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Dynamics of water innovation in African cities: Insights from Kenya, Ghana and Mozambique

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ABSTRACT

The last decades have seen changes in the water innovation landscape in Africa, with many countries introducing innovative approaches to managing water resources and the provision of water services. However, little knowledge exists on how water innovators operate in this changing environment. The objective of this explorative study is to shed light on the dynamics of water innovation in African cities. We draw on the experience of 12 water innovators from Kenya, Mozambique and Ghana, complemented by insights from key actors in the national innovation systems of the three countries. The study finds that the dynamics of water innovation in African cities are manifested at different levels: the innovation itself, the innovating entity and the innovation system. The three countries have made efforts to create an enabling environment for innovation, but many system gaps still exist that need to be addressed. Fragmentation of the water innovation systems and securing scale-up capital and long-term investment for water innovation appear to be the most important bottlenecks. The former could be addressed by actively promoting interactive learning-based approaches to innovation; the latter by developing new financing models that allow water innovators and financiers to share the risks and benefits associated with water innovations.

1. Introduction

The world faces a water security crisis due to factors such as fierce competition over water resources, water pollution and climate change effects, poor water management practices and unsustainable extraction of water (UN, 2015). To address these challenges, water innovation is nowadays recognized by policy makers around the world as imperative (UNESCO, 2014; Wehn and Montalvo, 2018). In Africa, like on other continents, this recognition has resulted in many efforts to foster both technological and non-technological water-related innovations at different levels (organisational, sector, policy), thus changing the water innovation landscape. Hence many innovative approaches to water management have been introduced, spanning from decentralised wastewater management to rainwater harvesting, ecological sanitation, delegated management, re-use and recycling of wastewater, sustainable urban drainage, novel water business models, and community involvement models. However, field experience shows that, in many cases, water innovations introduced in African cities have been simply piloted in a few places and have hardly been scaled up. There is also little empirical knowledge on how water innovators operate in this changing environment and the conditions that shape water innovation

activity in Africa.

This explorative research aims to shed light on the dynamics of water innovation in African cities. The analysis follows the dynamics of innovation perspective to identify and describe a variety of inter-related factors, the presence of which or absence thereof shapes the emergence and fate of water innovations. It should be emphasized that the dynamics that enable water innovation in one setting can be a barrier in another. Empirical evidence is collected from three African countries that arguably are at different levels of development, namely Kenya, Ghana and Mozambique. We analyse 12 water innovations supported by VIA Water, a Dutch programme supporting water innovation in African cities. This is complemented by insights from some key actors (e.g., ministries, incubators, and universities) in the national innovation systems of the three countries. The dynamics of water innovation examined in this study fall into two major categories:

(a) internal dynamics that relate to the nature of water innovations, the innovation approach followed by innovators, and the capabilities of innovating organisations; and

(b) external dynamics relating to the national culture and the historical and current macro socio-economic and political conditions in the respective country.

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The structure of this paper is as follows. Section 2 sets the scene for this study by describing the changing landscape of water innovations in African cities. Section 3 presents the theoretical context of the study drawing on the dynamics perspective of innovation. Section 4 discusses the methodology followed by this study. Section 5 presents and analyses the results. Section 6 discusses the results. The final section concludes the paper.

2. The changing water innovation landscape in Africa

The dynamics of water innovation in Africa relate to a variety of trends and developments that have characterized the continent over the past decades. First, there is the pressure to deliver on national and global water-related commitments (e.g., the Sustainable Development Goals) which push governments and other actors in the water sector to introduce water innovations (e.g., new water service models to reach out to the millions of Africans who still lack access to safe drinking water). Second, the fast spread of ICTs in Africa plays a major role; notably, the growing use of mobile telephones, internet, computers and mobile networks has opened opportunities to implement smart water systems in Africa (Ndaw, 2015; Mvulirwenande and Wehn, 2019a), which reflects the innovation path dependency of the water sector (Wehn and Montalvo, 2018).

A third influence stems from new perceptions on economic and population dynamics in Africa that have emerged over the past years. In that regard, the popular idea that doing business at the Bottom of the Pyramid (BoP) can be beneficial (Prahalad and Hart, 2002), the evidence that a middle class is emerging in Africa (African Development Bank, 2011), and improvements in business environments of many countries are some of the developments that have positively influenced the business image of Africa. Thus, foreign direct investment and local entrepreneurship have increased on the continent, promoting innovations. In the water sector, large companies such as the Dutch Vitens Evides International and Regional Water Authorities, or the French Veolia and Suez Environment have started partnering with African water sector actors (notably water utilities), thus introducing many water innovations. There has been also a rising number of small enterprises, NGOs and consulting companies innovating for the water sector in Africa.

The fourth influence relates to the shifts in the international development arena, particularly the dwindling of financial flows from donors, which posed many challenges to finance conventional water projects in Africa. This has triggered not only the introduction of emerging and cost-effective water technologies (e.g., onsite treatment systems, household water filters) but also innovative financing mechanisms (such as blending grants, revolving funds and pooled bond mechanisms) (OECD, 2014; van Bork et al., 2015).

Finally, the water sector in Africa is faced with enormous social and societal challenges that require innovative solutions. Events such as flooding and water shortages that occur in most cities in Africa (e.g., the recent water crisis in Cape Town, South Africa), and phenomena such as rapid urbanization and population growth that render conventional approaches ineffective have created a sense of urgency and paved the way for trying new water management approaches.

3. Theoretical framework

3.1. The concept of innovation

Innovation is often described as a multi-faceted and complex phenomenon (Schumpeter, 1934; von Hippel, 1990). In this study, we follow the simplest, yet operational and broad description of innovation as including any attempt to try out new or improved products, processes or ways to do things (Bell and Pavitt, 1993). A distinction is generally made between product innovation (new products or services) and process innovation (new methods, techniques and procedures)

(OECD-Eurostat, 2005; Manders et al., 2016); radical innovation (completely new) and incremental innovation (involving modifications of current innovations) (Coccia, 2016); technological and non-technological innovation (Damanpour et al., 2009; Crossan and Apaydin, 2010); and open innovation (using internal and external ideas and paths to develop and bring innovations to market) and closed innovations (driven and controlled internally by an innovating organisation) (Chesbrough, 2006). The systems approach (Lundvall, 1992; Weber and Truffer, 2017) considers innovation as an embedded phenomenon, implying that it does not take place in a vacuum, but is conceived and implemented as a collaborative process among many organisations who interact and learn from each other in their operating environment.

In line with Bell and Pavitt's (1993) definition of innovation, the term "water innovation" is used in this study to refer to any attempt to try out new or improved products or processes to improve the development and management of water resources. That is, innovative solutions with the potential to contribute to improving the performance of the water sector by increasing the efficiency and effectiveness of activities in the water value chain (e.g., exploration and abstraction of water resources, water treatment, and distribution). As illustrated by the innovations sampled in this study (Table 2), water innovation is highly diverse and involves solutions that are produced inside and outside the water sector (see also Wehn and Montalvo, 2018).

Water innovators in this study are understood as individuals or for-profit entities such as small and medium enterprises (SMEs), consultancies or industry (e.g., ICT-focused companies, design companies) as well non-profit organisations, who are aiming to develop and bring to market innovative solutions for a water problem identified at any stage of the water value chain.

3.2. Dynamics of innovation

Research into the dynamics of innovation dates back more than 50 years and provides various entry points and levels of analysis (Wehn and Montalvo, 2018). The literature often classifies the dynamics of innovation into two broad categories: internal and external. The internal dynamics relate to (a) the characteristics of innovating organisations such as market orientation and learning processes (Rothwell, 1992; Hurley and Hult, 1998; Salavou et al., 2004), age and size of the organisation, human and financial resources (Schumpeter, 1934; Freil, 1999; Rothwell, 1992; De Jong and Vermeulen, 2003), (b) the characteristics of the innovation itself (e.g., relative advantage, cost, complexity) (Rogers, 2003), and (c) the approach followed to implement an innovation project (Chesbrough, 2006).

In this paper, we use the concept of "innovation capabilities" of an organisation to analyse the influence of organisational dynamics on water innovation (Zawislak et al., 2012). The concept delineates the following four major capabilities which altogether capture most of the factors identified above: development, operations, management, and transactions capabilities. The *development* capability involves imagining and building innovations, and is responsible for a conscious search and application of new knowledge (e.g., research and development). The *operations* capability refers to the ability to produce products with quality, reliability and competitive cost (e.g., production methods and equipment, quality management system). The *management* capability allows an organisation to integrate all internal capabilities in a coherent way (e.g., planning, integration and coordination processes). The *transactions* capability links the innovating organisation to its external environment, both through purchasing or selling. Successful innovation results from the integration of these capabilities, each of which consists of both individual and organizational aspects (Zawislak et al., 2012). In the context of small organisations where innovation mostly depends on the main entrepreneurs, the individual characteristics of these people are an important aspect of innovation dynamics (Shane, 2000; Dimov, 2010). The influence of these characteristics on water innovation is considered in this study as well.

The external dynamics of innovation can relate to the regional, national and international environment or to a specific industry (Edquist, 1997; Dijk et al., 1997); and at national and regional level, these dynamics are often referred to as innovation system (Lundvall, 1992). This study investigated the influence of the following key characteristics of the external innovation dynamics: the institutional framework (North, 1990), with a focus on the formal rules, policies and regulations governing innovation activities in a country; the national culture, with a focus on the entrepreneurial culture (Feldman, 2001), competition culture (Schumpeter, 1942) and language; historical factors, including legacies of colonialism (Miles, 2014) and traditional water management practices; and the country's macro socio-economic and political conditions, by focusing on business and market environment (Dutta et al., 2015), the human capital stock (Barro and Lee, 2000) and the quality of government institutions (Huang and Xu, 1999).

4. Methodology

4.1. Research design: case study approach and selection of cases

This research follows a qualitative case study approach (Yin, 2003) and draws on the experience of water innovators supported by VIA Water, a Dutch programme that supports water innovation in cities in Benin, Ghana, Kenya, Mali, Mozambique, Rwanda and South Sudan, with four wildcards for projects in Senegal and Ethiopia. The programme is hosted by Aqua for All - a Dutch, non-profit WASH organization. The support provided to water innovators comprises seed funding and a variety of other innovation support services (e.g., coaching, training and networking). Further details on this programme can be found in Nagel et al. (2018) and Mvulirwenande and Wehn (2019a). The study used purposeful sampling (Blumberg et al., 2008), implying that the choices of countries, water innovators, and other informants were deliberately made based on their potential to provide relevant evidence needed to achieve the study's objective.

Three countries with slightly different levels of development were selected, namely Kenya, Ghana and Mozambique. Table 1 displays some socio-economic indicators of these countries. It was assumed that they have different levels of innovativeness too (including in the water sector) and therefore can help to generate a comprehensive picture of the dynamics of water innovation in Africa. As a matter of fact, the three countries have a large share of the VIA Water projects portfolio: out of a total of 64 projects, Kenya, Ghana and Mozambique feature 42 projects (with 19, 14 and 9 projects respectively) (VIA Water, 2018).

For practical reasons, we investigated 12 water innovation projects (i.e., 4 projects in each country) that had been implemented for at least one year, implying that many of them were not completed yet at the time of interviews, but had already generated many insights to share. Table 2 displays the list of these projects, with a short description of the innovations involved and the leading innovating organisations. We selected cases from VIA Water because of the following reasons: the

Table 1
Selected socio-economic indicators of Mozambique, Ghana and Kenya.
Source: www.countryeconomy.com

Socio-economic indicators	Mozambique	Kenya	Ghana
GDP per capita (US\$, 2017)	426	1595	1114
Competitiveness Ranking (out of 144 countries) (2018)	133	93	106
Doing business Ranking (out of 189 countries) (2019)	135	61	114
Corruption Ranking (out of 180 countries) (2018)	158	144	78
Innovation Ranking (2018)	115	78	107
Human capital Ranking (2017)	116	78	72

programme operates in many African countries, which enabled the selection of countries that represent most of the African realities; the supported innovations cover almost all aspects of the urban water cycle, implying that our sample reflects the complexity of water innovation in African cities; and choosing projects supported by one programme eased cooperation and access to information.

4.2. Data collection and analysis

The data used in this study is mostly qualitative and was collected from primary and secondary sources. Primary data was gathered by means of semi-structured interviews and focus group discussions (FGD) with different categories of people (see Table 3), as well as informal discussions with VIA Water project owners at different events organised by VIA Water. The latter include the sharing skills seminar in Ghana (November 2017) and learning tours organised in Ghana (June 2017), Kenya (September 2017) and Mozambique (February 2018). The interview and FGD protocols drew from the conceptual framework of this study: they included questions about internal and external dynamics of water innovation. For some aspects of the analysis, the paper uses the data obtained from a broad quantitative online survey administered for all VIA Water-supported innovators (but the data reported in this paper relates only to Ghana, Kenya and Mozambique).

Secondary data was collected from a variety of documents, including VIA Water internal documents and relevant literature on innovation and entrepreneurship.

Different methods were used to analyse the data. The qualitative material was first coded and categorized into conceptual categories informed by the theoretical framework and then subjected to content analysis. This process was done first at country level, followed by a cross-case synthesis which is reported in this paper. For the quantitative survey, 34 questionnaires from Kenya, Ghana and Mozambique were fully completed and usable; the resulting survey material was subjected to basic statistical analysis.

5. Results and analysis

The analysis follows the two major conceptual distinctions described in Section 3. We examine first the internal dynamics, and then the external dynamics of innovation.

5.1. Internal dynamics of water innovation

5.1.1. The characteristics of water innovations

The analysis shows that the 12 water innovations investigated in this study have some characteristics that influence their implementation and outcomes (see Table 4). On the one hand, most of them are social innovations: they have the potential to address either unmet social needs (e.g., sanitation, unemployment of the youth) or societal challenges (e.g., climate change effects such as floods) (European Commission, 2011) facing many African countries. Our analysis suggests that such water innovations tend to be positively valued and can easily attract seed capital (to test them out) from development partners and donors.

However, the very social nature of these innovations poses some challenges regarding their diffusion, particularly in African cities. To start with, scaling up social water innovations requires capital either from public institutions or the private sector. Yet, many governments in Africa cannot finance innovations due to budget limitations, and conventional financiers (such as venture capitalists and commercial banks) hardly provide credit for risky innovations. Besides, social water innovations have difficulties to diffuse among the people in need at the Bottom of the Pyramid (BoP) due to their inability to pay. The interviewed water innovators who have started commercialising their innovations (e.g., Safi Sana's seedlings in Ghana and Sanivation Blue Box toilet in Kenya) indicated that it is hard to find consumer models –

Table 2
Water innovation projects investigated in Ghana, Kenya and Mozambique.

Name of project	Short description of innovation	Lead innovator	Type of organisation
Ghana			
1 Vegetable nursery using recycled sludge	Produces seedlings using processed sludge and treated waste water.	Safi Sana	SME
2 Flash flood forecasting app	Provides early warning for flooding via state-of-the art modelling techniques. Satellite data is transformed into highly detailed rainfall data. An innovative algorithm provides rainfall forecasts. This is input for a flood model that provides flood maps on street level.	Royal HaskoningDHV	Consultancy
3 EnterWASH: business support for unemployed youth	Enhances the capacity of unemployed youth in the area of WASH and entrepreneurship through training, mentorship and financial support (crowdfunding).	MDF Ghana	Consultancy
4 Closing the water loop for carwashing stations	Develops a technology to recycle wastewater from car washing stations for re-use. The technology omits the expensive nano-filtration aspects for car wash wastewater treatment used in other countries but achieves a comparatively high treatment efficiency.	NHance	SME, start up
Kenya			
5 Roof tiles from recycled plastic and glass	Recycles non-biodegradable waste fractions (such as plastics and glass) into building materials (such roof tiles and bricks)	Trace	SME, start up
6 Chezo Serious Gaming	Gives gaming companies an ICT-based perspective into creating games other than purely fun games, which could add revenue streams.	Upande	SME
7 Sanivation: fuel from human waste	Install toilets in the homes of the urban poor for free, with a small servicing fee. Then, waste is collected, processed and transformed into charcoal briquettes.	Sanivation	SME
8 Soil-less farming in small urban spaces	Enables urban dwellers to make optimal use of small spaces for farming (e.g. rooftops, blind walls and fences) through affordable vertical hydroponics units. Grows plants without soil in a nutrient water solution using local materials. Crops can use 80 % less water and realising higher yields.	Hydroponics	SME
Mozambique			
9 Smart water meter reading	Allows water utilities to bill their customers more efficiently and transparently using advanced smartphone technology that registers water consumption by taking a picture and automatically communicates validated usage values to the billing system of operators.	Mobile Water Management	SME
10 Biological Urban Sanitation (BUS) project	Uses a Black Soldier Fly larvae to reduce the sanitation chain to practically no waste. The larva can eat up to 10 000 times its own weight in about 30 days before it becomes a fly. The black fly lives for 8 days and can meanwhile deliver up to 500-900 eggs which need to eat the same amounts. Attempts to create the right environment in which this cycle can take place inside a pit latrine. Includes redesign of toilets and pits.	Annemarieke Mooijman Consulting	SME
11 Brick and Bag gardening	Turns urban trash into vermicast (worm manure), raises bed panels and gardening tools while channelling grey water into vegetable and fruit gardening. The use of the raised vegetable beds made with bricks, polyester sacks and plastic containers allows for vegetables and fruits to be grown with limited space, water, chemicals and money.	Global Industrial Marketing and Distribution	SME, start up
12 Reduction of nitrate levels in groundwater wells	Reduces the inflow of nitrogen into the groundwater, by collecting urine and faeces from toilets. The urine then is converted to struvite and faeces into compost, for which a business model is tested.	SWS International	SME, start up

Table 3
List of respondents and interviewees.

Method	Data collection tool	Category of informants	Number
Quantitative	Online survey	Water innovators in Kenya, Ghana, Mozambique	34 ^a
Qualitative	Semi-structured interviews	VIA Water programme managers (based in the Netherlands)	4
		Water innovators in Kenya, Ghana and Mozambique	24
		VIA Water country liaisons in Mozambique and Ghana	2
		Key actors ^b in the innovation systems in Kenya, Ghana, Mozambique	27
	Water innovation users and or customers	20	
	Focus Group Discussion	Representatives of innovation projects selected to attend the Water Week in Amsterdam (the Netherlands) ^c	1 FGDs (14 people)

^a Ghana (n = 10) Kenya (n = 18), Mozambique (n = 6).

^b The latter category comprised policy makers (e.g., representatives of Ministry in charge or science and innovation), managers of innovation enablers (e.g., incubators, technology hubs, and technological parks), researchers from universities and other knowledge institutes, water agencies, utilities, representatives of NGOs and consulting companies promoting water innovation.

^c Note that 8 out of the 14 represented innovation projects were included in our sample for in-depth investigation.

particularly pricing models - that allow for a profit while reaching out to the poorest segments of the population in African cities. Our interviews with the users of these innovations revealed that they still considered the prices as unaffordable, despite the many efforts by the innovators to develop inclusive business models. Under these

circumstances, water innovators are forced either to shift their target markets or abandon their innovation ideas.

On the other hand, most of the 12 water innovations are emerging innovations in the context of African cities. This gives them a perceived relative advantage (compared to available conventional options) which

Table 4
Key features of 12 water innovations analysed in Kenya, Ghana and Mozambique.

Country	Innovation project	Pressing water need (s) addressed	Innovation approach	Origin of Lead innovating organisation	Education level of lead innovator	Degree of Novelty	Tech/non-Tech	Business/ Social focus
Mozambique	1 Smart water reading project	Drinking water Sanitation	Open	Foreign (Dutch)	MSc	Incremental	Tech (ICT)	Business
	2 Biological Urban Sanitation (BUS) project	Drinking water Sanitation	Open	Foreign (Dutch + Swedish)		Incremental	Tech	Social/business
	3 Bricks and Bags gardening	Agriculture Water Sanitation, Water quality, Groundwater	Closed	Local	BSc	Incremental	Tech	Business
	4 Reduction of nitrate levels in groundwater wells	Sanitation, agriculture water	Open	Foreign (Dutch)	BSc	Incremental	Tech	Social/business
	5 Vegetable nursery using recycled sludge	Sanitation, agriculture water	Open	Foreign (Dutch)	Msc	Incremental	Tech	Social/business
	6 Flash Flood Forecasting Application	Data, institutional strengthening, Floods and droughts	Open	Foreign (Dutch)	PhD	Incremental	Tech (ICT)	Social/business
Ghana	7 EnterWASH: business support for unemployed youth	Drinking water, institutional strengthening, Financial arrangement	Open	Local	Msc	Incremental	Non-tech	Social/business
	8 Closing the water loop for carwashing stations	Water quality, sanitation	Closed	Local	Msc (PhD student)	Incremental	Tech	Social/business
	9 Roof tiles from recycled plastic and glass	Sanitation, Urban planning	Open	Local	Msc	Incremental	Tech	Social/business
	10 Chezo Serious Gaming	Drinking water Sanitation	Open	Local - (Dutch boss)	PhD	Incremental	Tech (ICT)	Business
Kenya	11 Sanitation	Drinking water Sanitation	Open	Local (USA founded)	Msc	Incremental	Tech	Social/Business
	12 Soil-less farming in small urban spaces	Agriculture water	Closed	Local	Msc	Incremental	Tech	Business

increases their attractiveness and can, eventually, promote their diffusion (Rogers, 2003). This is notably the case for the ICT-focused water innovations, with their potential to enable smart management of water systems in Africa (Mvulirwenande and Wehn, 2019b) and thus providing solutions that are more cost-effective (e.g., gathering and sharing of data related to floods through direct involvement of “ordinary” citizens) than mainstream approaches (Wehn and Evers, 2015; Wehn et al., 2018).

A final intrinsic feature of the water innovations analysed in this study, which confers to them some relative advantage, is that they generally provide simple and context sensitive solutions (e.g., affordable and easy to use) to urban water problems in Africa. In our interviews, the early customers of these innovations seemed to perceive them as low cost in comparison to alternatives available on the local markets. For example, at the time of interviews, Trace’s roof tiles were selling at 800 Kenya shillings per square meter, while alternative tiles made from clay were at 910 shillings. Although it is still early to conclude that these innovations really provide cost-effective and robust solutions, there are positive signs that they can compete with alternatives and have the potential to diffuse.

5.1.2. Approach to water innovation

In most cases, the sampled innovators follow the open innovation approach; their water innovations are implemented through partnerships that bring together foreign and domestic organisations as well as other relevant stakeholders. The water innovators indicated that this approach has enabled them to contribute a variety of complementary resources (e.g., knowledge, financial, network) and thus create stronger innovation capabilities (this point is further explored in Section 5.1.4; see also Mvulirwenande and Wehn, 2019b). Our analysis suggests that the water innovators who preferred to follow a closed approach to innovation experienced some problems, notably in terms of meeting the deadlines agreed with VIA Water. For example, NHance, the start-up implementing the Car Wash station project in Kumasi (Ghana) has reportedly spent too much time developing the prototype. The innovator also experienced challenges to develop a sound business model due to a lack of in-house expertise.

In particular, our study found that the majority of innovators develop their innovations in conjunction with potential customers, a phenomenon known in the literature as co-production or co-creation (Verschuere et al., 2012). The results displayed in Table 5 show, on the one hand, that most water innovators in our sample consider co-creation as beneficial. In fact, only one innovating entity (3%) did not engage potential customers or clients in their innovation process. The rest of the water innovators (97 %) did, although to different degrees.

On the other hand, the results show that the degree of customer involvement varies. The majority of water innovators (41 %) argue that they have maintained ongoing dialogue with their customers to support the different stages of their innovation processes. Another group (27 %) indicate that they consulted their potential customers to seek their needs and wishes during the design phase of the innovation process. These two forms of involvement were confirmed by the interviews with the water innovators; they acknowledged that involvement occurred notably through stakeholder consultations. The final group (29 %) report that they integrated some of their potential customers in their project teams; this implies that they worked closely with them in the day-to-day implementation of the innovation activities, which created optimum conditions to use customer knowledge.

5.1.3. Strategic water innovation areas

The water innovation projects analysed in this study cover different strategic water innovation areas, or the so-called pressing water needs identified by VIA Water in African cities. These are: drinking water, sanitation, water in urban agriculture, water harvesting, groundwater, water quality, data, institutional strengthening, water allocation, financial arrangements, urban planning and floods and droughts (Nagel

Table 5
Extent of co-creation of water innovations (with customers).

Involvement of innovation customers ^a	Number of responses	%
We did not actively engage our potential customers in the innovation process	1	3%
We consulted our potential customers about their needs and wishes during the design phase of our innovation project	9	27
We maintained ongoing dialogue with our potential customers to support the different stages of our innovation process	14	41
We integrated some potential customers in our project team in order to effectively involve them in our innovation activities	10	29
Total	34	100 %

^a “Co-creation” was assessed using two measures: whether water innovators practice it or not (presence) and to what degree (level). The first statement reflects the “non-presence”, whereas statements 2, 3 and 4 reflect “presence” of co-creation. Each of the last three statements further indicates the depth of co-creation or involvement of customers, which is shown by the clear increasing trend in the answer options. Because each surveyed innovator had to select a single option, the responses to the four statements add up to 100 %.

et al., 2018).

This study sought to understand how these pressing water needs influence the form and content of water innovation processes in African cities. Our analysis suggests, on the one hand, that irrespective of the type of pressing water needs addressed, all the 12 water projects involve incremental innovations. These seem to be more attainable for African cities where the existing innovation capabilities (e.g., human, financial, technological) do not allow water innovators to venture into costly radical innovations.

On the other hand, the pressing water needs seem to command product and process innovations, of both technological and non-technological nature. A typical characteristic of the pressing water needs in African cities which negatively affects water innovation processes is the lack of data. According to the innovators, access to reliable water-related data is very problematic, which makes it difficult to support innovation-related assumptions. In some cases, relevant data just does not exist in usable formats or exists but is scattered across different organisations and/ or sub-sectors (there is a lack of data aggregation or integration mechanisms); in others, the institutions holding data are not easily accessible mostly because of their organisational culture and policy regarding data sharing.

Our study also wanted to understand the experience of water innovators with innovation to address specific pressing water needs in African cities. They were asked to agree or disagree with a number of statements reflecting possible influences of the water needs on the design and implementation of water innovations. The results in Table 6 summarize the insights from the innovators, suggesting that they are somewhat in agreement with most of the statements, as evidenced by the low but still positive average scores. During interviews and focus group discussions, the innovators generally agreed that most of the pressing water needs are complex and involve a multitude of heterogeneous stakeholders, which decisively affects the innovation process. This complexity implies, among other things, that water innovators ought to take a partnership approach (based on open innovation) if they are to be successful. In the same vein, the innovators seem to somewhat agree that many pressing water needs (e.g., floods and droughts, ground

water, water quality; water allocation) can best be addressed through innovations that take into account the water– agriculture–industry nexus (mean = 3.58).

As indicated earlier (Table 4), the majority of the innovations analysed in this study have a business focus. However, the results in Table 6 suggest that not all the surveyed innovators are unambiguously convinced about the potential to develop profitable innovations for the pressing water needs in African cities (mean = 3.29). This perception could be partly explained by the fact that, at the time of the survey, most of the innovators were still in the early stages of their innovation processes and did not yet have a clear idea about whether their innovations can actually make it to the market and be profitable. The results from our focus group discussions and interviews suggest that developing profitable water innovations in African cities is challenging due to how the water sector has been managed historically. For example, water utilities are generally interested in innovations that can help improve their operations, but their long tradition of donor funding often makes them shy away from uptaking innovations from private providers.

Finally, many water innovators tend to agree that addressing the pressing water needs in African cities involves costly innovations which require special financing mechanisms (m = 3.68); or that some of the pressing water needs (e.g., ground water, floods and droughts, water quality) involve a public property (or resource) and that related innovations necessarily require public money to be implemented at a larger scale (mean = 3.34). In the same vein, the surveyed innovators tend to agree that water-related innovations can hardly attract private investors because it is difficult to ensure returns on investment (mean = 3.33). All these insights were consistently confirmed during the interviews: it appears that innovating in the water sector requires a lot of investment which many potential innovators in Africa do not have access to. This is further complicated by the fact that, as we explain later, the water sector in general is still perceived as a high risk area, which makes the private sector shy away from committing long-term investments in the sector.

Table 6
Experience of innovators with innovation to address pressing water needs (n = 34).

Statements: the main pressing water need addressed by our innovation	Mean	SD
Involves costly innovations which require special financing mechanisms	3.68	1.08
Is best addressed through innovations that take into account the water – agriculture – industry nexus	3.58	1.04
Is a major concern of the public - including poor citizens, so it is easy to engage them in related innovations	3.38	1.26
Related innovations are institutional in nature and take time to be accepted by stakeholders	3.38	1.16
Has so much to do with a public property (or resource) that related innovations necessarily require public money to be implemented at a larger scale	3.34	1.05
Related innovations can hardly attract private investors because it is difficult to ensure returns on investment	3.33	1.17
Is not so obvious to many stakeholders – so it is difficult to engage them in the related innovation processes	3.29	1.18
Allows easy development of innovations that are profitable (business oriented)	3.29	1.27
Requires typical new/radical solutions, not much exists that can be adapted	3.09	1.15
A lot of innovations exist already elsewhere to address the need - we can just adapt (or slightly modify) them to fit the local context	2.88	1.21
Does not easily allow to find partners because apparently not so many organisations are working on this pressing need	2.59	1.06

Note: Likert scale from 1 to 5, where 1 = strongly disagree and 5 = strongly agree.

5.1.4. Characteristics of innovating organisations

The findings of this study show that the characteristics of innovating organisations matter for effective design and implementation of water innovation projects. On the one hand, our analysis suggests that the sampled projects benefit from the education and experience of the lead innovators and their teams. As shown in Table 4, the originators of ideas underlying these projects hold university degrees (some are water-science related). The advanced education of these people appears to have increased their innovation competences; e.g., they all have a variety of professional skills (including good IT literacy) which they tap into to effectively implement their innovations.

We also found that the innovation experience and know-how of the water sector have a positive influence on the innovation processes. Some of the innovators clearly indicated that without good knowledge of the water sector in their home countries and the network of relationships developed over many years, it would have been extremely difficult to implement their innovations. Less experienced innovators, notably those innovating for the first time, acknowledged that they faced many challenges, since they had to learn almost everything about innovation management from scratch through VIA Water incubation.

This research showed, on the other hand, that most of the sampled innovation projects are implemented by small scale organisations (e.g., start-up enterprises, NGOs and consultancies). Conventional innovators such as universities, research centres and large companies are not well-represented as lead innovators in our sample, but this reflects the situation of the VIA Water supported innovation projects (VIA Water, 2018; Mvulirwenande and When, 2019a).

Our analysis suggests that the small size of the innovating organisations has had a mixed influence on the water innovation processes. First, many of the innovators indicated that consultation with their partners was relatively easy, mostly because they were all small organisations. The VIA Water managers also acknowledged that, in the absence of many layers of management in these organisations, dealing directly with the top managers facilitated communication and speeded up project implementation. Second, the water innovators acknowledged that, taken individually, their organisations had capability gaps (including limited financing and deficiency of skilled labour) associated with their small size which they filled through innovation partnerships.

The survey results suggest that most of the consortia had good levels of innovation capabilities at the start of the innovation project (Table 7). By facilitating exchange of complementary resources (knowledge, financial, material, network), the partnerships allowed to create new innovation entities that were able to imagine and actually produce sound water innovations and to interact with relevant third parties.

5.2. External dynamics of water innovation

5.2.1. Influence of contextual factors – a quick scan

In the online survey, the water innovators from Ghana, Kenya and Mozambique were asked to indicate the extent to which specific contextual factors have influenced their innovation processes. The respondents' answers (summarized in Fig. 1) already provide indications of the positive or negative influences of these factors. In each of the three countries, the availability of local expertise, mentality of local

Table 7

Self-assessment of innovation capabilities of partnerships (n = 34).

Innovation capabilities	Mean	SD
Development capability (imagine innovative solutions)	4.05	0.98
Management capability (plan and coordinate innovation activities)	3.87	0.79
Operations capability (produce innovation)	4.04	0.85
Transactions capability (interact with external actors)	3.71	0.73

Note: Likert scale from 1 to 5, where 1 = very poor and 5 = excellent.

organisations about innovation, and the country's business environment are perceived to have somewhat positive influences on water innovation processes. Conversely, governance, attitude of water sector actors to new water management approaches, and policies and regulations appear to have negative influences on water innovation processes in Kenya and Mozambique (compared to Ghana). Language barriers and (national) culture aspects (such as risk avoidance, tolerance of failure or lack of thereof) are reported to have negative effects on water innovation in Mozambique, but a positive influence in Ghana and Kenya. The water innovators in Ghana reported somewhat more positive influences of each factor and with higher scores than their counterparts in Kenya and Mozambique. Mozambique has the lowest scores on most contextual factors, though.

Thus, overall, these findings suggest that the three countries have created – though to different degrees - an enabling environment for innovation activities, but a lot of gaps still exist that need to be addressed. The reported negative and positive influences of contextual factors were confirmed by our interviews and focus group discussions as well as existing literature. In the following sections, we analyse the qualitative information collected on the actual impact these factors have had (or are likely to have) on water innovation processes in Kenya, Ghana and Mozambique. Four sets of factors are considered: cultural, institutional, socio-economic and historical. The discussion draws on the interviews with the water innovators and with selected key actors in the innovation systems of the three countries.

5.2.2. Cultural factors

The findings from Kenya, Ghana and Mozambique show that the level of entrepreneurial culture, the language spoken and the degree of competition (spirit) in these countries negatively or positively affect innovation in general and water innovation activities in particular. On the one hand, the interviewed innovators consistently argued that their decision to venture into water innovation stemmed from the growing innovation and entrepreneurship culture in the respective country. In the cases of Kenya and Ghana, for instance, this is evidenced by the increasing number of individuals who have successfully created new businesses and the growing number of institutions that support them (e.g., incubation programmes, tech hubs, innovation funds).

In each of the three countries, there is conviction at national policy level of the need to systematically foster innovation and entrepreneurship as a driver of economic development (e.g., through creation of new jobs). This belief is reflected in particular in the countries' development strategies (e.g., Vision 2030 in Kenya, National Agenda to Combat Poverty in Mozambique). Over the past decades, the three countries have also seen a steady rise in interest in entrepreneurship education, particularly at the higher education level (Robb et al., 2014). These conditions have apparently increased the level of passion for doing things differently and encouraged a risk taking attitude among the populations of Kenya, Ghana and Mozambique, especially the youth. Nevertheless, the three countries have reached different levels of innovation and entrepreneurship development, which explains to some extent their performance differences in terms of water innovation. For example, the data available at VIA Water shows that, out of the 523 applications received by VIA Water, Kenya and Ghana have the highest number of applications (137 applications in each case), winning 19 and 14 contracts respectively; while Mozambique had nine contracts out of only 57 applications¹ (VIA Water, 2018).

Further evidence confirms that entrepreneurship in Kenya and Ghana seems to be more advanced than in Mozambique. In the case of

¹ Note that this rather high ratio resulted from the fact that during the selection process, VIA Water gave preference to 'low scoring' countries (i.e., countries with fewer applications and/or low number of awarded contracts) (i.e., not Kenya or Ghana)

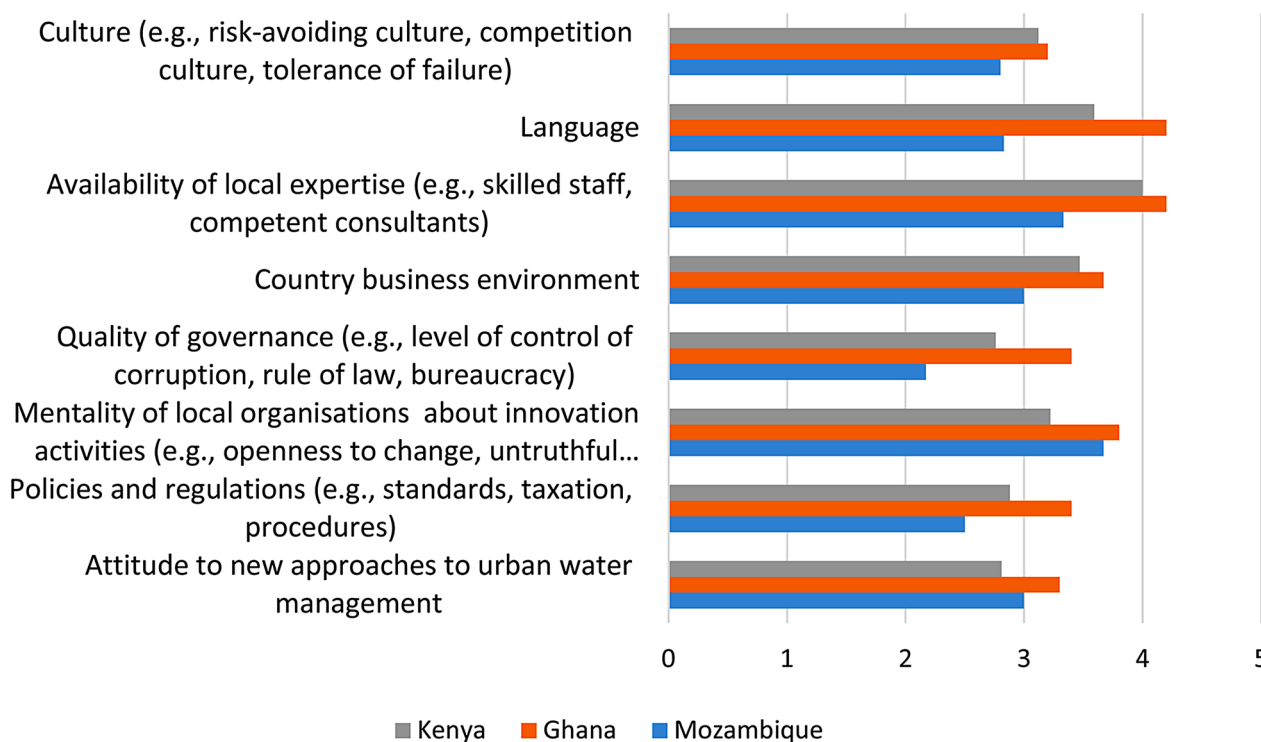


Fig. 1. Influence of contextual factors on water innovation (n = 34).

Note: Likert scale from 1 to 5, where 1 = very negative influence, 2 = negative influence, 3 = neutral, 4 = positive influence, and 5 = very positive influence. Ghana (n = 10), Kenya (n = 18), Mozambique (n = 6).

Ghana, most of our interviewees argued that the entrepreneurship spirit/culture is *emerging* but still constrained by factors such as the prevailing fear of failing and weak culture to think out of the box, to critically challenge the status quo. A sense of entrepreneurship already exists in the Ghanaian society, but entrepreneurs tend to innovate out of necessity, with little ambition to go beyond the “good enough level”. In Mozambique, most interviewees contended that entrepreneurship culture is still at its *infancy stage*. A variety of efforts are being deployed to boost entrepreneurship in this country, but many institutions and organisations are still characterized by the legacies of a collectivist culture. Some actors in the Mozambican water sector claimed, in fact, that it is difficult to innovate in this sector because water institutions are so centralised, conservative and oriented towards operations. The fact that many families and communities still discourage entrepreneurship initiatives (e.g., of graduate students) was consistently highlighted as a factor that kills a lot of innovations and businesses in Ghana and Mozambique. In contrast, most of the interviewees in Kenya argued that the innovation and entrepreneurship culture in this country is *maturing*, despite some institutional limitations which still prevent people from bringing their innovations to the market.

On the other hand, the water innovators interviewed in Kenya and Ghana indicated that English being their first or second language helps them to easily get access to relevant knowledge and other innovation-related opportunities. It also enables them to penetrate many segments of the Kenyan society and easily communicate about their innovations. In Mozambique, on the contrary, the fact that most people speak Portuguese appears to be disadvantageous for water innovation. The interviewees argued that not speaking English prevents potential Mozambican innovators from connecting with innovation systems beyond the local level.

Finally, in Kenya and Ghana, there seems to be a stronger competition culture which results in higher levels of innovativeness and entrepreneurship (across all sectors of the economy) than in Mozambique. The water innovators indicated, however, that too much competition

sometimes becomes a threat to innovation activities as some individuals tend to copy other people’s innovations and implement them so badly that it affects the credibility of the original products or services. The interviewees in Mozambique generally argued that this country (having come from a socialist/communist culture) is not yet a competitive society, and that the population has just started feeling the pressure to compete for available opportunities.

5.2.3. Socio-economic and political factors

The first socio-economic and political factor investigated in this study is the *availability of human capital and how it affects water innovation* in Kenya, Ghana and Mozambique. The water innovators from the three countries argued that, in general, they did not face significant challenges to find talented and skilled people to involve in their projects. This is consistent with the survey findings according to which the degree of supply of local expertise (e.g., skilled staff, competent consultants) has positively influenced the innovation processes (see Fig. 1). The major challenge emphasized by most innovators is how to attract and keep competent personnel. Many of the innovators being start-ups companies or public sector organisations, they can hardly offer competitive working conditions – so in many cases, recruited staff quit them as soon as greener pasture opportunities show up.

Overall, these findings suggest that the issue of human capital shortages has been increasingly addressed in Ghana, Kenya and Mozambique. This is largely explained by the emergence of many (public and private) institutions of higher learning which produce many graduates (including water professionals) annually and the increasing number of foreign (water) experts who operate in Ghana, Kenya and Mozambique. In spite of the increased number of graduates from local universities, many of the interviewees indicated that the quality of education is still an issue. Many universities remain theoretical in their teaching, and their graduates often lack critical competences on how to create value out of their knowledge.

The missing competence often cited by water innovators and other

interviewees is the lack of business skills, notably the ability to develop a business plan for an innovation idea. The managers of local incubators interviewed in this study (as well as VIA Water managers) confirmed that, in many cases, the projects submitted to them for incubation generally score very well technically but suffer enormously from poor financial and commercial analysis. In the case of water sector projects, potential innovators tend to have a technical background (e.g., civil engineers) and have difficulties to package their innovations into bankable projects.

The second factor we analysed is the *availability of financial mechanisms to foster water innovation or lack thereof*. Our findings show that water innovation activities in Kenya, Ghana and Mozambique are still constrained by a lack of strong financial support instruments. In Mozambique, the VIA Water programme appears to be the most significant innovation support instrument focusing on water; others include the Dutch Orange corners, recently initiated by the Netherlands Embassy. In Ghana and Kenya, instruments such as the Climate Technology Program (initiated by InfoDev and the World Bank) which initiated the Climate Innovation Centres in both countries, and VIA Water are among the most structured water innovation support instruments. Another substantial instrument in Kenya is the NETFUND Incubation programme, promoting “green” innovations (in energy, water and agree business sectors). Across the three countries, there are also several organisations (generally NGOs such as SNV and World Vision) that attempt to implement or support the implementation of ideas for water innovations but on a limited scale.

Outside the water sector, each of the three countries has many instruments that promote innovation and entrepreneurship activities in general but can also benefit those innovating for the water sector. They include a variety of innovation spaces (e.g., business incubators, technology hubs, accelerators), generally established under the umbrella concept of “entrepreneurship development”. There are also schemes created to support science, technology and innovation (STI) activities in general, or those targeting the development of water resources and services in general. For example, in Kenya, such schemes include the National Research and innovation Fund, and the National Environment Trust Fund. In Mozambique, they include the National Innovation Programme, which includes an STI Fund. At the time of interviews, the Government of Ghana had initiated the process to establish an STI Fund.

The innovation support instruments described above are at different levels of development in the three countries. In Mozambique, they seem to be either not well-established yet or nascent – implying that their performance is still low (e.g., in terms of beneficiaries served). In Kenya and Ghana, they appear to be functional, but still face governance and trust issues (particularly those that are government-run), which makes people shy away from approaching them for support. A common observation about innovation support instruments in Ghana, Kenya and Mozambique is that they generally provide support either for doing basic research or piloting innovations. Thus, raising funds to scale successful water innovation pilots was consistently emphasized in this study as the greatest challenge to most innovators. The limited opportunities to obtain scale-up capital often create situations of “endless” pitching for many potential innovators. That is, they end up pitching the same novel ideas at different places over and over again to get seed capital – because this is relatively easy to mobilise.

The third factor considered in this study is the state of a *country's business and market environment*. The interviewees in Kenya, Ghana and Mozambique acknowledged that, overall, the business and market environments in respective countries have improved over the past decades, citing the World Bank Doing Business reports as evidence of this improvement. However, they also indicated that many weaknesses still exist which constrain innovation activities, including in the water sector. To start with, difficult access to bank loans was highlighted as the major hindrance to water innovation/entrepreneurship activities in all three countries. Commercial banks are still not considered as an

attractive source of finance for innovation projects, due mostly to their high interest rates² and collateral requirements.

Acquiring bank credit appears to be particularly difficult for innovative water projects because of the perceived high risks and long pay-back times associated with such projects. Some interviewees indicated that even when securing a bank loan is possible, some innovators might be unwilling to go for the loan because they are not sure if their innovative businesses will be profitable. Thus, they prefer to use their own money or borrow from family members (at very low or no interest at all) in order to avoid the consequences (e.g., lose collaterals), in case of failure to reimburse the bank loan. That is also one of the reasons why many innovators in Africa generally prefer to go for donor funding. The problem of credit is further complicated by the fact that the water sector itself is still perceived by conventional financiers as a risky sector (e.g., compared to the energy sector). Since there is still a knowledge gap on how commercial financing could work in the water sector, banks usually shy away from funding water innovation projects: they may understand the risks involved (e.g., difficulty to use water infrastructure asset as collateral) but lack knowledge on how these can be mitigated (Bender, 2017).

Another aspect of the business environment influencing the fate of water innovations is the availability of market. The water innovators interviewed in this study argued that they see promising market opportunities for their innovations, both locally and globally, emphasizing the low-cost nature of their innovations (in comparison to alternatives) as their competitive advantage. In fact, our research found that some of the water innovators supported by VIA Water have already started exporting their innovations to other countries. For instance, Hydroponics Africa has introduced its “soil - less farming” technology in Rwanda; while the Flash Flood forecasting Application started in Ghana by Royal HaskoningDHV is currently being used by the City of Parramatta in Australia.

The fourth factor investigated is the *quality of governance* and how it affects innovation activities. On the one hand, most of the interviewees acknowledged that (petty and grand) corruption and unnecessary bureaucracy are still serious issues negatively affecting water innovation (and business) activities in Kenya, Ghana and Mozambique. In particular, the water innovators from these countries generally indicated that engaging government officials (especially at decentralized levels) in innovation projects has been a major challenge. In some cases, poor collaboration stemmed from government bureaucracies which often delayed innovation processes (e.g., to get an official MoU, or a permit). In other instances, local officials were difficult to engage, either because they were busy with local politics or expected but did not get direct benefits from the innovation projects.

On the other hand, low levels of law enforcement (e.g., environmental protection and water quality laws) and lack of transparency in government affairs were reported by the interviewees as major limitations to water innovations. Finally, most of the interviewees in Ghana, Kenya and Mozambique considered their countries to be generally characterized by stability of political institutions, which has a positive influence on innovation activities and other development endeavours.

5.2.4. Institutional factors

This study examined two elements of the institutional context in Ghana, Kenya and Mozambique: (a) formal policies, rules and regulations governing innovation at national level, and (b) the extent of interactions among the different actors contributing directly or indirectly to (water) innovation processes. The findings show that in each of the three countries there are a lot of actors who in principle make up the national innovation systems. In addition to the “triple helix” actors (academia, government and industry), a variety of innovation

² The interviewees in Ghana, Kenya and Mozambique stated interest rates ranging from 14 % to 35 % per year

intermediaries have emerged in Ghana, Kenya and Mozambique. They include business incubators, accelerators, technology parks, and many other forms of innovation spaces. However, as indicated before, the performance of these institutional actors is still constrained by factors such as insufficient funding and lack of trust.

On top of that, what is common to all three countries is that their national innovation systems in general, and the innovation systems for water in particular, suffer from poor interactions and lack of cooperation between the supply and demand sides of innovation. In that regard, little interaction exists between water science entities (e.g., universities, research institutes), technology organizations, users of water innovations (e.g., water utilities), and business incubators. These system gaps negatively affect water innovation activities in different ways. Notably, a lot of duplication in terms of support for innovation occurs and many innovators might want to take advantage of this situation (e.g., by seeking seed capital from different organisations and for the same innovation idea).

The innovation system actors in Ghana, Kenya and Mozambique are increasingly aware of these challenges, and different efforts are made to trigger actor interactions. These efforts include national and yearly events (e.g., the Innovation Exhibition programme in Mozambique, or the National Science and Innovation Week in Kenya) that bring together researchers, innovators, and financiers to discuss innovation issues, and the creation of institutions such as technology transfer centres which foster linkages between universities and industry. However, these efforts seem to be more advanced in Kenya (than in the other two countries) with more permanent structures being established at national level (e.g., the association of incubators and accelerators operating in Kenya, the Kenya National Innovation Agency) to foster interactive learning and continuous dialogue between the demand and supply sides of innovation.

With regard to the formal rules and regulations governing innovation, it appears that policy makers in Ghana, Kenya and Mozambique have developed and promoted relevant policy and legal instruments over the past decades. These include Science, Technology and Innovation (STI) Acts, STI policies, and Intellectual Property Rights frameworks. In comparison to the other two countries, Kenya has even made a step further and established a system for measuring STI. The latter informs about the status and progress made in policy implementation and provides evidence to inform policy review and evaluation (MEST, 2016). However, the interviewees in Ghana, Kenya and Mozambique expressed many concerns with regard to the effect of these instruments on innovation activity. Some argued that the existing policies and regulations are still disconnected from local innovation realities and hardly make a difference between different categories of innovators, which leads to the absence of tailor-made innovation incentives (e.g., fiscal incentives for small scale innovators). The issue that the capabilities are missing to ensure that the policy and legal instruments put in place are functional and credible was consistently highlighted by the interviewees. For example, many innovators still question the professionalism of the Intellectual Property Agency in Kenya because it arguably does not employ staff with integrity. The process to protect inventions and or trademarks from imitators is also generally perceived as too long, which discourages innovators in Kenya.

In Ghana and Kenya where innovation and entrepreneurship activities are more intense (than in Mozambique), it has been reported that small-scale innovators and entrepreneurs are burdened with the many legal requirements they have to abide by. As soon as a company is registered, it is supposed to have a number of licences and certificates (e.g., from environmental protection agency, different ministries) the acquisition of which costs a lot of money. The newly registered company is equally supposed to pay a variety of taxes before it has even started making sales. All these burdens were consistently highlighted in this study as potential “killers” of innovations and businesses. It should be indicated that, according to some interviewees, the absence of regulations and or policies regulating innovation can sometimes positively

affect innovation processes. They indicated that governments always lag behind in terms of regulating breakthrough innovations. So, as policy makers try to understand such innovations and how to regulate them, innovators take advantage of the regulatory vacuum to advance with their innovation process (e.g., trying them out).

5.2.5. Historical factors

This study found that the societal philosophies (or visions) of governance and development that historically characterized Ghana, Kenya and Mozambique prove to be a strong factor of (water) entrepreneurship and innovation in these countries. Most of the interviewees in Mozambique associated the low level of innovation and entrepreneurship in this country with the socialist/communist vision that continued to dominate during the post-colonial period. Despite the introduction of a liberalized economy since the 1990s, the country systems (e.g., economic, social and cultural) and people’s mental models continued to be influenced by the legacies of the socialist philosophy. Therefore, the individualistic mentality, generally associated with innovation and entrepreneurship culture, is not yet established in this country. The Mozambican society is still perceived as community-based and family oriented, with little competition spirit among citizens.

The interviewees reported how parents and communities in Mozambique often discourage their children to venture into entrepreneurship, because it is perceived as risky, and does not guarantee that children will be able to provide support to their parents and communities. In contrast, as former British colonies, Kenya and Ghana have embraced capitalist and liberal philosophies and associated individualistic values for many decades. The mentality that everyone is expected to look after himself or herself and his immediate family is widespread in these two countries, particularly in Kenya. Although it has taken time before Kenya and Ghana systematically started fostering innovation and entrepreneurship, the informal sector has always been far more vibrant in these two countries than in Mozambique.

Another historical factor that affects water innovation in Ghana, Mozambique and Kenya is the legacies of traditional water management practices. The interviewees in these countries indicated that many water sector institutions have historically functioned on the basis of short-term (and often donor-funded) projects, which has been an important barrier to innovation. Their water sectors have hardly had long-term plans that could accommodate and sustain novel approaches to water development and management. The legacies of these practices sometimes lead to negative attitudes or resistance vis-à-vis innovative approaches that are likely to alter the status quo and move people out of their comfort zones. This study further found evidence that the legacies of centralised management of water resources and services negatively affects the introduction and implementation of innovative water approaches in Mozambique, Kenya and Ghana. Historically, the three countries have been characterized by centralised States, but have recently adopted devolution as a system of governance. In this context, some water management functions have been decentralised to lower levels of governance (e.g., county level in Kenya, Provincial level in Mozambique). Yet, as indicated by many of the interviewees in this study, the conventional centralised mentality of water management still characterises the thinking and action of water sector actors. Notably, the challenges of bureaucratic inefficiencies and corruption that previously characterized the centralized governance structures still linger at decentralised ones.

6. Discussion

In this section, we discuss the major insights generated by this study in view of relevant innovation literature for the two major categories of innovation dynamics (internal and external) described in Section 3. We also reflect on the study limitations.

6.1. Internal dynamics of water innovation

On the one hand, the study showed that the “social” nature of water innovations implemented in African cities gives them a positive image and increases their ability to attract seed capital, but, at the same time, poses a challenge for diffusing them among the urban poor living at the BoP through market logics. These findings challenge, to some extent, the increasingly widespread claims that BoP populations in developing countries constitute a large market that businesses should tap into (Pralhad and Hart, 2002). The findings suggest also that creating changes in the enabling environment (e.g., legislation, policies, development plans) seems to be the realistic way to diffuse social water innovations among the poorest citizens in African cities, or the so-called vertical (or institutionalisation) approach (Westley et al., 2014; Ubels and Jacobs, 2016).

On the other hand, the study results indicate that successful design and implementation of water innovations benefited from the advanced levels of education and experience of the lead innovators. This is consistent with the literature on innovation and entrepreneurship in SMEs, emphasizing individual characteristics of innovators and entrepreneurs as a major influence on innovation outcomes (Westhead et al., 2004; Dimov, 2010). Finally, the analysed water innovators deliberately chose to implement their innovations through partnerships, which positively influenced the innovation processes through exchange of resources. This finding confirms the view that open innovation as an approach allows usage of inflow and outflow knowledge and capacity for accelerating innovation (Chesbrough et al., 2006). In particular, the fact that most of the analysed water innovation projects benefited from the active involvement of innovation users confirms the relevance of co-production in innovation processes (Desouza et al., 2008; Chen et al., 2011a,b). In that regard, the study results also reinforce the conclusions of recent research on frugal water innovation which demonstrated that involving water innovation users allows innovators and entrepreneurs to customize their products to the needs and purchasing power of customers (Annala et al., 2016). Nevertheless, in this respect, it depends on who the customers are; as discussed above, reaching out to the BoP customers in African cities remains a challenge for water innovators.

6.2. External dynamics of water innovation

First, we found that the three countries analysed in this study have reached different levels in their efforts to create enabling environments for innovation and entrepreneurship, which has implications for how people react to water innovation opportunities.

Notably, the innovation culture, the business and market environment, the quality of governance and the stability of political institutions in these three countries are perceived by many people as having improved over the past decades. However, there are still many gaps (e.g., corruption, high taxes, and low levels of law enforcement) that negatively affect water innovation processes and need to be addressed. The improvements and gaps described in this study regarding the institutional and macro-economic conditions of Kenya, Ghana and Mozambique and their influence on innovation and entrepreneurship activities were also identified by earlier research on innovation in Africa (World Bank, 2014; Egbetokun et al., 2016).

Second, securing scale-up capital appears to be an important bottleneck in water innovation processes in African cities. This challenge has been highlighted by recent studies on innovation and entrepreneurship in Africa (The Africapitalism Institute, 2015; Wang, 2016; Voeten, 2017). The major explanatory factor is that conventional sources of scale-up capital are either missing or not willing/ready to invest in (water) innovations. On the one hand, commercial banks have not only prohibiting interest rates but are also so conservative that they hardly invest in uncertain and risky sectors. Venture capitalists, another important innovation financier, are just emerging in Africa. However, even if they were developed on the continent, that would not

necessarily guarantee their investments in the water sector, still perceived as risky due mostly to the long pay-back times of water projects. Research has shown that venture capital funds tend to be invested in areas and projects of high potential growth and where commercial viability is established within a short period (three to five years) (Ghosh and Nanda, 2010).

On the other hand, many governments in Africa can hardly fill this gap, due partly to their budget constraints. The prevailing (neoclassical economics - based) view that the role of government in promoting innovation should be limited to facilitating innovations also explains the limited funding from governments. As argued by Mazzucato (2013), based on a review of experiences in the most successful economies, the role of the state should expand beyond creating conditions for innovations to flourish. Governments should indeed play a more active role, notably by investing in risky but strategic innovation areas that pose too much risk for the private sector, *in casu* the water sector.

Third, our study found that the innovation systems in Kenya, Ghana and Mozambique suffer from poor interactions and a lack of cooperation between innovation actors, which limits interactive learning between the supply and demand sides of innovations and the development and diffusion of water innovations.

These systemic gaps can be partly attributed to the fact that many people still view innovation as a linear activity, where different actors play separate roles, with little or no overlap in functional relationships (Bach and Matt, 2005; Godin, 2007). In line with the innovation systems literature (Lundvall, 1992), this narrow perception fundamentally constrains interactive learning and therefore hampers water innovation. To address this, policy makers in Ghana, Kenya and Mozambique have developed innovation policy and legal frameworks that seem to embrace the systems approach to innovation. However, in practice, these instruments tend to be Science and Technology oriented and focus more on scientific knowledge providers (e.g., university and research institutions) to the detriment of other aspects and functions of the innovation system.

By putting too much emphasis on science and research, these policies overlook the fact that innovation does equally come from experience-based knowledge and that players other than universities play an equally important role and should be given the same attention (Lundvall, 1992; Godin, 2007). In addition, similar to other African countries, innovation policies in Ghana, Kenya and Mozambique are mostly oriented towards the private sector. This is probably the reason why the water sector – which is largely considered as a public sector in these countries is still less innovative. Yet, just like in the private sector, innovation in the public sector does not happen by itself: it must be equally fostered through targeted legal, financial and policy instruments and via the interaction of relevant actors and stakeholders.

Finally, the study results showed that water innovation and entrepreneurship activities in Kenya, Ghana and Mozambique are shaped by distinct historical legacies. In that regard, the communist or socialist philosophy which still permeates in many Mozambicans’ mental models seems to have limited the impact of initiatives intended to foster water innovation. In contrast, the capitalist or liberal economic model that was introduced to Kenya and Ghana since the colonisation era has had positive effects on innovation and entrepreneurship activities in many sectors, including the water sector. These findings confirm the insight from the development literature that the legacies of colonialism continue to affect the development of former colonies in the post-colonial age (Acemoglu et al., 2000; Miles, 2014). In the same vein, the centralised approach to water management historically practiced in Mozambique, Ghana and Kenya proved to have adverse effects on water innovation in these countries. This finding confirms the conclusions of previous research on the negative role of the legacies of traditional water management practices in promoting water innovation. In the context of water reforms in Brazil, Engle et al. (2011) provide evidence of how such legacies yielded shortcomings and incomplete transitions in water resources management in some States of Brazil.

6.3. Limitations of the study

This study has limitations stemming from its sample. First, the research involved only water innovators who were donor-funded and participated in an incubation programme. Second, the study focused on only three Sub-Saharan African countries (Kenya, Ghana, and Mozambique). These sample aspects may have introduced a systematic bias in the collection, analysis and interpretation of the data. Thus, they constrain the generalizability of the study findings to other groups of water innovators (e.g., those who innovate outside incubators or do not receive support from donors) and to other African regions (e.g., North/Arab Africa). Nevertheless, our study examined not only innovations and the innovators themselves but also the innovation systems within which they are embedded. These arguably pertain to both, the innovators in our sample and those outside our sample, and therefore insights of our study at the level of the innovation system and the financial sector are generalizable for the three countries included in our sample.

7. Conclusions

This study produced empirical insights which have practical implications for fostering water innovations in African cities. On the one hand, the dynamics of water innovation are manifested at three different levels: the innovation itself, the innovating entity and the innovation system. This finding implies that the promotion of water innovations in African cities requires multi-level and multi-faceted efforts and, given that countries are heterogeneous, with different historical paths and socio-economic and cultural patterns, these efforts ought to consider the specificities of each country and city if they are to be successful. On the other hand, the water innovation systems in Kenya, Ghana and Mozambique are unfolding, but they appear to be still fragmented and dominated by the linear approach to innovation, which negatively affects their performance. Such water innovation systems can be strengthened by explicitly acknowledging and actively promoting interactive-learning based approaches to innovation.

Furthermore, securing innovation scale-up capital has proved to be a major challenge, not just for water-related innovations but for innovation in other sectors as well. The challenge is often associated with the fact that existing financial instruments generally limit their innovation support to pilot projects, assuming that the “private sector” will naturally take over the diffusion of successful innovation pilots. However, empirical evidence of this study shows that it is difficult to create greater impact from water innovation activities by just supporting pilot projects. In many cases, business-oriented or commercial funding is the critical missing link to create this impact. We argue that, in developing economies such as in Africa where private venture capitalists and commercial banks are not ready to invest in risky innovations, it is unrealistic to expect that market mechanisms can arrange for the scaling of water innovations.

This implies that those who currently support (water) innovations in Africa – notably governments and development partners – should go beyond their “piloting” approach to fostering innovation and indeed take the risk to actually invest in the upscaling of innovations that have the potential to become game changers in the water sector. In the context of small scale innovators, for example, the innovation support should expand beyond the proof of concept and cover other prerequisites to take water innovations to the next level. At the very least, the support should allow innovators to become “investor ready”, notably by helping them to commercialise their innovations early and have initial sales records. At the very most, governments and development partners should devise innovative models that allow them (or other financiers) to invest in the most promising water innovation projects and to share the risks as well as the rewards from these innovations with the innovators themselves.

Finally, it is concluded that, given the sample limitations of the study, further research is needed to validate our findings. Notably, research focused on other African countries and collecting data on water innovations implemented in conditions other than incubation or involving innovators who did not receive any donor support (or received it from sources other than donors) might produce additional insights and increase the generalisability of our conclusions.

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CRedit authorship contribution statement

Silas Mvulirwenande: Conceptualization, Methodology, Investigation, Formal analysis, Writing - original draft. **Uta Wehn:** Conceptualization, Methodology, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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