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Article

Water Footprints and ‘*Pozas*’: Conversations about Practices and Knowledges of Water Efficiency

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Abstract: In this article we present two logics of water efficiency: that of the Water Footprint and that of mango smallholder farmers on the desert coast of Peru (in Motupe). We do so in order to explore how both can learn from each other and to discuss what happens when the two logics meet. Rather than treating the Water Footprint as scientific, in the sense that it is separate from traditions or politics, and Motupe *poza* irrigation as cultural and, therefore, thick with local beliefs and superstitions, we describe both as consisting of intricate entanglements of knowledge and culture. This produces a more or less level playing field for the two water logics to meet and for proponents of each to enter into a conversation with one another; allowing furthermore for the identification of what Water Footprint inventors and promoters can learn from *poza* irrigators, and vice versa. The article concludes that important water wisdom may get lost when the Water Footprint logic becomes dominant, as is currently about to happen in Peru.

Keywords: water footprint; (*poza*) irrigation; mango export; knowledge practices; ethnography; Peru

1. Introduction

In June of 2015, the Peruvian National Water Authority (*Autoridad Nacional del Agua*, ANA) presented a report which introduced the concept of the Water Footprint as one of the pillars of its National Water Resources Strategy and Policy [1]. The Swiss Development Organization and the World Wildlife Fund collaborated in the development of the report, whereas the overall Strategy and Policy Plan were developed with a loan from the World Bank. Three months after the launch of the report, the ANA issued a decree: RM 246-2015-ANA. The decree offers farmers the opportunity to obtain a ‘blue water certificate’ (*certificado azul* in Spanish) if they agree to have their water footprint measured, and if they commit to using water more efficiently and sustainably in the future. When we discussed these initiatives [2] later that same year, in December 2015, with local water officials (*Autoridad Local del Agua*, ALA) and leaders of Water User Associations on the north coast of Peru they showed a clear interest. Although many had not heard of the concept of the Water Footprint, they positively associated its efficiency concerns with the introduction of so-called modern technologies like drip irrigation. We also talked about the Water Footprint ideas with some smallholder farmers. They were less enthusiastic, expressing reservations about drip irrigation and indirectly about blue water as well. Already for centuries, they have been irrigating their crops through a method they refer to as *poza* irrigation [3,4]: a method developed to make optimal use of the water that is intermittently available in the desert area where they live and farm. They were worried about what would happen if

the blue water certificates start dictating how irrigation should be done: would they indeed be forced to adopt the Water Footprint measurements and calculations to prove that they have irrigated their mangos in water-wise ways?

Engaging with this question, in this article, we compare the water logic of Water Footprint initiatives [5–7] with that of smallholder farmers on the desert coast of north Peru [4,8]. With ‘water logics’ we refer to a particular way of framing water problems and proposing solutions, which are often anchored in a specific conceptualization or definition of water. We use the comparison to explore how the two logics can learn from each other and to discuss what happens when they meet. Our starting premise is that both logics have evolved in response to a similar concern: that of making do with limited and perhaps declining quantities of water. Yet, and as we show, the temporal and spatial scales at which the two logics articulate and address this concern are different, while they also use different definitions and indicators of productivity and efficiency.

The first water logic we describe is that of smallholders who grow mangoes for agro-export in the Motupe valley on Peru’s arid north coast (6°09′07″ S, 79°42′51″ W). There are several thousands of farms, all of which are connected through irrigation systems. Since the agro-export boom that happened in Peru in the 1990s, Motupe has become the country’s second mango production zone. Here, as in similar adjacent valleys, agriculture is made possible through large scale irrigation systems that divert water from the Atlantic basin to the Pacific coast. In contrast to other agro-export crops which are often produced by agribusiness companies or large-scale producers, mango production in Peru is characterized by a large presence of small scale farmers [9]. Because these farmers have restricted access to water for irrigating their mango trees, they have devised sophisticated methods to optimize their water use.

The second water logic of our analysis is that of the Water Footprint concept. The Water Footprint is an idea and initiative that emerged from and co-developed with a steadily increasing international policy recognition that water is a precious and limited resource [10,11]. This recognition is (re-)invigorating existing scientific efforts to measure, tabulate, map, model, and predict current and future scenarios of the world’s water sources [12]. The Water Footprint is one of those efforts; it is a concept to make legible the amount of water needed to produce goods or services [7,13]. Building on the idea of ‘virtual water’ [14,15] to express how a person’s or country’s water consumption includes the water needed to produce goods and services, the concept introduces supply chain thinking in an already established science of hydrology and water management to raise water awareness and make actors account for the water they use [7,13].

In this article we ethnographically explore and compare these two water logics: that of smallholder mango producers on the desert coast of Peru and that of the Water Footprint. In our analysis, we try treating these two logics in symmetrical terms by showing how both have emerged in specific (or local) networks of people, technologies, and practices as part of particular traditions and languages (cultures) of care, control, and calculation [16,17]. Hence, rather than treating the Water Footprint as ‘scientific’ (or universal)—and, therefore, as something that is separate from traditions or politics—and irrigation as ‘cultural’ (or local)—and, therefore, thick with local beliefs and superstitions we describe both as consisting of intricate entanglements of knowledge and culture [18]. We do this to, virtually, create a more or less level playing field where the two logics can be compared with each other. Is there something that those who developed and promote the Water Footprint can learn from *poza* irrigators, and vice versa? What, if anything, gets lost when one water logic becomes dominant, as is currently about to happen on the desert coast of Peru with the Water Footprint?

We want to emphasize that our aim is not to expose either the Water Footprint (WF) or smallholders’ logics as wrong, or to establish one logic as superior. On the contrary, with this paper we hope to contribute to the ambition articulated by WF proponents to open up “a new interdisciplinary field of research . . . (interested in) the analysis of how different techniques and practices, policy strategies, and governance mechanisms can contribute to increasing sustainability, efficiency, and equitability of water footprints” (this special issue). By comparing and contrasting WF with other

ways of using and managing water efficiently and other ways of relating to and accounting for water, we aim to arrive at a specification and delimitation of where, when and under which conditions WF can be a useful instrument to improve wise water use, while also exploring how it can be combined with other forms of water wisdom and awareness.

Our attempt consists of tracing, describing and unravelling the networks of people, instruments, and stories through which the WF logic on the one hand and the water logic of Motupe smallholders on the other came into being, exist, and apply or obtain relevance. After describing how the two different versions of accounting for water, water efficiency, and productivity are performed, we use the discussion section for staging a virtual dialogue between the two water logics, exploring what each can learn from the other. We end the paper with a reflection on how the two logics, or versions of water, interfere with each other in the current Peruvian context. We conclude that there are tensions between them, and that supporting the WF over the smallholder version may result in irretrievable losses of water wisdom and ultimately of water. Our overall suggestion, therefore, is that the ability of the WF concept to help promote wise water use improves when it is explicitly treated as just one possible way of relating to, understanding, and indeed using or managing water [11,19,20], rather than as the only just, universal, or correct one. Our recommendation, therefore, is that any assessment [7] of the scope to increase water awareness and any attempt to improve accountability for water use should be informed by situated decision-making processes that ground the assessment of what is sustainable, efficient, and resourceful in a sound understanding and measurement of existing water use practices.

2. Materials and Methods

To research the water logics of the WF and of smallholder farmers in Motupe, we make use of qualitative research methods. Our approach is ethnographic, which means that it focuses on describing people's daily practices that are always situated in specific surroundings, cultures, histories, and power relations [21,22]. The people studied include traditional smallholders as well as water professionals; their surroundings can, therefore, be a desert hamlet as well as a hydraulic laboratory [23]. Important methods in an ethnographic approach are participant observation and interviewing. The former is a method of data collection in which the researcher is present during and in, for example, irrigation activities and village meetings or, for that matter, in scientific peer-discussions or academic conferences where research results are presented [24]. The advantage of an ethnographic approach for studying water behavior is that the in-depth information it generates, reveals how people's understandings of efficiency and productivity, or what water is and how they relate to it, are grounded in their actions and societal contexts.

As noted, our methodological approach treats the water logics of the WF and that of smallholders in symmetrical terms [16,17], unravelling the material culture, associations, and technologies of both [25]. The symmetric treatment of science with other forms of knowledge [18] serves to bring all actors, including researchers, together in a non-dichotomous or non-hierarchical way. With regard to making sense of a desert valley and extreme weather events, a database with multi-year rainfall records is analytically no more or less accurate than the collective memory of smallholders. This principle of symmetry is, therefore, a methodological position from which differences, tensions, and spill-overs between different forms of knowledge and sense-making can be articulated and studied without a priori favoring one of them [26,27]. We do not, and perhaps it is good to emphasize this here, use the WF logic to quantify the practices of Motupe smallholders, nor do we use the water logic of smallholders to either validate or discredit the WF concept. Instead, the aim of the paper is to show that there is merit in engaging in an in-depth process of mutual comparison and learning, identifying how the two ways of relating to water can converse with and learn from each other, beyond the confines of their own method assemblages [17].

Our work is inspired by science and technology studies and feminist technoscience studies [17,25,28] that call into question the divide between science and politics (and by implication between nature and society). Truths, in these bodies of thinking, are not universal [29]; they are only 'realized' in definite

form within the networks of practices that perform them. The paper, therefore, starts from the premise that both the way in which WF's proponents make sense of water problems and how smallholders do this are local or situated [27]; both 'happen' or come about in specific networks (or systems of circulation) of funding, people, and tools. That the WF logic is more mobile—or travels farther—is not because of its intrinsic superiority or universality, but a result of the greater influence and span of the networks in and through which it circulates.

In order to build the smallholder case study, two of the authors spent two mango campaigns in the Motupe valley and wider region (between 2013 and 2015, for a total of 14 months), visiting farmers and learning about their irrigation practices. During that time, we observed, interacted, and followed Motupe farmers not only in their irrigation activities but also in other agricultural practices. We further interviewed officials from government agencies and non-governmental organizations (NGOs) and collected field observations about water management tasks, which included visiting the Huallabamba canal in the Andes of Lambayeque.

As for the case study of the Water Footprint, we attended the EURO-AGRIWAT Conference (EUROpean AGRICulture WATer use and trade under climate change) held in Wageningen in March 2016, at which we also presented. Two of the authors themselves were trained in water science at Dutch Universities, are frequently involved in water productivity and efficiency discussions [30], and are partially connected to the Water Footprint initiative through institutional and collegial affiliations. Additionally, in 2015, two authors were asked by one of the contributors of the national report of Peru's WF [1] to help design a Water Footprint and sustainable development study in the Chira watershed just north of Motupe.

3. Results

3.1. Poza Irrigation

When we first met Fabio Obando in August 2013, his mango orchard was in bloom, as most mango trees in Motupe are during that time of the year. The Motupe valley used to be controlled by large haciendas, but a radical land reform had redistributed these lands to thousands of ex-serfs during the 1970s. Fabio's father, who traditionally grew maize, was the first smallholder in this region to start experimenting with mangoes for export in the early 1980s. Today, most of his siblings have left the farm, leaving only his sister Matilde and their mother with him. In Peru, the majority of export mango production is in the hands of smallholders like Fabio Obando, with Motupe producing almost a fifth of the total export.

Fabio's understanding of mangoes and irrigation practices stem from a life of intimate engagement with his farm, going back almost 40 years. He knows each of his trees individually while caring for hundreds of them. "Trees are like human beings", he explained to us one day, "they come in all sorts and all characters and, therefore, have different needs". Fabio and the trees were literally raised together. He can tell how they feel and knows exactly when and where to cure them. He also meticulously knows the specific soil characteristics of every spot in his farm and can identify the places where water infiltrates more quickly. Fabio's irrigation logic is based on this knowledge, but it also extends well beyond his own farm. We attempt to shed light on this below.

The Obando farm is surprisingly symmetrical. The trail that connects the farmhouses near the entrance gate to the end of the farm divides it in two halves. Each of these are divided in smaller rectangular sections where maize or mangoes are grown. The sections are further subdivided in basins: the so-called *pozas*. Fabio's basins measure between 1200 and 1600 m². Many are about 80 m long, but he subdivides them again in smaller sections through bunds (see Figure 1). Other farmers also have *pozas*. These come in different shapes: there are smaller ones that are irregular in shape, but there are also bigger ones that follow the contour lines. The Obando family owns 9 hectares of land, which is registered as private property. The mango orchard measures some four hectares which surround the living quarters. Another four hectares are used for annual crops, mostly maize, and are located

further away. Within the orchard, in between the mangoes, some other crops are sown, like lentils and beans, and even pineapples. The final hectare is their *huerta*: a homestead orchard garden with various fruit trees, like avocado, tamarind, and lúcuma. Although scattered throughout the farm area, the most water sensitive trees (of the *huerta*) are purposely planted close to the secondary canal that borders the farm to allow them to benefit from the seepage water when others irrigate. While the *huerta* and the annual crops are managed exclusively by Fabio, with his sister Matilde and their mother, all siblings continue to have a stake in the mango orchard. Or better put, they have a stake in the production of the mango trees that were planted by their father, not in the lentils or pineapples used for daily consumption.

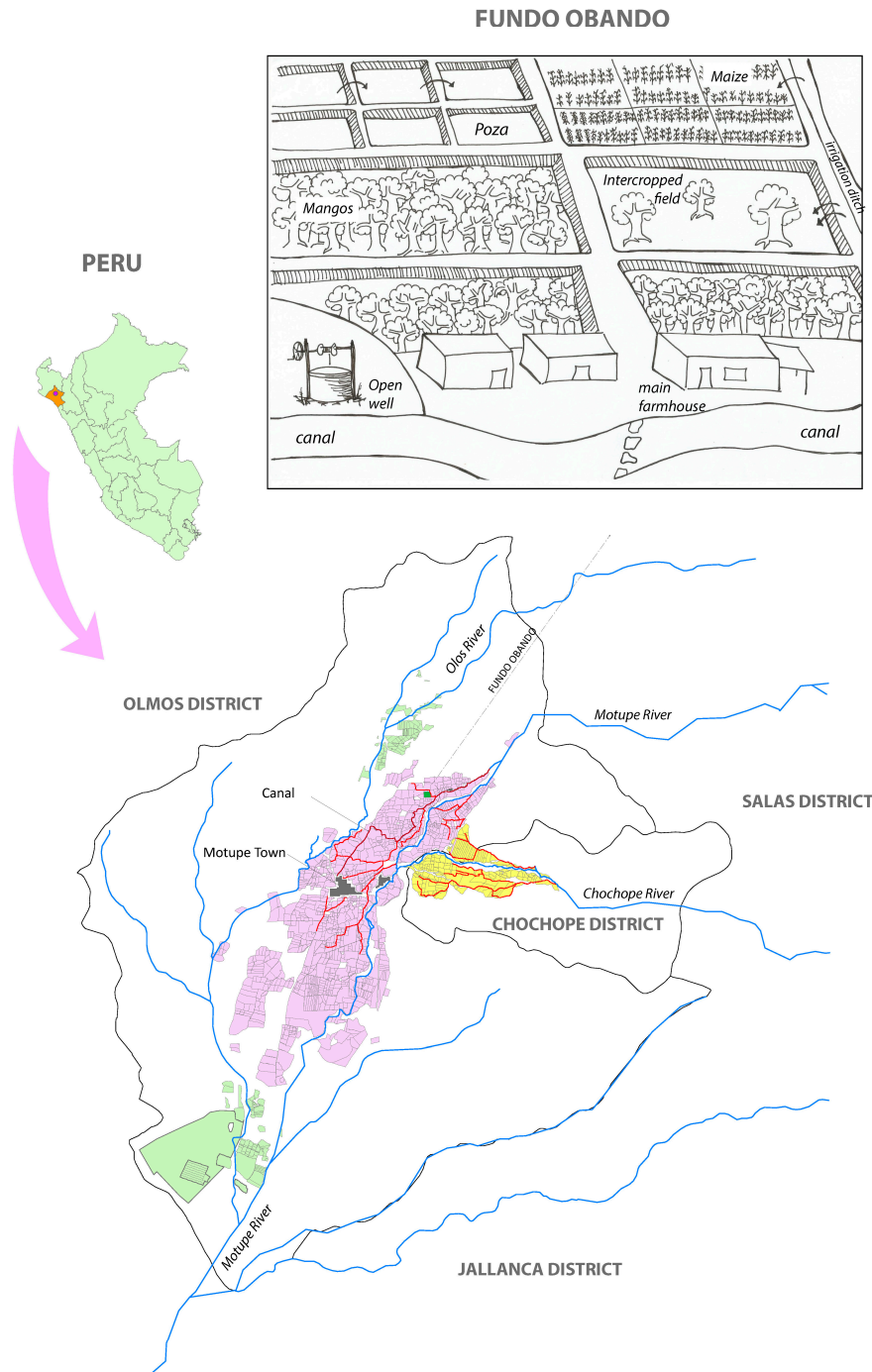


Figure 1. Motupe district and irrigation system (information facilitated by SENASA-Motupe).

Mango farming in the Obando farm, in several ways, runs counter to the way many agronomists envision modern mango orchards. Their expert advice has it that trees should be trimmed to remain between 2 and 3 m of height for easy picking and pest control. They also recommend planting trees close together, spaced at 5×5 m (some even say 3×3 m). Moreover, they hold that trees drop in productivity after a certain age, which is when they should be cut down and replanted. The trees in the Obando farm are tall (over 8 m), spaced 10×10 m and among the oldest in Motupe. What is also different is that there are no polytubes across the farm, no drippers next to each trunk. Instead, Fabio's trees stand tall in the place where water comes to rest: in his *pozas*.

The farms, hamlets, and Motupe town are all located in a desert valley with the same name. In fact, the entire Pacific coast of Peru is a desert strip that contains several dozen river valleys that receive water from the Andes. The first months of the year are considered the rainy season, yet precipitation is varied and erratic over time and in quantity. Peru's national meteorology service, SENAMHI, gives an average rainfall figure of 100 mm (measured from 1965 to 2003), with 85% falling between February and April. During the 2013–2014 campaign, it rained during two weeks in March (29 mm) and one day in October (6.5 mm). Water is scarce, and the Motupe river, like many rivers, runs dry for the greater part of the year. Irrigation happens thanks to the Huallabamba diversionary canal constructed in 1939, which transports water from the Atlantic side of the Andean mountain range to the headwaters of the Motupe river. This canal is the lifeline of Motupe, as Fabio refers to it. From here, water flows down naturally. Once in the valley, water is taken in by one of the main canals and transported to one of the secondary offtakes. One of them leads to Fabio's farm (see Figure 1).

Once the padlocks that immobilize the gates at the *Tres Tomas* offtake structure are removed and the sheet metal gate lifted, water roars into the secondary canal, pushing itself through the concrete flume to ease only when it reaches the broader earthen canal bed. As it moves forward, it wets the soil that various plants and weeds on the canal banks will draw upon. The width of the canal varies: sometimes it is more than three meters and shallow, sometimes it is less than one meter and deep. One of the three gates (or *tomas*) opens to the Arrozal secondary canal. From the gate, water quickly escapes under the main road to re-emerge on the other side, where it twists and turns towards farmer fields. The contrast with the Manuel Cortez main canal is huge. The latter is straight, with concrete lining and several drop structures to adjust to altitude changes. It can carry five times more water. That amount would flood the Arrozal secondary canal, which can only carry '*un riego*', a local irrigation measure that corresponds to about 160 L/s. After a while, the water in the Arrozal canal collapses head-on with a recently constructed earthen heap. As if confused, the water accumulates turbulently before the heap, and rises, until at some level it finds its way to the left. This is where it enters the Obando farm, where it is quickly divided over a number of smaller irrigation ditches. In comparison to the Arrozal secondary canal, the ditches on the Obando farm are relatively clean—without vegetation—and straight. Water advances through the network of ditches; humans busy with spades and shovels close and open the pathways they want water to follow. After yet another turn, the small dikes that hold the water and propel it forward seem to disappear. Here, water spreads out over a large basin and comes to rest; it becomes stationary and apparently immobile: the *poza*.

Fabio attributes the success of his mango orchards to his irrigation method. His *pozas* are shallow basins of up to 0.4 m in depth. Once filled with irrigation water, the water 'sits' in these basins so that it slowly infiltrates to the root zone of crops. Infrequent seasonal rains may also fill up the *poza*, but the last time this happened was in 2008. When Fabio's farm needs water, he walks to the village to request a water turn from the Irrigator's Commission. Some anticipation is needed, since water in his sector is only available for 9 days each month. During his turn, he has three or sometimes four hired persons—known as *irrigadores*—who help him steer and guide the water to the right *pozas*. Their main tool for doing this is a shovel, with which they either open or close the bunds that delimit the basins. Due to a 24-h rotation, roughly half of the annually allocated irrigation hours occur at night. Once the water enters a *poza*, the *irrigadores* make sure it does not stagnate in a particular spot by guiding and manipulating it with their shovel. An important part of their task is also to check the bunds for

consistency and stability, as the process of filling the *poza* might lead these bunds to crumble (when the earth they are made of gets saturated with water, they become muddy and spongy and easily give way, and there are over eight kilometers of bunds on Fabio's farm).

Fabio rarely gets to irrigate his entire farm. With the current irrigation schedule and allocation, that would take more than 30 h. Based on the '*unriego*' irrigation measure (of 160 L/s), three hours of irrigation is allocated to one hectare of fruit trees, and one hectare of maize receives up to four hours. Yet in September 2013, Fabio only got 12 h, just enough to irrigate his 4 hectares of mangos (if water is scarce he would get less). He has to make do with this water until his next turn. "Twelve hours is not enough", Fabio complained, "not all my *pozas* are filled". He emphasized how important it is to give trees lots of water. "The mango, you only need to irrigate three or four times a year", says Fabio, "but with plenty of water". The first irrigation happens after harvesting and pruning in March or April. This "takes out the plant's stress, after one or two months you will see that they start dressing up (blossoming)". In July, mango trees need a cold period of around 16 degrees to start blossoming. After that it is important to make sure that most of the flowers turn into fruit. For this, "you postpone irrigation. If you give water too early, the plant starts growing leaves and not fruit!" says Fabio, referring to how the trees may enter into vegetative reproduction. He tinkers with his water gift, withholding his trees from water until September. The third irrigation takes place in December, during the ripening of the fruit. This is when Fabio's main preoccupation is that the fruit gains in weight. *Pozas* are good for this: "The fruit will not grow more at this point; it swells a little bit. With one *riego* more, it gains weight . . . The tree absorbs the water through the roots and the fruits gain weight". A possible fourth irrigation turn, we later learned, may occur in February if both harvest and rains are delayed and if the third gift fell early. The actual timing of irrigations is subject to many uncertainties: temperature, precipitation, irrigation demands of fellow irrigators, and the moods of the mango trees themselves. During the 2013–2014 campaign, Fabio received a total of 71 h of irrigation water (160 L/s) for his 5 hectares of fruit trees (mango 4 ha.; *huerta* 1 ha.).

In Motupe, *poza* irrigation is a common practice. Only a dozen or so large farmers (>50 ha.) use tube wells and drip technology to irrigate their mangoes and other agro-export crops. Fabio has a non-motorized open well and, thus, solely depends on surface irrigation to fill his *pozas*. Regardless, he prefers irrigation water from the Huallabamba canal in the high Andes over well water, as do most smallholders. This water is said to be cooler, richer in nutrients, and preferred by mango trees. Yet, in addition to using surface irrigation, he also makes optimal use of groundwater, which in his field is 5–7 m down. He does not use a pump or his well. The roots of his trees go deep. Fabio is very much aware of the connection of his *pozas* to the groundwater underneath the orchards. As do others. We were taken to a place below Arrozal where, in the dry riverbed, water reappears. This is attributed to upstream irrigation. Immediately, we were pointed to an intake structure that guides the surfaced water further onwards to fields on the opposite bank. Furthermore, in the collective memory of Motupe farmers, stories about heavy rains that occurred during the "El Niño" phenomenon abound. It fills and may keep *pozas* filled for months at a time. Here, the mango tree is a robust companion of the smallholders as it tolerates water logging. All that water infiltrates and, after the immediate devastation, the valley is also renewed.

Fabio links the importance of abundantly filling the *pozas* to how the roots of his trees take in water. He contemplates that with frequent irrigations in smaller quantities, especially with *riego tecnificado* (modern drip irrigation technologies), water does not reach very deeply. "While this is perhaps good for trees that are recently planted, once they start growing and bear fruit, they need moments with lots of water". Furthermore, "with drip irrigation, water does not reach the mango roots. Roots that grow deep. As a result, mangoes remain small". He is convinced his *pozas* are more efficient than supposedly efficient drip irrigation technologies. His long experience of living in and with the orchard and producing good yields back him up. Fabio boasts about how his tall trees can also withstand long periods of drought: they can survive for over a year without being irrigated, much longer than the smaller drip irrigated mango trees. "Which are more efficient than?" he wonders.

In this way he dismisses vendors of modern irrigation supplies. Likewise, he disputes the wisdom of government officials and agronomists who frequently visit the farm and advise Fabio to standardize and homogenize, to replant and adjust spacing. For one, his mother grows other crops—such as lentils and cassava—between the mango rows, crops that they use for their own consumption. What is more, he says: “each tree is different, you can’t just cut them down! Look”, Fabio continues, “in this world, we are of all sorts. Some are tall, thin and thick, black and white and blond. The same goes for plants, and this is how they will produce . . . These plants give fruits one year, others not, that’s understandable, they get tired as well”. For Fabio, the trees are more than just a source of income. He explains that he does not force trees to deliver higher yields with chemical induction. He also accepts that the fruits high up in his trees might not be suited for export and have to be sold to local dealers. The trees do and mean something else for him. “They are strong because they are tall”, he says when comparing his trees to the smaller ones of modern agriculture. For many agronomists, it is difficult to understand Fabio’s ‘stubbornness’. Yet, the majority of smallholders in Motupe engage in farming practices that are very similar to that of Fabio.

His refusal to follow the suggestions of water engineers or agronomists does not mean that Fabio does not take care of his production; he does. He keeps meticulous monthly records of farm activities, investments, and yields. In 2014, Fabio exported 2500 crates of 30 kilos. In addition, he estimates that another 30% was sold on the national market. The price of the first is negotiated per crate, depending on the need of the broker. For the latter, he settles on a price that gives the broker access to his entire orchard to take whatever can be harvested. Fabio, furthermore, takes notes of how often he administers water to the plants and makes cost-benefit calculations of the products he gives to his trees. This he explains to us by using the ground as a schoolboard, with a twig to write calculations in the sand, or to draw the layout of the irrigation system, as a water professional would do on paper or on his computer.

3.2. *The Water Footprint Concept*

By the time we met the founder of the Water Footprint, Arjen Hoekstra, the concept had become a popular approach in the water management sector, with both companies and civil society organizations displaying enthusiasm about using it. This is because the WF offers an attractive response to the widespread realization that all over the world water is becoming scarce. Hoekstra, a Dutch water scholar, was the key-note speaker at a conference organized by the European Cooperation of Science and Technology (COST) in March of 2016, in which we also participated. At the conference, the results of the project “Assessment of EUROpean AGRiculture WATer use and trade under climate change (EURO-AGRIWAT)” were presented. This assessment used Water Footprint (WF) and virtual water trade (VWT) as the main methodology to create “guidelines for more efficient water resource management in relation with agricultural activities under climate change and variability” (<http://www.cost-es1106.eu>, accessed on 10 August 2016).

Here, Hoekstra explained to an audience consisting almost exclusively of water scientists and agronomists what was new about the Water Footprint concept. This audience was made up of both critics and advocates of WF. One trusted proponent commented to us that Hoekstra had some concern about the concept being captured in the International Organization for Standardization (ISO) and national certification schemes. In his presentation, full of maps and graphs derived from developed databases, Hoekstra referred to the global water problem, relating it to ‘our’ consumption patterns and the crisis ‘we’ are facing. The rhetoric was that of a worried water scientist and global citizen, someone concerned about the world at large; “as it is in our own interest to make water use sustainable, not only nearby but also elsewhere, because we depend on it” [13] (p. 32). To save the world, he explained, water efficiency has to be viewed at a global scale. The red regions on the presented world map need to become smaller by better matching crop water requirements to the available water. The Peruvian coast and Motupe were among the regions that appeared in red, and were thus identified as places where this matching ought to be considered (see also [31]); for example, by telling Fabio to grow manioc, not

mango. Hoekstra also emphasized, however, that acceptable water footprint values should be decided locally. The maps and graphs will help to inform these decisions.

The water footprint concept introduces supply chain thinking in water management. According to the Water Footprint website, the concept intends to determine and offset “the amount of water used to produce each of the goods and services we use. It can be measured for a single process, such as growing rice, for a product, such as a pair of jeans, for the fuel we put in our car, or for an entire multi-national company. The water footprint can also tell us how much water is being consumed by a particular country—or globally—in a specific river basin or from an aquifer” (<http://waterfootprint.org>, accessed on 13 July 2016) (see also [13]). A four-step method is suggested to assess a water footprint [7]. The first step is setting the goal of what process or product should be measured, followed by calculating the water consumption and determining the footprint of that process or product. The third step is to assess its efficiency and sustainability and, finally, actions are considered to reduce or offset the water footprint [7,31,32].

What is precisely determined and measured, Hoekstra explained during AGRIWAT, are the blue and green water consumption (and the water needed to dilute pollution, so-called grey water). Someone in the audience, an old Dutch engineer interrupted him: “what is precisely blue water?” The answer was straightforward: blue water means fresh surface and groundwater, the water in lakes, rivers, reservoirs, and aquifers. Many in the audience nodded. Blue water also includes irrigation. Green water refers to precipitation, or differently put, the rain water stored in the soil that is available to crops [5,6]. The idea of green water was coined by hydrologists in the 1990s who were also concerned about global water scarcity, and suggested that, often, available soil water was a cost-effective and in many ways efficient source of water that remained underexposed in policy circles [33,34]. How did these claims of blue and green water consumption and of efficiency and productivity come about? What (practices) had to be done, with what resources?

Peter Gleick’s seminal book, ‘Water in Crisis’, shows the water availability of countries in units of 10^6 m³. One of the countries, Peru, according to this book, has merely 40,000 of these units available. Through the Food and Agriculture Organization (FAO) databases, information can be retrieved, like the annual yield of agricultural produce per country—from banana to wheat. Mangoes too appear: for Peru, an average yield of 17.6 tons per hectare and a total production of 191,000 tons (obtained from <http://faostat3.fao.org/>, accessed on 10 August 2016. For other data, see [5,10]). These numbers, combined with a modelling program called CROPWAT, are crucial for a water scholar to quantify (virtual) water flows. CROPWAT was developed by another Dutch water and irrigation scientist working for the FAO. It was meant to enable future generations of water and agriculture professionals to calculate and compare crop water requirements (CWR) around the world. The CWR of a particular crop is defined by the water loss through evapotranspiration (per unit area); this includes water lost through the evaporation of water from the soil and canopy on the one hand, and through the transpiration via the plant’s pores or stomata on the other (per unit area) [35]. For this purpose, CROPWAT uses the Penman-Monteith equation which is considered as the world standard for estimating evapotranspiration, or ET [36]. For the validity of the equation, a single crop on a large-enough planting area is considered [6]. Mixed cropping systems and irregular fields make determination of canopy properties, ground cover and aerodynamic resistance, needed for modelling, virtually impossible [6].

Like in the book “Water in Crisis” [10], these tools are used by water scientists to know a given water reality, frame water problems, and prescribe solutions. All of them are designed with an academic purpose and are built on longstanding methods of calculation. They enact a particular version or logic of water, one that matches their search for planetary-scale solutions for a global resource in crisis [11]. The very idea of a large water crisis, and concerns of climate change and variability as well as population pressure, are not new [37], but such concerns used to be addressed locally or regionally. The idea that water is a universal good [12,38] emerged at the turn of the century. In line with a long tradition within the water scientist’s community of wanting to save the world, one of the solutions

offered by WF proponents for water problems was, thus, to consider water use efficiency on a different scale: the global one [39]. The starting point of this solution is that it matters where water is used and who consumes the goods and services that water produces [5]. This is particularly inspired by the idea that there is much water to be gained (or saved) in agriculture by more efficiently matching water gifts to crop requirements and agreeing on benchmarks [13,39]. This way of knowing water combines the much repeated statement that most freshwater is used in agriculture, with the widely held belief that much of this water is used inefficiently [40–42]. Hence, identifying where water can be used, or utilized, more efficiently and finding ways to hold users accountable for their water and irrigation practices is an important objective of the WF initiative. The conviction is that standardizing and improving the availability of accurate physical knowledge about the world's sources and uses of blue and green water will go a long way in realizing this objective [7,13,39].

This is indeed a particular way of speaking about and measuring water use efficiency, and at a particular scale: the scale of the globe. It is in this language of efficiency that water sustainability is appraised and responses are formulated. Hoekstra and Hung [5] (p. 10) state that “the overall efficiency in the appropriation of the global water resources can be defined as the ‘sum’ of local water use efficiencies, meso-scale water allocation efficiencies and global water use efficiency”. The authors go on to mention that regarding the former “there is quite some knowledge available” and “improvements have actually been achieved already” [5] (p. 9) while suggesting global use efficiency as a way to solve “water in crisis” [10]. The scaled efficiency approach also reveals different perspectives or disciplines; local water use is linked to technologies and irrigation engineers, while allocation efficiency is seen as a property rights issue. This makes global use efficiency the scientific responsibility of hydrologists. It becomes something to be dealt with through the proper conceptualization and quantification of the hydrological cycle, which is the basis of modern water science and informs modelling programs like CROPWAT and geographic information system (GIS) mapping of regions and river basins, and hence the WF concept. This hydrological cycle, including the computer programs, maps, and models through which it is calculated and expressed, help enact or “help structure a [very] particular understanding of water” [43] (p. 630): one that makes sense and is real within the rapidly proliferating international policy-science networks that define efficiency at a global scale by connecting places of water abundance with places of water scarcity—and, thus, have vested their hopes on the possibility of modifying or intervening in virtual flows of water.

In recent years, WF studies have emphasized the role of place and time in determining water footprints, arguing that basin caps and water footprint benchmarks are context-specific [13,44]. With growing databases, improved spatial resolution, and advanced computer models, attempts are made to capture local natural conditions, such as climate variability and soil characteristics, in global assessments [39]. It infers a scaled hierarchy that is not necessarily valid beyond the WF logic. We use the next section to discuss and connect both the logics of WF and Motupe smallholders.

4. Discussion

Vos and Boelens [45] discuss how the emerging (international) issues of fair trade, environmental sustainability, and corporate social responsibility in relation to water are generating efforts to account for water as if it were the same everywhere, so that it can be compared across places and times. This is, indeed, what happens with the Water Footprint Assessment [11]; its success lies precisely in its ability to talk to different people and places. In the process, there is a risk that the WF comes to appear as if it is the only possible version of water; something that promotes measures that make other possible water logics disappear. The opportunity to obtain a ‘blue water certificate’ (*certificado azul* in Spanish) as a result of the decree RM 246-2015-ANA issued by the Peruvian National Water Authority (*Autoridad Nacional del Agua*, ANA) is such an initiative. We emphasize that the certificate in Peru is an implementation of the WF concept, here used as a tool and based on ISO standardization. This appropriation of the WF in Peru underlines the concept's fame, but also carries the risk that WF terminology is used differently from its scientific project.

We have shown that WF water itself is a very particular version (or logic) of water, one that is enacted through the devices, databases, and scientific publications of the Water Value Series published by UNESCO-IHE—based on specific measurement logics, definitions, and calculation traditions. In this sense, the WF water logic is as contextual and ‘local’ as the *poza* logic: both emerge in and as part of specific cultures of knowing and dealing with water.

This explicit recognition of the ‘localness’ of WF, together with a serious consideration of how generations of living with water in specific places yields important wisdom, sets the stage for conversations to take place between the WF logic and the *poza* logic. By treating these two logics in symmetrical terms, they can enter into a dialogue about their similarities and differences, and about what they can learn from each other. We use this section to imagine such a dialogue, focusing on how the two logics enact and use different versions of efficiency and sustainability. We structure this imagined conversation in four topics: crop characteristics, irrigation methods, groundwater dynamics, and fruit trade.

First, the Water Footprint concept emphasizes *global* water use efficiency to solve the growing scarcity observed and experienced around the world. It does this by mobilizing models like CROPWAT, which help to establish which crops should be grown where—in terms of comparative water advantage. Based on that logic, mangoes are not the right fit for the Motupe desert valley. In Fabio’s reasoning, however, mango trees are very water efficient: given Motupe’s variable climate and water availability, mango trees are remarkably drought resistant, while also tolerating high levels of water logging. More so, the fact that Fabio’s tall trees are irrigated only 3–4 times a year to have a successful harvest, and the flexibility they allow when it comes to irrigation scheduling, means that mangoes make more sense than less consuming but more water sensitive crops.

Second, Fabio is constantly confronted by government and private sector irrigation engineers and water professionals who deem his *pozas* as wasteful of water because of infiltration and evaporation losses. This attitude stems in part, in Motupe and Peru at least, from the deep entanglement of the private sector with water governance. For, unlike pumps, polytubes, and drippers, *pozas* cannot be marketed. Water professionals in Peru may be quick to link their assessment of *pozas* as wasteful to the WF insights of water efficiency. However, both logics of WF and Motupe smallholders underline that water which infiltrates is *not* lost or inefficient, but can be recaptured and used, for example, further downstream [5,6] or even connect it to flows “essential for the functioning of ecosystems and of societies” [13] (p. 32). Furthermore, expertise on how best to irrigate trees in *pozas* resides not with engineers but with the farmer who knows the specific water needs of each tree and location of each wet spot in his or her field. The reflex of agronomists and engineers upon seeing large ponds with standing water may be to dismiss the *poza* method as wasteful, but is this justifiable?

The Motupe farming system has historically evolved around the challenge of dealing with very little water; chances are high that there is some interesting wisdom in the *poza*-method that scientists could help make useful for other places and smallholders. Here, hydrological and WF expertise could, for instance, be invested in assessing the transpiration and evaporation components of an orchard of grown mango trees, as it might well be that (as recent evidence [46] suggests) the former is many times greater and dominates continental evapotranspiration. Scientific expertise could also help to figure out what happens to soil evaporation when mangoes are irrigated with *pozas* as compared to when they are irrigated with drip irrigation. With *pozas*, soil evaporation occurs only during the period when the top layer is wet. In Fabio’s orchard, with 3–4 irrigation turns per year, this period of only 4–6 weeks compares favorably with drip irrigated mangoes, where evaporation occurs year-round (see also [41]). As modern agriculture reduces the spacing between trees to 5×5 m (or even 3×3) the total area annually exposed to soil evaporation may be greater in drip irrigated farms than that on Fabio’s farm.

Third, and much in the same way, precise measurements and calculations would be useful to compare how Motupe smallholders and the Water Footprint scholars differently make sense of soil moisture and groundwater. In the Water Footprint logic, these two waters appear as green and blue water respectively, and the two thus appear as separated and detached. For Fabio, instead,

groundwater is intricately related to the deep (tap)roots of his trees, while groundwater levels also are connected to his surface irrigation method. For Fabio, in other words, green and blue water often overlap; something WF logic is only recently exploring [41]. Motupe farmers are, historically, accustomed to living with droughts, floods, and erratic rain. In fact, their pre-Columbian predecessors practiced a technique to explicitly deal with some of these vagaries of the weather: they constructed ‘sunken fields’. These fields were several meters below ground level, close enough to the water table to allow crops to access soil moisture, while protecting them from desert winds. The ancestors of Fabio also constructed hydraulic works to irrigate or replenish groundwater in times of abundance [47,48].

Some of the principles of these techniques are retained in the *poza* practices. *Pozas* transform from irrigation basins into a water harvesting technique when, as in times of severe *El Niño* rains, they are filled up to recharge the groundwater reserve [49]. Motupe farmers, thus, use an age-old technique to make beneficial use of precipitation (that can be up to 40 times the average rainfall) in a longer-term water strategy for their farms. In contrast, in the multi-year rainfall databases utilized by CROPWAT or put forth by meteorological services like SENAMHI, *El Niño* occurrences or other weather vagaries appear as unwanted statistical anomalies and are excluded from annual rainfall figures. They are, thus, also absent in water footprint calculations. This example, in addition to showing how water traditions may be full of wisdom, also illustrates that *poza* irrigators do not optimize water use over a single season, but over several seasons.

Fourth, smallholders and mango workers in Motupe have already learned from global water discourses and (indirectly from) the WF logic, in terms of ideas about the virtual water (and labor) that becomes embedded in their fruits when these travel elsewhere. They expressed this on several occasions in interviews, when proudly discussing about how their fruits arrive and are presented in Dutch supermarkets. Through farmer associations, among others, smallholders in Motupe are becoming more aware of consumption patterns, but also of (water-related) responsibilities on the consumer site. At the same time, for them, their fruits are more than just a water volume. Fabio, as well as many other smallholders that do agro-export, also take pride in their own particular variety of crops and trees, nurturing these partly for their own sake and cultivating them, not just to maximize profits, but also for reasons of (to mention just a few) taste, beauty, or heritage. In addition, Fabio’s interest goes beyond optimizing crop or income per drop: he also aspires to improve the ease of farming operation, for instance, or wants to spread risks.

5. Conclusions

What do these lessons hold for the future of Water Footprint Assessment? This paper recognizes and appreciates that WFs ambitions of universality and commensurability are needed to realize its goals of solving the world’s water problems or raising global water awareness. Yet, we argue that it would be counterproductive if the effect of its success would be that the WF logic comes to be seen as the only possible or most appropriate water logic, thereby overlooking, belittling, or even forcefully replacing other ones.

In the case of Peru, the Water Footprint has made its way to national water policy. Here, as part of governmental efforts to use water more efficiently, the National Water Authority (ANA) has adopted a normative decree (the RM 246-2015-ANA) to provide farmers and companies with the opportunity to voluntarily measure their water footprint and obtain a ‘Blue Water Certificate’ or *Certificado Azul*. With this certificate, users commit to take actions to reduce their water footprint and use water more efficiently in the future. The decree mirrors the stepped process of the Water Footprint Assessment, including quantification of water, sustainability assessment, and response formulation [7]. An international scientific language created primarily to make Western consumers more aware of how much water is needed to produce what they consume, thus, travels back to Peruvian farmers’ fields to co-shape their irrigation behavior. In the certification process, the issue is no longer which crop can best be grown in a particular climate (global efficiency), but becomes one of how and by whom a crop grows best. In Peru at least, global efficiency gets, thus, translated into a question of local

productivity. This not only fits and reifies the well-established normal expertise of irrigation engineers in improving agricultural water use efficiencies, but also conveniently synergizes with the efforts of drip manufacturing and design companies to expand their market in Peru's booming agro-export sector. These fits and synergies partly explain why the Water Footprint spread so easily and fast in Peru, but at the same time imply that there is a risk that if WF comes to be seen as the only or the superior water logic, it will destroy the wisdom embedded in other water logics, such as that of *poza* irrigation.

In this paper, we argued that privileging and supporting only one particular water logic is undesirable. The Water Footprint logic, for example, only 'fits' some realities, specifically those farms which, and those farmers who, have the desire and the technological and financial means to optimize their water use against yields or incomes. Often, these are agribusinesses with homogenous and single cropped fields. Singling out the WF logic as a superior one automatically makes other methods and ideas of efficiency appear as wasteful or backward, irrespective of the wisdom they embody. To avoid this from happening, this paper staged a symmetrical conversation between different logics as a way to arrive at a fair comparison and discussion between the two.

Constructing this more level playing field requires, first, recognizing the 'localness' of the WF logic as only one of many ways of making sense of water, based on the acknowledgment that WF stems from and is tied to specific knowledge traditions, networks, and funding streams. Second, it requires the willingness and ability to recognize and accept the wisdom of farmers; accepting that generations of living with water (as in Motupe) often yield intricate techniques for looking after, transporting, and caring for it—techniques that may form part of and are embedded in wider socionatural mechanisms for sharing available water across places and times. The paper shows that this symmetrical approach for dealing with the existence of different water logics provides an entry-point for studying water [28] and creates useful opportunities for multiplying possible scenarios for dealing with water problems.

In more practical terms, the implication of acknowledging other water logics calls on the WF assessment to invert its four-step process [7]. Rather than determining the scope for doing a Water Footprint Assessment as the first step, a more desirable course of action would be to include from the onset an explicit reflection (see also [32]). This reflection could be about how the WF logic—and its definitions and calculations of sustainability and efficiency—relates and compares to the logics, definitions, and calculations used by local producers and irrigators, including their notions of sustainability and efficiency. Doing this requires the willingness and patience to engage with and understand other than the familiar professional engineering ways of dealing with and speaking about water. In this sense, it may involve bringing in the expertise from anthropologists or other social scientists and broadening the context-specific characteristics of WF [13,41]. The purpose here, as we have shown, is not to 'adapt' the WF logic to a specific use context, but instead is to challenge *both* logics by comparing them with each other, with the objective of improving both. This, indeed, needs to be a thorough interdisciplinary endeavor. Our paper is a modest contribution towards these goals.

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