeed, switching scales can drastically change one's assessment of water efficiency from poor to good when water initially regarded as 'wasted' is beneficially re-used (Clark and Aniq, 1993; Guillet, 2006)

2.5 Discussion and Conclusions

The review of scientific studies as presented in this article shows that the evidence about the water saving potential of drip irrigation is far from conclusive. First, a larger majority of studies present findings from very localized experimental situations, specifically carried out to assess how the use or application of water can be optimized at plot level. Results of such experiments leave out a very important 'variable' in determining water efficiencies: farmers and their practices. The importance of this is not to be underestimated. The first studies undertaken in the context of a larger research program on drip irrigation, of which this article forms part, reveal why and how farmers use drip irrigation. These show that (a more) efficient use of water is seldom the main concern of farmers. Spanish (van der Kooij, 2009), Moroccan (Benouniche et al, 2011) and Zambian (Tuabu, 2012) farmers for instance indicate that they shift to drip irrigation because of its greater ease of use or a reduction of labour costs, or because it allows to irrigate on steep slopes (Sese Minguez, 2012). Without a sound understanding of how different farmers deal with (scarce) water, predictions about the actual water savings that drip irrigation can achieve remain far-fetched speculations. This would require a better understanding of farmers' practices, related to issues such as the perceived CWR.

Second, the reviewed studies use a wide variety of different definitions of similar efficiency terms. WUE_{crop} and IWUE are the terms mostly used, but authors also refer to other terms such as application efficiency and water productivity. Efficiency can refer to the uptake of water in the root zone of a plant, but can also refer to how much water is lost when it flows through piped canals. In some definitions, the term just takes irrigation water into account, but in others also rainwater or groundwater are accounted for. Efficiency gains may refer to actual water savings, or instead may indicate higher agricultural production per unit of water. IWUE is the efficiency term that is most often used in the reviewed studies, yet it is probably the most confusing term of all: van Halsema and Vincent even labelled it a 'non-fertile cross-breed' (van Halsema and Vincent, 2012, p.12).

The wide variety of definitions and equations in use to express water efficiency show that each study uses its own specific measurements, in accordance with the specific concerns the study sets out to address and reflecting the priorities and interests of the authors. Yet, the use of similar terms and the lack of discussion about them create a suggestion of agreement and consensus, or indeed of scientific unity. This suggestion becomes even stronger because studies generalize results and compare them with those of other studies; efficiency measures from specific experiments are compared with those of other experiments as if they are interchangeable and as if they address the same components of the water balance. In doing this, none of the reviewed studies display awareness of the larger debate about how to define and measure efficiency in irrigation.

Creating a suggestion of comparability and generalizability can perhaps be partly explained by its strategic convenience in helping create legitimacy for studies on the efficiency of drip irrigation. The statement that drip irrigation is (more) efficient, especially when water resources are under pressure, is likely to help assure future research and development funding for drip irrigation. Our analysis suggests that the prevailing epistemic culture and scholarly tradition to which most reviewed studies belong provides another explanation. This tradition is technology-centred. Researchers aspire to ascribe specific characteristics and abilities to a technology, implicitly assuming that similar technologies will display the same behaviour everywhere. Hence the desire to compare performance across technological systems: it allows to 'diagnose' what can be improved or what is wrong in engineering terms. Faithful to this tradition, most efficiency assessments of drip irrigation follow a particular scientific procedure designed to achieve a form of objectivity that works to hide the specificities of the research location and the researchers. This happens through the reduction of an overwhelmingly complex world to an isolated laboratory-like setting, a closed system-model in which a small number of controllable variables determine water flows. There is nothing intrinsically wrong with this procedure, but it becomes problematic when the presentation of the results does not show how the 'laboratory' was constructed and when findings from such specific 'laboratories' are compared to those of other 'laboratories' without properly assessing whether or to what extent they resemble each other. It also becomes problematic when such findings are generalized for real-world situations, inappropriately jumping scales and contexts (see also van Halsema and Vincent, 2012).

The reviewed studies show, in different ways, that drip irrigation potentially allows using less water for a single plot without compromising (or even improving) yield. This is an interesting finding, but it reveals little to nothing about the water saving potential of drip irrigation at the river basin or watershed level. This is what Seckler called a 'composition problem': a certain calculation can apply to part of the system, but not to the whole as return flows come back into the system (Seckler, 1996). The reviewed studies using some definition of IWUE for calculating efficiencies all assume that water drained is lost, but (unless it goes to sinks) this is water that can potentially be re-used elsewhere. It may for instance be recaptured for use by the same farmer or system, which in a closed river basin (Molle et al., 2010; Seckler, 1996) will lead to a reduction of downstream water flows and thus implies a de facto re-allocation of available water (see also Molden 1997; Molden and Sakthivadivel, 1999; Seckler et al, 2003; Guillet, 2006; Lankford, 2006; Perry 2007; van Halsema and Vincent, 2012). This example not just shows that calculations about 'savings' and 'losses' are always scale-sensitive, but also that they are of little practical use without further specification of who incur these gains and losses. To whom does the saved water flow, who has a right to access and use this water? Is the 'more efficient' farmer the best and most progressive, and the one who therefore deserves more support (cf. Boelens and Vos, 2012) even if her efficient use of water means that downstream farmers are deprived? Indeed, in this sense calculating efficiencies is not a politically neutral exercise, but directly tied up with complex distributional questions.

In sum, our analysis clearly shows that there is no conclusive scientific evidence to support a general belief in drip irrigation as a water saving device or as a tool to help solve the water crisis. Our analysis thus serves as a warning against the general and unspecified association of drip irrigation with greater water efficiency. In terms of research, our analysis suggests that studies about the efficiency of drip irrigation would benefit from a more explicit recognition of the specificity and constructedness of the efficiency terms used for characterizing drip irrigation situations, and by more meticulousness and modesty about the comparability and generalizability of results. Assessing the water saving potential of a technology like drip irrigation, moreover, requires better awareness of the implications of improving efficiencies at one scale level for other scale levels, and of the allocational implications of changing water flows. In terms of policy, our conclusions caution against too much enthusiasm about the water saving potential of drip irrigation. Promoting the introduction of drip irrigation to bring about water savings at national or regional scales should not be based on studies that report efficiency gains achieved at plot levels only, as these cannot be generalized for other scales.

Chapter 3

Re-allocating yet-to-be-saved water in irrigation modernization projects. The case of the Bittit Irrigation System, Morocco.

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Abstract

Responding to the challenge of producing more food for a growing population with less water, several countries are modernizing their irrigation systems by introducing water saving technologies. Efficient irrigation technologies increase agricultural production and potentially save water, which can be allocated to other users or uses. However, because 'losses' from 'inefficient' irrigation practices are often re-used downstream this allocation process can also be seen as a re-allocation. By analysing the modernization projects in Ain Bittit, a small-scale farmer-managed irrigation system in Northern Morocco, we suggest that the reference to high efficiency numbers de-politicises re-allocations of water. Shifting to efficient technologies (such as drip irrigation and canal lining) entails a promise of water 'gains', which different actors claim and actually use for their purposes. Ultimately this results in an increase of the pressure on water resources.

3.1 Introduction

While the world faces a growing demand for food, water availability is limited. To find solutions for producing more food with less water available, countries with the support of international donors aim at modernizing irrigation systems (Playan and Matéos, 2006; World Bank, 2006; EEA, 2009; OECD, 2010). Modernization means the "upgrading" (Burt, 1999, p.15) of irrigation systems with management arrangements and technologies that stimulate efficient water use (van Halsema, 2002). Increasing the efficiency of irrigation systems will increase the productivity of the irrigated sector – in terms of more production per hectare or more production per cubic meter water available. In addition, the modernization of irrigation means for policy makers that farmers increase competitiveness, which makes them prepared for the liberalization of markets and a reduction in subsidies (Lecina et al., 2010).

Increasing the efficiency of irrigation systems often happens through the introduction of more efficient irrigation technologies such as drip irrigation or the lining of earthen canals although irrigation scholars such as Burt and Styles (1998) have argued that modernization cannot be achieved through improvements in the hardware only. Playan and Matéos (2006) advance several reasons why decision makers prefer a technological solution: modern irrigation technologies improve working and living in rural areas; it can be beneficial to the environment when modern technologies limit leaching of salts and nutrients and it is attractive as it avoids making hard choices on decreasing the water demand of (some) users and changing the water allocation. This last argument follows the line of argumentation proposed by Allan (1999), i.e. the introduction of efficient technologies is attractive as apparently there are no specific losers in the modernization project. No-one has to limit agricultural production and neither will incomes of farmers decrease. Soft solutions that aim at reducing water use through a change in management, for example through water pricing, seem a more political choice than introducing drip irrigation and can count on protest of water users.

Although presented as a win-win situation, the introduction of efficient technologies can be considered political processes of re-allocating water (Lankford, 2012a). The suggestion that water will be 'saved'[6] provides the opportunity to allocate the yet-to-be-saved water to other users or uses. This part of the re-allocation process is deliberate and open, though usually presented rather as
an allocation (of 'gained' or previously 'wasted' water) than a re-allocation of water. There are two reasons why these allocations of yet-to-be-saved water are often re-

6 What is perceived as 'losses' or 'savings' depends on the proprietor's perspective (van Halsema and Vincent, 2012) hence such perspective dependent terms are placed in parenthesis.

allocations of water. First, it is unclear whether the anticipated 'savings' are indeed attained; whether the new technology is indeed as efficient in use as expected. Field studies suggest that this is not necessarily the case. Benouniche et al. (2014) for example show how the actual irrigation efficiency and uniformity of a drip irrigation system depends on farming practices and can either confirm the high expectations of drip irrigation, or even be less efficient than surface irrigation. Farmers can indeed attain 90% efficiency with drip irrigation, but do not necessarily ambition so, for example when they engage in the production of high-value crops. They may over-irrigate to avoid water stress on their valuable crops (Benouniche et al., 2014). Also Wolf et al. (1995) mention disappointing efficiencies with drip irrigation. Lower efficiencies in practice means the water 'gain', already allocated based on high efficiencies, might not become available and the allocated water has to come from other destinations.

Secondly, it is impossible to just create 'more' water (Perry, 2011, refers to the law of conservation of mass). 'Losses', seen from the perspective of the single crop at the plot level, might not be 'losses' at basin scale (Seckler, 1996; Molden 1997; Molle et al., 2004; Jensen 2007; Perry, 2011). The previous 'losses' could well be used downstream, unless these 'losses' are inaccessible or of too low quality to be re-used, for example when they recharge a polluted aquifer or flow into sea. The water users dependent on the 'losses' would thus lose their water resources when irrigation practices upstream become more efficient through modern irrigation technologies and increased water consumption. Yet, this re-allocation of 'invisible' water uses downstream seems unintended and might only become noticed when the efficiency intervention is implemented. This re-allocation can be called 'unintended' re-allocation (Hooper and Lankford, forthcoming), as it is often unknown, and perhaps even undesirable to know, who used the downstream water generated through 'losses' upstream.

A well-known example of a re-allocation of water via efficiency interventions is the All American Canal. The All American Canal diverts water from the Colorado River to farmers in the Imperial Irrigation District, which was blamed for its disproportional water use – possibly a 436,700 ML per year could be saved (CGER, 1992). The idea that these 'losses' could be saved, and thus allocated to a new user, resulted in a water-deal: the All American Canal would get lined, financed by the Metropolitan Water District, and the 'saved' water would be used for drinking water. However, in this water deal it did not transpire that the previously 'lost' water was actually re-captured by farmers downstream in Mexico. After lining the canal Mexican farmers dependent on the 'losses' of the All American Canal lost the water that previously percolated through the earthen All American Canal (Jenkins, 2007).

Here we focus on the first part in the re-allocation process: the deliberate allocation of the yet-to-be-saved water. This builds further on the suggestion of Allan, 1999, that efficient technologies are attractive tools for modernizing irrigated agriculture, as they apparently do not create explicit losers. Based on empirical results from a case study of the farmer managed Ain Bittit irrigation system in Northern Morocco, we explore the re-allocations that accompany modernization projects. The recent introduction of drip irrigation in Morocco and more specifically in Ain Bittit illustrates the paradoxical situation that can emerge from modernization interventions: as different parties claim the yet-to-be saved water, it seems that rather more than less water is used for irrigation[7]. By analysing the past lining projects of Ain Bittit, we develop an understanding why efficiency projects might be such attractive interventions. The promise of water savings from efficiency projects allows for a re-allocation of water, which is de-politicized. Seemingly only the 'saved water' is allocated to specific users, while other users would not notice a change in discharge. Yet, in Ain Bittit, we observed an increase in water abstraction and a limited availability of water for the command area: only 1/4th of the command area can be irrigated.

3.2 Methods

We base our study on fieldwork carried out by the first author, who followed the irrigation practices in the secondary canal Khrichfa of the Bittit irrigation system during two irrigation seasons (in 2012 and 2013). To explore the reconfigurations of water distribution that accompanies the drip irrigation projects, 15 drip irrigation users of the Khrichfa Canal or near the Khrichfa Canal were interviewed. For tracing how efficiencies shaped the history of the Ain Bittit irrigation system, interviews were carried out with water users (ca. 40); (ex)officials of government institutes (10) and various actors that have been involved in the modernization projects in Bittit. In addition, use was made of documents obtained from government institutes and water users.

3.2.1 Ain Bittit irrigation system

Ain Bittit is a small-scale, farmer managed irrigation system in Northern Morocco covering approximately 2,000 hectares cultivated with cereals, forage crops, tobacco, horticulture (onions and potatoes) and fruit trees. Its irregular layout and scattered plots mark its community-built origin, while frequent state-interventions have influenced the lined irrigation infrastructure and the management of the system. The Ain Bittit water ('*Ain*' meaning spring in Arab) is shared between the State, which obtained since 1929 the right to 60% of the springs' discharge – used by the drinking water company of Meknes – and two rural communities, Ait Ouallal and Ait Ayach, which are each

7 We focus in this chapter on the notion of efficiency as 'saving water', although 'efficiency' is also tightly linked with increasing productivities, or with issues of equity and reliability, which we do not discuss here.

allocated 20% of the springs' discharge. Here, we will focus on the secondary canal Khrichfa within the Ait Ouallal community (Figure 4). Khrichfa's share of the springs' water is ca. 100 l/s and as an additional water source, the Khrichfa water users make use of a collective tube-well that releases ca. 40 l/s to the Khrichfa Canal during the peak demand of crops. In total, the water availability in Khrichfa is only sufficient to irrigate 1/4th of its total command area.

Over the past two decades, several farmers in the Khrichfa region introduced drip irrigation. The drip projects are based on surface water from the Khrichfa Canal and/ or groundwater pumped by tube wells. Drip irrigation can irrigate the steep and undulating land above the Khrichfa command area, which increases the value of these previously rain-fed lands. Investors from the nearby cities bought plots in the rain-fed zone, where they drill tube-wells and install drip irrigation. Khrichfa water users, having both land in the command area and rain-fed land, also convert the rain-fed land into irrigated lands with drip irrigation. They do so by using their water rights from the Khrichfa Canal: they store the surface water in a storage reservoir, from which they pump the water into their drip irrigation system. Some farmers strategically combine surface water and groundwater in their drip irrigation projects[8].

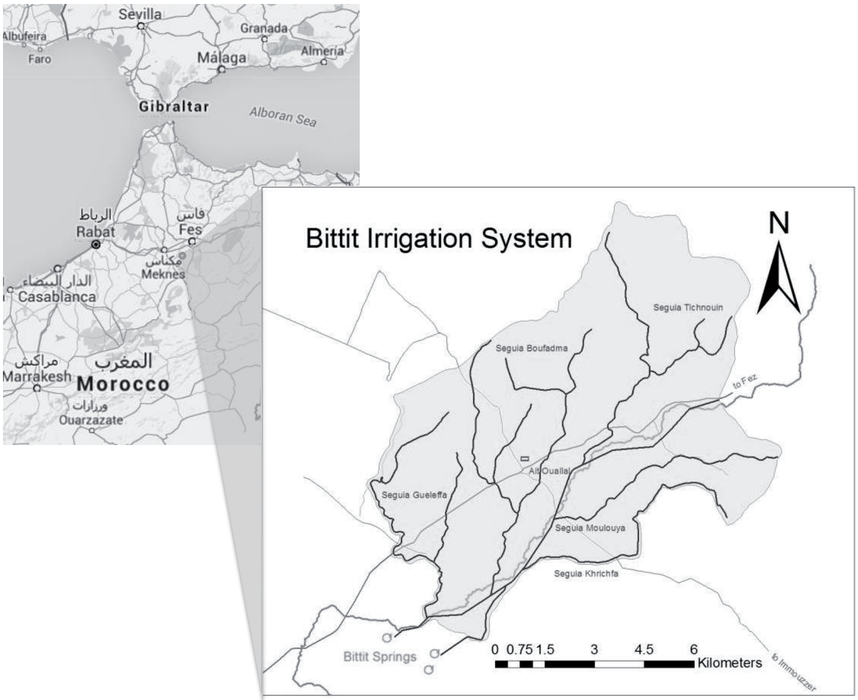

Figure 4. The Bittit irrigation system.

8 Khrichfa water users do not (yet) notice a direct relation between the use of tube-wells and the springs' discharge.

3.3 Modernization 1: Drip irrigation in Morocco for sustainable extension of agriculture

Morocco faces declining groundwater levels, negative water balances and half-full dams which figure prominently in the discourses of the ministry of agriculture and the water basin authorities to call for modernization of the irrigated sector (ElMeknassi, 2009; El Haouat, 2012). In reaction to the alarming figures, the Moroccan government subsidizes the reconversion from surface- to drip irrigation with subsidies that cover 80-100 % of the investment costs. The drip irrigation subsidies are a prominent part of the National Irrigation Water Saving Plan of 2007 (Plan National d'Economie d'Eau en Irrigation, PNEEI) to counterbalance the deficits in the water sector on the basis of theoretical efficiencies of 90% of drip irrigation. More specifically, the PNEEI aims to 'save' 826 Mm^3 per year, of which 514 Mm^3 will be 'saved' in the large scale irrigation systems. The water 'saved' in the large scale irrigation projects will be used to compensate structural deficits within the irrigation systems, thus increasing agricultural production while diverting the same amount of water from the dams to the large scale irrigation systems. The PNEEI expects to 'save' 312 Mm^3 per year within the private irrigation sector, which mainly uses groundwater. As this water will not be pumped by farmers, the PNEEI argues, the 312 Mm^3 is expected to remain in the aquifer thus containing the overexploitation of groundwater (Ministère de l'Agriculture du Développement Rural et des Pêches Maritimes, 2007). Later interpretations of the PNEEI are more optimistic about the possible water savings. Arrifi, 2009 and Belghiti, 2009 (both associated with the Moroccan Agricultural Ministry) expect that within the private irrigation sector 740 Mm^3/year (Belghiti, 2009) or 700 Mm^3/year (Arrifi, 2009) will remain in the aquifer and in the large scale irrigation systems 700 Mm^3/year (Belghiti, 2009) or more than 750 Mm^3/year (Arrifi, 2009) will be used to fulfil the irrigation requirements that currently cannot be satisfied. The different estimates of the water savings from different authors indicate that the amount of water to be 'saved' with drip irrigation seems open for interpretation, but clearly the 'saved' water has two (competing) destinations over which it will be distributed: increased agricultural production and protection of the aquifer.

The PNEEI from 2007 is encapsulated in the Green Morocco Plan, which guides Moroccan agricultural development since 2008. The Green Morocco Plan focuses on increasing agricultural development, both in economic terms and in terms of social welfare. With the strong focus on increasing agricultural production, the goal of the PNEEI now seems to shift towards using the 'saved' water for increasing production (as was already indicated for the large-scale irrigation systems in the PNEEI), rather than also safeguarding the aquifer: "The National Water Program … aims at filling the water gap which is considered the principal limiting factor in improving the agricultural productivity" (http://www.agriculture.gov.ma/pages/economie-de-leau, accessed on 29-

05-2015). In the efforts to make Moroccan agriculture competitive, the Green Morocco Plan stimulates farmers not only to shift to drip irrigation, but also to produce high value crops (which often demand more water) and to extend the irrigated area.

While the Green Morocco Plan thus interprets efficiency as more production per cubic metre of water, the Basin Agencies, responsible for safeguarding Morocco's water resources, are concerned about the negative water balances and interpret efficiency as less water diverted to agriculture and thus remaining in the aquifer. In their efforts to safeguard the aquifer system under the Saïss plateau (where Ain Bittit is located), the Sebou River Basin Agency aligns with the National Water Plan and the efforts of the agricultural ministry to stimulate the shift from surface irrigation to drip irrigation, based on its efficiencies which would lead to less abstraction of groundwater. They do so by adding training, subsidies and pilot technologies to the efforts of the agricultural ministry in reconverting Morocco's irrigation areas to drip (El Haouat, 2012).

'Efficient' drip irrigation makes it possible for the basin agencies and the agricultural ministry to work together towards an apparently shared future: one in which water is used 'efficiently', even while their goals compete. In the field, it becomes clear that the water to-be-saved is claimed by different parties who aim to direct the yet-to-be saved water to different destinations. The ministry of agriculture plans to use the water savings for increasing agricultural productivities; the farmers use the water on newly developed land; and the basin agency aims to keep the saved water in the aquifer. Paradoxically, the introduction of drip irrigation in Bittit leads to an increased abstraction of water, as also observed in other irrigated areas where drip irrigation leads to an extension of the irrigated area (Lopez Gunn et al., 2012; Berbel et al., 2013; Benouniche, et al., 2014).

Drip irrigation in the Khrichfa area in Bittit: increased groundwater use with tube-wells

The massive introduction of drip irrigation in the Saïss area started outside of the surface irrigation systems with groundwater users who wanted to economize on pumping cost, to intensify agricultural production or to irrigate more surface area with the available water (Ameur et al., 2013). In the area near the secondary canal Khrichfa in the Ain Bittit irrigation system, most drip irrigation projects are located on previously rain-fed lands (Table 1). Two main conclusions can be drawn from Table 1: 1) most drip irrigation projects rely on groundwater, abstracted via tube-wells, and 2) most drip irrigation projects extend the irrigated area and do not relate to re-conversion of already irrigated land, as the official policy proclaims, but could rather be characterized as extensions of the irrigated area.

Table 1. Location and water source of the drip irrigation projects in the Khrichfa area

Water source \ Location	Within command area	Agricultural Extensions	Overlapping command area and agricultural extensions	Total
Surface water (via storage reservoir)		2		2
Groundwater (via tube-wells)	2	6	1	9
Groundwater + surface water		2	2	4
Total	2	10	3	15

New settlers in the Bittit area, attracted by the availability of rain-fed land above the irrigation system with a high potential for finding groundwater, consider tube-wells as part of the drip-package, the set of technologies that accompany drip. They rely on groundwater as the main source for their drip irrigation installation. A tube-well secures access to water, making the investment in drip irrigation less risky than with a springs' variable discharge, and is readily available at hand enabling the farmer to irrigate whenever required.

Right holders to Khrichfa's water who want to use surface water as the main source for their drip irrigation project secure access to canal water by ensuring good relations with the WUA and by hiring water. However the conviction of many engineers is that a surface water source and drip irrigation do not fit: because of the unreliable discharge, because they consider the rotational water distribution too complex and because of a lack of incentives to save water as surface water is free of costs (Ministère de l' Agriculture du Développement Rural et des Pêches Maritimes, 2007; pers. comm. Mimoen El Mars, 28-10-2013). This is also why the Basin Agency, paradoxically, supports the drilling of tube-wells for farmers with water rights in a surface irrigation system wishing to convert to drip irrigation. One of the new drip irrigation projects in the Bittit irrigation system, a family cooperative of 25 members with plenty of surface water rights installed a tube-well subsidized by the Basin Agency on the rain fed land uphill from the Khrichfa Canal. The family cooperative aims to increase the productivity of their rain-fed land, previously used to cultivate cereals and for pastoral activities. Via the Provincial Department of Agriculture the cooperative arranged a subsidy of 100% on the drip irrigation installation. The initiators of the cooperative met the Basin Agency at a workshop on drip irrigation organized by an IDRC project from the Al Akhawayn University, which aims to: "determine whether demand management of water in agriculture can save the future of the SAISS basin" (p.1, ACCA, 2010). The Basin Agency told the family cooperative that they stimulated drip irrigation within surface irrigated areas, so they offered to finance the construction of a storage reservoir to stock their surface water from the Bittit springs. As using drip irrigation in a surface irrigation system is difficult - the Basin Agency argued – in terms of water turn and in terms of reliability of the source, they also subsidized the installation of a tube-well as supplement to the construction of the storage reservoir. The goal of the reservoir was to always ensure access to water. This drip project is now put forward by the Al Akhawayn University and the Basin Agency as a pilot project and an example to follow. Also other drip irrigation users of Khrichfa talk about drilling a tube-well, or have already installed a tube-well on the highest part of their rain-fed parcels. The increased use of tube-wells for drip irrigation thus puts additional pressure on the groundwater resources to support the introduction of so-called efficient irrigation technologies!

The drip irrigation projects in the Khrichfa area show that a paradoxical situation emerges from the Moroccan drip irrigation policies. Efficient drip irrigation gave a *carte blanche* to the entrepreneurial farmers with drip, who use drip to extend and intensify agricultural activities, which increases their total water abstraction from the Khrichfa Canal and from the tube-wells. While the Basin Agency supports a shift to drip irrigation to safeguard the aquifer, it also stimulates an increased groundwater abstraction for agricultural extensions. One could explain this situation as a lack of control and legislation and argue that extensions outside the command area should be prohibited. However, prohibiting extensions or measuring groundwater abstraction with meters on tube-wells would make clear that the Basin Agency and the agricultural ministry have conflicting objectives. A water meter on a tube-well would make the water savings tangible, leading to discussions about how the savings should be divided, which is exactly something that is carefully avoided. To avoid such political discussions, all parties claim (and if possible use) the expected water savings. The main indicator used by the agricultural ministry to predict and register water savings is the surface area equipped with drip irrigation. To further understand the attractiveness of the promise of water savings from water efficient technologies, we trace the process of re-allocating water that accompanied past modernization projects.

3.4 Modernization 2: Lining projects in Bittit, (re)-allocating the Bittit sources based on efficiency estimations

The city of Meknes was growing fast in the first half of the 20th century and the city's drinking water source – the river Boufekrane – was not sufficient and of bad quality (Direction des Travaux Publics; 1954). In search for drinking water for Meknes, the French administrators became interested in the sources South-East of Meknes, amongst which the Bittit sources which were used by the Ait Ouallal and the Ait Ayach tribe. The administrators started to measure the sources' discharge from 1934 onwards.

The French Governors in Morocco could not easily get control over the Ait Ouallal inhabitants. The Ait Ouallals belong to the rebellious Beni M'tir tribe and several Ait Ouallal landowners were part of the political opposition. To settle the Ait Ouallal tribe, the French Governors arranged the Ait Ouallal land rights in 1929. The Ait Ouallal farmers divided the water rights amongst each other, but these were not yet registered officially in the first half of the 20th century. The downstream community Ait Ayach had good relations with the French governors (Bazzi, 1987). One of the interests of the Ait Ayach farmers was to ensure a stable water supply for irrigation. They used to get the remaining water of Ain Bittit, which means that the discharge was limited in summer, and (too) high during the rest of the year. To support the Ait Ayach farmers and to gain access to the Bittit sources for drinking water, the French governors decided to register the rights on the Bittit sources. They made an inventory of the water use in 1949 based on the local water rights practiced in Ait Ouallal and Ait Ayach. The report of this inventory (Direction des Travaux Publics, 1949) stated that the farmers in Bittit and Ait Ayach only used 40% of the water from the springs, the rest were 'losses' that were not available for use, unless the infrastructure would be improved:

> "the water rights have been calculated according to the discharge that is used in reality… which is no more than 4/10th of the total discharge of Aioun Sidi Tahar, Sidi El Mir and Ain Sebaa (the three sources that together form the Ain Bittit springs), because of the losses that occur in the existing infrastructure. The committee clearly points out that the fractions of the discharge that represent the losses will not be available… until the infrastructure is lined and the marshes of the Bittit river bed are drained." (p.2, Direction des Travaux Publics, 1949)

The report proposed that the two communities would be allocated the water rights according to the water they "really used", while allocating the water "losses" to the public domain. After describing the shares of the different tribes, the report states:

> "the proposals of the inquiry commission are based on the customary water allocation, which is not applied on the total discharge of the springs but on the discharges that are really used. It (the committee) thus registers the losses of the current infrastructure as part of the public domain, as these (losses) were never part of the acquired water rights. But it stipulates that the fractions of the discharges that represent the losses are not available at the springs until the irrigation infrastructure is made water tight and the marshes of the Bittit riverbed are drained. This viewpoint, which is also the viewpoint of the Public Works Department, has been accepted by the users." (p.3, Direction des Traveaux Publics, 1949)
>
> 60% of the discharge could thus be assigned to the public domain:
>
> "…losses to be recovered by the Public Domain after lining works: 60 %, which is 6/10th of the discharge of the sources." (p.4, Direction des Traveaux Publics, 1949)

The State registered 60% of the discharge under the public domain and assigned Ait Ayach and Ait Ouallal both an equal share of the remaining 40%. By referring to the "losses" as the share of the State, the re-allocation of the Ain Bittit sources was de-politicised. Apparently, no-one used the 'losses' and it seemed as if the farming communities would be able to use the same volumes of water as before. To get access to the 60% 'lost' water, the State had to line the Bittit infrastructure. The public works department attracted attention to the water wastage of farmers by mentioning the water accumulation in the tail-end of Ait Ayach, and the problems of water-born diseases that it caused. This was meant to stress that this water was not used by others, meaning that the State's share amounted to the creation of new water rather than a re-allocation that concerned Ait Ouallal and Ait Ayach.

The French administration started the construction work in 1952. At the location of the sources, they constructed a division structure to divide the total flow in 60% for drinking water and 40% for agriculture. Based on the rule of thumb of

200 litres of drinking water per day and an estimation of the population growth, the French administration constructed a pipeline with a capacity to divert 400 l/s to Meknes (Direction des Travaux Publics, 1954). Even if the springs' discharge would be lower in summer, 400 l/s is still less than the State's water right of 60% (figure 5). Meanwhile, the main canal of Ain Bittit got lined (see figure 5 for an overview of the infrastructure). However, the French administration did not include the earthen secondary canals in the lining program. They designed the main canal in such a way that the large and political active landowners and some colonial farmers in Bittit got their offtakes directly on the main canal. This satisfied the most influential actors in Bittit both because the lining reached till their offtakes (thus making optimal use of the lining project), and because their private offtakes meant there was less need to cooperate with other farmers to get access to water. The Bittit farmers in less favourable positions expected that the State would also line the secondary canals. According to them, these canals were part of the irrigation infrastructure and had to be included to attain the water saving of 60%.

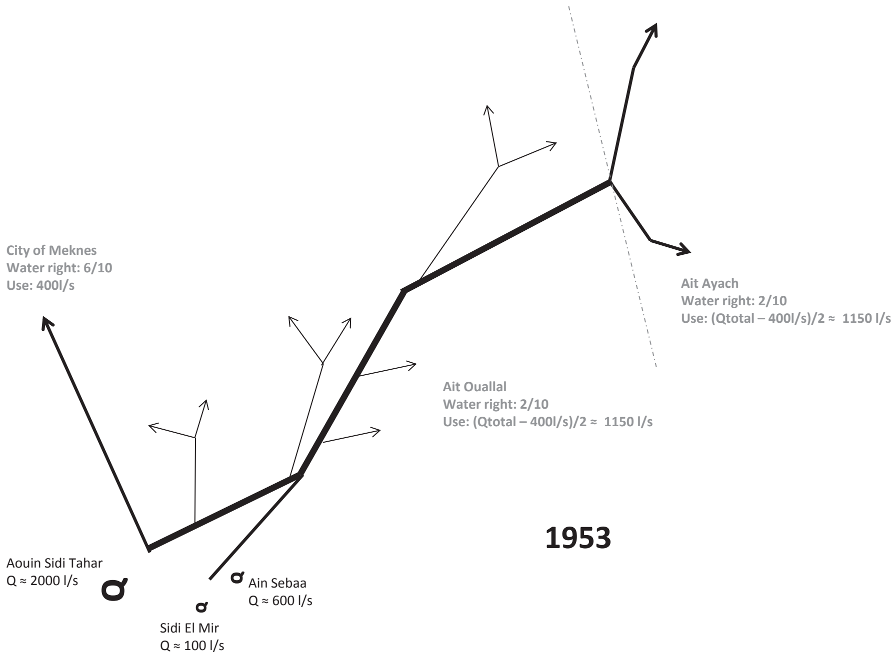

Figure 5. Sketch of the sources and irrigation infrastructure in 1953

The construction works had attracted labourers from different regions, and when the infrastructure was ready, the labourers made sharecropping agreements with the Ait Ouallal landowners to stay in the area. Many newcomers followed. This resulted in clearing of new land and an increased demand over water within the irrigation system. A new process of water re-allocations legitimized through lining happened later, in the 1980s, when both the water demand of Meknes and the water demand of the farmers had grown, resulting in a long period between two irrigation turns. A rehabilitation project financed by the World Bank created the context for re-negotiating water allocation. Lining the secondary infrastructure again created a promise of 'saved' water, which the drinking water provider of Meknes planned to use. The plan of the drinking water provider of Meknes to construct another pipeline, thus doubling their offtake to 800 l/s, in first instance resulted in protests of the Bittit farmers. However, the Bittit farmers were interested in lining the secondary canals – because it was promised to them in the negotiations over the Bittit springs and because it would speed up the rotation schedule, thus resulting in a shorter period between two irrigation turns (Lankford, 2012b).

The engineers of the rehabilitation project calculated that with lining of the secondary infrastructure, and minus the additional water use of Meknes of 400 l/s, the Ain Bittit farmers would still gain more water through the lining project than they had before, which could thus be used to irrigate new lands. The calculation was as follows: in total 914 hectare was irrigated with 1282 l/s, thus with an available discharge of 1,41 l/s per hectare, which the engineer considered as too much. As a rule of thumb, he argued, each hectare would rather need 0.7 l/s, assuming tobacco cultivation, the main crop produced in Bittit at that time. The engineer thus concluded that the system worked at an efficiency of 50 percent before lining. He estimated that the efficiency of the irrigation system – taking into account the 'losses' in the quaternary canals and at the farmers' fields - could be improved to 65% through lining (Bazzi, 1987). The net efficiency gain from lining the secondary infrastructure would be more than the additional 400 l/s that would be allocated to Meknes (in total resulting in 800 l/s for Meknes). The remaining water could thus be used for new land within the irrigation system and de-stoning land to extend the command area was thus considered an integral part of the project (Bazzi, 1987). All users of the Bittit springs seemed to gain a part of the water-to-be-saved with lining. After lining the secondary infrastructure and de-stoning of new land, it became clear that the rule of thumb water duty of 0.7 l/s per hectare was not sufficient. Water percolated through the lined infrastructure which was not maintained well enough and the water distribution with orifices in the lined canal went less smoothly than in the earthen canals. As a result, because not all plots could be irrigated, farmers chose which plots they irrigated and which plots they reserved for rain-fed crops.

The use of efficiency terminology suggests that more water is created, which the State could allocate to the drinking water company of Meknes without objection of the Ait Ouallal farmers. If we re-tell the history of allocating the Bittit springs without putting 'efficiency' central, it would become a different story, one about the politics of gaining control over resources. The discharge of the Bittit springs does not change, so it is still the same amount of water that is shared, and over which competition arises. The reference to "losses to be recovered" gives the illusion that this water would otherwise not be used. However, theoretical efficiencies might not be attained in the field and the 'losses' could well be used elsewhere when they flow through the Oued Bittit or recharge the groundwater. The history of allocating the Bittit springs is thus also a story of a state taking control over a communities' water source, which they re-allocate to the parties that matter for them: the city, the politically influential landowners, the downstream community.

3.5 Conclusions

Modernization projects such as canal lining and drip irrigation in Ain Bittit were initiated because of, or resulted in, a transfer of water to other uses and users. In addition, the modernization projects resulted in increased water consumption. Policies that promote a shift to technologies with high theoretical efficiencies entail a promise of water 'to be gained' for the ones that make the effort of introducing efficient irrigation technology. Different actors claim and actually use this water for their purposes, even before the water savings are actually attained.

Improving efficiency suggests that water is 'gained' as previous 'losses' are re-captured. The re-captured 'losses' are treated as if these were new, untapped resources waiting to be used (for the ones that make the effort of avoiding these 'losses'). However, local 'losses' were re-used elsewhere in the basin for instance through the extensive groundwater use in the area and through downstream springs. The improvements in efficiency thus result in limiting the access to water of downstream users. In this line of thought, the implementation of drip irrigation or lining could be explained as a re-allocation of water from one use(r) to the other.

The use of efficiency terminology and the discourse about re-capturing 'losses' gives the impression that the 'saved' water can be separated from the actual water use. However the saved water mixes with the rest of the canal- and groundwater, making it difficult to trace how much water is actually 'saved', and by whom it is used. In the case of drip irrigation, the water savings are not just claimed by one user, but by several users who were involved in implementing drip irrigation. Each of them contributed to the drip irrigation projects: by providing land and labour, by giving subsidies or training. Different parties assume that the saved water is theirs, resulting in multiple claims on – and actual use of - the savings. This, in turn, results in more, rather than less water abstraction. In this way modernization projects are accompanied by an increase in water abstraction at the cost of the aquifer from which more water is pumped.

How efficiently drip irrigation is actually used, or how much water is actually saved at the system or basin level through the efficiency projects is rarely asked: counting on the promises of high efficiencies and thus large water savings is more politically expedient as it allows for (re) allocating more water. In the history of the Ain Bittit irrigation system the introduction of efficient technologies are rarely accompanied with measures about its impacts in the field (neither before nor after the implementation). The promises of high efficiencies of drip irrigation are only based on laboratory-like settings, where all variables are controlled (van der Kooij et al., 2013). It is not accidental that efficiencies of drip irrigation in practice are rarely measured. Besides the difficulties that measuring entails (Lankford, 2013), it is also useful not to measure whether and how much water is 'saved'. The high promise of drip allows for an allocation of 'yet-to-be-saved water' while other users of the same source seem to maintain access to water just as before. The yet-to-be-saved water can be allocated without difficult questions about whether people lose access to water – which would be the case when water would be re-allocated without a technical efficiency intervention. In the case study of Ain Bittit, no-one claims to have lost water because of modernization projects upstream. Besides from the difficulty of measuring, and the strategic aspect of not knowing, questioning modernity and progress is hard. For water users to point at the negative impacts of modernization projects easily results in being blamed for being backwards and wasteful, as opposed to modern and efficient.

Chapter 4

The material of the social: the mutual shaping of institutions by irrigation technology and society in Seguia Khrichfa, Morocco

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Abstract

In this paper we draw attention to the important role technology plays in co-mediating institutions, opening up some courses of action and closing off others. Irrigation studies generally recognize the importance of institutions in making technologies work, but tend to take the precise functioning of institutions for granted. Studies that analyse institutions often do not pay enough attention to the mediating role of technology in allocating benefits, risks and burdens. We show in this paper that (irrigation) institutions are moulded by and come about through the interactions between the technical and the social in dynamic and often contested processes of adaptation to changing environments. We argue that a critical understanding of what institutions do requires more explicit and detailed attention to technologies. We base this argument on a detailed historical analysis of the functioning of Seguia Khrichfa, a farmer managed irrigation scheme in Morocco. Through time, irrigation institutions in the Seguia Khrichfa have undergone transformations to match the changing demands of a heterogeneous and growing group of irrigators, an increased command area and changing cropping patterns, and the introduction of new technologies such as drip irrigation. These institutional transformations consisted of recursive cycles of modifications in technological infrastructure and the rules of allocation and distribution. Technical adaptations prompt alterations in the water rotation schedule and vice versa. We anchor our case in descriptions of a specific technology that played a crucial role in co-steering institutional change: the introduction of open/closed gates. Our analysis of the co-evolution of society and technology in shaping institutions in the Seguia Khrichfa shows how technologies become enrolled in (sometimes implicit) processes of re-negotiating relations of authority and responsibility while obscuring institutional politics.

4.1 Introduction

The first impression one gets when visiting the Seguia Khrichfa irrigation system in Northwest Morocco is that it is a place of tranquillity, tradition and harmony. One sees a well-maintained canal, filled with clear irrigation water (potable, as the water users will proudly add) from the Bittit springs. One may run into one of the canal operators on his bicycle, chatting with farmers waiting for their irrigation turn. When the visit takes place just after the harvest of wheat in June, one sees sheep and goats grazing the wheat stubbles in the fields. It is also the time when some farmers will plant tobacco, standing with their feet in the wetted fields. On adjacent fields, bright green onion plants will be growing and further away one will see fruit trees full with almost-ripe fruits. The Seguia Khrichfa winds through this restful landscape. It has irrigated the fields already for a hundred years or more, as the president of the water users' organisation will explain. The only thing that seems not to fit the rural idyll are the black, plastic drip irrigation pipelines on several fields. Drip irrigation is generally associated with private groundwater wells and high-value crops, rather than with collective surface water systems and family farming. These modern irrigation artefacts therefore appear to belong to a different and more modern agricultural era, one centred on profit-making individuals competing with each other rather than on collaborating farmers who enter into mutual agreements to share available resources among themselves. Yet, both farmers and engineers referred to the introduction of drip irrigation as yet another manifestation of the modernity and success of the Seguia Khrichfa.

This paradox forms the starting point of this paper. We use the technology as an entry point to trace and analyse the functioning of institutions for sharing and managing water. We show that the Seguia Khrichfa is not as stable and harmonious as it may seem at first sight. Rather than a radical break with unchanging traditions, the contemporary changes in Seguia Khrichfa around the introduction of drip irrigation form part of a long historical sequence of sociotechnical modifications. These new technologies were mixed and blended in flexible and seemingly easy ways with old canals and water sharing practices in response to changing conditions. Indeed, the durability and success of Khrichfa appears to lie in its ability to continuously adapt to changing circumstances: variable annual rainfall patterns; varying spring discharges; new crops with new water demands; new irrigators; new technologies.

One important objective of these adaptations precisely is to maintain (an appearance of) harmony and social order and the avoidance of open struggles.

Water users in Khrichfa are a heterogeneous group, comprised of farmers of different ethnic origin, settlement histories and land-tenure status (landowners and sharecroppers). These, combined with differences in the location of one's plots along the canal (head-end or tail-end) and the fact that there is not enough water in the canal to irrigate all land - with only a quarter of the land that can be irrigated with the available canal water - creates a potentially fertile ground for competition and conflict over water. Yet, although each modification in the water distribution entails (sometimes subtle) shifts in relations of power and authority between involved actors, irrigators in Khrichfa rarely directly confront each other in explicit disputes (Abdellaoui, 2009). Instead, and as our study shows, in the Seguia Khrichfa irrigation system, conflicts and struggles are dealt with through frequent interactions, often by encapsulating or absorbing them in continuous social and technical negotiations and adaptations to the system.

We use our analysis for a reflection and discussion on how to understand institutions. We make two points. First, our analysis suggests that institutional rules are not just social, but are also expressed in technologies and infrastructures. Tracing the many changes that the irrigation system went through in the last decades illustrates how institutional changes happened through mutually dependent modifications in technologies and rules. Neither the technical nor the social are fixed, but co-shape each other in recursive and often contested processes of socio-technical re-ordering. Second, following on from the early observations of Geertz (1972) based on his comparison of irrigation institutions in Bali and Morocco, we put forward the suggestion that what institutions are and what they do is intimately linked to the types of distributional dilemmas they have to deal with.

In the next section, we discuss possible ways to understand the relation between resources, social organization and technologies, and propose ways to link these to critical institutionalism. We proceed with a detailed description of a number of key socio-technical changes in Seguia Khrichfa which illustrate that the institutional efforts to maintain cohesion were simultaneously social and material, with new or adjusted technologies prompting new allocation practices which in turn required new forms of discursive legitimacy. We finish with further reflections on how to understand the material of the social in critical institutional analyses: how to capture the role of (changing) technologies in justifying, modifying or 'fixing' relations of authority and responsibility in natural resources management?

4.1.1 Theorizing institutions as sociotechnical systems

Irrigation institutions form, and are formed by relations between different actors. They form an important part of the bundle of arrangements through which the distribution of water is regulated, defining not just whom is entitled to how much water when, but also stipulating who can make these decisions and on what basis (Zwarteveen et al., 2005; Zwarteveen and Boelens, 2014). These institutions comprise formal rules, organisation and authorities but also consist of implicit, less clearly defined norms and rules (Cleaver, 2012). Because they deal with distributional questions, which are inherently contested, irrigation institutions are intrinsically political and often reflect and shape social relations of power between users (Cleaver, 2012; Leach et al., 2010). Explicitly acknowledging the political and contested nature of institutional arrangements draws analytical attention to how institutional frameworks and relations need to be constantly re-confirmed and re-negotiated. Such negotiations can be openly confrontational, but can also consist of more subtle processes consisting of different strategies that are partly bounded by technological and institutional path-dependencies or cultural preferences.

Recognition of the important role of technology in mediating and co-constituting distributional choices in water management is not new. Starting in the 1980s, social studies of irrigation highlighted how social arrangements interact with the physical infrastructure to create particular distributional outcomes. Social scientists drew attention to the importance of 'the social' for explaining what technologies do as part of attempts to change a hitherto predominantly technical irrigation profession. Central to this body of work was an understanding of "irrigation management as a socio-technical process consisting of a technical infrastructure and an institutional framework which determines the use of that infrastructure" (Uphoff, 1986), an understanding which was developed and tested through meticulous studies of farmer managed irrigation systems (Coward, 1980; Pradhan, 1989; Martin and Yoder, 1986; Ostrom, 1992). Likewise, in Morocco, Pascon (1984) insisted on the need for "soft technology" when intervening in the hydraulic infrastructure of farmer managed irrigation systems, in order to have the "least injuries in the social fabric" of the communities concerned. Many social scientists thus 'talked to' engineers, to make them aware of the social and political choices that their designs embodied. Here instead, we want to use insights from the institutional contents of technology to draw attention to the 'material of the social': how are institutions simultaneously social and technical, and how can recognition of the 'also-technical' character of institutions contribute to critical institutionalism (Cleaver, 2012)?

Two schools of thought have provided important sources of inspiration to grasp the simultaneously social and technical character of irrigation and water management (Mollinga, 2003; Bolding, 2004): the Social Construction of Technology school (SCOT) (Winner, 1986; Bijker and Law, 1992) and actor-network approaches (ANT) (Latour, 1987; Law, 1992). The basic premise of both theoretical approaches is that "technologies do not only mediate people's relationships with bio-physical processes, but also shape the social (people-people) relationships that co-structure how resources are controlled" (Mollinga, 2003). Rather than looking for intrinsic characteristics of either the technology or the institutions, scholars working in these traditions direct the attention to the interactions between people and technologies (Bolding, Mollinga, and Zwarteveen, 2000) to explain the durability of systems and the actual water flows and distributions that they produce. More generally for water, a recent stream of mainly geographical scholarship echoes notions of socio-technicality to express that the boundaries between nature, technology and society are never pre-given, but themselves the effect of the hard construction work of the actors involved, and of particular political histories of struggles over water (Swyngedouw, 1999; Bakker, 2010; Mollinga, 2014). Particularly influential are Actor-Network approaches, which treat all elements in a socio-technical network as relational. These are subject to re-ordering and thus 'potential sites of struggle' (Law, 1992, p386). In explaining how heterogeneous networks of human and material elements become patterned, these approaches do not a-priori reserve a shaping role to humans (Law, 1992).

4.2 Methods

One important implication of socio-technical approaches for understanding institutions is that the rules and the organization of rules existing at a particular point in time cannot be taken for granted: they exist through the various networks of which they form part, and require continuous work to re-assert boundaries, relations and rules. Acknowledging this dynamic aspect of socio-technical networks implies that institutions cannot be approached from a single point in time. Instead, the focus shifts to how connections and patterns (re-)order the everyday practices of actors in never-ending processes. Material substances - technologies and infrastructural lay-outs - partly reflect and co-shape (the outcomes of) these processes. Another interesting insight of Actor-Network approaches is that the work that has gone into making a technology tends to disappear once it is working– a process called 'black-boxing': all that remains is a 'matter-of-fact' artefact (Law, 2008, Heeks, 2013). This also means that 'unpacking' the technology (tracing the networks that made it possible and that constitute it) is an important methodological strategy for understanding and making visible the distributional choices that it helps producing (Veldwisch et al., 2009, Heeks, 2013).

We primarily based our investigations on around one hundred semi-structured interviews with water users and managers; repeated observations of water user – canal interactions; and participations in and observations of irrigation management activities during more than one year of intensive fieldwork (2012-2013). A typical semi-structured interview for this research included close observations of, and discussions about, the technology together with the informant. Asking questions about the material traces of other times, for instance, proved a fruitful strategy for invoking vivid memories of the social organization of the past.

4.3 The Seguia Khrichfa Irrigation System

4.3.1 Background

The Seguia Khrichfa is a secondary canal of the Ain Bittit irrigation system, located in the Saiss region (Northwest Morocco). Ain Bititt can be characterised as a farmer managed irrigation system, but it has benefitted from frequent state interventions. The Bittit springs (*Ain* meaning spring in Arab) provide water to five secondary canals, amongst which is the Seguia Khrichfa (figure 6). The Seguia Khrichfa brings water to three small villages (*douars*): Ait Moussi, Ait Amar and Ait Brahim.

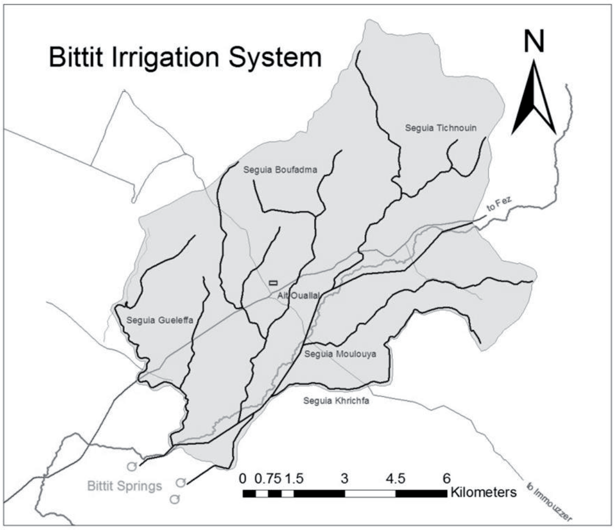

Figure 6. Bittit irrigation system, including the Seguia Khrichfa (secondary canal).

Dealing with change is a major characteristic of the Seguia Khrichfa. The water users are used to variable rainfall patterns (both within the year and over the years), which require adaptations in irrigation applications. Besides climatologic uncertainties, there are many other changes and dynamics that require the Seguia Khrichfa to continuously adapt. The available water in the canal, for instance, fluctuates as it is a proportion of the variable discharge of the springs. Water availability in the canal also depends on how much spring water is used by others. Also, the number of parcels to be irrigated differ each year, requiring creative ways of sharing the available water. In 2013, the total area of Khrichfa that could potentially be irrigated covered 400 hectares. Yet, the canal discharge of ca.100 litres per second only allowed irrigating a quarter of this area. Another major institutional challenge in the Seguia Khrichfa is to accommodate a growing group of water users of changing composition. The number of water users is growing because water users sub-divide water and land among large numbers of heirs and because new people settle in the area. These new people clear land adjacent to the existing command area and hope to be granted access to the water of the canal, thus creating additional demands to an already limited availability of water. The group of irrigators is very heterogeneous in terms of ethnic origins and land tenure status. In addition, crop-preferences continuously change and the water service thus has to accommodate changing cropping patterns. A last important source of change stems from the historically strong relations that exist between the irrigation system and the Moroccan State, resulting in State-sponsored technical interventions that transform the irrigation system, including its technologies, its water distribution and the organisation of water users.

The capacity to continuously adapt to all these changes is perhaps the most important characteristic of the irrigation institutions in Khrichfa. The often-heard answer of Khrichfa water users when asked for the reasons of a particular change, is telling in this regard: "*il faut bouger*", one needs to keep moving. It is clear that changes also redistribute water and power, and that different people strategically manipulate to steer such re-distributions in their favour. Yet, what is remarkable is the near-absence of conflicts or struggles, of open confrontations and clashes. There are many tensions in Khrichfa, for instance about the competition over water (rights) with other water users such as a downstream irrigation community and the drinking water provider of Meknes (who makes use of the same springs), or about the distribution of water between sharecroppers and landowners, who depend on each other for their existence in agriculture. These tensions, however, seldom erupt in the form of open confrontations or struggles. Geertz characterised co-operation around water in the Moroccan irrigation systems he studied as happening in an "agonistic sort of way" (Geertz 1972; p.32): he noted that institutional efforts are geared towards avoiding that the inevitable competition over water leads to exclusions, struggles or open conflicts. However, these rarely come in the open as actively maintaining an appearance of a well-functioning farmer managed irrigation system is very strategic in view of increasing chances of obtaining public projects and support to the area.

4.3.2 Water rights

The history of Seguia Khrichfa is marked by the establishment of water rights to the Bittitt springs, from which it draws its waters. The government administration proportionally divided the rights to the Bittit springs between the city of Meknes (for drinking water) and two ethnic tribes, Ait Ouallal and Ait Ayach during the French Protectorate (Abdellaoui, 2009). The Seguia Khrichfa is a secondary canal that serves part of the Ait Ouallal tribe. Water tenure is governed by a combination of collective and individual rights: at the system and canal levels, the management of the irrigation water is a collective affair of the community. Underneath this collective management, water is also the object of what resembles private 'ownership'. Geertz expressed this ownership as "something which one can possess only as an agency, not as an object, but no less firmly for that" (Geertz, 1972 p.32). All that an individual possesses is not substance, but rather a relationship (in time) with other users (Hammoudi, 1982) where water rights are "confined and limited in a complex system of social relationships" (Mahdi, 1989 p.182). Ownership in the Khrichfa Canal refers to the right to use a certain proportion of the available flow in the canal for a certain time. In operational terms, 'ownership' is the number of hours someone is entitled to irrigate per 'turn'. As the amount of water is not sufficient to irrigate all plots simultaneously, the total water flow is divided in sequential time-slots ('turns'), a rotation schedule that determines which plots are to be irrigated when. Each 'owner' thus gets a number of irrigation turns, and the number of hours determines when and how long he[9] can irrigate per turn. The period between two turns depends on the total number of irrigation hours that the water users collectively own.

In the Seguia Khrichfa, water and land 'are not married' as the expression goes; one can inherit, buy, hire, exchange or borrow water from an owner, independent

9 Throughout the paper, we use masculine terms to refer to farmers or irrigators. This reflects the fact that most people we encountered in the field and in the WUA board, and most of our interviewees, were men. Yet, farming and irrigation crucially depend on the productive and reproductive work of women, and the social domains in which water arrangements happen importantly also happen through the private and family domains associated with women (also see Bossenbroek and Zwarteveen, 2015).

from land ownership. Most water users of Khrichfa own, or work on, several plots located in different places along the canal. They themselves can choose where to use their irrigation hours in the most strategic way. They often do not 'own' enough water to irrigate all their plots, as the total irrigable area of the Khrichfa irrigation system is greater than the discharge that the canal can cover. The fact that water 'ownership' is unrelated to land ownership also implies that it is possible that someone owns water without land. The irrigation schedule is updated and agreed upon at the start of every season, based on the water right transactions of the past season and the location of the plots that right holders wish to irrigate.

The members of the secondary canals of Bittit are organised in Water Users Associations (WUA), which are managed by a board of six elected members and one board member appointed by the State. Created in 1996 in parallel to existing and less formal irrigation institutions (*jmaa)*, the Khrichfa WUA only became really active in 2004 in response to the increased tensions about water distribution. Before that, water right holders would only come together once a year before the start of the irrigation season to discuss the annual irrigation schedule, and entrust water distribution to canal operators (*waqqaf*). Much responsibility and power for everyday water management thus lay with these canal operators as they implemented the water distribution, creatively operating multiple arrangements to deal with change (see Hammoudi, 1982).

4.3.3 Land tenure

During the French Protectorate, the Ait Ouallal pastoralists living in the area received more water than they needed to irrigate their food crops (such as cereals and maize for own consumption). The relative abundance of water attracted settlers from other regions. Most of them entered into sharecropping arrangements with the Ait Ouallal landowners to engage in tobacco production. While the sharecroppers worked the land, the Ait Ouallal landowners identified themselves as pastoralists. Gradually, lands that were situated outside of the original irrigated area were also taken into production by the increasing number of sharecroppers, thus increasing the competition over water. Prevailing sharecropping arrangements stipulated that the landowner provided water and land, while the sharecropper contributed labour. The 'ownership' of water thus stayed with the Ait Ouallal landowners. The owner of water paid the canal operator, which gave the water 'owner' the right to influence the canal operator and discuss and decide about how the water distribution executed by the canal operator should happen.

Sharecroppers had none of these rights, even though they were the actual irrigators and thus had to activate the water rights of the landowner to make use of it. Especially in the village Ait Amar, sharecropping activities appeared successful with plenty opportunity for agricultural extension. The inhabitants of Ait Moussi, located in the head-end of Khrichfa and close to the communal grazing lands, continued with pastoral activities parallel to farming. In Ait Brahim, the tail-end village, land tenure was importantly shaped by the colonial farms, where the farm owners worked with labourers rather than sharecroppers. Nowadays, Ait Amar is the largest village along the Khrichfa Canal, and has the largest number of right holders to Khrichfa water (219 from the total 309 right holders).

Sharecropping can be financially risky for a landowner, and some landowners failed in making enough profits, which obliged them to sell their livestock. While recalling this, Hmidou, a sharecropper in Ait Amar, explained (19-07-2012) with pride the humiliation of an Ait Ouallal landowner who came to his father (the sharecropper) as he needed a sheep to celebrate a marriage. The landowner asked his sharecropper to provide him with a sheep in exchange for a small parcel of land – thus reversing the relation between the two. Other landowners obtained high profits from sharecropping arrangements, which gave them the possibility to send their children to schools and universities in nearby cities. Many of the second generation educated landowners moved to cities, where they often obtained government positions, which they used to channel support and resources back to their native communities. The Ait Ouallal community thus benefitted from many projects, including the introduction or improvement of electricity, schools, infrastructure and irrigation. Sharecroppers attempted to re-negotiate their relation with the absentee landowners by buying small parcels of often marginal land to construct their own houses or produce their own crops. Some also bought water in small quantities (e.g. 15 minutes) to obtain the right to participate in decision-making on canal management and to control the actual water distribution of the canal operator.

The Seguia Khrichfa thus serves a diverse and heterogeneous group of water users. Although tensions exist between the different groups, they do need each other for continuing their agricultural activities or to maintain and materialize their water rights. Here, we show how the dynamic relations between absentee landowners, landless sharecroppers and the three different villages were importantly co-shaped by technological transformations in the Seguia Khrichfa. We do this by telling the story of one specific technology: offtakes with open/closed gates.

We first describe the process that led to the choice for these proportional gates, and analyse what this choice entailed in terms of institutional modalities for distributing, accessing and controlling water.

4.4 Offtakes with open/closed gates: control over proportional water distribution

4.4.1 Rehabilitation of the Ain Bittit irrigation infrastructure

In the early 1970's, the agricultural ministry selected Ain Bittit for a World Bank financed rehabilitation project (Bazzi, 1987). It may have been chosen for technical support because it was already known by the agricultural ministry as it shared the spring water with the drinking water provider of Meknes, and because several Ait Ouallal landowners worked for the State. The project, implemented in 1983, consisted of the lining of the earthen secondary canals of the irrigation system. The engineer who designed the lined canals based his calculations on the 1949 water allocation as registered during the French Protectorate: each secondary canal was entitled to a certain proportion of the total spring discharge, expressed in shares[10]. The size of one share was based on an engineering rule of thumb, the 'main d'eau': the flow of water that one farmer can handle, 20-30 litres per second. The number of shares per secondary canal depended on the total number of 'owners' along the canal. The Seguia Khrichfa received three shares, in theory enabling three farmers to irrigate at the same time. However, due to ever-increasing numbers of water users, who gradually extended the canal's command area, there was more and more pressure on the available water. As a consequence, the duration of the interval between two water turns increased to sometimes more than 14 days. This led to disputes among farmers about the appropriate interval between two turns, disputes that originated in a lack of clarity about the number of people that were entitled to a share of the Seguia Khrichfa water. For example, had the appropriators of the previously French farms in Ait Brahim also obtained the water rights of the French land owner, or should these water rights instead be returned to the villagers of Ait Brahim, from whom the French had taken the rights in the first place?

10 The Arabic word used to express a share of water is fez, which means hoe. This refers to the discharge that one farmer can guide through the fields with a hoe when he irrigates. In Bittit, farmers use this word to express a certain proportional share of the total available water. For the sake of readability and ease of understanding, here we will use the word share.

4.4.2 Off-takes with circular orifices: calculated but un-transparent water distribution

The offtakes that the engineer designed as part of the rehabilitation project were gate-controlled circular orifices. These orifices consist of circular openings in the canal wall that can be opened or closed. The discharge that flows through the orifice is related to the difference in water height upstream and downstream of the opening (figure 7). According to the engineer's calculations, if three farmers would open these orifices at the same time at their respective offtakes, they would each receive 20-30 l/s (the precise amount depending on the actual discharge of the springs), equivalent to the calculated 'main d'eau'. If more farmers would open their gates simultaneously (which was not the intention of the engineer), the water height in the canal would reduce, thereby lowering the off-taking discharge flowing through each orifice (figure 8).

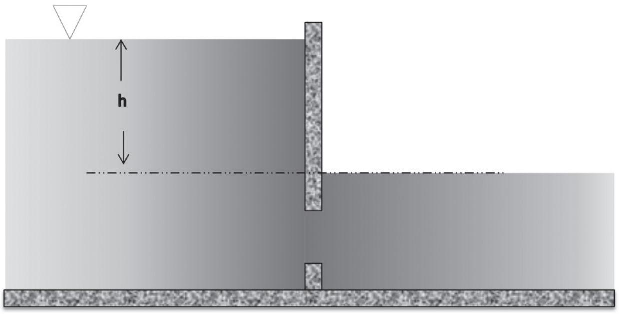

Figure 7. Side view of an orifice. The discharge passing through the orifice is a function of the height of the water above the downstream water height (h).

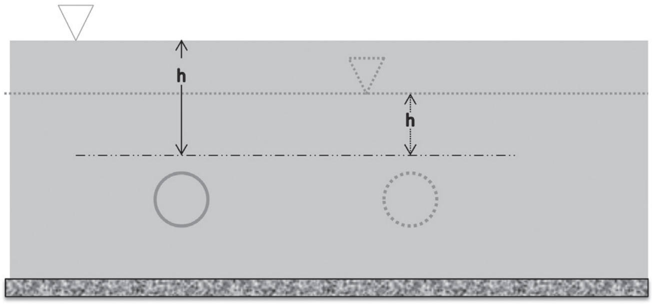

Figure 8. When an additional orifice is opened, the water height will lower (dotted lines), thus resulting in a lower discharge through each orifice.

These new gated orifices had important implications for how disputes over the sharing of water played out. As the orifices were located in the canal wall below the water line, they were invisible, making it possible for irrigators to tinker with their gates without being easily found out by others. In principle, only the canal operator had the power to control the use of the orifices, as he was in charge to guide the water from one water user to another and to distribute it in three equal shares. However, it was impossible for him to simultaneously control all the orifices along the whole length (7 km) of the canal. Some water users made use of the invisibility of the offtakes by secretly enlarging their orifice to create a higher discharge. At some places, farmers created their own, new offtakes by making openings in the canal wall. Over time, some orifices could not be properly closed anymore, resulting in water continuously flowing through these openings when there was water in the canal. Together, all the 'leakages', informal offtakes and increased discharges in offtakes in the upstream part resulted in a severely reduced availability of water for the downstream water users, located at the end of the canal. Some farmers remedied this by blocking the canal downstream of their offtake, increasing the water height at the offtake and thus the amount of water received. All this tinkering with the offtakes also led to a gradual deterioration of the infrastructure. An MSc thesis in 1987 thus concludes: "The hydro-agricultural infrastructure of the Bittit irrigation system, constructed in 1983, is in a deteriorated state. The lined canals are broken, the off-takes are destroyed and the gates are lost." (Bazzi 1987).
In sum, the orifices that were designed to allow three simultaneously irrigating water users to receive a similar discharge, literally reduced the transparency of water distribution in the Seguia Khrichfa. This made it relatively easy for upstream users to take more water than their entitlement. As the current president of the WUA concludes when recounting this episode of the Khrichfa history:

"*The holes (referring to the orifices), it isn't logical, it is not logical when working with shares. Maybe some-one takes more than his right.*" (9-10-2013)

4.4.3 Open/closed gates: making the proportionality visible again
In 1992, the Regional Directorate of Hydraulics proposed a solution to the water distribution problems in the canal, by suggesting the installation of three open/closed gates after each offtake, and removing all the orifices. From now on, these simple offtakes had gates that were either completely open or completely closed, hence the name: 'Tout Ou Rien' (T.O.R.), 'all or nothing' gates. All intakes - a total of fifty intakes in the main canal and in the major secondary canals – were replaced by new division boxes with four T.O.R. gates each. In contrast to the

hidden orifices, the T.O.R. gates made the proportional division of water in three shares (again) clearly visible to users, with the water flow visibly divided in three equal shares. The system was relatively straightforward and easy to operate (figure 9)

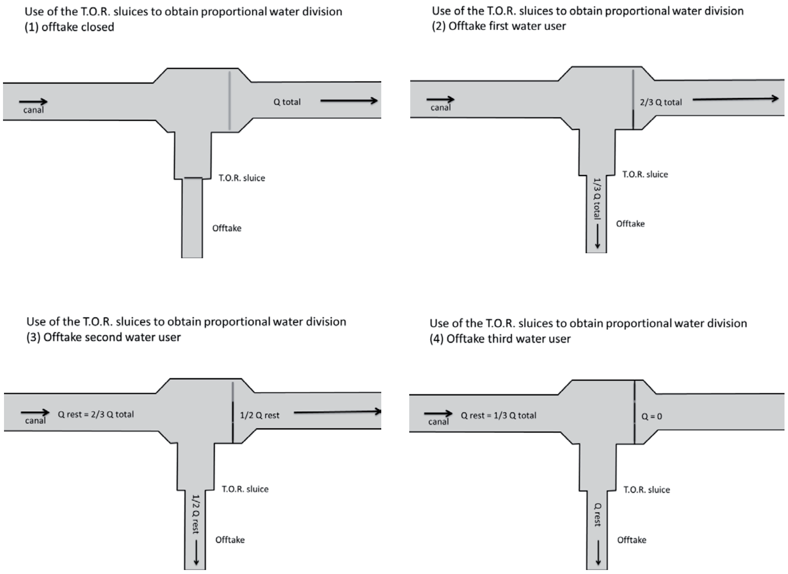

Figure 9. Use of the T.O.R. gates to obtain a proportional water division (starting in the upper-left corner, clockwise): 1) offtake of a water user who does not irrigate; 2) offtake of the most upstream irrigating water user; 3) offtake of the second irrigating water user; 4) offtake of the most downstream irrigating water user.

The T.O.R. gates made the water distribution transparent and less sensitive to tampering. At any point in time, visual inspection of how water is divided was possible. This allowed irrigators to hold each other accountable for when and how much they irrigated. Although the canal operator was still needed to indicate when a water users' turn would start and end, the T.O.R. gates prompted farmers to monitor water distribution themselves. Irrigators, especially from the tail-end villages, often irrigated with two family members: while one was irrigating, the other would monitor the canal to make sure no other farmer was taking water out of turn. The technology thus prompted a decentralization of the control over water distribution (from just the canal operator to all water users), by allowing irrigators to themselves check if water division happened according to the agreed rotation schedule.

The increased transparency of water division also made it possible to make changes to the rotation schedule: it was no longer necessary for farmers with neighbouring fields to irrigate simultaneously (which was the case at the time of the circular orifices, with the canal operator having to keep an eye on the open offtakes), but turns could be distributed to any potential field along the canal. In 1996, some farmers started to make creative use of this possibility, as they wanted to shift from tobacco cultivation to onion production.

4.4.4 Exchanging water turns

In the beginning of the 1990's, onion cultivation became a profitable activity in the Saiss as market prices for onions were high. Farmers along the Khrichfa Canal, however, were frustrated in their desire to grow onions by the rotational schedule of the irrigation system: the water turn of 14 days was too long for onions, which need to be irrigated every three to four days. The creative solution of a few youngsters was to exchange irrigation hours amongst themselves. To irrigate with shorter intervals, they irrigated one week with half of their own water turn while someone else irrigated further downstream with the other half of their water turn. The next week, they could then irrigate with half of the water turn of the other water user who would have his turn by then, while using the remaining half of the water themselves (figure 10). Hucine, who often travelled to regions where he saw onion cultivation, claims that he and his sharecropper first started this idea:

"I proposed to the sharecropper on my land: isn't it possible to divide the number of hours by two, and use one part this week and the other part next week?" (26-09-2013)

Others noticed their success, until

"Little by little, farmers did the same thing, till the idea reigned in the region" (26-09-2013)

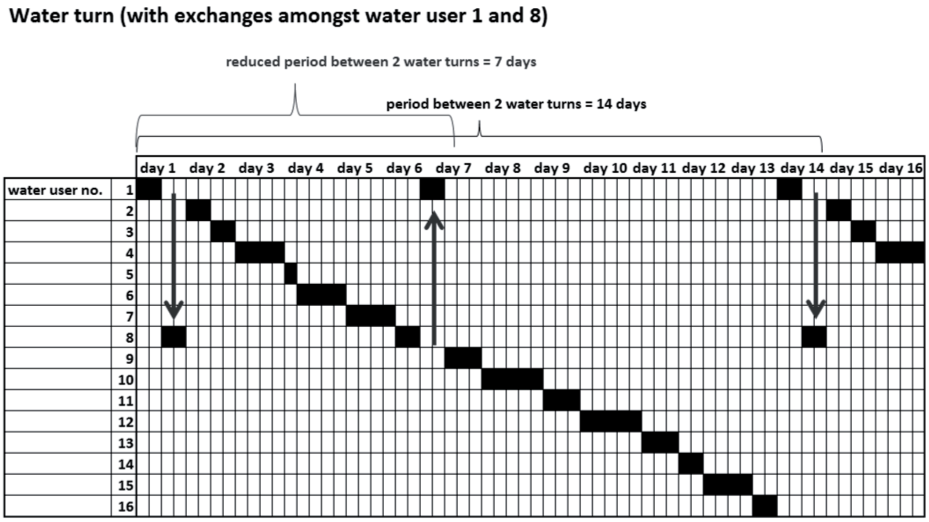

Figure 10. The exchanges of water at the Khrichfa Canal: water user 1 irrigates with half of his irrigation hours, then gives the remaining water to water user 8. After irrigating, water user 8 gives the water turn to the downstream neighbour of water user 1, thus water user 2.

Exchanging water was made possible because of the T.O.R. gates, as these enabled splitting the water turns amongst plots that are located far away from each other. From 1996 till 2004, more and more farmers started cultivating onions and exchanging water. However, for water users with a short water turn (many of whom were sharecroppers) – for example half an hour –it was not possible to engage in these water exchanges, as it would make their already short turns too short to manage. Also farmers in the tail-end village Ait Brahim, where the discharge in the canal was considerably lower and who had less contact with other users along the Khrichfa Canal, did not join the exchange system. Thus, T.O.R. gates enabled some water users to participate in the beneficial exchange of water turns, but not others.

4.4.5 A water rotation of seven days for all

The unequal possibilities for exchanging water turns were not the only source of tension along the canal. Also other inequalities caused frictions, e.g. between head-end and tail-end or between landowners and sharecroppers. These frictions led to disputes, and complaints to the local and provincial authorities. These finally prompted an institutional adaptation, consisting of the revival of the WUA in 2004. The WUA had officially been created in 1996 by the State, but it had never been an important body for decision making as water users continued to rely on existing forms of organization with the canal operator for water distribution. The revival of the WUA happened with the help of the *caid*, the local authority. In order to ease the tensions in the community, the *caid* enforced a voting system for *all* water users (and not just for water right holders) during the general assembly. The water users strategically proposed board members and lobbied for votes so that all interest groups would be represented. This resulted in the appointment of a retired technician from the agricultural extension service (originating from the group of Ait Ouallal landowners) as president of the WUA; the appointment of two sharecroppers (one of them had been canal operator, the other was part of the largest sharecropping family) and a newly installed investor with political connections as the other members of the board. The water users had high expectations that this new board would help solve the existing problems and tensions. Especially the new president was mentioned by many water users as a key person in the new board. He represented different user groups, as he was born in Ait Amar, while his mother originated from Ait Brahim. During his work for the agricultural extension service he used to advise the Khrichfa water users about tobacco, onion and potato cultivation, and after retirement he still continued to provide advice to farmers. If offered the chance, he enjoys recalling the history of the irrigation system – to us as researchers but also to youngsters in the Khrichfa area.

One of the first changes the new board made was to reduce the water turn from fourteen days to seven days for all water users. In addition, instead of giving the water turn to three neighbouring farmers, the new board members decided to divide the irrigation system in three sectors, each irrigating with 1/3 of the total canal discharge (i.e. 20-30 l/s) with a rotational schedule per sector. The objective was to make onion farming possible for all and to reduce the disparity in discharge between head-end and tail-end. The board of the WUA also changed the relation between water users and the canal operator by using the official regulations for water users associations, which stipulate that water users pay the WUA, who in turn pays the canal operator. Before, the water users directly paid the canal operator. Through this change, the WUA increased its own power as an intermediate body with the financial means and authority on water allocation and distribution. The new board of the WUA also decided to employ three canal operators instead of one, so that each of them could distribute one share of the total discharge within one sector of the Seguia Khrichfa. This reduced the area of influence per canal operator.

4.5 New modalities of water access through creative integration of groundwater and T.O.R. gates

The changes of the intake structures co-evolved with changes that shifted the control over water shares and their distribution from the canal operator to the WUA. The T.O.R. gates decentralized the control over water, and thus made the position of the canal operators weaker. The WUA board made use of these changing relations, and they justified their authority by referring to the national code for WUAs which stipulates that WUAs should assign, and pay for, canal operators. Material changes thus triggered changes within the socio-technical network, creating possibilities for some actors to draw new elements into the network and making their position stronger.

Other technological modifications followed the T.O.R. gates. In 1997, a rehabilitation project installed a collective tube-well, which created new modalities of accessing water. This project was the result of the successful lobby of the president of the Ait Ouallal community with the government for a new irrigation rehabilitation project. The project consisted of the equipment of several existing boreholes (once drilled to measure the groundwater level) with pumps. These pumps added groundwater to the secondary canals, thus increasing the water availability. For the Seguia Khrichfa, this created the challenge to combine the existing rotational water supply with an on-demand water source. Through recursive material and regulatory changes, the WUA board made the tube-well fit with the existing seguia system: they increased the height of the canal walls, and proposed a different way of counting the number of shares. While in the past, they counted only three shares, corresponding to the three T.O.R. gates of the main canal, the fourth T.O.R. gate of the off-take was now counted as well. Thus, when all four gates were opened, the canal water would be divided in four shares. The basic idea of the T.O.R. gates remained the same: the water division was proportional and visible to all. This cosmetic increase in the number of shares allowed the tube-well water to be used with the existing technology and within the existing logic of the system.

The tube-well created affordable, low-risk possibilities for accessing water, which was particularly beneficial for sharecroppers and irrigators in the tail end as they did not have, or only had few, water rights of their own. Yet, it also created its own, new set of questions: who should or should not be allowed to benefit from the tube-well and the Khrichfa Canal waters? The WUA tried to set clear rules. First, it changed the demand procedure for renting out tube-well water: only right holders (who already owned a water turn) were allowed to make a request to rent in additional water. This, however, did not stop several sharecroppers who did not own water themselves to also use tube-well water: they just asked a befriended right holder to make a request on their behalf when they were in need of water. In 2013, the WUA decided to make the tube-well share a part of the existing shares in the rotational schedule, thus making it impossible for non-right holders to get tube-well water.

The hiring out the tube-well water also implied that the WUA board became gradually involved in the sale of water, gaining legitimacy for making money from water deals. Through its water deals, the WUA board increased its income, thereby also strengthening its financial sustainability and asserting increased authority in the management of the irrigation system. Inspired by its new and stronger position, the WUA board also started exploring other ways to financially benefit from the canal water. Drawing on efficiency arguments, the WUA board decided to split the canal water in five shares instead of four, which allowed them to reduce the period between water turns (which was beneficial for onion farming) and which allowed the WUA board to rent out additional water. This change was possible because the old division boxes with 4 T.O.R. gates had been replaced with division boxes with 5 T.O.R. gates. The division boxes divided the water in the right amount of shares and still allowed the irrigators to use the water anywhere along the canal and to visually verify the water distribution.

Not only did the introduction of the collective tube-well strengthen the position of the WUA, it also created new modalities of accessing water. This particularly suited certain water users: sharecroppers who longed for loosening their ties with landowners started renting small parcels, where they began cultivating onions with tube-well water. As the cropping season of onions is short, they only asked a few hours from the tube-well to satisfy their needs. This was much cheaper than buying or hiring surface water rights. In this way, the collective tube-well thus changes relations between some sharecroppers and landowners.

4.6 Drip irrigation sets the irrigation system once again in motion

The new modalities of water access (both tube-well water and the additional water from the WUA) significantly increased the water security of some sharecroppers. In 2004 one of them - Hmidou - decided to install drip irrigation on his field. Previously, he could not irrigate this field as it was located above the canal. However, thanks to the pressurized drip irrigation system, and a small basin to store canal water, the water could reach Hmidou's plot, allowing him to make it suitable for onion cultivation. Others followed Hmidou's example, and in 2013 four individual farmers and a family cooperative of 30 members thus used drip irrigation systems using canal water. This in turn triggered the WUA to think about the introduction of drip irrigation on a collective basis: another technological change that would go accompanied with changes in the social organization of the irrigation system.

The new drip irrigation projects start to set in motion changes in the irrigation system. Rain-fed land uphill is now becoming more and more attractive as it can be irrigated with pressurized drip irrigation systems, while it is cheaper than irrigated land. These lands are also still fertile as compared to the exhausted plots in the irrigation system. In addition, these plots have not been subject to consecutive divisions because of inheritance and are thus larger than the plots within the irrigation system. This shifting valuation of hitherto rain-fed lands also creates shifts in social hierarchies: suddenly the owners of 'unproductive land' have 'land with potential'. Sharecroppers who had started to buy cheap, 'unproductive' land from the 1990 onwards, now suddenly find themselves in a new, advantageous position. The introduction of drip irrigation projects in Khrichfa goes accompanied with yet another round of changes in water allocation: drip irrigation needs a higher irrigation frequency and it can potentially 'save' water. To obtain this higher frequency, the drip irrigation owners have constructed basins to store water for some days. In addition, they use a similar trick as they did fifteen years ago to create an irrigation frequency that fitted onion farming: they exchange water turns.

Drip irrigation is known – and promoted as – an efficient irrigation technology: it allows irrigators to irrigate the same plot with the same crop using less water (van der Kooij et al., 2013). This thus 'saves' water, which the water user could potentially use elsewhere. The saved water can be used by the same owner to irrigate other crops with a higher water demand on the same field, or to irrigate new or expanded fields. Because of the profitability of drip irrigation on previously rain-fed fields, the owners of the drip irrigation projects in Khrichfa have all bought or hired more irrigation hours to serve their drip projects, thus putting higher pressure on the Seguia Khrichfa. Yet, the image that drip irrigation 'saves' water is pertinent, and creates discussions amongst irrigators: if Khrichfa will get drip irrigation on a collective basis, where will the 'saved' water go? Some speculate about a re-allocation of water within the irrigation system (for example, saved water might be used to irrigate all the rain-fed land above the canal, or it could make the cultivation of fruit trees over the whole irrigation system possible). Others are more cautious and pessimistic, and wonder whether the 'saved' water will stay with the Khrichfa irrigators, or whether it will prompt a re-allocation at basin level. As the episodes of the T.O.R. gates and the tube-well have shown, the introduction of the new technology may indeed generate unpredictable outcomes, re-patterning the water allocation of the Seguia Khrichfa, creating new contestations or injustices.

4.7 Discussion and Conclusion

Our research was triggered by curiosity about the presence of modern drip irrigation technologies in a traditional farmer-managed surface irrigation system. In our attempt to understand this unusual blend of tradition and modernity, we engaged in a socio-technical historical analysis. We aimed at tracing and explaining how Seguia Khrichfa deals and has dealt with ever-changing distributional dilemmas and choices. Our analysis suggests that an important explanation for the durability of the Seguia Khrichfa lies in its adaptive capacity. The history of the irrigation system as told here is a story of how institutions are "patched and pieced together" (Cleaver, 2012); a story of institutional bricolage, consisting of repeated ad-hoc adjustments that draw on existing and new forms of social organisation and material infrastructure. It is also a story of changing power relations, in which a heterogeneous and changing group of players continuously renegotiate their respective access to water, as part of and reflecting wider changes in social configurations of mutual dependency.

In spite of the increased competition over water, there are remarkably few instances of open struggle over how water is distributed in Khrichfa. Rather than open or violent confrontations, tensions and conflicts are subtly dealt with through almost continuous revisions and re-negotiations about how water is distributed. The importance of negotiations perhaps explains why the most open struggle in the history of Khrichfa was about the right of sharecroppers to take part in them, through votes in WUA meetings. In Khrichfa both availabilities and demands for water are variable and ever-changing as a result of a complex combination of natural, technological and social factors. As a result, the nature of the distributional dilemmas and tensions to be solved also continuously changes. Our analysis shows how technology plays an important role in co-defining both the contents of the distributional questions as well as the types of possible solutions proposed. For instance, the orifices installed during the first rehabilitation project implied a specific way of arranging water distribution through calculated discharges. Many irrigators did not agree with the unverifiable water distribution of the orifices, and tinkered with the offtakes. Likewise, the installation of the T.O.R. gates set in motion a gradual shift in the locus of control from the canal operator to the WUA board. New technologies also evoked new ways of talking about water distribution; drip irrigation for instance comes with a discourse of efficiency, re-framing distribution as partly a question of the avoidance of losses and waste. The need to pipe the water for drip irrigation will also provoke another shift in possibilities for monitoring water flows, and is thus prompting new discussions about distributions of water and authority in the Seguia Khrichfa. Drip irrigation also (again) provokes discussions about whom to in- and exclude in the group of legitimate water users of Khrichfa, as drip irrigation makes it possible to irrigate new parcels of land.

Our analysis shows that technological re-configurations and translations may offer elegant and implicit ways of reconciling diverging and sometimes conflicting interests and goals, something that neatly suits the 'agonistic cooperation' character of Moroccan irrigation institutions noted by Geertz (1972). Rather than openly articulating and addressing tensions and conflicts in formal spaces for deliberation, proposing new technologies, or enrolling old technologies into new configurations, allows actors to enforce changes in the irrigation system and its management without harming the precarious balance of cooperation and without anyone losing face. In Khrichfa, technological transformations thus serve to conceal or resolve contentious negotiations, altering social relations and agency in non-conspicuous and implicit ways. This potential capacity of technologies for hiding politics, however, is not something that is intrinsic to the technology but the result of the specific socio-cultural relations in which the technology is embedded. In other contexts, rather than helping to hide and solve tensions, technologies may become the (symbolic) representation of differences of interests and conflicts.

To draw attention to how institutions are often also technical, we have shown how technology mediates social relations in dynamic and interactive ways. A critical understanding of institutions, therefore, requires opening the black-box of technologies. This goes beyond merely stating that the physical matters (Cleaver, 2012), or acknowledging how technologies work. It instead entails acknowledging that technical modifications, innovations and tinkering form an intrinsic part of processes of institutional bricolage. Institutions are continuously evolving socio-technical networks, in which all elements are relational and are thus subject to re-ordering. Here it is important to realize that what technologies do is not necessarily the intended effect of wilful human strategies, but may be an unanticipated effect that emerges once they are combined with other human and non-human elements in networks.

The material of the social: the mutual shaping of institutions by irrigation technology and society in Seguia Khrichfa, Morocco

Chapter 5

A user-based conceptualization of irrigation performance: drip irrigation in the Khrichfa area, Morocco.

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van der Kooij, S. M. Kuper, M. Zwarteveen, C. de Fraiture.

Abstract

Conventional drip irrigation performance assessments based on irrigation efficiency indicators are normatively prescriptive in assuming that drip irrigation technologies should do what they are designed to do, i.e. improve efficiencies. While helpful in identifying gaps between actual and potential performance outcomes, such assessments do little to explain why and how different people use drip irrigation. In trying to understand why irrigators in the farmer managed Khrichfa Canal in Morocco engage with drip irrigation, we found that drip irrigation does much more than improving efficiencies: it helps in creating new and modern farming identities and forging new alliances, most notably between the irrigators and the State. To allow acknowledging that irrigation technologies may do more than what they are designed for, we suggest a process-based definition of performance as emerging through its interactions with actors, discourses and practices.

5.1 Introduction

Drip irrigation is typically promoted within policy documents and scientific literature for its capacity to bring precise amounts of water to plants; as a tool to help using available water more efficiently and increase productivities (for example, Gleick, 2002; Buyukcangaz et al., 2007; OECD, 2010). When assessed in irrigation-engineering terms, the performance of drip irrigation is thus normally measured based on how uniformly it applies water to the entire plot and on how efficiently it applies water to the root zone of the plant (Bielorai, 1982; Burt et al., 1997; Kang et al., 2001; Du et al., 2008). We use this article to present a case – that of the Khrichfa Canal, a farmer-managed irrigation system in Morocco - in which such a conventional performance assessment based on irrigation efficiency does little to explain why and how users engage and deal with drip irrigation.

Most of the water users of the Khrichfa Canal are not very interested in what drip irrigation exactly does in terms of water use. What they expect drip irrigation to do also changes over time. In Khrichfa, several individual farmers as well as a collective of 30 family members were the first to install drip irrigation in the Khrichfa area. Inspired by their enthusiasm for the technology, in 2012 the Water Users Association (WUA) of Khrichfa started to lobby the government to finance a collective drip irrigation project for all Khrichfa water users. Their aim was to convert the entire canal irrigation infrastructure to drip irrigation. The board of the WUA took the initiative to meet with representatives of the State and organised discussions with farmers and engineers to discuss funding possibilities and design the contours of this collective drip irrigation project. However, in 2015 and after several years of active planning and lobbying, the initial enthusiasm of the water users seemed to have waned. Instead of drip irrigation, the president of the WUA now focused his energies on the installation of a solar pump in the context of recent government initiatives on subsidizing renewable energy.

A conventional definition of drip irrigation performance in terms of its water-efficiency enhancing characteristics is clearly insufficient to explain and make sense of the experiences with drip irrigation in Khrichfa. In this article, we therefore use our analysis of what drip irrigation does with and for its users to propose and discuss a different way of defining and assessing the performance of drip irrigation, one that allows accounting for the other expectations that are or become attached to the technology. To do this, we make use of actor-network theories that help acknowledge that how a technology performs is not just a function of its intrinsic characteristics, but the result of how it relates and interacts with its context - other technologies, resources, people and discourses (Latour, 2005; Jansen and Vellema, 2011). Jansen and Vellema illustrate this point by explaining that an axe handled by a forester in a forest is something else than an axe handled by a confused lover. This also means that the particular goal with which a user employs a technology importantly shapes its working.

Different from conventional irrigation performance assessments, this definition of performance does not assume that the objectives that a technology is supposed to fulfil are independent of its use-context, 'built-in' as it were. For example, assessing the performance of drip irrigation in terms of efficiency predefines it as a device to save water. In line with actor-network definitions of technology, we instead propose to conceptualise the performance of drip irrigation as emerging in particular use practices, in the interactions between the user(s), the technology and the wider context. As these interactions can change over time, the performance of drip irrigation can also change depending on when it is assessed: it is a process rather than a stable end-product (Callon, 1986; Law, 1992).

Our re-conceptualization of drip irrigation performance has relevance beyond the specific case of Khrichfa. For one, it suggests that the mere presence of, or interest in, drip irrigation cannot be just interpreted as representing efforts to use water more efficiently or to produce more. Drip irrigation does much more, and sometimes many other things, than saving water and increasing productivities. Secondly, one could say that this capacity of drip to 'do more' than saving water is also somehow reflected in the wider water management and irrigation literature, including in this journal. Drip irrigation has come to be associated with a wide range of objectives: it is promoted as a pro-poor solution to help feeding the rural population (Postel et al., 2001; Pasternak et al., 2006); it is advertised as a technology that allows to irrigate safely with polluted water (Karg and Drechsel, 2011; Wichelns et al., 2011); it is a tool to save energy resources (Siddiqi and Wescoat Jr, 2013); a device to overcome drought periods in times of climate change (Burney et al., 2010); a technology to make rural areas attractive (Shah, 2001); and the introduction of drip irrigation is also proposed to counter groundwater overexploitation (Narayanamoorthy, 2010). To assess whether these expectations are met calls for a more encompassing definition of performance. Indeed, the many positive expectations that surround drip irrigation are themselves performative in having made drip irrigation into something that confers modernity and progressiveness onto those who associate with it.

5.2 Methods

The first author carried out fieldwork in the Khrichfa Canal during the irrigation season of 2012 and 2013. To understand how people engaged with drip irrigation, she combined field observations (including observations of the drip irrigation technology and of irrigation practices) with repeated interviews with 15 drip irrigation users of the Khrichfa Canal or close to the canal. She closely followed the process of planning and strategizing the collective drip irrigation project by continuously remaining in contact with the WUA board; by attending WUA board meetings; and by being present during negotiations between the WUA board members and water users. She also interviewed (ex-) government officials and engineers from the regional and provincial department of agriculture about their experiences with the Khrichfa water users and their perception towards the collective drip irrigation project. In total this research is based on around 100 semi-structured interviews.

5.3 Case study Khrichfa Canal

5.3.1 Drip irrigation in Morocco

The Moroccan government adopted the Green Morocco Plan in 2008 to stimulate agricultural growth and modernize Moroccan agriculture. The Green Morocco Plan consists of two main pillars. The first aims to increase productivities by stimulating large-scale, entrepreneurial and expert-oriented farmers to cultivate high-value crops (Akesbi, 2012), whereas the second is to support smallholders in marginal areas.

In the framework of the National Irrigation Water Saving Program (which was included in the Green Morocco Plan), the Moroccan government subsidizes drip irrigation, covering between 80 to 100 percent of the hardware costs. The National Irrigation Water Saving Program aims to convert 550.000 hectares to drip irrigation in the period from 2007 to 2022 (Belghiti, 2009). Large-scale farmers with more than 5 hectares can apply on an individual basis for the 80% subsidy and small-scale farmers with less than five hectares and farmers united in groups can apply for subsidies of 100%.

5.3.2 The Khrichfa Canal

The Khrichfa Canal is a secondary canal of the Ain Bittit irrigation system, a farmer managed irrigation system, which falls in the Moroccan category of small and medium size irrigation systems. Ain Bittit (Ain means spring in Arab) is a group of karstic springs that provide irrigation water to two rural communities and drinking water to the city of Meknes. The Khrichfa Canal lies close to the foot of the Moyen Atlas Mountains. Crops cultivated are vegetables (onions and potatoes); fruits (apples, prunes, grapes); tobacco and cereals. The Khrichfa Canal is seven kilometres long and its command area covers 400 hectares.

In recent years, several farmers in Khrichfa have installed drip irrigation individually or collectively (with a small group of farmers) either with or without government support. When doing field research, we encountered 15 drip irrigation projects in the area.

5.4 Performances of drip irrigation

In trying to understand why different people became interested in drip irrigation in Khrichfa, we discovered that drip irrigation performs in many ways, and that for each actor it does something else. Here, we discuss three performances of drip irrigation that were particularly remarkable as well as widespread. First, drip irrigation supports, and is part of, a move towards 'cleaner' agriculture; second, drip irrigation is part of the emancipation efforts of sharecroppers; and third, drip irrigation enables to link Khrichfa irrigators with the State.

5.4.1 Performance 1: Drip irrigation makes farming clean and modern

The first performance of drip irrigation that we discuss here is that of a 'modernizer' of agriculture, and by ricochet that of a modernizer of the image and self-perception of farmers involved with drip irrigation. For Khrichfa farmers, drip irrigation is a clear marker of modernity, something that partly stems from how the Moroccan Government and its Green Morocco Plan promote the technology, associating it with new and more entrepreneurial ways of farming.

The image of modernity, however, also stems from how drip irrigation makes the jobs of irrigating and farming cleaner and easier. To irrigate, the farmer only has to open the valve, make a walk around his plot to check whether all emitters work properly, and then close the valve again. In the words of an engineer of the Provincial Department of Agriculture: "with drip irrigation we will relieve the poor farmer, surface irrigation is hard!" (pers.com. 12-06-2012). Drip irrigation is not only easier in that it requires less hard work, it also keeps the irrigator and his clothes literally cleaner than surface irrigation.

Also in more symbolic ways, drip plays a role in transforming agriculture into a cleaner profession. This has to do with the shift in crops that drip irrigation facilitated. In Khrichfa, the process of fitting drip irrigation in the farmer-managed gravity irrigation system started with the introduction of onions. From

2000 onwards, farmers in Khrichfa exponentially expanded the production of onions, an expansion that accompanied the introduction of drip irrigation (Lejars and Courilleau 2014). Khrichfa farmers think of onions as a positive, clean and modern crop, even more when it is irrigated with drip irrigation. The cleanliness of onions starkly contrasts to the filth of tobacco, the crop that used to dominate the area before onions were grown.

The remark of Abdellah – himself a proud owner of a drip irrigation project with which he cultivates onions - when he saw a picture of his nephew standing in a tobacco field is telling for how tobacco symbolizes the dirty past: "*Meskin* (the poor one), with his hoe (representing surface irrigation) and his tobacco…". Tobacco is disliked and considered dirty in at least three ways. First, tobacco has negative cultural and religious connotations. It is not just *haram* (forbidden), but – and as government campaigns have made very clear - tobacco smoking also creates health problems. Secondly, the drying of tobacco leaves is a laborious and not much-liked activity, often executed by children. While lacing the tobacco leaves, sticky juice oozes from the leaves, staining one's hands. And finally, tobacco production creates an unwanted dependency on the tobacco cooperative. The tobacco cooperative offers a fixed price for tobacco, which is the reason that many engage in tobacco production as it offers a form of security. However, many youngsters are not keen to depend on the cooperative for their incomes and survival.

For them, the production of onions appeared to offer a neat and attractive alternative. Because onions are a prominent part of the national dish *tajine*, growing them makes cultivators proudly feel they are helping meet the country's food needs. In addition, market prices of onions in the early 2000s were very high, making onion cultivation into an entrepreneurial and thus exciting business. Moving into onion cultivation, and even more when irrigating this new commercial crop with drip irrigation, thus created an opportunity for youngsters to positively distinguish and emancipate themselves from their fathers and the old farming style (Quarouch et al., 2014, p.162). Yet, to be able to grow onions - which need to be irrigated once every two days during peak demand to get an optimal yield - with surface water (most onion cultivators in the region use groundwater), the Khrichfa water users had to adapt their rotational water distribution (which provides water every 5 to 7 days). They did this by smartly increasing the irrigation frequency and by installing small reservoirs (van der Kooij et al., 2015) that made their access to water less dependent on what happened in the rest of the irrigation system. The introduction of drip irrigation was a further innovation that contributed to making the growing of onions possible. Farmers explained how drip irrigation also allowed them to increase cropping intensities, as no space is needed for the furrows. In addition, the possibility that drip irrigation provides to mix fertilizers into the irrigation water (fertigation) is attractive, as it improves yields. When taken together, these changes – in crops, technologies, cultivation methods – allow young farmers to position themselves as cleaner, more modern and entrepreneurial farmers than their fathers.

Appearances can be misleading, though. Although new crops and technologies allow realizing quick and large profits when market prices are high, new forms of irrigating and farming are also much more risky. Onion prices fluctuate due to volatile markets, whereas the input costs for cultivating onions with drip irrigation are high (in terms of seeds, fertilizer, pumping costs, etc.). As a matter of fact, the dramatic decline in market prices for onions since 2012 (Lejars and Courilleau, 2014) obliged some farmers to 'go back to tobacco'.

Young farmers in Khrichfa closely associate onions with drip irrigation, seeing both as markers of a cleaner and more modern form of agriculture. Yet, these associations are largely symbolic, as there is no intrinsic connection between onions and drip irrigation. Technically, it is also possible to cultivate tobacco with drip irrigation; in fact, famers in nearby regions do this. In Khrichfa, farmers do not cultivate tobacco with drip irrigation. This is partly because for tobacco - a crop which can resist some water stress - there is less of an agronomic need to increase the precision of water applications, something that would justify using drip irrigation. More important, however, are the noted cultural-symbolic associations that mark drip irrigation as the clean future and tobacco as the dirty past. In the context of Khrichfa, drip irrigation thus forges associations - between irrigators and agriculture with onions, branding both as modern and clean – , thereby encouraging some crops and modes of behaviour, while actively pushing away others, such as (those associated with)'dirty' tobacco.

Those with an interest in tobacco cultivation, such as the tobacco cooperation, are well aware of this and have in fact tried to use the positive image of drip irrigation to also improve the reputation of tobacco. Through a pro-active media campaign, the president of the cooperation, tried to promote tobacco production and include it in the Plan Maroc Vert. One of his strategies to make tobacco attractive and indeed 'cleaner' was to propose the option of a subsidy for installing drip irrigation for tobacco producers.

In sum, drip irrigation in Khrichfa actively helps performing modernity and cleanliness. Water users see drip irrigation as a technology used by entrepreneurial, market-oriented farmers. Drip irrigation helps to culturally mark these farmers as independent. In how it changes the activity of irrigating, it also literally makes irrigating into a less dirty job while also reducing the physical effort needed to irrigate.

5.4.2 Performance 2: Drip supports the emancipation process of sharecroppers

A second performance of drip irrigation is that it supports and accompanies the emancipation efforts of (former) sharecroppers in Khrichfa. For those who used to be sharecroppers, drip irrigation was a tool that allowed to engage in irrigated farming on previously rain fed land, just outside of the command area of the canal irrigation system. Where it was difficult if not impossible for them to access plots inside the system, the hitherto unirrigated lands adjacent to the command area were still accessible. Drip irrigation not just made it possible for these sharecroppers to start farming on their own, but also turned them into the frontrunners of modernity as they were the ones to spearhead ‘clean’ onion production with drip irrigation.

The history of sharecroppers is that they came to the region from the 1960s onwards, attracted both by the availability of water in Ain Bittit as by the employment opportunities created by the tobacco cooperative in El Hajeb. The landowners in Ain Bittit had more land than they could cultivate. They were reluctant to have their own children, whom they had sent to schools in nearby cities, do the dirty work on the land with tobacco. This is why landowners started engaging in sharecropping arrangements with the newcomers. The sharecroppers worked on the land of the landowners, who also provided water and arranged the inputs through the tobacco cooperative. At the end of the season the two parties shared the harvest equally. While this arrangement was to mutual satisfaction of both parties at first, the sharecropping arrangements started causing frictions around 1990.

Mohammed explains, talking about the period of mid-1980s: “we had problems with the sharecropping arrangements. The problem was that the owner of the parcel could stay relaxed, while the sharecropper worked. It was as if the sharecropper worked for two households. At the end of the year, the owner of the land took his part, and the other part was for the farmer (sharecropper) who had to use it to cover his costs (of hiring additional labour, for example).” Sharecropping families felt increasingly constrained, both by the landowners on whose land they worked and by the tobacco company with its strict contracts and supervision. Not only did the sharecropping arrangements with the landowner limit the autonomy of the sharecropper, also the tobacco cooperative strictly controlled the agricultural practices of tobacco cultivation, further decreasing the autonomy of the sharecropper. Especially the second generation of sharecroppers, who had not experienced the situation from which their parents had fled (droughts, political unrest, competition over land) felt the urge to change their situation. Also, the total number of sharecroppers had increased, giving them more weight in local politics.

An important strategy to re-negotiate their relations with the landowners consisted of the sharecropping families buying their own land – marginal land with stones or outside of the command area – and some water rights. While continuing their work for them, in this way they also started to loosen their ties with the Ait Ouallal landowners. They for example constructed their houses on their newly acquired lands. Often, the new lands of the sharecropping families could not be irrigated with water from the Khrichfa canal, as they were located uphill or because the land undulated too much for surface irrigation. Drip irrigation therefore was a particularly attractive technology for the sharecroppers, as it made it possible for them to irrigate their own, newly acquired lands. An additional advantage of drip irrigation was that it allowed them to profile themselves as 'leaders' in agricultural development. To make use of drip irrigation, many sharecropping farmers installed a water reservoir next to the canal on the lowest part of the land, in which they stocked water. By pumping this water into a drip irrigation system, they succeeded in irrigating land located uphill from the canal.

Drip irrigation thus supported the emancipation efforts of the sharecroppers by increasing their productivities but also by altering their identity vis-à-vis others. It turned former sharecroppers and their families into respected members of the agricultural community, making them into a new reference of modern farming. At the time of doing the fieldwork for this study, visitors to the Khrichfa area would first be sent to the drip irrigating farmers as these were widely considered an example of their progress. Representatives of the WUA would thus sent students and researchers interested in drip irrigation to Abdellah and Aziz (both originating from a sharecroppers family), the two most prominent persons in the village Ait Amar. Even though Abdellah still had sharecropping agreements with landowners, he no longer felt dependent on them (also see Amichi et al., 2015 on the increasing importance of reverse tenancy in North Africa). The reverse almost seemed to be the case: the landowners of Khrichfa needed Aziz and Abdellah to learn from their experiences with drip irrigation; they were seen as the innovators of the community. The sharecroppers also led the way in demonstrating how drip irrigation could be used collectively. A group of family members that had inherited the rain-fed land of their grandfather created a family cooperative to collectively install drip irrigation on 20 hectares in order to grow onions. This project was subsidized by the State and the agricultural administration often hailed the experience as a successful collective drip irrigation project in the region.

Inspired by these ongoing drip projects, the Water Users Association of Khrichfa tried to obtain funding and support for a collective drip irrigation project for the entire canal command, thus providing further legitimacy to the work of the former sharecroppers. In 2012 the Water Users Organisation of Khrichfa submitted their first request for subsidies to realise a collective drip irrigation project to the DPA, the Provincial Department of Agriculture. The (former) sharecropper farmers played a leading role in this process.

Next to how drip irrigation allowed extending the command area, its performance as a 'modernizer' thus also contributed to redefining identities and restructuring social relations between (former) sharecroppers and landowners.

5.4.3 Performance 3: Drip irrigation forges relations between Khrichfa and the State

The third performance of drip irrigation in Khrichfa that we discuss here is its capacity to forge and strengthen the ties between the Khrichfa irrigation community and the State. For the developers of the National Water Saving Plan, the plans of a small-scale irrigation system such as Khrichfa to convert to drip irrigation were unexpected and surprising. For them, drip irrigation belonged to more modern forms of irrigation and farming. A footnote in the National Water Plan illustrates this: it indicates that because small-scale irrigation systems "are constrained by the traditional water turns" (PNEEI, 2007, p.33), they are unsuited for drip irrigation. The employees of the DPA likewise shared the view that drip irrigation does not fit in small-scale irrigation systems. They were reluctant to support Khrichfa's request for support to convert to drip irrigation, as they foresaw many challenges. For example, how to design for a collective drip irrigation project when the system consisted of small, scattered parcels with irregular terrains? How to connect the irregular source of water supply to the drip system?

To make the prospect of drip irrigation in Khrichfa appear feasible, the WUA board therefore had to actively lobby and seek support from different actors. The president and other members of the WUA board for instance collected signed documents of water users that indicated their interest in the collective drip project together with documents that confirm their land rights. The president of the WUA also invited one of the engineers of the DPA to Khrichfa. He gave the DPA engineer a guided tour of the area, showing that several irrigators had already installed drip, and that the functioning of the WUA was exemplary. The president thus went through conscious efforts to re-fashion the image of the Khrichfa irrigation system as an advanced and progressive system, thus making it eligible for support by the government in its efforts to convert to drip irrigation.

The president of the WUA effectively did change the representation of the Ain Bittit irrigation system, and of the secondary canal Khrichfa in particular, in the process of making it suitable for collective drip irrigation. When transmitting the request for collective drip irrigation in Khrichfa to the DRA, the Regional Agricultural Department, the DRA reasoned that the Bittit irrigation system (including the Khrichfa Canal) was actually the largest irrigation system in the area. Hence, although formally classified as a 'medium to small scale' irrigation system, its relatively large size would justify its candidacy for the subsidy program (pers. com. El Mars, 28-10-2013). Through this rhetoric move, Khrichfa was thus made to 'fit' the drip irrigation discourse of the government. It made Khrichfa count and matter in the eyes of the State.

In fact, actively re-defining the identity of the system to make it fit with agricultural policies and eligible for government support seems to be a recurrent feature in the history of the system. As the irrigation scheme is located close to the imperial cities of Fes and Meknes and because it has abundant and attractive land and water resources, it always has had received much State attention and support, starting in 1930 with a drinking water project for the city of Meknes (van der Kooij et al., forthcoming). When there was a lot of donor and policy interest in small-scale farmer managed irrigation systems in the 1980s, Ain Bittit was the first to be funded by a World-Bank program for small-scale irrigation systems rehabilitation. Similarly, in the mid-1990s, the Bittit municipality tactically ignored the presence of its irrigation system and portrayed itself as a rain fed area to become eligible for a government sponsored project to valorise rain fed land. A last example of how the identity of the system is fashioned to suit prevailing opportunities for support comes from the Khrichfa water users portraying themselves as private entrepreneurs to become eligible for a drip irrigation program in which the State would sponsor the installation of drip irrigation on individual fields of farmers for the cultivation of fruit trees. The State would also finance the planting of and care for the fruit trees until they would be mature and start to bear fruits. In the negotiations for this program, the representatives of the farmers represented Bittit agriculture in a way that made it fit with the discourse of supporting private, entrepreneurial irrigation. In sum, Bittit farmers, including the Khrichfa representatives, have a long reputation of successfully moulding their identity in efforts to obtain State funds and support - for irrigation rehabilitation, electrification, drinking water and the like. The State, in turn, has always been interested in procuring access to the resources of Ain Bittit, especially for the drinking water for the city of Meknes.

The process of obtaining support for a collective drip project constitutes thus yet another effort of the Khrichfa water users to become eligible for State support. Through the collective drip project, the WUA board members attempted to represent Khrichfa as an exemplary WUA in the framework of the Green Morocco Plan. During a visit to the local Extension Service (CT), they thus presented their WUA as a modern one, one that cared about the environment, and one that aimed to save water. They convincingly emphasized how well the WUA was functioning, and used their plans for drip irrigation almost as further evidence of their exemplary performance. The WUA Board members of Khrichfa succeeded in attracting the interest of both the CT and the Provincial Department of Agriculture (DPA). The DPA itself had an interest in making optimal use of the subsidies of the Green Morocco Plan for their region. They also liked the Khrichfa drip project because it promised a much needed boost to their own professional importance. For some of the engineers working at the DPA, the collaboration with Khrichfa reminded them of the successful rehabilitation project that they worked on in the Khrichfa region in 1996. It brought back positive memories of working together with farmers who were willing to improve their agriculture. In this way, the collective drip irrigation allowed both the farmers and the DPA engineers to reposition themselves as modern, in the process reinforcing the relations between them.

Drip irrigation thus performed as a network builder, helping Khrichfa appear as a modern, environmentally aware, entrepreneurial, unified group of farmers. It did not only strengthen the ties with the public agencies, it also attracted researchers, funds and eventually new projects, which were not directly linked to drip irrigation. These funds and projects happened through the networks that drip irrigation had helped create, as the lobby for collective drip irrigation had helped Khrichfa members to manoeuvre themselves into crucial positions. The WUA board members for instance got invited to workshops and conferences, where they gathered new information about agricultural projects and policies. In this way, the WUA president obtained a loan to buy agricultural machinery, which he rented out to farmers. One of the WUA board members also managed to obtain a central position in a newly started tobacco association, which represents the farmers of Ain Bittit in their negotiations with the tobacco company. In addition, plans to set up a milk cooperative in the region were implemented and a large scale fruit producer started exploring possibilities to link up with the farmers of Khrichfa through contract-farming. In sum, the lobby for drip irrigation led to very useful connections for the irrigation community.

5.5 Discussion and Conclusion

Triggered by our research findings about the multiple performances of drip irrigation in Khrichfa, we used this article to explore a conceptualization of performance that does not normatively pre-define and limit the functions and outcomes of the technology to irrigation efficiency and uniformity. Inspired by actor-network approaches, we did this by approaching performance as a process, happening in the interaction between the technology and its environment.

In our analysis we highlighted three performances of drip irrigation in the Khrichfa Canal. First, we showed how drip irrigation performs as a modernizer of farming and farmers, supporting a shift towards more entrepreneurial and cleaner ways of doing agriculture. This shift is simultaneously material and cultural: drip irrigation literally allowed irrigators to water their plants without becoming dirty, but it also contributed to culturally redefining farming as something clean as it was used for 'cleaner' crops, onions. A second performance of drip irrigation that we described is that it helped emancipating sharecroppers, making them less dependent on landowners. Drip irrigation allowed (former) sharecroppers to irrigate land outside of the command area, land that could not be irrigated with surface irrigation because of its elevation or slope. In addition to economic autonomy, their use of drip irrigation also re-defined (former) sharecroppers as progressive farmers. It effectively made them the new reference for modern, entrepreneurial agriculture; they were the ones outsiders visiting the system were directed to as they helped portray the system as an advanced one. The third performance of drip irrigation that we chose to depict is that of a network and alliance builder: in Khrichfa, drip irrigation functioned as a tool that helped the WUA board to strengthen relations with government agencies. To become eligible for support, drip irrigation contributed to re-define the irrigation system as a particularly effective, well-functioning and progressive one. In other words, Khrichfa

became an irrigation system that 'counted' within the Green Morocco Plan.
All three performances importantly hinge on the overall positivity that surrounds drip irrigation, on the fact that people like to be associated with it. Drip irrigation creates a model Water Users Association; it is associated with productive, entrepreneurial farmers and ideals of autonomy and emancipation; and it also works to make a 'traditional' irrigation system appear modern and progressive. We therefore conclude from our analysis that it is not only the materiality of drip irrigation that makes drip irrigation perform, but also and importantly the discourses and cultural associations that accompany drip irrigation. Farmers engaging with drip irrigation are not only interested in the object itself (the pipelines with emitters) but also in how the association with drip works to make them appear as modern.

The Khrichfa case suggests that drip irrigation can even perform without the materials being in place. The case of the collective drip irrigation project clearly showed that the positive image of drip irrigation itself already performs. When finalizing the field work for this study in 2015, the water users in Khrichfa were still waiting for the government agencies to start the collective drip irrigation project. Although they still said to be eager to have drip systems in their fields, they had stopped their active lobby for the drip irrigation project and appeared resigned to wait until it would happen. We surmise that this attitude of acquiescence can be partly explained by the fact that drip irrigation already performed in Khrichfa. Even though drip irrigation was not physically implemented in the fields of Khrichfa farmers, it did perform during the continuous negotiations between the Khrichfa WUA board, the State and the Khrichfa water users. It created new links, it re-defined the actors, and it formed networks. The collective drip irrigation project resulted in a re-assertion of the credibility of the WUA board; it attracted new organisations; it functioned to place Khrichfa members at strategic functions in new cooperatives and it made funds flow. With the new idea to lobby for a solar pump in Khrichfa, the president of the WUA found a new performer in his relations with the State and the irrigators.

Our analysis also shows that the performances of drip irrigation in Khrichfa cannot be unilaterally ascribed to the intrinsic characteristics of the technology. They emerge through the discursive and material interactions between the technology and its environment – people, other technologies, and resources. Many of these interactions happen because of the conscious hard work of the involved actors, work that is needed to keep identities and networks stable in place and time. Any performance of, or of any technology for that matter, thus requires continuous work to keep the network in the desired way.

5.5.1 Re-thinking irrigation performance

Efforts to conceptualize and (re-)define irrigation performance are not new. Concerned with low irrigation performances, scholars in the 1990s searched for ways to conceptualise irrigation performance that allowed comparing irrigation systems across places and times (Murray-Rust and Snellen, 1993). Proposed indicators included adequacy, equity and reliability (Bastiaansen and Bos, 1999). Based on these performance assessments, lessons of best practices could be drawn and suggestions for possible improvements made for different levels of an irrigation system, rather than only at the field level (Molden and Gates, 1990; Small and Svendsen, 1990). However, these attempts of opening up the evaluative framework of irrigation performance also attracted attention of irrigation scholars to bring consistency to the performance terminologies focussing on efficiency and uniformity (Burt et al., 1997; Pereira, 1999).

Our user-and practice-based conceptualization of performance does not replace or discredit these earlier efforts. It is important to determine the efficiency and uniformity of drip irrigation to assess whether the technology does what it is designed to do: bringing precise amounts of water to plants. Yet, these frameworks for assessing irrigation performance are less useful for understanding why and how users engage with a technology, while they are also problematic for suggesting that what a technology does (or how it performs) is largely dictated by its intrinsic technical characteristics. When taking together, there is a danger that conventional performance assessments become tools to normatively prescribe certain irrigation behaviours as more desirable or superior irrespective of the context in which such behaviours occur or in which irrigation technologies are used. We have shown that a user- and practice based definition of irrigation performance is useful to more agnostically describe why people engage with and use an irrigation system or technology. Our definition of performance allows recognizing that drip irrigation does other or more things than more precisely administering water. This also helps explaining why drip irrigation does not necessarily have to perform efficiently, as actors may be engaging with the technology for other performances, such as the image of modernity projected by drip irrigation (e.g. Benouniche et al., 2014).

Chapter 6

General Discussion

6.1 Conclusions

The origin of this thesis lies with my amazement and surprise when I first encountered drip irrigation in a FMIS. These feelings stemmed from how I categorized the two. While associating drip irrigation with modernity, I categorized FMIS with traditions and cultural heritage. When using the modernity-tradition binary which characterizes the irrigation modernization discourse, the combination of drip irrigation with FMIS is indeed an impossibility as something can only belong to one side of the binary. Indeed, irrigation modernization precisely consist of efforts to make irrigated farming more productive and efficient by transforming and modernizing 'traditional' irrigation practices and technologies such as those found in FMIS, which would make disappear the 'traditional' FMIS in the conversion process to drip irrigation. My observations of farmer practices in FMIS, however, seemed to suggest that irrigators belonging to a FMIS can be and are interested in drip irrigation. Apparently, drip irrigation does go together with FMIS. This thesis consists of my efforts to reflect on this apparent anomaly. In it, I set out to explain how drip irrigation performs in FMIS. This question necessarily entailed re-thinking the association of drip irrigation with 'modernity' and that of farmer-managed irrigation with 'tradition'. It entailed, in other words, re-thinking what drip irrigation is and does (its performance) when re-contextualized from the ideal conventional environment as imagined by engineers to other environments. Hence, to understand why and how drip irrigation in an FMIS works, I posed the research question "*How does drip irrigation perform?*"

I answered my research question in two steps. First, I made the construction of conventional performance assessments of drip irrigation visible: how is the link between drip irrigation and efficiency constructed, and what does this link do? Using an actor-network approach, I made visible how the efficiency reputation and discourse of drip irrigation is not a universal context-less characteristic of the technology, but the effect of specific construction work carried out by engineers at experimental plots. The efficiency of drip irrigation therefore is not so much (or not just) the outcome of inherent characteristics of the technology, but emerges when the technology interacts with a very specific context: a highly controlled laboratory-like setting. In other words, I showed that a 'modern' irrigation engineering context is required for drip irrigation to perform efficiently. Moreover, I also discussed how measuring increases of efficiency – and assessing the performance of drip irrigation technology – is itself dependent on context and perspective, and on temporal and spatial scales used, an observation discussed within an epistemic community of irrigation scholars but not recognized in wider debates on drip irrigation and irrigation modernization. Because the efficiency of drip irrigation resonates well with efforts to meet global challenges of water scarcity and a growing demand of water for agricultural production, it is a 'truth' that is eagerly retold and one that has assumed a life of its own, most notably beyond the engineering domain. This 'truth' for instance prompts national governments and donors to actively support the implementation of drip irrigation.

These insights paved the way for the next step in my efforts to answer my research question. The second step consisted of empirically examining and theoretically reflecting on what drip irrigation is, or does, when functioning in an unexpected context. I was particularly interested in understanding what drip irrigation is and does in the context of FMIS. I choose to understand what drip irrigation does in the Seguia Khrichfa, a secondary canal of the Ain Bittit farmer managed irrigation system. As much contemporary public irrigation support comes in the form of efficiency enhancing measures such as drip irrigation, the supposed incompatibility of 'modern' drip irrigation with 'traditional' FMIS risked marginalizing FMIS from policy attention and support. Documenting and understanding what drip is and does in a context of FMIS would also feed into answering the question of how to (best) define and assess the performance of drip irrigation. Alternative definitions of the performance of drip irrigation are needed in order to understand how drip irrigation performs in a FMIS, because conventional performance assessments are normatively prescriptive, limited to determining irrigation performance at the plot level and caught up with the modernity-tradition binary.

As a basis for taking these two steps, I made use of a socio-technical approach to performance, inspired by insights from actor-network thinking. I defined performance as:

> *Performance is the art of ordering the relations and interactions between people and objects. Performance emerges from practice and results in contingent, surprising outcomes. Technologies do not perform alone, and neither do humans. Rather, technologies and humans perform in interaction with each other and their wider environment.*

This definition of performance focuses attention to drip irrigation technology-in-practice. It considers performance as the emergent outcome of networks of heterogeneous elements (both 'social' and 'technical') which continuously (re-)

shape each other. Besides re-conceptualizing the performance of drip irrigation I also had to rethink my conceptualization of FMIS to be able to understand how the two could 'marry'. I approached FMIS and their institutions as dynamic processes that continuously change and adapt depending on changing and heterogeneous needs and circumstances.

In what follows in this concluding chapter, I further elaborate my answers to the overall question "*how does drip irrigation perform?*" I have categorized these answers into three sections. I start with a general discussion of how drip irrigation performs, and then continue with a reflection on how performances perform. In use the last section of the conclusions to discuss how irrigation categorisations perform.

6.2 How does drip irrigation perform?

That drip irrigation performs efficiently – in terms of (irrigation) water use and water productivity - is made very clear in the articles I reviewed for Chapter 2. Drip irrigation can apply precise amounts of water to plants which can either result in reductions in the amounts of water applied to plants or in higher productivities. The capacity of the technology to improve the precision with which water is administered to plants can also be mobilized in support of innovative irrigation strategies, like deficit irrigation (Badr et al., 2010; Karam et al., 2007) or partial root wetting (Du et al., 2008). In addition, drip irrigation can also facilitate the precise dosing of fertilizers (Goodwin et al., 2003; El Hendawy et al., 2008). In sum, scientific articles show (or rather, perform, as I propose in this thesis) drip irrigation as a highly efficient technology.

Drip irrigation does not only perform, drip irrigation is also performed: drip irrigation becomes what it is through interactions with actors and objects. Drip irrigation performs as and is performed as a water-efficient technology by drip irrigation researchers on experimental sites. Here, crop water requirements are precisely calculated and met, and all 'external' factors and 'disturbances' are eliminated. In scientific texts, in prominent articles, in policies and on websites, the drip irrigation performance as a modern, water saving technology that solves problems of water scarcity and competition over water is the one that is perhaps best known. Scientific texts perform drip irrigation as a positive technology that contributes to a sustainable future while – and here comes the beauty of drip – not compromising agricultural productivities. Drip irrigation even allows to produce more, while using less water! This message is eagerly re-told and circulated in international debates and irrigation policies (Chapter 2), it is what has created the positive imagery that surrounds drip irrigation.

Yet, when connected to farmers, becoming part of agricultural enterprises, or included in national water saving plans, drip performs and is performed differently. Indeed, when defining performance, as I do in this thesis, as something that emerges from practice (Chapter 1 and 5), drip irrigation can perform (or be performed) in many more and in many different ways than 'efficiently' alone.

The drip irrigation that performs high efficiencies, promises at the same time to make available more water: by shifting from technologies with low efficiencies such as surface irrigation (typically 40-60% efficient) to drip irrigation (90% efficient) supposedly 30 to 50% of water 'losses' can be recovered and allocated to (other) use(r)s. This promise of 'saving' water is itself an attractive performance of drip irrigation: it allows avoiding or postponing having to deal with difficult political questions of water distribution. The water that drip irrigation will 'save' in the future is still virtual, which allows it to be simultaneously appropriated by many users. In the case study of the Khrichfa Canal, some argued that the 'saved' water should be used to replete declining groundwater tables, others expected to use it for extending irrigated areas or for crops that demand more water, and yet others aimed to divert it to other use(r)s – for example to the drinking water sector (Chapter 3).

Whether and how much water is actually saved after drip irrigation has been implemented is rarely measured or discussed. It may well be that when it would be known how much extra water drip irrigation actually makes available, all actors interested in this additional water would have to enter into difficult negotiations about who can use which part of it. A certain amount of vagueness about potential water savings in the future may thus be instrumental in avoiding or postponing contentious choices and decisions. Yet, and as noted in Chapter 3, not knowing how much water is actually made available with drip irrigation or other modernization projects is what makes drip irrigation perform as a tool to cover up or justify the further depletion of water resources.

All the positivity that surrounds drip irrigation (as a modern, efficient, rational, high-tech technology) by itself makes it into something that many people like to be associated with: engaging with drip irrigation then becomes a means to confer the positivity of drip onto themselves, it becomes a means to modernize and upgrade their status and identity (Chapter 5). Farmers that associate themselves with drip irrigation are seen as (more) modern, efficient, and environmentally aware agricultural entrepreneurs – an image that favours them in the contacts they have with others. In the same manner, drip irrigation positively alters the identity of irrigation engineers, of a farmer managed water users association or of a PhD student. Drip irrigation can therefore also be said to perform as an identity changer or modernizer.

Beyond promises and discourses, the introduction of drip irrigation technology also has material effects: it re-configures socio-technical networks including the (organisation of the) distribution of water, responsibilities and control (Chapter 4). As I illustrated with the historical analysis of the T.O.R. gates in Chapter 4, a technology such as drip irrigation can change how control over water is distributed over the members in an irrigation community. The role of the canal operators in Khrichfa in controlling water distribution gradually became less important within the irrigation system, as it was taken over by the T.O.R. gates in collaboration with the individual water users. Likewise, drip irrigation changes the distribution of water, responsibilities and control. The conversion to drip irrigation creates a moment that relations between people and objects get re-ordered – a moment which can be used by some to direct the changes in their desired directions. Also, drip irrigation defines legitimate reasons for accessing water (efficiency, productivity, modernity) and can materialize or challenge existing water rights.

Interestingly, these technological changes do not seem so political at the moment when they are implemented. Introducing T.O.R. gates, for instance, did not seem like a 'coup' on the position of the canal operator. Other technological changes, especially the ones concerning the collective tube-well, did help in de-politicizing ongoing issues about in- and exclusion of water users as the changes were presented as a purely efficient and rational way of selling tube-well water to Khrichfa members. Not only do technological changes de-politicize issues of control, responsibility and in- or exclusion, but also, when they go accompanied with discourses of efficiency, sustainability and rational water use like drip, they are difficult to oppose without becoming a spokesperson or a representative of 'irrational' and 'unsustainable' behaviour. It is thus very attractive for the water users and the WUA board to implement change via the technology.

6.2.1 Implications - what is supported with Moroccan drip irrigation subsidies?

The Moroccan government spends a lot of money on drip irrigation subsidies while it is unclear whether it indeed makes available and accessible the anticipated water – especially considering the complexity of scale and the rare field studies which show that obtained efficiencies vary. If the Moroccan government does not 'save' water with the drip irrigation subsidies, it would be good to understand what it does actually pay for. From this thesis, I conclude two important points 1) the drip irrigation subsidies allow for the ministry of agriculture and the basin agency to work together towards an apparently shared goal (Chapter 3). However this goes at the costs of the aquifer from which more and more water is drawn; drip irrigation is not a long term solution. Although it might be comfortable not to discuss actual water 'savings', I would argue for measuring actual 'savings' in field situations, even if it evokes conflict. In the longer term, an open discussion about the actual water 'gains' made by drip irrigation might lead to finding more sustainable solutions. Secondly, drip irrigation supports entrepreneurial farming identities and large scale irrigation. By seeing performance in a more processual and contingent way (Chapter 5) I came to the conclusion that drip irrigation can also be used to further these identities: to make a small scale, farmer managed irrigation system count within 'modern' agriculture by associating itself to drip irrigation. However – not only drip will do this. Before drip, lining projects made Khrichfa count and a shift to onions made several farmers in Khrichfa more modern and entrepreneurial. Apparently there is a demand for such a technology, although it does not have to be a technology, and neither does it have to be physically present (Chapter 5), that can be used for furthering identities and forming alliances. It might be interesting to reflect on other ways to make farmers and irrigation systems count in modern-day Moroccan agriculture which could be cheaper (in the sense of less expenses, or not at the costs of the aquifer).

6.3 Performances perform

Not only drip irrigation performs. Also performances of drip irrigation -in particular efficiency- perform: they order relations between people and objects. Based on performances, decisions are made about how to (best) manage water; which practices and irrigation technologies are favoured over others.

Like drip irrigation, performances perform in multiple yet interrelated ways. Efficiency studies call for a wide implementation of drip irrigation and support for continuing drip irrigation research. Even if they are based on different conceptualizations of the water balance and include different flows, they speak in apparent harmony. However, they do come to similar conclusions: drip irrigation is efficient, thus agriculture needs drip irrigation to solve water related issues (competition over water, overexploitation of groundwater, water scarcity, and the like) without compromising agricultural production (Chapter 2). This message performs strongly because the different studies speak together, but also because the message is re-enforced by the urgency of the problems that drip irrigation can solve. The efficiency performance of drip irrigation travelled beyond the domain in which it has been created (irrigation engineering) to a wider domain of policy makers due to its attractiveness for solving water- and productivity problems.

Performances are situated, they are created within a specific context, with specific objectives and are measured from a specific perspective. In other words, performances are performed. Even in the case of a seemingly straightforward performance such as Irrigation Efficiency, a term which is presented by scholars as being uniform and easily comparable from one situation to the other, the perspective of the analyst matters, a notion which is referred to as the proprietor's perspective by van Halsema and Vincent (2012). From one perspective – for example the perspective of a farmer - the water leaving the agricultural enterprise is a loss. Yet, from the perspective of someone responsible for managing and allocating water at another level, for instance the basin level, this same water may be considered as a gain when it can be used for other purposes. Depending on ownership or responsibility over water, different analysts will thus draw the boundaries of water balances differently and in- or exclude different parameters, simply because different water flows matter differently to them (Chapter 2). Each analysis has a particular perspective, identifying with an (imagined) proprietor of water. Even a basin approach to efficiency – which might seem a 'neutral' assessment as it encompasses all users – is perspective dependent. A basin approach sets boundaries in terms of time and space and might exclude internal flows. It determines, for instance, that the boundaries of the watershed are more important than the boundaries of an underlying aquifer. Or it determines that measurements over a timespan of a year are the most 'appropriate' to use, without taking into account at which frequency water is available to farmers. Such a representation impacts water management decisions, it is a performance which re-orders relations between water users and between water users and policy makers.

Not only is a performance assessment perspective dependent because of the measurer's perspective on water use, performance assessments are also perspective dependent because of the measurer's assumption of what the technology should do, which function it should fulfil. Performance assessments are often based on the question how good a technology fulfils a specific function. For drip irrigation, this means that the technology is assumed to apply water efficiently to crops, resulting in a performance assessment based on efficiency indicators. Which function a technology is assumed to fulfil depends on the perspective of the one engaging with it – the user or the performance measurer for example. Drip irrigation can indeed be implemented because of its efficiency (for example, when water needs to be 'gained' for allocation to other uses or users) but a water user can also engage with drip irrigation for other reasons – for example to relate to its modernity. Performance assessments are thus perspective dependent because of the water balance that they draw and because of the task that they assume that the technology should fulfil.

I aimed in Chapter 5 to reconceptualize the performance of drip irrigation independently of its pre-defined task, as the goals that drip irrigation serves might change over its users and over time. In practice the tasks that drip irrigation fulfils are more complex and muddled, as I conclude from the collective drip irrigation project in Khrichfa where the project serves to extend the irrigated area but also as a network builder and a modernizer. These different performances are linked: because of the efficiency of drip irrigation (constructed in engineering domains), drip irrigation can perform as a modernizer for people engaging with drip irrigation.

I argue that performance studies perform, just like my own PhD study, also a story of performances, performs – although I do not know yet to which extent, and which actors will align with it. I explored here an alternative conceptualization of performance which enabled the wider analysis of performances of drip irrigation with which I aimed to stimulate a debate. I did not describe these performances to counter the meta-narrative on efficient drip irrigation. Rather, I aimed to show that alternative versions and conceptualizations of the performance of drip irrigation are possible. When only one performance – efficiency - becomes dominant, a hierarchy emerges: other performances become inferior. As performances relate to the goals and tasks that people ascribe to the technology, a hierarchy in performances also means that some goals and tasks of some people will become subordinate. A dominance of efficiency is thus also a dominance of a worldview (one of modernity, rationality and control over resources); a dominance over 'others' that do not fit in.

6.3.1 Implications - How to measure performances?

The conclusion that drip irrigation performances are perspective dependent and multiple raises the question who should measure performances. The answer is not an independent, objective institute – because they will also inevitably measure performance from a specific perspective. Rather, it is important that performance studies are done in different ways, and that they acknowledge the perspectives of the measurers. Choices about the task that the technology is assumed to fulfil, or which water flows are in- or excluded, should be made explicit. If the perspective of the measurer is put up front, the performance studies explain how drip irrigation is performed, and for whom it performs. For whom does drip irrigation work and at the cost of what?

I thus propose a celebration of different performances of drip irrigation ànd their making to bring nuances and enable a debate. Such an openness to different performances of drip irrigation would for example be useful to the Moroccan State to decide whether and how to continue supporting drip irrigation. It will be difficult to propose different performances as the meta narrative (of efficiency, modernization and control over water) is powerful and supported by many. The technology-centred performance of drip irrigation, centred around efficiency, could fade away alternative performances that respond to other objectives and perspectives. Yet, acknowledging and valuing multiple performances might advance debates on resource scarcities and social development, including questions of social justice (Leach et al., 2010) Performing different performances thus requires network building, which means that some will be more successful than others. Is an open space for exploring different performances possible? For example like an online platform where different performances can be posted on a pin-board (Law, 2002)?

6.4 Irrigation categorisations perform

Categorizing irrigation, often linked to a modernity-tradition binary, means ordering the relations and the interactions between people and objects. They perform when categories are applied to a specific irrigation system, when categorisations define who is eligible for support and subsidies and when categorisations (of the irrigation systems and of policies) meet each other.

Categorisations are applied to an irrigation system at a certain moment: the classification is registered, stored in archives and printed on maps, reports and project proposals which makes them durable. Meanwhile, irrigation systems continue to evolve – possibly confirming their classification, possibly challenging it. Yet, once an irrigation system is classified, its classification does not change so easily, and as we noticed in Khrichfa, it might well be that an area is classified as 'rain-fed' on official maps (which form the basis for assigning projects to areas) while the irrigation system and the practices of water users have changed.

I showed that classifications in reality are bendable. As narrated in Chapter 5, the irrigation system of Ain Bittit is classified as 'small to medium scale irrigation', but government agents suggested (in the context of searching for more areas to be converted to drip irrigation) that Ain Bittit is actually the largest irrigation system of the area, which would make it eligible for support from the Green Morocco Plan. Yet, although categories are bendable and with efforts they can change, irrigation systems themselves can evolve quicker than the categorisations that define the system. The categorisations that define irrigation systems such as Ain Bittit and Khrichfa – and that define which irrigation systems and which irrigators need support – do influence how the irrigation systems develop; what they can do and what they cannot, and for what policies or support they need to do effort to 'fit in'.

In the first instance I found it problematic that the National Water Saving Plan excluded FMIS from the drip irrigation support because of their 'traditional' practices. I considered this exclusion as unjust for Moroccan FMIS. Over time, I noticed that this exclusion is not rigid – Khrichfa water users do efforts to fit in anyway, and seem to be successful in this. Farmers actively work to adapt (themselves and the irrigation system) to an ever changing world. In Khrichfa, the farmers are very creative, tactic and smart in doing this. Khrichfa is as traditional as it is modern, and as small as it is large.

The Green Morocco Plan subdivides the support that the Moroccan State gives to agriculture in two categories: entrepreneurial farming and rural development. Water users can often access both categories, in a strategic way. Khrichfa water users discuss in which of the two categories they see potential (because they expect that the funds are not yet exhausted, or because of their chances to successfully fit in this category are high) and work hard on their performance to 'fit in'. In the case of Khrichfa, this means that it actually does not really matter whether the subsidies are divided into two categories, or rather 'pillars' in the terms of the Green Morocco Plan. While the term pillars suggest two separate groups of farmers and irrigation systems that are addressed, they can actually both serve the same farmers – only work is needed to perform the right category, and not every FMIS will be able to do so.

In sum, choosing to align with certain categories is not a neutral act: it does matter for how projects look like, in which direction the irrigation system develops, and who is included or excluded from the project. For example, it matters whether the plans for collective drip irrigation will be executed via the first or the second pillar of the Green Morocco Plan: either the focus lies on sharecroppers on the rain-fed land, or on the large-scale Ait Ouallal landowners who can afford individual basins (Chapter 5).

6.4.1 Implications - drip irrigation and the farmer managed Khrichfa Canal: a meaningful marriage

I started this research with a feeling of unease: I did not consider drip irrigation as compatible with a farmer managed irrigation system based on the categories that I used to make sense of both. I reconceptualised my understanding of drip irrigation performance and of farmer managed irrigation systems in such a way that allowed the two to come together. In Khrichfa, drip irrigation and FMIS indeed came together in a meaningful way. A conversion to drip irrigation forms part of the farming practices and livelihood struggles of the Khrichfa water users. I thus understood the function of drip irrigation in the Khrichfa farmer managed irrigation system and I also understood that drip irrigation does not necessarily disrupt the farmer managed irrigation system's functioning – it could also underscore its functioning or even support its continuation – for example in the light of safeguarding the water rights on the Bittit springs. In Khrichfa, change happens all the time, in the irrigation infrastructure, the rules guiding the water distribution, the crop choices etc. The changes in the Khrichfa irrigation infrastructure discussed in Chapter 4 provide some useful insights in how changes in Khrichfa happen in such a way that they support Khrichfa's continuation. I conclude from the past changes in Khrichfa that the changes are never radical – changes are proposed as such that it is always possible to go back to the previous situation. The Khrichfa WUA board for example proposed to 'test' a new water distribution based on existing infrastructure, even if that requires some creativity to make it work (Chapter 4). When water users do not oppose, they can also adjust the infrastructure to fully implement the change, or when water users do oppose, there is the possibility to go back to the previous form of water distribution. For the collective drip irrigation project, this means that it could be useful to search for a design that allows farmers to continue with surface irrigation. Even if they will not use the old infrastructure it is useful because it gives the irrigation institutions time to adapt, and adapt to, the drip irrigation system while having the security of the surface irrigation system.

6.5 Performing drip irrigation

The efficiency of drip irrigation performs far beyond the experimental plots where irrigation efficiency is measured. Yet, because drip irrigation is performed efficiently on experimental plots, it performs on the people that engage with drip irrigation and on the irrigation system where drip irrigation is or will be implemented. Drip irrigation functions to create identities and to form alliances, and it also performs (or is performed) to re-allocate water and depoliticize issues of water distribution and control. For scholars writing about performances of drip irrigation, this research implies that those who write about performances, perform drip irrigation themselves: they are part of making drip irrigation what it is.

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Summary

Drip irrigation is represented in literature and agricultural policies as a modern and water saving technology. Because this technology is often associated with 'modern' agriculture and development, it seems out-of-place in 'traditional' farmer managed irrigation systems (FMIS). Thinking along the binary modernity-tradition leaves little room for the possibility that drip irrigation and FMIS could come together in a meaningful way as they place FMIS and drip irrigation in two mutually exclusive representational categories. Yet, the water users from the Khrichfa Irrigation Canal, part of the Ain Bittit Irrigation System, a 'traditional' FMIS in Northern Morocco, opt for 'modern' drip irrigation as technology of their choice. To explain this apparent contradiction this PhD thesis develops an approach to rethink the performance of drip irrigation in the context of farmer managed irrigation systems. The question "*how does drip irrigation perform?*" guides this research. In irrigation engineering literature the performance of drip irrigation is centred around the notion of water use efficiency – the prime task that drip irrigation is supposed to fulfil. However, to understand drip irrigation in FMIS, a more processual and less prescriptive approach to performance is explored. Drawing on actor-network approaches, the thesis understands performance as *"the art of ordering the relations and interactions between people and objects, a process of ordering which emerges from practice and which results in contingent, surprising outcomes."*

This study starts by 'unpacking' the efficiency of drip irrigation by exploring what efficiency means, how the strong link between drip irrigation and efficiency was constructed, and what this association of drip irrigation as an efficient technology does. Because of its renowned efficiency, drip irrigation introduction is stimulated in many countries. Yet, efficiency is not an uncontested term. From the academic debate on efficiency complexity, it is clear that efficiency terminology is scale and context specific. Rather than studying drip irrigation with a pre-defined scale of analysis, this thesis focuses on how efficiencies, and their assumptions about scales and context, are used in irrigation projects and descriptions of drip irrigation performance. This PhD study critically engages with questions about efficiency and searches for alternative ways of understanding performance. To understand how drip irrigation and FMIS can come together in meaningful ways, this PhD study does not only re-define the performance of drip irrigation but likewise re-thinks conceptualisations of FMIS. FMIS are approached as dynamic entities that continuously change – which allows to see the introduction of drip irrigation as yet another change, rather than a disruption of 'tradition'.

The farmer managed Khrichfa Canal in Northern Morocco is selected as a case study to understand how drip irrigation performs in a FMIS with a historical analysis. The Moroccan government stimulates the introduction of drip irrigation because this efficient technology addresses problems of groundwater depletion ànd supports a growth in agricultural production. In the Khrichfa area, several individual farmers have converted to drip irrigation and the water users organisation is planning for a collective drip irrigation system. The existing drip irrigation systems and the collective plans provided fertile ground for exploring how 'modern' drip irrigation and 'traditional' FMIS can go together.

This thesis begins with a literature review on the efficiency of drip irrigation in Chapter 2. Chapter 3 is an analysis of what efficiencies do in the field, how efficiencies are used to re-allocate water in (drip) irrigation projects. In Chapter 4 and 5 alternative conceptualisations of performance are explored: in Chapter 4 by analysing the intimate relation between technologies and institutions, and their capacity to mutually shape each other, and in Chapter 5 the focus lies on understanding the performance of drip irrigation as emerging from the interactions between the technology and its (potential) user.

The literature review in Chapter 2 aims to understand the scientific basis for the expectations that drip irrigation is efficient with water. Efficiency studies underscore the need for drip irrigation as a device to counter water scarcity, groundwater depletion and competition over water and align with a modernization discourse – aiming at improvement and upgrading of irrigation. The efficiency of drip irrigation is constructed at very localized experimental stations with a wide variety of efficiency terms and definitions used by different research communities. Although the term efficiency gives the impression of unity, the studies that measure and define efficiency have remarkable differences in conceptualizing water balances and measuring water flows. However, the resulting efficiency numbers are treated as if they were comparable amongst each other. This results in a widely supported consensus that drip irrigation saves water. This creation of unity might be strategic for continuation of research practices and funding, but it says little about how drip irrigation will perform in the fields of farmers. The practices of farmers are left out of the experiments reviewed in literature. Besides local farming practices more 'context' is left out of the equations: with water-tight plastic borders all flows in the experiments are controllable. The research on the efficiency of drip irrigation is thus very technology-centred, i.e. the performance of the technology and its capacity to bring water efficiently to plants is attributed to the material objects.

Chapter 3 shows that efficiency numbers do have influence as they embed a promise of the creation of more water. Apparently previously 'lost' water would be captured, thus resulting in a water 'gain'. This is not specific for drip irrigation – the promise of water 'gains' is also present in other irrigation technologies and modernization projects. For example, previous modernization projects in the Ain Bittit irrigation system, of which the Seguia Khrichfa is a secondary canal, focused on lining of the infrastructure in order to re-allocate the 'saved' water for drinking water to the city of Meknes. All modernization projects in Ain Bittit have been preceded or accompanied by a process of re-allocating yet-to-be saved water. For example, the many actors involved in the conversion to drip irrigation all claim that the water 'gain' would be theirs. As this is never openly discussed, it is only when projects are implemented that competition over the 'saved' water arises. Yet, this competition is not brought to the open and each actor claims the 'saved' water, resulting on multiple claims on the yet-to-be saved water. Within the irrigation system, the 'saved' water mixes with the rest of the flows in the basin. This makes it 1) impossible to know how much water is actually saved, and thus how much water could be re-distributed, and 2) invisible to others who actually uses the 'saved' water. Only silent actors in a powerless position – like the aquifer – lose out. Chapter 3 concludes with the suggestion that not measuring actual water gains is strategic because it de-politicises re-allocations, allowing several actors to appropriate the yet-to-be-saved water without confrontations.

Chapter 4 describes the performance of technology as co-defining the water distribution in an irrigation system, and its role in defining possible solutions. The technology has a function in co-shaping institutions, which forms also depend on the distributional questions that institutions aim to tackle. For drip irrigation, this means that the introduction of drip irrigation technology is shaped through and also provokes distributional questions. Which water users are in- or excluded from the system? What are legitimate reasons for accessing water? The introduction of drip irrigation brings with it discourses on efficiency, productivity and avoidance of waste – which shape the framing of distributional questions. Surprisingly, these questions do not lead to open conflicts in Khrichfa. The conclusions of Chapter 4 suggest that this is because technologies can play a role in de-politicizing change. Suggesting new technologies or drawing old technologies into new configurations allows actors to enforce changes in the irrigation system without anyone losing face. When difficult questions on in- or exclusion are defined as issues of efficiency and modernization – and thus as progress and the way forward – these are hard to openly oppose.

Chapter 5 explores socio-technical performances of drip irrigation in the Seguia Khrichfa area by approaching performance as emerging from practice. The positivity of drip irrigation (constructed through efficiency experiments in laboratories which travelled to agricultural policies and donor-led debates) radiates on drip irrigation users and the administration and works in the field to create identities and form alliances. In Khrichfa, drip irrigation contributes to a shift towards modern, entrepreneurial and clean agriculture, and strengthens the ties between the irrigation community and the State. These are performances of drip irrigation that come into being in wider networks in which the technology interacts. In other situations (at other moments, in interaction with other actors, another environment) drip irrigation could perform in different ways. In the most extreme cases, drip irrigation does not even have to be in place physically as an object to perform as we show for Khrichfa. Talking about drip irrigation, aligning with drip irrigation and its discourses of efficiency and modernity also performs. Yet, the socio-technical focus on processes of network ordering hints at the fragility of the performances of drip irrigation: actors need to actively keep the network they constructed in place to maintain identities and alliances. This understanding of performance also means that drip irrigation can perform in many ways, but this does not mean that these performances can be expected in other contexts. Likewise, one cannot expect that drip irrigation is always efficient. Drip irrigation only becomes efficient through practice, when actors, technology and the environment all work towards the goal of using water efficiently.

The general discussion concludes by answering the main research question on how drip irrigation performs. Drip irrigation performs as an efficient technology, which is often translated in irrigation policies as needing less water while increasing productivities. The suggestion that water is 'saved' that would otherwise be 'lost' creates a promise of water gains which can be re-distributed. Drip irrigation also performs as network builder and creator of identities. Both modern drip irrigation and notions of performance (such as efficiency) are strategic for de-politicizing re-allocation issues. Changing water allocations via efficiency arguments or transforming institutions via technologies is attractive as it silences opposition. This thesis also highlights how performance assessments – for example based on irrigation efficiency – perform (and are performed); they re-order the relations and interactions between people and objects. Likewise, FMIS, as a category to define irrigation systems perform. Any definition or categorisation implies certain possibilities or restrictions, and the water users of the Seguia Khrichfa know well how to use these in their favour. As implications of this research for the Moroccan agricultural policy, this study suggests that it is doubtful whether drip irrigation makes available the anticipated water, as the Moroccan government is not the only actor that claims access to the 'saved' water. Yet, this thesis suggests that drip irrigation does help farming communities to experience that they 'count' in modern agriculture – though other cheaper ways of attaining this could be possible. In addition, the suggestion is made to more explicitly measure multiple performances – to celebrate their differences rather than creating a suggestion of unity. Being open to the multiple performances of drip irrigation will help to explain for whom drip irrigation works and how, and at the costs of what. The thesis concludes with a personal reflection that drip irrigation and FMIS can very well go together, at the condition that both are re-conceptualized.

Acknowledgements

After five years, my PhD project comes to an end. As a consequence I have rather ambiguous emotions: unhappy to put halt to my curiosity about drip irrigation questions, yet ready to start new adventures. Relieved to end a tough time of writing, and still sad to end a research project with such motivated and stimulating colleagues. I am looking back at five years of intensive learning, which was only possible because of the support of many. Here I would like to thank all who have contributed to this thesis, in one way or another. It will be difficult to name everyone, but I will do my best to acknowledge the majority of those people who have contributed to the successful and joyful finishing of this thesis. Thank you all for making this possible.

I would first of all like to thank my promotion team: Margreet Zwarteveen, Marcel Kuper and Charlotte de Fraiture. Margreet – I've learned such a lot from you, which already started with doing a Bachelor thesis under your supervision. You've always encouraged my creativity, and you stimulated my curiosity. You taught me how to structure and analyse my stories and how to write an appealing text. These things are all invaluable to me. Marcel, I'm happy that we met, that evening that I started the organisation of an excursion for WUR students to Morocco. You have guided me into Moroccan culture, shown me how to do fieldwork, and greatly contributed to my understanding of Khrichfa. Margreet and Marcel – a PhD student could not wish for a better team. Charlotte, thank you for guiding me through the last stretch of the PhD program, when you joined the team as my promotor, for which I am grateful. Linden, it is a shame that your health did not allow you to continue as my promotor at that time. I won't forget the valuable moments with you in Morocco, and how you helped me to expand upon my reflections of farmer managed irrigation.

In 2009 I was given the opportunity to write a PhD research proposal at the Irrigation and Water Engineering Group (IWE) at the WUR. I am grateful to Margreet Zwarteveen and Rutgerd Boelens for initiating this, and to all the staff members of the IWE group who supported me in constructed my research plans. In particular, Gerrit van Vuren (†) and Harm Boesveld reacted positively on my plan to work on drip irrigation, which then stimulated me to write a research proposal on this exciting topic. I am very happy that I got the opportunity to start this PhD in 2011 with a grant from the WASS Research School.

The NWO-funded DRiP project formed a warm basis for exploring questions on drip irrigation. Margreet, Harm, Marcel, Charlotte, Mostafa Errahj, Jean

Philippe Venot, Jonas Wanvoeke, Lisa Bossenbroek, Maya Benouniche, and all the others who joined the project along the way - the extended DRiP family – it was inspiring to work with you. We challenged each other to think further, while each still being able to take our own approach – a process which I very much appreciated. Jonas, you have set the example for finishing our DRiP PhDs!

I experienced the former IWE Group (currently named Water Resources Management) as a group of researchers with a mission. During my studies I appreciated seeing you defend farmer rights and aligning with the struggles of farmers, something that motivated me to join this group for my PhD research. In my first years of working at the IWE group I taught in the course Research Approaches with Alex Bolding, which also helped me to shape my own research proposal. Alex, thank you for guiding me into teaching and research. In a later stage, the office door of Harm and Gerardo van Halsema was always open for me when I had technical questions on crop water requirements or drip irrigation materials. Thank you both for sharing so many insights with me! Petra Hellegers and Gert-Jan Veldwisch helped me structure my conclusions at a moment that I found it difficult to see the overall picture. All interactions with other colleagues has been equally valuable. Bert Bruins, Deepa Joshi, Jeroen Vos, Jaime Hoogesteger, Christina Yacoub, Pieter van Oel, Henk Ritzema, Frans Huibers, Edwin Rap, Kai Wegerich and of course Maria, you've been a warm support. Gerda – I could always count on you, for all practical issues and for lunchbreak chats!

The PhD students of the Water Resources Management Group have been a great platform for sharing fieldwork experiences, peer-reading each other's texts and sharing the same troubles. Jonas, Lisa, Jaime, Wouter Beekman, Cesário Cambaza, Juana Vera Rosa Delgado, Rinchu Dukpa, Tran Duc Dung, Janwillem Liebrand, Khilola Masharipova, Le Thuy Ngan, Melle Nikkels, Melvin Nyathi, Wahib al-Qubatee, Jean Carlo Rodrigues de Francisco, Milagros Sosa Landeo, Fulera Tahiru, Pranita Udas, Patricio Mena Vasconez, Andres Verzijl, Vo Thi Minh Hoang and of course Arjen Zegwaard, my roommate in times of joy and trouble, thank you all for being my peers.

In Morocco, I was welcomed by the Génie Rural Department of the Institute Agronomique et Vétérinaire Hassan II in Rabat where Marcel and a team of MSc and PhD students were eager to introduce me to drip irrigation in Morocco. Lisa and I were 'adopted' by Maya, Farah Hamamouche, Fatah Ameur and Rhoda Fofack, who introduced us to the village of Ain Taoujdate including all

its particularities: breakfast at the gasoil station and bread from the neighbours. Ain Taoujdate became the hotspot of drip irrigation research: many ambitious students joined us. To all students with whom I shared time in Ain Taoujdate: I was amazed by your full-time dedication and energy.

When overloaded with impressions from the field, we were welcome at the École Nationale de Meknes where Mostafa, Nicolas Faysse and their colleagues helped us to reflect on our research. When Meknes was not far enough for distancing myself from the field, I could come to the IAV in Rabat for a writing retreat, discussions with Marcel, coffee from Fatiha, information-dense interviews with professor Oulhaj and of course a coffee with milk in the morning sun with Maya. Also based in Rabat, the NIMAR institute for Dutch-Moroccancollaboration, with Jan Hoogland as director, facilitated my start in Morocco. Jan, while we prepared the student-excursion to Morocco I learned a lot from you about Morocco, and perhaps you learned from us about irrigation. I really appreciate that years later you visited me in Khrichfa, to see what I had learned from the Khrichfa farmers. Before starting the 'real' fieldwork, I made a visit to Morocco together with Lisa. Lisa, driving in our bright green Kia Picanto, with the whole research ahead of us, was a delightful experience which made me look forward to the years to come. In this explorative phase we were helped by many, to whom I like to say thanks for giving my PhD such a wonderful start.

I owe most thanks to the water users of Khrichfa. They have explained every detail of the irrigation system and its functioning to me, even when it was so logical to them that they could not imagine that anyone would ask about it. They made time for me, precious time they could have also used for their busy farming activities. I am grateful to all the farmers who shared their life stories with me, who shared tea with me, who made me feel at home in Khrichfa. Several farmers told me that they are my family there, and that is indeed how it felt to me. I admire the Khrichfa water users association, with the president who is always active in improving Khrichfa's performance. I've learned a lot from you. Also to the other board members, thank you for all the explanations, and for allowing me to be in your midst. To the aguiadiers, the canal operators – in my opinion the ones that make the Khrichfa water flow - thank you for all the moments that we shared, and all your explanations about how the water distribution happens in practice. Naming all the farmers of Khrichfa who contributed to my research will be impossible, you are with many and I do not know all your names, but you all helped me in one way or the other. Your hospitality, openness and interest in a foreign student has amazed me. Thank you all.

Rachid Radouani was my best help ever; he was more than a translator. His observations, hypotheses and gut feelings helped to advance my research. I have learned a great deal from you, in terms of agronomics, Moroccan culture and of course driving like a taxi-driver. I would also like to thank your family, which gave me a warm welcome, great meals and relaxed afternoons on your small farm.

I learned a lot from the MSc. and BSc. students who joined me for internships or thesis research. Ftaima Alroumi, Koen van Bezu, Eva Diestelhorst, thank you for showing me different perspectives on the field! I supervised Saioa Sese and Obed Tuabu for their MSc. thesis on drip irrigation in other countries, which led to valuable new stories that made me see the particularity of drip irrigation in Morocco. To all students, thank you for your contributions!

Beyond the colleagues at the WRM Group, the Génie Rural Department of the IAV in Rabat, and the ENA of Meknes, many others have contributed to my academic growth. The research school WASS facilitated inspiring courses and discussion platforms. I enjoyed the Summer School at the STEPS Centre in Brighton with so many like-minded PhD students and dedicated lecturers. Rebecca Howard, you especially made those weeks great - two companions on bikes! During the Critical Institutionalism workshop in London I met Hermen Smit. What a recognition, we both tried to bring the same message across: the material matters! Thanks for your detailed reading of my chapter, that has been a great help. I would also like to thank the co-authors of my articles, it was nice to work together. As this thesis is compiled on the basis of scientific articles, most chapters have been peer-reviewed. The reviewers of these chapters, often anonymously, contributed greatly to improving my work. Somehow, your timing has been wonderful. Positive reviews came at moments that I needed stimulation, and critical reviews when there was space for improvement. You helped in refining the concerned papers, but most of all you helped me in developing my ideas further, so it might be that you recognise your contributions within some of the chapters.

During the writing process of this PhD, I enjoyed living in Wageningen. Several people made Wageningen (and surroundings) a nice environment to live and work. Boudewijn, Judith, Baukje, thank you for always being interested in my work (Baukje even visited me both in Yunquera and in Ain Bittit!). My climbing friends from IBEX have been a great support. Physical activity, challenging outdoor adventures, bbq's and board game evenings – you knew how to give me new energy for a next writing day. Jorien and Sigrid, you helped me relax even in the last phase of the research when I told everyone to stay away. I'm looking forward to my defence with you as my paranymphs. You will make a stressful, intimidating ceremony look like the joyful organisation of an adventure race!

For my family, this PhD research won't have been a surprise. My mother stimulated my interest in foreign cultures and my father (†) taught me how to look at landscapes and my grandmother (†) taught us all to think critically. I would like to thank my mother for always being interested in my work, for your visit to Morocco and for the practical advice on the cover design. Not so many mothers will know as well as you do what their daughter actually does in her work! To Katinka, Charlotte and Ischa, my two sisters and my brother, I am happy to have you as family. I think we recognise more and more how much similarities we share! Although technically not a family member, I see Marian (†) as a person to be thanked here in the family section. Marian, you were my companion through life, together with you I felt confident exploring the world. I wish we could continue doing that together.

Joost and Jinte, I love you. Joost, thank you for your optimism and for giving me all the space to follow my own plans. Especially thanks for all the moments we have shared together in nature– mtb-rides on the Veluwe or hikes through the Pyrenees - those were needed for taking distance, gaining perspective and seeing my research in a new light. You have always listened to all my plans, doubts, ideas and stories and supported me. Jinte – I wish I could see the world like you do. Seeing you grow, from baby to toddler, has been amazing, and I know there is much more to come. I'm looking forward to our shared future, Joost and Jinte, without the deadlines of a PhD (article) continuously gnawing away at the back of my mind. I also look forward to all the new projects that lie for us ahead!

About the author

Saskia van der Kooij was born in 1983 in The Hague, where she followed secondary education at the Dalton Scholen Gemeenschap (VWO). In 2002 she finalized the first year (*propedeuse)* of the Willem de Kooning Art School in Rotterdam after which she moved to Wageningen to study International Land and Water Management. During her studies Saskia became interested in farmer managed irrigation systems and drip irrigation, two topics that came together in her MSc. thesis research in Yunquera, Spain, in 2008. Meanwhile, she started working at the Irrigation and Water Engineering group as student-assistant, providing assistance in education and curriculum development projects. In 2009 Saskia finalized the Master Irrigation and Water Management with distinction, with a minor in Innovation and Communication.

In 2009 Saskia was invited at the Irrigation and Water Engineering Group (currently the Water Resources Management Group) to develop a research proposal for a PhD and to teach in the study program International Land and Water Management as a junior researcher. Her work as a junior researcher resulted in an individual PhD grant from the Wageningen Social Sciences research school (WASS) and in the NWO-funded project Drip irrigation Realities in Perspective (DRiP) which shaped the context for her PhD research.

While doing her PhD, Saskia has been actively involved in teaching and education activities. She initiated, facilitated and supervised yearly study excursions to Morocco for second-year Bachelor students. She lectured in a diversity of BSc. and MSc. courses; assisted with the course Research Approaches and supervised individual students in their thesis and internship projects. During her PhD, Saskia initiated a peer-reading group for PhD students of the Water Resources Management group.

Next to her PhD study, Saskia has organised study and sport activities, like debate-evenings, study excursions, climbing weekends and adventure races. During holidays she has worked as a volunteer at organic farms in the UK and in Spain she contributed to the reconstruction of an abandoned village.
Saskia writes and speaks fluently Dutch and English. She speaks French and Spanish and understands Moroccan Arabic.

Academic publications

van der Kooij, S., M. Kuper, M. Zwarteveen and C. de Fraiture. *Submitted for publication to Water International.* A user-based conceptualisation of performance: drip irrigation in the Khrichfa area, Morocco.

Sese, S., H. Boesveld, S. Asins, S. van der Kooij and J. Maroullis. *Under review*. A 25 year journey: The transformation from surface to drip irrigation in the semi-arid Cànyoles watershed, Valencia, Spain. *Water Alternatives*.

van der Kooij, S., M. Kuper, C. de Fraiture, B. Lankford and M. Zwarteveen. *Accepted for publication*. Re-allocating yet-to-be-saved water in irrigation modernization projects. The case of the Ain Bittit irrigation system, Morocco. *In: Drip Irrigation for Smallholders: efficiency, innovation and development. Eds: Venot, J.P., M. Kuper and M. Zwarteveen*.

van der Kooij, S., M. Zwarteveen and M. Kuper. 2015. The Material of the Social: The Mutual Shaping of Institutions by Irrigation Technology and Society in Seguia Khrichfa, Morocco. *International Journal of the Commons* 9(1):129-150. http://www.thecommonsjournal.org/index.php/ijc/article/view/539;

Venot, J.P.; M. Zwarteveen; M. Kuper; H. Boesveld; L. Bossenbroek; S. van der Kooij; J. Wanvoeke; M. Benouniche; M. Errahj; C. de Fraiture and S. Verma. 2014. Beyond the promises of technology: a review of the discourses and actors who make drip irrigation. *Irrigation and Drainage* 63, 186-194.

van der Kooij, S., M. Zwarteveen, H. Boesveld and M. Kuper. 2013. The efficiency of drip irrigation unpacked. *Agricultural Water Management*, 123, pp 103-110.

Saskia van der Kooij

Wageningen School of Social Sciences (WASS)

Completed Training and Supervision Plan

Wageningen School of Social Sciences

Name of the learning activity	**Department/Institute**	**Year**	**ECTS***
A) Project related competences			
Fine tuning research proposal	WUR/WRM	2011	2
DRiP workshop 1 'Thinking about Technology and Ethics'	WUR/WRM	2011	1
DRiP workshop 2 'Research and re-orientation of drip topics'	WUR/WRM and Unesco IHE	2013	1
DRiP workshop 3 'Ethics, Efficiency & Innovation'	ENA Meknes	2014	2
DRiP workshop 4: DRiP book writing & Planning	Unesco IHE	2015	0.5
B) General research related competences			
WASS Introduction workshop	WASS	2011	0
Topic tot Proposal	WASS	2011	4
Masterclass Interpretive Analysis	WASS	2011	1.5
Qualitative Data Analysis: Procedures and Strategies (YRM 60806)	WUR	2011	6
PhD workshop Science, Technology and Development	WTMC	2011	1
Organisation & participation PhD peer review group	WUR/WRM	2012	2
Basic Moroccan Arabic	Radboud University	2012	2
Scientific writing	WGS	2012	1.8
Summer School Pathways to Development	STEPS Centre	2013	3
The agency of the Seguia Khrichfa in reconfiguring irrigation institutions	Workshop Capturing Critical Institutionalism, Kings College , London and WUR	2013	2
Beyond Tradition and Modernity, the resilience of a farmer managed irrigation system in transition to drip irrigation	Resilience Conference, Resilience Alliance Network	2014	2
C) Career related competences/personal development			
The efficiency of drip irrigation unpacked	WASS PhD day	2012	1
Supervision of 2 BSc internships; 2 BSc theses and 2 MSc theses.	WUR/WRM	2011-2015	2
Organisation and guidance of excursions to Morocco for second year BSc. students International Land and Water Management.	WUR/WRM	2011-2015	1
Guest lectures in BSc. and MSc. courses, amongst others in: Irrigation and Water Management; Irrigation and Development; Design in International Land and Water Management and Research Approaches.	WUR/WRM	2011-2015	1
Total			**36.8**

*One credit according to ECTS is on average equivalent to 28 hours of study load

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