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A Multi-Perspective Discourse on the Sustainability of Water and Sanitation Service Co-Production in Global South Cities

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Abstract
The article contributes to the debate on the sustainable provision of water supply and sanitation (WSS) services in Global South cities by developing a comprehensive understanding of the concept of sustainability when applied to the analysis of WSS co-production in these contexts. The study moves from the hypothesis that an integrated conceptualization of WSS co-production requires a re-discussion of evaluation approaches to questioning the sustainability of these unorthodox forms of service delivery. To this end, the study explores key dimensions of service sustainability through a complementary reading of the processes and the outcomes of WSS co-production practices on the basis of three theoretical perspectives: a governance-institutional, a socio/political-ecological and an incremental-urban. The objective is to frame a series of principles and criteria relevant for assessing the sustainability of WSS service co-production in Global South cities. The analysis is based on a systematic review of cross-cutting literatures on service co-production in the Global South, sustainable urban water management and urban studies. The review is integrated with empirical insights from four city-case studies of WSS co-production in the Global South, namely Hanoi (Vietnam), Addis Ababa (Ethiopia), Cochabamba (Bolivia) and Dar es Salaam (Tanzania).

Keywords: co-production; sustainability; water and sanitation services; governance; political-ecology; urban; Global South

1. Introduction

Poor access to water supply and sanitation (WSS) services is still a pressing challenge in many urban contexts in the Global South. It undermines the quality of life of the most vulnerable inhabitants and poses difficult questions on sustainable urban futures. In cities

in the Global South, the provision of WSS services through conventional planning models, based on centralized networked infrastructures managed by public or private sectors, has often been unable to keep up with rapid urbanization processes and growing water and sanitation demands (Bakker et al., 2008; Coutard, 2008; Coutard and Rutherford, 2015; Furlong, 2014; Moretto et al., 2018). In many urban and peri-urban contexts, the inability of WSS centralized systems to ensure an effective and universal service has de facto led to the emergence of alternative practices for accessing water and sanitation, hybrid or decentralized, individual or community based (Allen et al., 2017; Bakker, 2003). These practices seldom rely on multiple sources, socio-technical arrangements and determinate selling/redistribution dynamics that are complementary to the municipal networked system (Faldi et al., 2019; Kjellen, 2000). Accordingly, attention to the sustainability of users' active roles in service provision and to alternative user-provider arrangements is growing at the international level.

The concept of co-production, developed primarily in the public governance and management literature, was recently introduced into WSS studies. Co-production was once defined as "the process through which inputs used to produce a good or service are contributed by individuals who are not 'in' the same organizations" (Ostrom, 1996:1073). With respect to WSS services, service co-production has been mobilized mostly in reference to decentralized community-based systems, and unofficial hybrid systems produced and operated through a regular long-term collaboration between state actors and communities during some or all the phases of the service delivery cycle (planning, design, delivery and assessment) (Faldi et al., 2019; Joshi and Moore, 2004; Moretto et al., 2018; Nabatchi et al., 2017). As highlighted by international bodies (United Nations, 2016) and scientific communities (Allen et al., 2017; McMillan et al., 2014; Mitlin, 2008; Moretto et al., 2018; Moretto and Ranzato, 2017), the interest in service co-production has recently increased. It is now recognized as a way to secure sustainable access to WSS services, especially for the poorest inhabitants.

Some studies have suggested that co-production may improve the equity and efficiency of provision, while also contributing to citizens' empowerment and local governments' effectiveness (Allen, 2013; Mitlin, 2008; Moretto, 2010). However, others have highlighted how it may also be subject to resource capture by elites and to conflicts among groups over service management (Ahlers et al., 2014; McMillan et al., 2014) and lead to environmental decay and urban fragmentation (Cabrera, 2015; Faldi et al., 2019; Moretto et al. 2018). Social, environmental and economic questions over co-production may therefore emerge, ones that deserve to be examined against sustainable urban service provision goals.

Despite this increasing interest, an integrated and transparent discourse on the sustainability of co-produced services has not yet been produced at the scientific level. When addressing the sustainability of WSS service co-production, there is a clear gap in the consideration of the complexity of the practice in sustainability assessments. On the one hand, research has often made reference to the general literature on WSS infrastructures, which has largely been arguing over the sustainability of alternative user-provider arrangements and decentralized solutions, mostly employing conventional triangular socio-economical-environmental approaches. As an example, while some authors have pointed out the management, environmental end equity challenges associated with decentralization (De and Nag, 2016; Domenech, 2011; Dos Santos et al.,

2017; Furlong, 2014), others have highlighted its potential capacity to reduce production and distribution costs and to increase users' flexibility when dealing with water stress (Ali, 2010; Domenech, 2011; McGranahan, 2013; Opryszko et al., 2009). On the other hand, specific studies on WSS co-production have mostly analysed the practice from specific conceptual perspectives – such as its management and governance systems (Mitlin, 2008; Moretto, 2010) and the relations between formality and informality (Ahlers et al., 2014; Allen, 2013) – and most studies have addressed specific aspects of co-production by often mobilizing single principles of sustainability (e.g., equity, efficacy, ecological integrity, citizenship) without providing a systemic reading of their relations.

Recently, some studies (Faldi et al., 2019; Moretto et al., 2018; Moretto and Ranzato, 2017) have suggested the need to analyse the co-production of basic services, such as water and sanitation, through an interdisciplinary approach taking into account their natural, social and spatial dimensions. Indeed, WSS co-production involves different dimensions: managerial, which concerns the relationships between users, intermediaries and providers; techno-environmental, which includes the technical infrastructures for resource distribution and treatment; and spatial, which includes the socio-spatial configuration of the service, with its accessibility and its geographical scale (Faldi et al. 2019). The understating of trajectories of WSS co-production in a specific urban context therefore requires consideration of the multidimensional interrelations between user/provider/intermediary relationships, the resource flow, and the technological and settlement/land characteristics of the service.

This study moves from the recognition that analysis of the sustainability of WSS co-production needs to rest on an integrated perspective, as basic service co-production cannot be understood outside its integrated conceptualization (considering natural, social and spatial dimensions). Such conceptualization therefore requires a re-discussion of key principles for questioning the sustainability of these unorthodox forms of service delivery. This paper is aimed at contributing to the debate on sustainable provision of urban services by specifically developing a comprehensive understanding of the concept of sustainability when applied to the analysis of WSS co-production in the urban South. To this end, the study explores key dimensions of service sustainability through a complementary reading of the processes and outcomes of WSS co-production on the basis of three main theoretical perspectives that cover multiple elements of the practice from different vantage points: governance-institutional, socio/political-ecological and incremental-urban. The final scope is to frame a series of conceptual principles/criteria and their interrelations relevant for assessing the sustainability of WSS service co-production in the urban South. The analysis is based on a systematic review of cross-cutting literatures on service co-production in the Global South, sustainable urban water management and urban studies. The review is integrated with empirical insights from four city-case studies of WSS co-production in the Global South, developed within the framework of an ongoing research project.

The chapter is organized in three parts. First, the limits and challenges of conventional sustainability assessment of WSS services are individuated. We stress the need for a holistic view of sustainability, especially with reference to a conceptualization of co-production that understands the practice in the relation between actor relationships, resource flows, technological dimension and area dimension. Second, the integrated reading of sustainability following the three theoretical perspectives is deployed while

exploring the outcome and process elements, and their connections, relevant for studying WSS co-production. Finally, a complementary reading of these perspectives allows us to design a systemic framework highlighting principles and criteria to consider when assessing the sustainability of WSS service co-production in the urban South.

2. Sustainable WSS Services: The Need to Employ an Integrated Evaluation Approach for Co-Production

Sustainability and sustainable management of urban WSS services are complex issues involving different stakeholders, scales and temporalities and requiring multidisciplinary knowledge and understandings. The meaning of sustainability (and thus the scope of a sustainability assessment) can vary widely, depending on how it is considered by different actors and decision-makers.

In the last 20 years, the literature on sustainable urban water and sanitation has extensively engaged in setting principles and criteria and defining approaches and methods, capable of navigating this complexity. Some key features of the concept, which are now agreed among different researchers and practitioners, are fully embraced in the present study. These include the holistic and multidimensional nature of sustainability, which stresses the interrelations and interdependencies between and across socio-economic and biophysical systems, multi-scale levels, space and time (short and long terms); the existence of certain inviolable limits of these systems; the contextual characters (location-specific) of many considerations about sustainability; and the focus on supporting the present and future quality of life, a key component of sustainability that refers to people's objective and subjective needs for improving personal well-being (Gibson, 2006; van Leeuwen et al., 2012; van Kamp et al., 2003; Weaver and Rotmans, 2006; Wiek and Larson, 2012).

Notwithstanding such common ground, the debate on sustainability has not yet produced universally applicable definitions of sustainability. Numerous approaches and frameworks to WSS management have emerged in the last few decades. They have often employed different perspectives when addressing the challenges and looking at the features of sustainability (Carden and Armitage, 2013; Foxon et al., 2002; Lockwood et al., 2003; Ostrom 2009; Pahl-Wostl et al. 2010; Wiek and Larson, 2012). Rijsberman and van de Ven (2000) classified the existing approaches into four main groups – ratiocentric, carrying capacity, ecocentric and sociocentric – on the basis of their primary focus on people's needs vs. environmental problems and on quantitative norms vs. qualitative values. More recently, a stronger claim for integration of these multiple conceptual perspectives as the key to address WSS service complexity has emerged as the mantra of WSS sustainability science (Bertrand-Krajewski et al., 2000; Kallis et al., 2006; Wiek and Larson, 2012).

From a conceptual point of view, integration has been largely expressed through the *triple bottom line* (TBL) approach, which offers a comprehensive framework to look simultaneously at the economic, environmental and social dimensions of sustainability (Leigh and Lee, 2019; Levett, 1998; WWAP, 2015). This triangular model was mostly used as a background condition to define principles and criteria for assessing the performance of a specific WSS service or initiative, including questions of economic

viability and incremental costs of alternative infrastructures, ecological outcomes, human safety and institutional governance (Guest et al., 2010).

From an operative point of view, part of the literature on sustainable WSS services has strongly advocated for an integrated approach to service management, grounded on multi-dimensional sustainability principles and considering WSS services as components of larger physical and organizational systems (Carden and Armitage, 2013; van de Meene et al., 2011). Studies on integrated urban water management (IUWM) have highlighted the need to consider WSS services coordinately as the basis for addressing issues of environmental protection, economic growth, equity in water access and community well-being (Butterworth et al., 2010; Carden and Armitage, 2013; Leigh and Lee, 2019; Maheepala and Blackmore 2008; Pearson et al., 2010). Within this strand, the question regarding the potential of service decentralization has been crucial in nourishing the debate on the sustainability of alternative WSS services in recent years, including co-production arrangements in the Global South. On the one hand, the focus on decentralization of delivery functions, responsibilities and technology draws attention to system innovations and stakeholder participation as essential keys for ensuring a better quality and sustainability of WSS services (Leigh and Lee, 2019; Serageldin, 1995; Wilderer, 2004). On the other hand, concerns regarding difficult management of the services, health issues and inequality due to service fragmentation have left open questions over the sustainability of decentralized WSS solutions (De and Nag, 2016; Domenech, 2011; Faldi et al., 2019).

Notwithstanding this effort to include public and societal questions in water sustainability discourses, understanding the interrelations and feedback between the multiple subsystems of sustainability involved in producing an urban WSS service still remains a mayor challenge, especially in the case of alternative infrastructures in the Global South. This is due for several reasons. First, the majority of studies, initiatives and policies still adopt sectorial (i.e., looking just at some component of water sustainability or at isolated water systems) and technically rigid (i.e., over focused on technical elements) paradigms when assessing the sustainability of WSS services (Olalla-Tárraga, 2006; Wiek and Larson, 2012). In most cases, practical applications of the TBL approach have failed to consider all aspects and related principles of sustainability equally and to grasp the interrelations between dimensions of the service. As Wiek and Larson (2012: 3153) suggested, "a comprehensive perspective on water sustainability that equally recognizes depletion, justice, and livelihood issues in the long-term" is currently lacking in most of the mainstream approaches.

Still, studies on sustainability of IUWM and service decentralization have predominately addressed the management issues of the water service (water supply, wastewater treatment) or the engineering, economic and environmental aspects of technical innovations (following principles of cost effectiveness, social acceptability and wise use of natural resources). Conversely, studies have left little space for cultural and political considerations and for aspects related to the quality of life of service recipients (Butterworth et al., 2010; Pearson et al., 2010; Wiek and Larson, 2012; Wilderer, 2004). In fact, as Tàbara et al. (2008:48) highlighted, most of the current paradigms for the sustainable management of WSS services adopt tools and methods that address a "single area of reality", without considering the multiple ways of understating factors of change related to the overall sustainability problems. This is the case in most of studies focusing

on alternative WSS services in the Global South, where the question of sustainability has been predominately addressed with environmental, social and economic metrics, but without really highlighting the systemic relations between and the impacts of the multidimensional aspects characterizing decentralized or hybrid services (Carden and Armitage, 2013).

Second, a non-transparent display of values and principles guiding a specific WSS initiative and an over focus on its outcomes were also evidenced as strong limits of mainstream sustainability evaluation approaches, especially when referring to decentralized solutions in the Global South (Bertrand-Krajewski et al., 2000; Leigh and Lee, 2019; Wiek and Larson, 2012). As Pearson et al. (2010) showed, sustainability should be increasingly recognized not just as an outcome, but also as a process; it is "not a state to be arrived at but a broad evaluative framework for understanding and justifying social practice" (Lundie et al., 2005:1). A stronger focus on the cognitive and behavioural processes connected with sustainable water management is therefore needed, going beyond the mere measuring of the achievement of a certain output. In fact, IUWM has prevalently employed measurement approaches based on metrics of sustainability defined in relation to qualitative and quantitative outcomes of the services, such as TBL reporting, life cycle analysis, ecological footprint, analysis of water quantity and quality, and cost-benefit and multi-criteria analysis (Balkema et al., 2002; Erbe et al. 2002; Hellstrom et al. 2004; Hellstrom et al. 2000; Lai et al., 2008; Lundin and Morrison, 2002; Pearson et al., 2010; Rees, 1992). As Guest et al. (2010) and Montgomery et al. (2009) suggested, metrics looking at the functionality of the practices that can capture the evolutionary characters of the service in relation to managerial, economic and community demand components are required.

Overcoming these emerging challenges in the evaluation of alternative WSS services in Global South cities makes it necessary to embrace an holistic view of sustainability, namely to "look beyond single factors (e.g., water supply or water quality) to the interactions of multiple factors, all of which may be important but impacted differently by various actions and actors" (Davis et al., 2016:120). The peculiarity of WSS co-production – a complex practice made up of managerial, techno-environmental and spatial dimensions – emphasizes the need to look at the connections and the integrated elements that can influence the sustainability of the practice. When addressing the sustainability of WSS service co-production, there is still a clear ambivalence reflecting a lack of systematic understanding of the key sustainability values and principles that may be involved in the evolutionary trajectory of the practice. When, where, for whom and with respect to which principle is co-production desirable? Which factors of co-production can relate to sustainability? Are we looking to both the process and the outcomes? By treating sustainability as an outcome, a triangular guiding question can emerge: does co-production deliver environmental, social, economic and political sustainability? Otherwise, the following could be a process question: is co-production a form of delivery that is politically, socially, environmentally and economically sustainable? Such questions express a general gap in the understanding of which process and outcome elements are worth observing when analysing the sustainability of WSS co-production.

By addressing this emerging gap, the study contributes to overcoming the limitations of using conventional triangular approaches to assess the sustainability of

unorthodox WSS services, such co-production initiatives in the Global South. This requires the disentangling of the concept of sustainability when applied to service co-production, namely exploring its meaning within the different literature strands that have differently addressed the multidimensionality of co-production. The goal is to combine different theoretical perspectives with empirical evidence to provide a systemic view of the concept of sustainability when applied to the study of WSS co-production.

3. Perspectives for Interpreting Sustainability of Water and Sanitation Co-Production

Alternative socio-technical arrangements for producing basic services, such as co-production of water and sanitation, have been studied in different literatures, from social sciences to applied sciences. Three theoretical perspectives in the study of WSS co-production, which have explored the interrelations between the managerial, techno-environmental and spatial dimensions of the practice in different ways, are identified in the present research: governance-institutional, socio/political-ecological and incremental-urban (Figure 1).

The governance-institutional perspective has the strongest legacy in the study of service co-production since the first conceptualization of the co-production model by Elinor Ostrom in early 1970s (Bovaird, 2007; Nabatchi et al., 2017; Ostrom, 1996). This perspective, belonging to political theory, public administration and management scholarships, has primarily looked at the managerial dimension of WSS co-production with less interest in grasping its techno-environmental and spatial characters. It has studied the potential benefit that co-production could offer to urban public governance through the development of decentralized management systems and the redistribution of certain levels of power and control from the state to citizens (Moretto et al., 2018; Osborne and Strokosch, 2013; Ostrom, 1996; Pestoff et al., 2012). Studies have mostly looked at the roles and responsibilities of actors (users/providers/intermediaries) involved in different levels (i.e., co-planning, co-design, co-managing, co-delivery, co-assessment) and scales (i.e., individual, group, collective) of service co-production (Bovaird and Loeffler, 2012; Nabatchi et al., 2017; Verschuere et al., 2012) and at the institutional regulatory frameworks facilitating co-production (Bovaird, 2007; Pestoff et al., 2012; Verschuere et al., 2012), including questions related to identification of leading initiators (citizens or governments) (Jakobsen, 2013) and motivations to co-produce (van Eijk and Steen 2014).

The socio/political-ecological perspective, belonging to scientific ecology and urban political ecology scholarships, has primarily explored the relations between the managerial and techno-environmental dimensions of co-production. Unlike the widespread technocratic and apolitical approaches dealing with infrastructure development in the Global South, studies have addressed questions of poverty, marginalization, inequality and informality (Allen, 2013; Kooy, 2014) related to different socio-ecological configurations that are produced and transformed by socio-economic and political processes (e.g., urbanization, social power, capitalism and economic transactions) (Heynen et al., 2006; Monstadt, 2009; Swyngedouw et al., 2002). This perspective has mostly looked at material characters of WSS co-production

(quality/quantity/technology) within broader political and ecological contexts, being particularly focused on understanding which socio/political and ecological dynamics activate WSS co-production and how the materiality of co-produced WSS services influences social and ecological structures at different scales (Ahlers et al., 2014; Budds et al., 2014).

The incremental-urban perspective, belonging to contemporary studies on participatory urbanism and on the spatial nature of socio-technical infrastructures in the Global South, has mainly stressed the relationships between the spatial and managerial dimensions of co-production. Studies have mainly addressed the technologies of everyday life, namely technologies and techniques through which urban flows, infrastructures and spaces constituting the social life of cities are produced, maintained and reconfigured on a daily basis by ordinary citizens (Coutard and Rutherford, 2015; Graham and Marvin, 2001; Graham and McFarlane, 2014; Rosati et al., forthcoming; Silver, 2014; Simone, 2004). In particular, this perspective has mostly explored the roles of community in producing the urban space through evolutionary socio-technical WSS infrastructures and observed how co-production contributes to changing socio-spatial relationships, which ultimately can bring significant advances in the quality of, and access to, urban services and settlements (Faldi et al., 2019; Moretto et al., 2018).

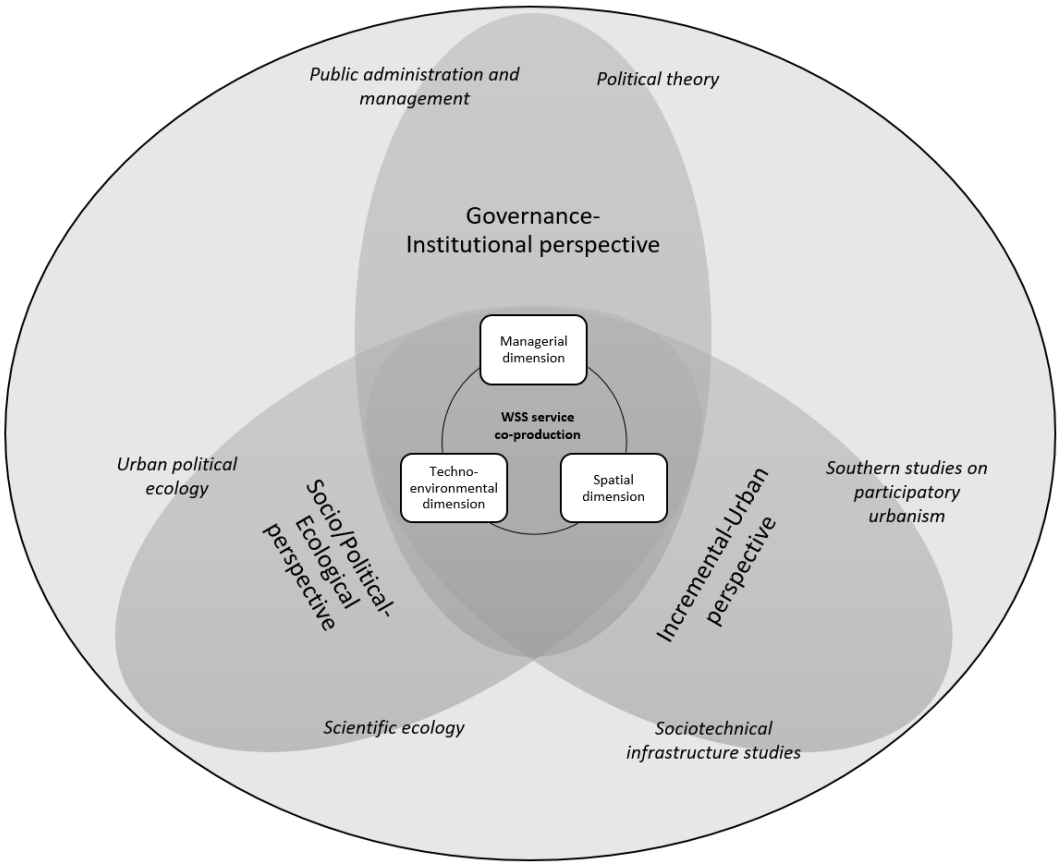

Figure 1. Conceptual perspectives addressing the multidimensionality of WSS co-production

The three perspectives cover the social/political and physical-technical evolutionary characters of WSS co-production in different ways, by alternatively mobilizing specific principles of sustainability to grasp the outcome and process elements of the practice. Through a review of the theoretical arguments on sustainability of WSS co-production within these different perspectives and an analysis of empirical cases, this study enhances the knowledge of how the concept of sustainability may be used when applied to WSS co-production. The research explores the key principles of sustainability, their interrelations and selective interpretations, and the relative outcome and process elements that have been used in each perspective for analysing the characteristics of the practice.

The literature review is combined with empirical insights from four case studies in the Global South, namely Hanoi (Vietnam), Addis Ababa (Ethiopia), Cochabamba (Bolivia) and Dar es Salaam (Tanzania). Empirical evidence is selectively used to sustain or counterbalance the conceptual discourses regarding the outcome and process elements of sustainability emerging from the review of each theoretical perspective. The four city-cases represent rapidly urbanizing environments where WSS co-production is a non-marginal phenomenon, which has developed with different managerial, techno-environmental and spatial characters (Table 1). They have been selected to exemplify a wide range of WSS co-production practices in Global South cities – from decentralized (such as community wells or shared wastewater treatment plants) to hybrid systems (such as communal tap or neighbourhood secondary drainage) – coexisting with other networked or non-networked infrastructures. Case study analysis is grounded on desk-based reviews of WSS policy and urban planning documents and a collection of face-to-face surveys, interviews and focus groups with inhabitants and local stakeholders, carried out by the authors between 2016 and 2020.

Table 1. Managerial, techno-environmental and spatial characters of WSS co-produced practices in the four city cases

	Managerial	Techno-Environmental	Spatial
Hanoi	- Co-funding and co-management of water infrastructures (i.e., pumps and water tanks) by individuals. - Co-planning and co-management of secondary drainage system by users' groups.	- Hybrid system: co-produced water infrastructures (pumps, water tanks) connected to the municipal centralized network, and shared secondary drainage connected to municipal channel system. - Emerging questions of lowering quality of surface water due to growing contamination pose environmental and management issues for co-produced practice.	- Group co-production of secondary drainage mostly occurs in peri-urban areas and former villages. - Individual water co-production mostly emerges in both collective housing blocks and peri-urban new urban areas incorporating older settlements. - State-driven urban development is transferring management of water and sanitation to households and groups respectively.
Addis Ababa	- Co-management of shared water tap by water users' groups - Co-funding and co-management of water infrastructures (mainly water tanks) by individuals.	- Hybrid systems: co-produced water infrastructures (shared taps, water tanks) connected to the municipal centralized network. - Emerging questions of water scarcity in the centralized systems due to poor water sources pose management issues for co-produced practice.	- Group co-production has historically occurred in slums, while individual co-production is currently emerging in both slums and publicly subsidized condominiums. - The increasing water demand in the city is deeply connected with such forms of urban development.
Cochabamba	- Co-planning, co-design and co-management of collective water networks, funded and operated by basic territorial organizations (OTB). - OTBs are officially recognized by the state after claims of a "human right to water".	- Decentralized system: use of groundwater from shared well fields. - Emerging questions of lowering groundwater table pose environmental and management issues for co-produced practice.	- Co-production emerges in growing peri-urban areas not served by the municipal centralized water systems. - The water networks do not follow a specific urban pattern.
Dar es Salaam	- Co-planning, co-design and co-management of shared water networks, funded by local authorities and operated by water user associations (WUAs). - Co-management of shared water taps by water users' groups, formally recognized and supervised by local governments. - Co-management of decentralized wastewater systems, owned by local governments and operated by private intermediaries.	- Decentralized system: use of groundwater from community well, and of shared wastewater systems (DEWATS). - Hybrid system: co-produced water infrastructures (shared taps, water tanks) connected to the municipal centralized network. - Emerging questions of lowering quality of groundwater due to growing contamination of shallow aquifer and seawater intrusion pose environmental and management issues for co-produced practice.	- Decentralized group co-production occurs in southern peri-urban areas not served by the municipal centralized water systems, while hybrid group co-production has historically occurred in consolidated slums. - Co-produced practices always emerge at the territorial level of the local administrative unit.

3.1. The Governance-Institutional Perspective

Outcome Elements of Sustainability

Within the governance-institutional perspective, the discourse on the sustainability of co-production mainly involves key principles of service efficacy/efficiency and the socio-economic equity of practice outcomes. Efficacy/efficiency corresponds to the capacity to allocate a service (i.e., efficacy or effectiveness) with the lowest economic and social cost involved (i.e., efficiency) and in such a way that no further reallocation is needed (Ingram et al., 2008). Co-production has been primarily considered as a service delivery strategy with the potential to increase the cost-effectiveness of local governments' actions (Parks et al., 1981). Economic aspects are seldom the primary reason for the engagement of governments in co-production, even if "improving effectiveness and service outcome are much more important for most governments than increasing productivity or cutting cost" (Pestoff, 2014:385). As Pestoff (2014) and Hudson (2012) suggested, strengthening end-user involvement in collective co-production at any level may result in improved service quality and economic viability with respect to individual co-production.

In the governance-institutional perspective, the efficacy/efficiency of the co-produced practice is mostly related to actor and management elements, such as the nature of the end-users' group, the type of service involved and how it is organized (Pestoff, 2014). Such elements determine the feasibility and durability of the action. When referring to services relying on natural resources, such as WSS, the organizational dimension of a collective action has been extensively explored through Ostrom's principles for the governance of common pool resources (Ostrom, 1990; Ostrom et al., 1999). Overexploiting water sources can lead to subtractive benefits for users at different urban scales (Pestoff, 2014). System management mechanisms are therefore the elements where the outcome sustainability of the practice resides. Such elements include: (i) the flexibility of institutional user/providers' relationships in defining collective arrangements and rules for limiting uncontrolled use of resources and for adapting to social and ecological changes; (ii) the introduction of elements to regulate WSS practices such as monitoring, graduated sanctioning, and conflict-resolution mechanisms; and (iii) the access and sharing of information about the state of the system and the action of other actors involved in the practice, to allow flexibility, learning, goal renegotiation, and strategy modification as needed (Anderies et al., 2004).

In line with Ostrom's principles, in the case of the OTBs in Cochabamba, we observed how the introduction of norms for regulation for water supply was fundamental for giving durability to the practice, in a context of increasing scarcity of resources due to limited groundwater. In Cochabamba, the shared definition of mechanisms of control and extraction of the common resource became the means to increase the efficiency of the service, limit water loss and minimize the costs of the purchase of water from private vendors. This case shows how the existence of pro-social motivations and the recognition of the collective value of a good/service can be the drivers to create ownership, increase managerial skills and finally define an effective management strategy.

Other studies (Jakobsen and Andersen, 2013; Pestoff, 2014) dealing with the governance dimension of co-production, have shown how the discourse on service efficacy/efficiency and management mechanisms to improve service quality, is strictly correlated with the key principles of socio-economic equity. Equity refers to the capacity

of the services to provide an output performance able to allocate benefits and costs of the services to all the users efficiently, fairly and affordably (Wiek and Larson, 2012). It is not defined in an absolute sense but with respect to the needs of people (Pena, 2011; Talen, 1997) and it is therefore based on a comparison of groups (Kooy et al., 2016), identifiable with respect to income, gender, ethnicity, geography or use of a service (conventional vs. alternative).

When referring to WSS co-production, studies have highlighted how discourses about service equity consider a series of objective and subjective outcome elements, including physical, economic and social accessibility to the WSS service (to resources and technology); the distribution of costs and benefits among users of the co-produced service and among citizens in general; the level satisfaction of users' needs and expectations with respect to the quality and quantity of the service; and the perceived value and acceptance of the service (willingness to pay or complaining) (Demsey et al., 2011; Kooy et al., 2016; Marques et al., 2015; Wiek and Larson, 2012). The benchmark is usually represented by people's access conditions before the introduction of the co-produced service and by the performance of the existing conventional networked systems.

However, the relationship between equity and efficacy/efficiency may be bivalent. Increasing the quality and efficacy/efficiency of the co-produced service may or may not correspond with an equal service outcome for the involved citizens. As Jakobsen and Andersen (2013:705) suggested, "distributional consequences" of co-production are directly related to knowledge and tangible resources of co-producers: "unbalance in knowledge and available resources may exacerbate gaps between advantages and disadvantages [for] service users".

The case of Dar es Salaam clearly shows such ambivalence and the variability of the equity principle when referring to different benchmarks. In southern peri-urban Dar es Salaam, we observed that the cost of water from co-produced systems, based on community wells managed by WUAs, is often higher than the water cost from the centralized municipal network reaching the most affluent areas in the north of the city (relative inequity), but still less than the cost of water purchased from private vendors (relative equity). If, on the one hand, the co-produced wells have given the inhabitants the chance to enjoy their basic needs in an area otherwise deprived of water sources, on the other hand, the access to the local systems often depends on the economic resources of inhabitants and the distance to the main water infrastructures. In many areas, the equity of the system is directly proportional to the efficacy/efficiency and quality of the service. When WUAs have the management and financial capacities to develop and upgrade their own systems, through increases in revenues from the registration of new users and technological improvements (expansion of main pipe-lines, endowment of new pumps/reservoirs and drilling new wells), the quality and quantity of the service have improved and the benefits have been redistributed in a more equitable way. Furthermore, in some peri-urban areas of the city, this renewed access to water has given users the chance to develop new income activities, such as urban agriculture, food processing and livestock. This example testifies to how equity discourse requires considering the types of users' use and consumption of water/wastewater and their collective or individual economic activities. These elements convey users' needs and determine people's interest and responsibility in co-production. This also shows the importance of including evaluations of the potential role of co-produced practices within sustainability analysis to

increase people's opportunities of pursuing economic activities beyond securing their livelihoods.

Process Elements of Sustainability

The governance-institutional perspective identifies the process elements of sustainability within the typology and mechanisms of participation in co-produced practice, considered as a potential catalyst for democratization and renewed political citizenship. Some studies (McMillan et al., 2014; Mitlin, 2008; Nabatchi et al., 2017) have reflected on the role of co-production in pursuing "participation as citizenship" (Hickey and Mohan, 2005:238), as a result of its potential to increase democratic governance and to empower users. Nabatchi et al. (20017:767) have suggested that co-production has a "normative value for society in terms of citizenship and democratic governance, and social capital". Mitlin (2008:339) has shown how the promotion of self-help groups and transparent collaborations may "enable individual members and their associations to secure effective relations with state institutions that [both address] immediate basic needs and enable them to negotiate for greater benefits".

This literature considers co-production more than a simple users' consultation because it involves citizens in the planning and delivery of a service (Nabatchi et al., 2017; Pestoff, 2014). In fact, synergic relations among users and between users and providers, as well as direct involvement in the production of the service, may favour users' ownership over the practice, learning and building skills and capacities resulting from knowledge exchanges between actors (Moretto et al., 2018; Pestoff, 2014). Nabatchi et al. (2017) and Pestoff (2014) indicated that the potential to foster democratic governance and citizenship, especially for the poorest and most marginalized inhabitants, resides in the collective interaction and greater responsibilities assumed by users within the co-production process. However, Moretto et al. (2018:438) highlighted the risk that this potential can be neutralized and instead bring "depoliticization of the service production and delivery process". Community participation can bring also along some significant limitations, such as the gap between rhetoric and reality, when speaking about participation in urban services (Moretto, 2015), which means a differentiation between the "formal level of participation" and "the way that participation operates in practice" (Tunstall, 2001:2512), or the risk of an instrumental role in citizens' involvement (Jessop, 2002; Miraftab, 2004; Swyngedouw, 2005).

The cases of Cochabamba and Dar es Salaam testify to the bivalency of the process sustainability of different forms of participation in co-production. In Cochabamba, WSS co-produced practice emerged from a social movement for "the right to water". This created those synergistic group connections that gave process sustainability to the practice. The political imaginary produced by the idea of direct users' involvement in urban production, and the legal recognition of OTBs that came in a second phase, assumed the key role in increasing social capital and in giving shape to a principle of citizenship. In Dar es Salaam, WSS co-production in the southern peri-urban areas was mainly connected with the need to satisfy a primary individual demand in a situation of the total absence of a reliable and fair source of water. The development of WUAs was the result of an infrastructure development strategy from the state that had local leaders and local water committees as the leading initiators of the initiative. Even if the users are involved in the election of the managerial board of the association, in many cases of

community wells in Dar es Salaam, the absence of any real involvement of the community since the beginning of the process, and the consequent lack of ownership over the system, have led to the failure of some projects (as an example, the impossibility of maintaining the infrastructure when financial management boards have not secured the surplus funding to invest in improving the system). In the most successful cases, the cornerstone was precisely the ability of leaders and board managers to involve the majority of the inhabitants of the area in a process that was not just a consultation to ensure the necessary financial and human resources were available to support the development of the system. In some cases, WUAs have reached 5,000 users having started with a few dozen.

These examples show how a co-production model could help to establish new democratic and sustainable institutions only when citizenship rights to produce the service are secured and when it is promoted by participatory processes that are inclusive, transparent and symmetrical from a communicative level. As Moretto et al. (2018) suggested, the early involvement of the users in the co-planning process of WSS systems may favour the creation of conditions that provide a renewed political citizenship for the co-producers. However, in most cases in the literature, WSS co-production could not provide adequate space for new democratization, being mostly limited to the co-management phase.

3.2. The Socio/Political-Ecological perspective

Outcome Elements of Sustainability

Within the socio/political-ecological perspective, co-production is intended as an alternative service provision modality "produced as a result of the articulation of socio-political, economic, biophysical and infrastructural drivers whose interaction constitutes new practices, thereby producing new meaning" (Ahlers et al., 2014:2). WSS co-produced service provision is therefore the result of the interactions between users and providers through a "dynamic set of social and material relations to access, provide, and control water supply" and disposal (Ahlers et al., 2014:2) that influence the characteristics of water and its circulation (Budds et al., 2014). In such a perspective, the outcome elements of sustainability are defined in the relationship between the ecological integrity of the resource flow (considering both centralized and decentralized services, with their technological arrangements), with equity/justice in access to service.

In the literature, the principle of system ecological integrity refers to the capacity of maintaining the fundamental function of the water resource system by reproducing the fund elements in the metabolic process characterized by a material flow across the socio-ecological system (Falkenmark, 1997; Madrid et al., 2013; Wiek and Larson, 2012). Such a principle involves a balance between the needs of the co-producers (and of the other inhabitants) and the current and future capacities of the water system (Wiek and Larson, 2012). It recognizes the physical connection between hydrogeological and socio-economic systems and the interconnectivity between the spatial and temporal scales of the co-produced practice. In this view, the question of ecological integrity requires considering the existence of certain boundaries of the co-production practice (qualitatively and quantitatively), from the upstream (take) to the downstream (disposal), and between different groups of users or inhabitants in general. The physical trajectories

of the water cycle of co-produced service involve certain inputs and outputs of the system, including the sources of water (quantity of resources), the technology employed, the quality of water (potable, non-potable, wastewater, pollution sources) and people's consumption of water/wastewater to sustain needed activities and related practices of reuse/recycle and the disposal of water (Button, 2017).

However, some studies (Faldi et al., 2019; Moretto et al., 2018) have shown that ecological integrity (and the closure of the local water cycle) is a relevant challenge for the sustainability of co-production and the quality of life of inhabitants. For example, in the cases of Dar es Salaam, Addis Ababa and Hanoi, we observed that none of the existing co-produced socio-technical arrangements considered the circularity of the water cycle. These is mostly due to poor capacity or a lack of centralized wastewater treatment systems, poor inhabitants' awareness, and management and financial problems related to the operation of decentralized wastewater treatments. More specifically, in Dar es Salaam, we observed that some co-produced decentralized sanitation systems (e.g., DEWATS), built by NGOs and donated to local authorities and communities, have not been made operational for two main reasons: poor users' willingness to pay desludging fees and a lack of agreement between private operators and local leaders regarding the percentage of service revenues to be redistributed to the community. As a result, diffuse untreated disposal into surface or ground water is deeply affecting the quality of urban agriculture and creating health risks for inhabitants.

In the socio/political-ecological perspective, as also highlighted in the previous examples, the trajectories of the water cycle and its ecological integrity are not just related to its physical and spatial elements, but also to how societal norms, organizational arrangements, and in general specific relations between certain actors, have determined (or not) a more equal service. As in the governance-institutional perspective, discourses of equity refer to economic, physical and social accessibility to service, but the socio/political-ecological perspective is more interested in analysing the allocation of benefits, who gains and who loses (and how) from a certain WSS practice that entails a socio-environmental change (Heynen et al., 2006). In other words, the principle of equity does not refer to economical and physical distributional questions only, but it also includes an understanding of the evolution of political and ecological contexts that have determined certain conditions of inequality (Perrault, 2014). In such a political perspective, equity is intimately correlated with a discourse of social and environmental justice, where justice corresponds to "the need for the socially [*and environmentally*] excluded to be acknowledged as legitimate claimants, to be recognized as having valid political, social and cultural standing" (Perrault, 2014:239), expressing their right to obtain a certain quality of life. In fact, especially in the cities of the Global South, inequality in accessing the service can be grounded in conditions of deep ecology vulnerability and elite capture of the best option within a diversified landscape of available WSS infrastructures. Service fragmentation in "archipelagos" is often the result of service privatization policies and/or decentralization policies, growing environmental pollution, limited availability of water resources, or poor infrastructure capacity of the centralized systems. These dynamics can work at different urban scales, given the multi-scalar nature of the water resource system, from global to local (Moretto et al., 2018).

In this perspective, looking at the equity of WSS co-production therefore involves understanding of the existing barriers to WSS access, including possible mechanisms of

marginalization and exclusion in accessing the collective action, and socio-economic and ecological changes determining eventual disparities between groups of inhabitants with respect to their access to existing services, either co-produced or not (Kooy et al., 2016; Perrault, 2014). First, such understanding induces consideration of if and how the quality and quantity of the accessed water fulfil all users' consumption needs and desires or, by contrast, the limited consumption of a certain group renders the access of a wealthier one more secure. Second, it requires an analysis of how biophysical processes and WSS infrastructures may influence the everyday politics of water and reproduce mechanisms of inequality (Ahlers et al., 2014).

The cases of Addis Ababa and Dar es Salaam clearly show how marginalization in access to WSS services may occur. In both cities, water co-production is a mechanism to fill the gaps in the centralized municipal network: in Addis Ababa in the form of hybrid systems, connected to the centralized network but independently managed; in Dar es Salaam mainly in the form of decentralized systems, existing within a landscape of different modalities of accessing water. In both cases, the boundary conditions of quality and quantity of the resource are affecting management options and equity/justice in accessing water service.

In Addis Ababa, in the slums and in the condominiums, the co-production of water service takes place at an individual level. It is used to fill the deficiencies of the centralized municipal system, which cannot provide a satisfactory water supply, due to the limited volumes available (i.e., there is 100% connection rate, but the service is limited to some days/week). As a consequence, inhabitants are obliged to store water individually and/or to buy water from private vendors at costs much higher than the network tariff. The current urban development strategy, which entails the relocation of slum dwellers in collective block housing, presupposes a transition to more energy-intensive technologies (e.g., from pour flush to normal flush toilet). This will require a further use of co-production at the level of resource storage, the cost of which is not affordable for the poorest citizens.

In Dar es Salaam, access to the municipal centralized system is a privileged condition for the planned city. The centralized network serves the richest areas (i.e., the connection rate is about 40%), while unplanned settlements are often not connected or partially connected through public fountains. Consequently, multiple water supply practices emerge, an archipelago of sociotechnical systems with different resource qualities and costs per unit. The quality of the groundwater plays an important role in such a waterscape, as most of these alternative practices involves the use of groundwater as a primary source. These include the endowment of private boreholes, which redistribute water to group of inhabitants, and the installation of community boreholes managed by public water committees or by WUAs. In a city almost lacking a centralized sewerage system (i.e., the connection rate is about 7%), groundwater pollution – mostly due to percolation into the shallow aquifer of effluents from pit latrines and other agricultural and industrial pollutants (Mato, 2002), and to growing seawater intrusion caused by over-pumping (mostly by industrial activities) (Faldi and Rossi, 2014; Mjemah, 2007) – makes the use of decentralized co-produced practices very risky for the inhabitants of the poorest areas, and it often requires them to purchase water from private street vendors at very high cost.

Process Elements of Sustainability

In the socio/political-ecological perspective, the process dimension of sustainability is situated in the existing power dynamics across the wider socio-ecological systems in which co-production operates. As previously stated, the political ecological literature has clearly highlighted that "socionatural arrangements and water politics either enhance or challenge the unequal distribution of resources and decision-making power in water governance" (Boelens et al., 2016:2). Metabolic flows of water and wastewater through the socio-ecological system may induce "enabling" or "disabling" conditions for different individuals and groups, producing conditions of empowerment and disempowerment (Heynen et al., 2006:10). Consequently, WSS co-production cannot be always considered a neutral collaborative practice. It may instead reproduce asymmetrical relations of power and thus determine contested WSS services (Ahlers et al., 2014; Perrault, 2014).

Uneven relations may emerge among different users, especially when WSS co-production is coupled with other WSS service arrangements. Meehan (2014) has underlined the role of complementary technology (such as water tanks and booster pumps) as a means of power that allows inhabitants who can afford such artefacts to secure their individual access to the best WSS options, in the framework of the general conditions of limited water quality and quantity at the urban level. In the cases of Addis Ababa and Dar es Salaam, we observed that individual water tanks become instruments of power in the poorest areas. Equipping with such devices allows individuals to take a prominent position in the community, due to a more secure access to water and, when coupled with a private source (e.g., a private/group well), the possibility of reselling water to neighbours lacking other service options. These examples highlight how complementary technologies for adapting to disruptions in centralized systems can create new power relationships between inhabitants within the co-production process.

Faldi et al. (2019), Jaglin (2012) and McMillan et al. (2014) have shown that uneven power relations may also emerge between users, provides and intermediaries as a consequence of the contradictory role that WSS service co-production may have in the Global South. In fact, the state can consider co-production as a regulated transition phase towards an ideal universalization of the service through a fully centralized network. Still, co-production has sometimes been mobilized to justify the reduction of state responsibility and investments, especially when coupled with a service commodification policy (Faldi et al., 2019; Jaglin, 2012). In such cases, "coproduction arrangements work to legitimate unequal power relations, not to change them" (McMillan et al., 2014:203). Here, water supply and sanitation might play a different role where water supply is conventionally driven by private and market interests that can negatively affect co-production consolidation, while common interest in reducing pollution through sanitation in decentralized systems might support and motivate the involvement of users and private intermediaries, even if management and financial challenges persist, as highlighted above in the case of DEWATS in Dar es Salaam.

Infrastructure policies, key actors and their power relations (i.e., competition between power arrangements and competition in the long run) are therefore fundamental elements for assessing the process sustainability of WSS co-production in a socio/political-ecological perspective. As an example, what may happen when the conventional network arrives in settlements previously served by co-produced services? Cases of African cities show that social relationships and community power dynamics

may disappear once the public network arrives, leaving space for new stakeholders and power relations. In fast growing cities, the competition between different types of WSS arrangements is increasing in peri-urban areas, with huge consequences in terms of sustainability of co-production (Jaglin, 2002, 2012). As an example, in the cases of Addis Ababa and Hanoi, the transition from a collective form of co-production to an individual one is a recurrent dynamic connected with the development of new urban areas. In Dar es Salaam, the water authority is currently implementing a policy of recentralization of community-based fragmented infrastructures and replacement of local management boards with public ones. Such changes imply a reformulation of users' capacity to act within the socio-ecological system and of power dynamics across the socio-ecological system.

Still, political ecology research has highlighted how the presence of multiple practices of accessing water with various technologies (i.e., the complexification of the hydrosocial cycle) can translate into higher users' capacity to cope with urban and environmental transformations (increasing pollution, climatic variability and change, environmental hazard, urban expansion etc.), but it can also increase inequality – especially in the case of pollution of the main water source, where the costs of alternative solutions are higher and not affordable for the poorest inhabitants (Button 2017; Kooy et al., 2016) – and finally determine different organizational and power arrangements. By contrast, a recentralization of power may reduce users' adaptability to changing urban and environmental conditions, especially in contexts where the ideal of WSS universalization has been largely disputed (Coutard, 2008; Furlong, 2014).

In a social/political-ecological perspective, ensuring sustainability of WSS co-production therefore resides in the enhancement of the "democratic content of socio-environmental construction by means of identifying the strategies through which a more equitable distribution of social power and a more inclusive mode of environmental production can be achieved" (Swyngedouw et al., 2002:125). In their study about co-production of WSS services in Caracas, McMillan et al. (2014) defined co-production as sustainable when it is embedded in a wider political process that challenges asymmetric power dynamics and forms of patronage leading to elite captures, and when it is promoted through the full recognition of users' political, social and environmental rights to produce the service, a real prerequisite to ensuring (any form of) social and environmental justice (Perrault, 2014). In line with such a statement, the case of Cochabamba has clearly shown how the question of rights was the lever to ensure the process sustainability of the OTBs' co-produced water systems.

3.3. The Incremental-Urban Perspective

Outcome Elements of Sustainability

The incremental-urban perspective considers WSS co-produced infrastructures as locally produced materialities that adapt and evolve, on an ordinary basis, within the socio-material assembly of the city. The literature has mostly analysed the role of community participation in the production of urban space and infrastructures with a specific focus on the socio-spatial outcomes produced by incremental sociotechnical arrangements (Coutard and Rutherford, 2015; Graham and McFarlane, 2014; Moretto et al., 2018;

Rosati et al., forthcoming; Silver 2014; Simone, 2004). This perspective identifies the outcome elements of sustainability within a discourse on efficacy/efficiency, spatial equity and socio-spatial cohesion emerging in the relation between the sociotechnical configurations of the co-produced practice and the spatial-economic accessibility to the service, within multi-scalar patterns of urbanization.

In the literature, the question of efficacy/efficiency is primarily connected with the recognition of the potential capacities of users to improve service management (Moretto et al., 2018; Rosati et al., forthcoming; Watson, 2014). As Watson (2014) suggested, state and citizens (service users) may have different but complementary forms of knowledge that together can contribute to improve the final outcome and, consequently, to move the services toward a more efficient and sustainable condition. Still, studies (Cabrera, 2015; Moretto et al., 2018; Rosati et al., forthcoming) have underlined how the deployment of these co-production capacities demonstrates a pure socio-spatial value, as WSS services are strictly related to the mechanisms that drive the production of human settlements. In fact, co-production may trigger some degree of social and spatial change that emerges at different but interconnected spatial scales (Moretto et al., 2018; Rosati et al., forthcoming). In this view, the efficacy/efficiency of co-production is linked to the capacity of involved actors to integrate their technological and management knowledge with the production of local shared spaces and economy.

The cases of Cochabamba and Hanoi clearly show such relationships. In Cochabamba's southern areas, for example, the states can produce trunk services while citizens can produce related feeder services. Given the inaccessibility of groundwater, in a number of neighbourhoods, the municipal water company regularly provides water to collective water tanks, co-funded by citizens and governments. The construction and management of the piped network for water distribution in the neighbourhood is handed over to water associations or water committees which not only have the ownership and control over the infrastructure, but also invest water-related funds to improve the neighbourhood public spaces and facilities for residents. Likewise for sanitation, in Hanoi, we have observed that the government manages the main drainage pipes at the inter-commune level, while communes are engaged in construction and maintenance of secondary drainage and irrigation canals within the territories under their jurisdiction. This allows communities, traditionally engaged in water-fed production (like rice production or fishing) to reuse waste (wastewater) and to turn it into a valuable resource (water for irrigation), while contributing to a primary, and often the only, form of wastewater treatment.

Within the incremental-urban perspective, other relevant debates around the outcome sustainability of co-production of WSS services mobilize the concepts of spatial equity and socio-spatial cohesion. With respect to principle of spatial equity, some studies (Faldi et al., 2019; Moretto et al., 2018) have shown how limitations in accessing a co-produced service might be affected by past or present conditions of spatial marginalization correlated with access to land and house tenure. State-citizen co-production is unlikely to take place in squatter areas or informal settlements, especially when governments and urban planning departments have interests over land for redevelopment (Bakker, 2003). Addressing the question of equity through an incremental-urban perspective therefore requires a look at the settlement evolution with respect to the distribution of land accessibility to WSS services (with their technology) in

the urban area and the existing governance forms and regulatory frameworks with respect to land. The analysis of spatial equity is therefore concerned with comparing the locational distribution of facilities or services (people's proximity to the resource/service) to the locational distribution of different socioeconomic groups (service costs and income distribution) in multiple urban typologies and land tenure positions (Talen and Anselin, 1998). In this perspective, the idea of spatial equity can be applied both within the area where co-production occurs, and in different settlements in the city.

With respect to principle of socio-spatial cohesion, some authors (Cabrera, 2015; Moretto et al., 2018) have suggested that co-production can reinforce the dynamics of socio-spatial fragmentation, based on the perimeter of the shared resources, while triggering urban sprawl. However, co-production may also foster a shift toward a more inclusive way of governing the city and managing urban settlements, grounded on self-ruling mechanisms and participation in the sharing of resources and public space (Moretto et al., 2018; Silver, 2014; Simone, 2004). In this sense, co-production may allow forms of spatial reconnection in the city.

The case of Cochabamba is particularly illustrative of this bivalency. Here, we observed that community-based service providers play a relevant role not only in the planning and maintenance of the water infrastructures (generally mini-networks connected to wells or water tanks), but also in the production and consolidation of urban settlements. The water tariffs are often reinvested to improve the quality of shared spaces (i.e., street paving, tree planting, construction of public facilities) to strengthen social ties and solidarity among neighbours (i.e., economic support to funerals, festivities), and to prepare to cope with environmental transformations that could affect the robustness of their co-produced services (i.e. emergency funds in case of drought). However, neighbouring quarters are often competing for access to a supposedly common pool resource at risk of overexploitation. Given the lowering of the aquifer water table, in a number of neighbourhoods, we observed that new dwellers have been excluded from the connection to the existing network, and therefore they have to rely on more expensive water sources, such as purchasing from water vendors. Moreover, in a number of cases of community-based water networks, clientelistic logics, corruption and poor management of collective economic resources have been reported.

This example shows that the evaluation of the outcome sustainability in an incremental-urban perspective implies verifying whether WSS co-production fosters social cohesion between communities or, vice versa, it determines forms of exclusion of specific social groups from the decision-making process. Spatializing the distribution of benefits or the boundaries of co-production therefore helps us to understand whether co-production leads to a fragmentation of the urban environment or contributes in creating premises for a better cohesion.

Process Elements of Sustainability

Within the incremental-urban perspective, the process elements of sustainability have been associated with users' and technical infrastructure capacities to learn and adapt to the incremental logic of urban production (Graham and McFarlane, 2014; Graham and Thrift, 2007; Hamdi, 2004; King, 2016; Silver, 2014).

The literature on Southern participatory urbanism has moved from the recognition that "incremental", "tactical", "handmade" world cities are rapidly growing outside and

beyond planning processes. While cities are rapidly urbanizing and infrastructure networks are evolving, the participation of communities in the production of contemporary cities, namely the processes of formation and consolidation of urban settlements and related serviced infrastructure, is considered as a fact. As co-designers and co-producers of the urban space, communities are described as the change processes or catalysts of change that can substantially contribute to more equitable and sustainable urban development (Hamdi, 2004; McFarlane, 2011; Silver, 2014; Simone, 2004).

In this perspective, incrementalism can describe how the sociotechnical processes of maintenance and repair of urban infrastructure by ordinary citizens produce knowledge and innovation. Accordingly, the co-production of WSS services, which is made by constant adaptation and reconfiguration of infrastructure systems, embeds a learning process, by which, through sharing different forms of knowledge, urban dwellers learn about their cities, their limits and the conditions of possibility (Graham and Thrift, 2007; McFarlane, 2011; Silver, 2014; Simone, 2004). The cases of peri-urban areas in Hanoi and condominiums in Addis Ababa clearly show how such a learning process often implies a direct action of the users within the service cycle through complementary technologies. In both cases, we observed how users' adaptive knowledge was mainly oriented toward the optimization and upgrade of the networked water infrastructures through individual technologies to improve drinking water quality while guaranteeing a regular supply through the use of booster pumps and private storage tanks.

Co-production initiatives, like all sociotechnical systems, may induce profound transformations of broader urban processes (Graham and Marvin, 2001; Monstadt and Schramm, 2015; Moretto et al., 2018). The literature on sociotechnical infrastructure in the Global South has largely explored the constant evolution of "unfinished networks", addressing the "incremental nature" of co-production by looking at how trajectories and transformations of co-produced initiatives constantly adapt to changing spatial conditions to feed their life-cycle (Jaglin, 2014; King, 2016; Rosati et al., forthcoming; Silver, 2014; Zerah, 2000). As the physical elements of the water cycle are spatially located, there is an intimate relationship between socio-technical arrangements and settlement typologies that makes co-production profoundly differ from one case to another (Rosati et al., forthcoming).

The shaping of the physical, but often invisible, boundaries of urban metabolic flows of WSS services is embedded in the governance structure of the city and related services at large scales. Moreover, as water and sewerage pipes are embedded in the physical boundaries of housing systems, dwellers operate differently in the technical lifecycle with respect to their housing systems at a local scale (Habraken and Teicher, 1998). The cases of Hanoi and Cochabamba exemplify the potential influence over the process sustainability of such adaptive dynamics between socio-spatial urban patterns and co-production arrangements. In both cases, urban households are continuously extending, upgrading and reshaping their living space, producing incremental urban development. A study on Hanoi planned settlements (Rosati et al., forthcoming), from Soviet collective housing blocks to current new urban areas, has revealed that the original settlement structure, building units and WSS infrastructures have served as supports on which infills, re-arrangements and extensions have provided inhabitants a meaningful participative role in the design process. Following these transformations, WSS co-production initiatives have evolved from the collective to the individual scale. By contrast, in recent

neighbourhoods in peri-urban Cochabamba, where residents are not yet connected to piped schemes, co-production has evolved from individual (households supplied by water vendors) to collective (small scale piped schemes) scale.

4. A Systemic Framework to Evaluate Sustainability of WSS Co-Production

The literature review and the insights from empirical cases have shown how the trajectories of WSS co-produced practices are related to multidimensional elements that define its process and outcome sustainability in specific contexts. The research has revealed multiple elements related to the sustainability of WSS co-production, displaying the key principles that should be mobilized for the study of co-production in the Global South, their interrelations and their possible bivalency. In particular, the analysis has framed a set of outcome and process principles and criteria that systematically come into play when evaluating the trajectories of sustainability of WSS co-production in urban contexts in the Global South. The resulting framework is articulated in four outcome and three process principles and their relative criteria: efficacy/efficiency, ecological integrity, socio-spatial cohesion and equity as outcome principles; learning/empowerment, democratization/citizenship and adaptability as process principles (Table 2). These principles integrate the managerial, techno-environmental and spatial dimensions of WSS co-production differently, and they deeply intersect each other on two levels (Figure 2).

Table 2. Principles and criteria for assessing outcome and process sustainability in WSS co-production

Sustainability Principles	**Criteria – Governance-Institutional Perspective**	**Criteria – Socio/Political-Ecological Perspective**	**Criteria – Incremental-Urban Perspective**	**WSS Co-Production Dimensions**
Outcome elements				
Equity	- Physical, economic and social accessibility to the WSS service (to resources and technology) - Distribution of costs and benefits among users - Distribution of WSS services compared to previous conditions and to the performance of the conventional networked service - Level of users satisfaction and users' willingness to pay for the service	- Physical, economic and social accessibility to the WSS service (to resources and technology) - Allocation of benefits among users (who gains, who loses) - Fulfilment of users' needs and desires - Inclusion or existing barriers to access WSS services and marginalization in accessing collective action - Consideration of political and	- Distribution of WSS services to different settlement typologies and socioeconomic groups (proximity to the resource/service) - Presence of condition of service marginalization correlated with land entitlements and environmental degradation	*Managerial, Techno-environmental, Spatial*

	- Economic opportunity beyond securing livelihoods	environmental conditions that have determined ecology vulnerability for users and service elite capture (*social and environmental justice*)		
Efficacy and Efficiency	- Organization and management mechanisms (nature of the group, type of service, monitoring and control, flexible tariffs and subsidies) - Collective norms for limiting uncontrolled use of resource (enhance water-use efficiency) - Access and sharing of information		- Improved service management capacities of users - Self-ruling mechanisms and participation in the sharing of resources and public space	*Managerial, Techno-environmental*
Ecological Integrity		- Maintenance of the fundamental function of the water resource system - Balance between users' needs and the capacity of the water system - Upstream to downstream integrity (consideration of water cycle circularity)		*Techno-environmental, Spatial*
Socio-Spatial Cohesion			- Maintenance of social-spatial relationships when changing infrastructural and urban boundary conditions - Equal distribution of benefits avoiding spatial fragmentation	*Managerial, Spatial*
Process elements				
Learning and Empowerment	- Knowledge exchanges between actors - Building users' skills and capacities	- Equitable distribution of social power and a more inclusive mode of environmental production (addressing asymmetrical power relations and uneven services) - Enabling conditions for marginalized groups	- Complementary forms of knowledge - Learning process (new skills and awareness of service-users)	*Managerial, Techno-environmental, Spatial*

		- Knowledge of the resource/tech service - Complementary technology as a means of power		
Democratization and Citizenship	- Level of inclusiveness of participation (symmetrical communication level) - Legal or institutional legitimation to co-produce - Securing citizenship rights and including marginal groups from co-planning - Ownership over the practice	- Policies bringing common interests between users, intermediaries and providers - Wider radical political project for changing state-society relationships - Full recognition of users' political, social and environmental rights		*Managerial, Techno-environmental*
Adaptability		- Users' capacity to cope with urban and environmental transformations	- Constant adaptation and re-configuration of (urban and) infrastructure systems	*Managerial, Techno-environmental, Spatial*

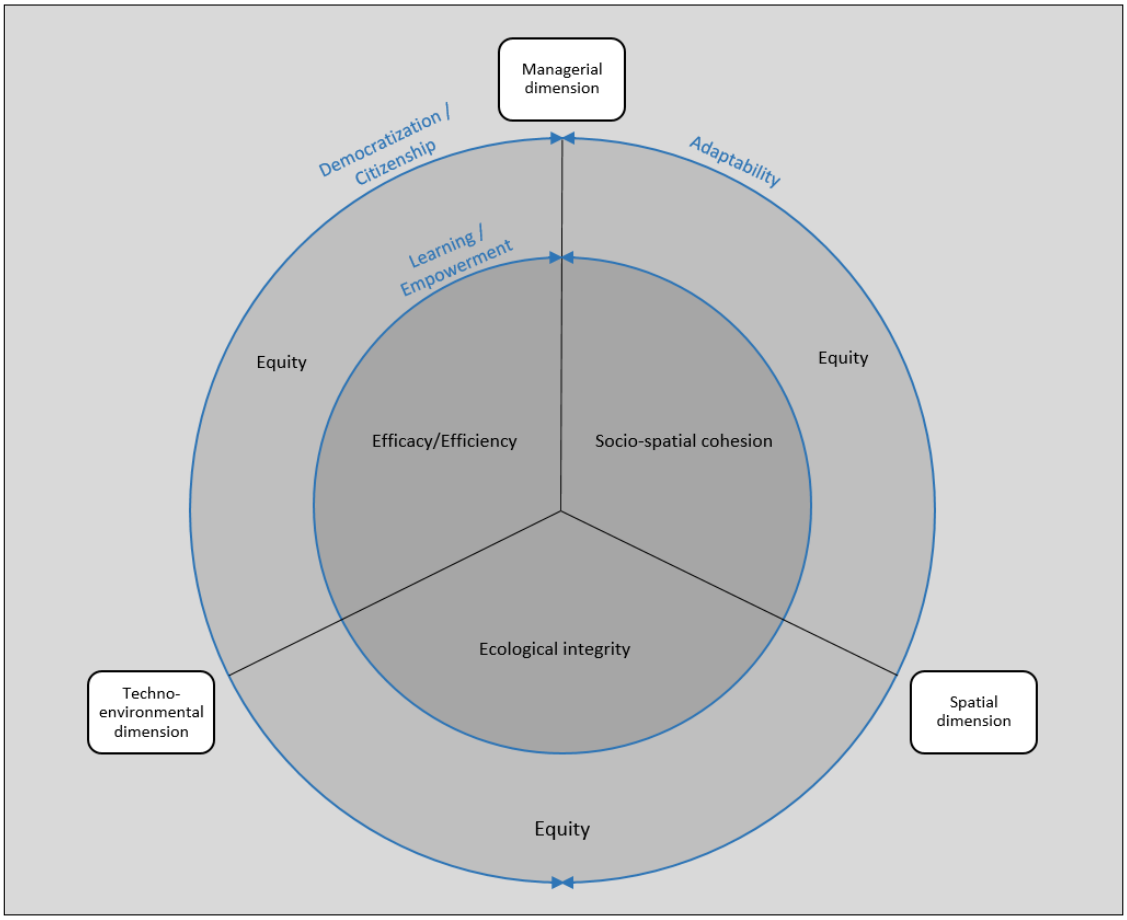

Figure 2. Sustainability framework for WSS co-production

The primary level of intersection folltabows the logic of the TBL model and defines the outcome elements of sustainability in the relationship between the principles of efficacy/efficiency, ecological integrity and socio-spatial cohesion. Interrelations between these principles are deeply connected to the process mechanism of users' learning with regard to the economic, environmental and social management of the co-produced system, such as sharing of information and knowledge, investments in technology development, or monitoring and control mechanisms to avoid uncontrolled used of the resource, spatial fragmentation and economic collapse of the practice. Within the three theoretical perspectives, the managerial aspect of WSS co-production is therefore considered as the key dimension to build those actors' capacities to facilitate outcomes that are economic efficient/effective and socio-spatial cohesive, and to minimize problems related to poor ecological integrity of the practice. The emergence of such capacities is deeply connected with the conditions of the learning process embedded in co-production, namely the level at which users can intervene in the physical space and in the decision-making process, as well as the level of inclusiveness, communicative symmetry and transparency of the participatory process.

The secondary level encompasses the primary outcome principles, and it is related to the principle of equity, which appears to be the cornerstone for most of the literature on WSS co-production. The principle of equity defines the interrelations between the elements of WSS co-production in its outcome and process values, which emerge at multiple interacting scales. At the local scale, the three primary outcome principles interface with respect to how equity is guaranteed by the co-produced service. In fact, specific performance of a WSS co-produced practice, measured in terms of efficacy/efficiency, ecological integrity and socio-spatial cohesion, is often subordinated to the redistribution capacity of the practice, measured with respect to socioeconomic and spatial accessibility to WSS services and to the limitation of selective benefits from conditions of environmental, spatial and technological advantage or marginality of individuals or groups. An equal WSS co-produced system therefore connects objective aspects related to the fair and affordable performance of the service with subjective aspects related to the satisfaction of users' needs, namely the possibility of improving quality of life from the obtained benefits.

On the municipal scale, the question of equity involves the consideration of the relationship between WSS co-production with the existing policies for infrastructural development and the ensuing environmental and urban transformations. In fact, case studies have showed that WSS co-production in the Global South may occur spontaneously as a form of adaptation to the deficiencies of the centralized system or, otherwise, it may be supported as a deliberate strategy following the process of decentralization and commodification of the WSS services. In both trajectories, co-production facilitates a dynamics of redistribution of material and immaterial advantages or disadvantages to users. Considering the relationships between resources, technologies, space and leadership/governance dynamics at multiple levels appears as the only procedure for observing the equity of WSS co-production.

Still, equity is often the outcome of a process of users' learning/empowerment and recognition of the right to co-produce, which in turn may facilitate citizenship and users' capacity to adapt to changing institutional, urban and environmental boundary conditions. Such a process may redefine the relationships between users, providers and intermediaries

and related power relations. The consideration of equity as a principle involving multiple interactive levels implies the need to recentre the mainstream discourse on socio-economic equity typical in the literature on sustainable water management towards considerations of social and environmental justice and quality of life.

The principles of democratization/citizenship and adaptability therefore provide criteria that allow us to assess the potential connection between the outcome elements of sustainability and the progressive recognition of users' needs and political, social and environmental rights within the co-production process. As the literature review showed, the elements that can influence the process sustainability of the WSS co-production include the evolution of the governance arrangements in place at multiple scales, participation levels, regulatory frameworks and legitimation of user/provider relationships, and users' adaptive capacities. Still, case studies have shown how the principles of democratization/citizenship and adaptability can sometimes contrast in many urban contexts in the Global South. Both principles imply users' learning/empowerment and the progressive awareness of users' own capabilities. Such process elements should be based on a form of active participation capable of creating the conditions to transform the co-produced system towards more desirable outcomes. However, this theoretical assumption has some practical limitations when observed in the case studies. In fact, in urban contexts of the Global South, the adaptability of WSS co-production has often lain in users' autonomous arrangements to cope with service shortcomings, without a real recognition of rights and of division of responsibilities between users and providers.

Through the literature review and insights from empirical cases, this study has therefore shown how assessing the sustainability of WSS co-production means understanding the trade-offs between objectives/principles and the feedback between the dimensions/elements of the practice. Co-production practices may have a positive process/outcome performance compared with some principles/criteria but a negative one compared with others. For example, questioning the sustainability of WSS co-production in a specific context may imply evaluating whether more adaptive processes lead to outcomes that are fairer, that are more efficient or that maintain system ecological integrity; or whether active participation and synergistic distribution of responsibility/power between actors is actually associated with fairer and more cohesive outcomes. The systemic framework developed in this study has provided an organized set of principles and criteria to assess the sustainability of WSS co-production practices in multiple case studies in the Global South and to explore the interrelations and trade-offs between process and outcome elements affecting the sustainability trajectories of WSS co-production.

5. Conclusions

This study has reviewed how the question of the sustainability of the WSS co-production functions within three different conceptual perspectives that have largely covered the outcomes and processes of the practice in the Global South. By considering the sustainability of WSS co-production in relation to its managerial, technical-environmental and spatial dimensions, the review has complemented the general

literature on sustainable water management. At a theoretical level, it has provided a deeper understating of how to integrate the TBL approach, avoiding sectorial paradigms but considering the interrelations between the social, economic and environmental dimensions of sustainability with political and societal questions. At a practical level, it has framed a series of principles and criteria for assessing the outcome and process sustainability of WSS co-production within a discourse of IUWM and WSS service decentralization in the Global South.

Such results may contribute to a better comprehension of what "sustainability of WSS co-production" may mean and for whom, and with respect to whose quality of life. This represents a fundamental step towards clarifying the impact and trajectories of WSS co-production in different contexts in the Global South, with respect to other forms of service. Is WSS co-production the best way of reaching the poor or not? What is the relationship between decentralized WSS services and the development of the centralized network? Which are the sustainability issues to address when dealing with WSS services in the Global South? How is it possible to increase the sustainability of WSS co-produced services?

To answer these questions, this study has demonstrated the importance of considering the connections between the elements of WSS co-production and the related principles/criteria of sustainability. When questioning the sustainability of the practice, it is worth analysing whether the relations between co-production elements determine conditions that, according to some principles, affect the quality of life of one person/group with respect to others. The analysis of the process/outcome performance of co-produced systems with respect to the conventional networked systems and to previous contextual conditions is also fundamental to revealing the changing trade-offs and tensions between groups and inhabitants.

Fostering a sustainable WSS co-production implies supporting actions/practices that favor win-win solutions between the process and outcome principles. This requires a search for a balance between process and outcome principles, based on a clear understanding of trade-offs and feedbacks between dimensions, and a clear explanation of political and strategic priorities over the practice. In general, the review has highlighted that there is no general measure of sustainability of WSS co-production. Sustainability represents a contextual dynamic condition that may change constantly within a systemic relationship between outcome and process principles, which instead should be prioritized through a transparent enunciation of the objectives that WSS co-production may have in a specific context.

However, further research is needed to operationalize the measurement of the provided principles and criteria. Evaluating sustainability criteria requires a further definition of indicators and analytical methods to employ. The difficulty in identifying indicators and selecting appropriate measurement methods that drive the interface between social and applied science is a well-known issue in sustainability studies (Levett, 1998; McCool and Stankey, 2004). We agree with Levett (1998:291) in the claim for a "fit for purpose" approach employing "different indicator sets for different purposes". Universal indicator sets for measuring the sustainability of WSS co-production are not available. Thresholds and indicators are in fact context-specific, and they should be defined within the different case studies in accordance with the outcome and process principles that are relevant in the specific context. We hope that the present study may

provide researchers and decision-makers with a conceptual framework capable of facilitating sustainability metric selection for the analysis of process/outcome performance of WSS co-production trajectories in the cities of the Global South.

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