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Abstract

Purpose: A case study of niche governance is developed to analyse the governance of rainwater systems in the Amazon.

Methodology: A visualization of the interactions of stakeholders was made with the use of Social Network Analysis (SNA), where data was collected through interviews to experts from the region. A framework based on niche management and the Safe, Resilient and Sustainable (Safe-and-SuRe) principles were used to interpret the results.

Findings: The work identifies key players and issues influencing governance for the implementation of rainwater systems; and capture of decision making powers by agents making evident redundancies in the management of rainwater in the region; highlighting issues of lack of inclusion in the decision-making process, planning and implementation; threatening the sustainability, resilience and governance of rainwater systems in Belem.

Implications/Impact: Methodologically, this work is the first of its kind for the amazon and contributes to the exploration of tools and frameworks to assess governance in the implementation of rainwater systems.

Key Words: Rooftop Rainwater Harvesting; Stakeholder Analysis; Social Network Analysis, Niche Management; Safe and SuRe; Belem-Brazil

1. Introduction

1.1. General context: Clean water, Millennium and Sustainable Development Goals

Clean water provision has been a priority for the UN in the last three decades, as more than 40% of world's population was affected by limited access to clean and secure water; and 41 countries experienced water stress by 2011 (UNDP). In response, the United Nations Development Program (UNDP) was commissioned, setting up the Sustainable Development Goal initiative, being the goal 6 of its agenda 2015 the provision of clean and secure water for all (UN, 2015). Adding to these efforts, the UN Millennium Development Goal initiative was set up, having as its development

goal 7 the safe and reliable water supply as crucial to ensure environmental sustainability (UN, 2000; 2012). In 2015, the Millenium Challenge reported an increment from 76% to 91% on the number of people with access to clean and safe drinking water (UN, 2015). However, the UNDP suggests that by 2050 one in four people will experience recurring water shortage.

Aligned with the UNDP goals, in the last decade in Brazil 28 million people moved out of poverty and 36 million ascended to the middle class (Oliveira, 2015). Despite these enormous changes on alleviation of inequality; social mobility; and the positive impacts on the economy in general; 16.2 million people still live in situations of social extreme vulnerability as reported by the Brazilian Institute of Geography and Statistics (IBGE, 2010). To provide continuity on social inclusion and development, the Federal Government implemented the "Brazil Without Misery Plan": A set of actions involving the creation of new programs and the expansion of existing initiatives, in partnership with states, municipalities, public and private companies and civil society organisations to include the most deprived populations in the dynamic of economic and social development of the country.

Within this context, the Amazon is one of the most challenging regions, where local municipalities must cope with the complexities of logistic access, largely reliant on the rivers as the key transport link. This fact imposes severe constraints to the provision of clean water; evidenced by high local rates of waterborne disease, often aggravated by untreated water supply systems, inadequate/inexistent sewage treatment facilities and open-air dumps; as consistently documented by the independent works of Gnadlingler (1999, 2007); Joventino et al (2010); Souza et al (2011); Veloso (2012); and Silva et al (2012).

To appreciate the magnitude of the problem, the local Municipal Sanitation and Management Plan reports that 91% of the municipalities in the Amazon region have water supply systems; however, in 100% of the Amazon municipalities the water quality does not comply with the minimum standards for human consumption as defined by the Ministry of Health (International Workshop on Solid Waste, Manaus / AM - 2013). In response to these challenges, rainwater has been explored as an appropriate solution for the provision of clean water to rural communities in the Amazon basin. Such rainwater supply technology is characterized by institutional arrangements where the construction of a system of common use (mostly serving family units) and its maintenance, demands collective action with rules of access and

definition of roles for the building and maintenance of the system - like the ones described for irrigation systems by Ostrom (1990, 2005); Ostrom and Gardner (1993) and Janssen and Anderies (2013). Consequently, some of the problems faced by these communities in the Amazon region - beyond the technical and logistical issues - involve social dilemmas related to natural resources and environmental governance.

1.2. The case of rainwater - international context

Gnadingler (2000), Tomaz (2003) and Kautsoyiannis et al (2008) have documented the use of rainwater for human consumption in the past by many cultures with different methods. Contemporary methods mostly depend on the use of roofs to collect the rainwater. This technique - Rooftop Rainwater Harvesting (RTRWH) - has proved to successfully cover basic water needs in many different countries (UNEP 1998), for example: Zhu *et al.* (2004) and Zhu and Yuanhong (2009) report that in Ganzu (China) this technology benefits 2.5 million people; in New Zealand for 11% of the country's population rainwater is the main source of water for consumption (Ministry of Health, 2006); in Thailand, 4.3 % of the urban population and 25.7% of the country's rural population access drinking water through the collection and storage of rainwater (ONESDB/UNCTT, 2004). Additional documentation exists on the use of RTRWH in Venezuela, Maldives, Turks and Caicos, and Bermuda as well as insular territories of Portugal and Greece (Oliveira, 2008). UN-HABITAT (2005) further describes different institutional arrangements for private or publicly owned systems; and different actors including governments, national and local authorities, international development agencies and social organisations in Bangladesh, Singapore, Honduras, the United States, Tanzania, and Kenya.

In general, the advantages and growing interest in the use of RTRWH are related to increasing problems of contamination of superficial and groundwater sources; distribution systems failures, maintenance and operational problems; increasing water demand in rural areas due to industrial agriculture and population growth; the increasing availability of impermeable low cost materials such as tiles, veneers and galvanised iron roofing components as replacement for straw roof as well as the more economical and effective water storage devices (Fawkes, 1999). More recently, studies on the use of rainwater are focusing on its use and governance mechanisms in urban environments, where maintenance and operation in the hands of users is

perceived as critical for the success of the implementation of this technology (Moglia et al, 2011); where research is needed to better understand and design institutional and socio-economic support to facilitate the adoption of this technology by urban communities (Campisano et al, 2017); or integrating the use or rainwater with emerging concepts such as circular economy (Gleason, et al., 2018). Ward and Butler (2016) add to the trend on these new studies the use of Social Network Analysis (SNA) to analyze the interactions of stakeholders and provide a theoretical framework (Safe and SuRe) to assess the relationship between infrastructure, actors and the sustainability resilience and governance of the rainwater systems. In a similar direction, Cardoso et al (2018) used SNA to analyze the relationships of key actors in the implementation of rainwater systems in rural areas in the amazon. However. the issue of governance of these systems in rural areas in developed countries remains under-researched.

1.5. Use of rainwater in the Amazon. The case study of Belem.

Belem is composed of 39 river islands, making 66% of the district area in which the provision of water has not been officially registered and managed. It is also one of the best-documented examples in the Amazon region for the provision of potable water to riverside communities in the Amazon, due to its diversity in terms of the number of organizations related to the management of water distribution and exploration of solutions location; its complexity and diversity in terms of population (Veloso, 2012; Veloso et al, 2013; Cardoso et al, 2018).

Despite the relative abundance of water, the region suffers from the widespread degradation of water springs due to the growth of urban and agro-industrial developments. In the last ten years, Belém's population has grown to more than 2 million inhabitants implying a high urbanization rate close to 99.14%. Also, the city does not have basic sanitation and deposits all the domestic, commercial and industrial wastewater in the city's drainage system that dumps it directly in Bahia do Guajará (Gregório and Mendes, 2009; Souza et al 2016) - see figure 1.

Aragon (2004) states that the limitation of hydric resources for human consumption is due to the quality of water. This was made evident by the effects of urban growth and heavy metal pollution originated from the mining activities in Barcarena (Fenzl and Mathis, 2004); affecting the quality of water around the islands upstream the river due

to the influence of the tides and the water flows; adding to the high levels of Iron emanating from the local groundwater deposits which are above the limits for human consumption. For example, the underground system in Ilha Grande is inoperative (despite its good condition) and the quality of the water delivered is questionable in terms of its iron content (Veloso and Lopes, 2014).

As an institutional response to this situation in 2004, a UNESCO initiative developed technical studies for the availability of potable water both, in Belem and the wider Amazon region.

- INSERT FIGURE 1 HERE -

Figure 1: Belem (Edited from: //www.google.com/maps/place/Bel%C3%A9m+-+State+of+Par%C3%A1/data=!4m2!3m1!1s0x92a46669f5986e5f:0xe336db2d6ab189cc?ved=2ahUKEwjBvqjWjITfAhVJvZAKHUgdAYsQ8gEwAHoECAIQAQ

From this initiative, Veloso (2012) reports that in Ilha Grande and Murutucu 45% of the riverside population buy water from informal distributors: boatmen (delivering 20lt barrels of - untreated - water collected either from the surface of underground sources) and 20% consumed water directly from the river. The study also revealed that the common practice is to combine the use of different sources of water; for instance, to buy water from the mainland to drink and to use water from the river for cooking. In Ilha Nova, 100% of the water for human consumption comes from rainwater collectors (Souza, 2012); and Fenzl et al (2010), registered the case of the only two islands where the water is distributed via public aqueduct (Mosqueiro and Outeiro islands).

The consensus in these studies is that rainwater is an appropriate source of water for human consumption in Belem (and the Amazon in general) due to the logistic challenges experienced in this region (e.g. no/few roads or other transport/communication infrastructure different to the rivers; vegetation growth, river tides, high humidity, instability of the subsoil) and the wide geographical dispersion of the rural communities that would adversely impact distribution methods for clean water.

In this sense, Veloso (2012) registered that in 2004 a first modern initiative using rainwater collection systems in Belem (Ihla Grande) to get access to clean water, was later impulsed by the catholic church- leveraged by their strong tradition of

involvement with the local communities (Almeida 1992; Maués, 2010) - financed by the Ministry of Agrarian Development (MDSA); within the context of the centralized Brazilian federal policy to support the construction of local water supply system (Veloso & Mendes, 2014).

The system was an adaptation of the cistern technology implemented in the semi-arid region of Brazil via the '*One Million cisterns*' program, consisting on concrete plaque cisterns for multiple users (ASA); implemented through partnerships with individuals, the private sector, cooperation agencies, and the federal government. However, concerns were expressed regarding the quality of water by a range of independent studies carried out by Gnadlingler (1999, 2007); Joventino et al (2010); Souza et al (2011) and Silva et al (2012). This technology was proved as not suitable for the bioclimatic conditions of the riverside communities of the amazon, subject to river tides and high levels of instability and humidity of the subsoil (Veloso, 2012).

In 2009, the Catholic Church via their NGO CARITAS delivered fully subsidized RTRWH system (called SODIS), using associative and cooperative strategies (Lobo et al 2013). This implementation model exposed the communities for the first time to deal with issues related with the maintenance and governance of the system; similar to the vulnerabilities described in the literature of the commons (Ostrom 1990, 2002; Ostrom, Gardner and Walker 1994; Hoogesteger, 2013, 2015).

These vulnerabilities were related to the interference of external actor in the systems' governance: the shared use and maintenance of the system and the community learning processes. Consequently, the centralized management by CARITAS resulted in poor maintenance, lack of community learning and appropriation of the system, and the failure of the implementation of this technology in Belem (Lobo et al 2013).

Thereafter, the University of Para (UFPA) developed an improved version of SODIS for the riverside communities. This solution has been well documented both, on its advantages considering the bioclimatic conditions of the region; and the impact to the riverside communities in terms of access to quality and quantity of clean water, health and economic viability (Veloso et al, 2013). The implementation process of this RTRWH followed a slightly different scheme as its implementation was fully funded by the government; involving the interaction of multiple federal and local agencies, NGOs with strong influence in the region, and community organizations, before the delivery to the final users.

However, systematic identification of stakeholders and issues affecting the

implementation and subsequent maintenance of the rainwater systems has not been adequately understood and documented.

An example of this derives from the nature of the Brazilian federalism with high concentration of the process of elaboration and implementation of public policies in the national sphere, that generates an entrenched culture of dependence on the sub-national spheres of government (Souza 1999; Samuels and Abrucio 2000; Macedo & Facchina, 2014; Ozge 2015). This conduces to the standardization of policies that do not contemplate the territorial diversity of the country (Lipsky, 1980, Evans & Harris, 2004, May & Winter, 2007; Sevä & Sandström) with direct impact on the outcome of public policies (Lotta & Favaretto, 2016) as was evident in the implementation of ASA in the region.

A second effect of the centralization in the Brazilian federal model is expressed in the street bureaucracies which have a high degree of discretion and can, at the time of implementing the policy, change their nature or implementation protocols provided by the national body. At the local level, given the lack of financial autonomy, these street bureaucracies strategize to capture the policies launched, financed and coordinated at the national level. This strategy turns out to be similar to regulatory capture (Stigler, 1971); adding to the local partisan policies that end up making its positioning a mechanism for maintaining the bureaucrat in office and maximizing his budget and adherence to a party ideology (Bhrem & Scott Gates, 1977). Niskanen, 1969, Evans & Harris, 2004).

In this context, actors such as the Secretaria de Estado de Assistência Social, Trabalho, Emprego e Renda (SEASTER) and Municipal Agency for the regulation of Water and Sewage Services (AMAE) are organizations who behave like street-level bureaucracies as they are responsible for the intermediation of the financing of sanitation policies that originate in the high national bureaucracy. These bureaucrats seek to capture these policies and ensure locally the maintenance of positions and the budget. In general, a first exploratory description of the institutional - and stakeholders - relations was made by Cardoso (2018), providing a glimpse of the complexity for the governance of rainwater systems in Belem.

This issue is particularly relevant as the Amazon region is characterized by being under the jurisdiction of several offices at different administrative levels in the Brazilian government, and contains a multiplicity of dissimilar communities - In the case of Belem, in the archipelago are more than 100 different communal

organizations, aborigines, afro descendants, ribeirinhos, seringueiros, and no less than 10 different Christian sects/churches with active influence in the decisions of the local communities; making of the region a case of high complexity for policy-making and socio-economic and technical interventions Cardoso et al (2018). Hence, the adoption of RTRWH can be seen as a new socio-technical arrangement that implies co-evolution and occurs as a fragmented phenomenon in relatively isolated groups (geographically, socio-culturally) in the form of niches.

In this sense, this paper presents an interpretation of such complexity through the identification of issues and stakeholders affecting the governance of the implementation of rainwater systems using methods related with the analysis of complexity such as Social Network Analysis and concepts and theories of governance of water resources.

2. Methodology

In 2016 the data collection was performed, taking into consideration the ethical procedures of both, the University of Para and Leeds Beckett University. The methodological design followed a two-stage explorative research process where stakeholders were identified and classified based on an iterative process that drew on a combination of methods (e.g. 6 expert opinions - semi-structured interviews in English and Portuguese; ethnographic observations in 16 municipalities involving 40 user families), following the suggested multi-method approach by Brugha and Varvasovszky, (2000) and Reed et al, (2009). To identify stakeholders, the respondents were asked to 1) mention all stakeholders and issues that may influence or are affected by the implementation of water infrastructure - rainwater systems. 2) Quantify the influence of each stakeholder exerts on water infrastructure planning (Brugha and Varvasovszky, 2000). We merged very similar stakeholders (e.g. community organizations). The participants were purposively selected based on cross-references (from experts and other participants interviewed), relevance and availability.

A relational categorization matrix was created based on a typology to classify them along the vertical axis, i.e. from national, federal, county, local, and off-site levels to a local, on-site level. A further typology also made a distinction between those agents who affect (determine) a decision or action and those affected by this decision or

action. The matrix also included the issues identified in the conversations with experts and how these issues related to the different actors.

The SNA was made using UCINET (Borgatti et al., 2002). The potential influence of actors in a policy process was assessed in network terms via its connectivity to others. To assess this feature, we used measures of centrality as described by Freeman (1979). More specifically, we took into consideration the measurement of degree centrality, which considers the ties that an actor shares directly with other actors. It looks at the local structure in which an actor is embedded (Ansell, 2003; Crona and Bodin, 2006). These standard SNA techniques for the mapping of stakeholders were used, developing on the methodologies previously presented by Prell et al, (2007); Lim et al, (2010) and Lienert et al, (2013); particularly on the use of centrality measures to assess the importance of stakeholders.

In policy networks, actors with high degree centrality have better and more direct access to information and have considerable potential for framing the planning process. Power and importance were assessed via betweenness centrality (Freeman, 1979; Ingold, 2011). Betweenness centrality calculates the number of times an actor is on the path between two not-interlinked nodes. An actor with high betweenness centrality can thus act as a gatekeeper or mediator. If absent, the network would fall apart. Hence, the more central an actor is, the better he or she is integrated into the network and can influence the planning process in resource management policy. To interpret the results from the SNA, we adopted elements from the framework suggested by Ward and Butler (2016) such as Niche Governance and the "Safe and SuRe".

In this context, niche governance - and Strategic Niche Management - as described by Loorbach and Van RaaK (2006), provides elements to assess: the necessary changes in technology and in the institutional framework for the economic success of the new technology; the learning about the social desirability of the options; the further development of these technologies and achieve cost efficiencies in mass production and; the building of a constituency behind a product – of firms, researchers, public authorities – whose semi-coordinated actions are necessary to bring about a substantial shift in interconnected technologies and practices. Complementary, “Safe and SuRe" (Ward and Butler, 2016) provides the concepts and definitions of resilience and sustainability with emphasis on performance at the

service level; specifying and emphasizing the characteristics of a system that might result in resilience and sustainability (e.g. safety, sustainability. resiliency, threats, impacts, consequences, learning capacity, recovery capacity).

3. Results and Analysis

Table 1 describes the list of stakeholders identified in the interviews; from which a matrix was created registering their interconnections and their relationship with the issues that emerged during the interviews.

- INSERT TABLE 1 HERE -

Table 1. List of stakeholders (As identified in the interviews with experts).

The following figure (figure 1) reflects the results of the use of SNA for the mapping of issues and stakeholders related with the adoption of rainwater systems in Belem; where the values of centrality (degree) for UFPA, Residents, CARITAS, AMAE highlight the relevance of these stakeholders in the implementation of RTRWH. Also, it identifies the importance of funding, relationships, and education as the most sensitive issues for the implementation of the rainwater systems. Figure 3 shows the values of betweenness for the same network where actors such UFPA, Residents and AMAE concentrate the higher values of brokerage; whereas funding, education and relationships are seen as recurrent issues.

- INSERT FIGURE 2 HERE -

Figure 2. Identification of issues and stakeholders for the implementation of rainwater systems in Belem. In the figure, the issues are represented in red and the stakeholders in Blue. The size of the node represented its value of centrality (Degree).

- INSERT FIGURE 3 HERE -

Figure 3. Identification of Influencers in the network. The size of the nodes denotes their value of betweenness. Nodes in red represent issues and nodes in blue agents.

Based on their structural position and the role/function within the network as well as their values of centrality (degree and betweenness) the following classification was

made in order of importance:

Stakeholders

- Residents: Their high level of centrality is easily explained as these are the direct recipients of the rainwater systems. As the direct beneficiaries of the system, they have numerous links with the rest of the stakeholders. Despite their high level of connectivity, (High degree - in-degree) their capacity to influence other stakeholders or the governance system of the network, is not strong as they are at the receiving end of the network.
- UFPA: The Federal University is the following well-connected organization with strong links with governmental agents. Its brokerage role is crucial as is the only agent in the network with links with scientific empowering institutions such as FAPESPA and CNPq. UFPA is also an actor with a strong influence on the high funding bureaucracies of the system such as MDSA and with those that are intermediates of the financing. This central position makes the UFPA have a performance similar to a street-level bureaucrat. The intention of making the system replicable in several other locations in the state may be the reason why UFPA has several connections with bureaucracies at all levels of the federation.
- CARITAS: Is perhaps the most influential organization (Catholic NGO) at the ground level. Is well connected with all the key governmental organizations at all levels (Federal, County, and Municipality) and has strong links with the communities and community organizations in the region. As previously mentioned, the Catholic Church has played a historic role in the region through the provision of assistance; sometimes acting as a watchdog of public policies directed to traditional communities. Its centrality stems from its role as a key external actor that holds power and resources (finances, assets, and knowledge) to act as an entrepreneur together with residents and other stakeholders.
- SEASTER: Its high level of centrality is explained as it is the only organization at the regional level with the function of control of the delivery and implementation of rainwater systems. They act as brokers for federal agents and point of contact and coordination for local agencies. The role of SEASTER as a bureaucracy of the state at the federative level is ambiguous. As a bureaucracy SEASTER has captured the role of another bureaucracy, SAAEB; which should operate water and sanitation

policies in districts where the system has been implemented, but it does not appear as a stakeholder. COSANPA is the water supply and sanitation service agency in the state of Pará. However, SEASTER, which is linked to the provision of social assistance in the region, was the mediator of the provision of the rainwater supply systems. This transfer to SEASTER of this type of system ends up reinforcing the assistance character that involved the process of supplying the rainwater system to local the communities. This type of capture of the policy for a supply of a water harvesting system by a bureaucracy with no technical capacity in sanitation increases the complexity of the bureaucracy in the implementation of the system since training for the maintenance of the system is not offered by SEASTER but depends on the technical knowledge allocated to the UFPA.

- Community Associations: Their centrality is explained as they act as intermediaries with final users for the implementation of rainwater systems. They have high levels of complexity due to their number and variety. Community associations also represent the complexity of residents' interests. Considering the associative freedom that exists in Brazil, the emergence of these associations also reflects the inefficiency of local bureaucracies in providing public services. In this way, the Associations reflect the collective action of the residents facing the need to have their demands for public services served. Parallel to the religious initiatives, most of these associations have ties with political parties that seek to capture the collective action of the associations to have salience in the political scenario.
- Forum das Ilhas: its high level of connectivity relates to its function as a broker at a local level. Structurally equivalent to CARITAS, It lacks the connections with organizations at the federal level. The Forum das ilhas is also influenced by the Catholic Church. Its emergence is disputed and presented by political parties as an initiative of local residents with high degrees of party commitments. The Forum, while characterized by having a scope that encompasses all the islands and thus becomes representative, is also an overlap of representation interests of the residents when considering Community Associations.
- Unions: Their centrality relates to the connections with local organizations at the community level. Structurally equivalent to community associations.
- Material traders & Water Traders: They are not connected with any of the delivery organizations suggesting that they have not been involved in any stage of the development and implementation of rainwater systems. are listed here due to their

significant low values of centrality. These actors are negatively influenced by the implementation of rainwater systems as their economic activity is related and dependent on the existence of such autonomous water supply systems.

To better interpret these connections, the following table summarizes the elements of niche governance and the "Safe SuRe" (see table 2).

- INSERT TABLE 2 HERE -

Table 2. Niche and Safe and SuRe characteristics of the RTRWH in Belem.

Issues:

- Funding: With the highest value of centrality (degree and betweenness) this issue is the most connected to stakeholders and seems to be determinant for the future implementation of the rainwater system. The fact that the funding comes mainly from federal sources (government: MDSA and Federal Government via public bank - BASA; and research funds - FAPESPA, CNPq) makes the implementation extremely dependent and sensible to the public budget. As this initiative is not the result of the demand form a collective action to affect policy; the provision of public funds for the implementation of rainwater systems is susceptible to street level bureaucracies taking over on the coordination of the policy; hence, the potential conflict between SEASTER, BASA, AMAE and CARITAS with subsequent competition to control financial resources. Such dependency on public funding is also evident by the subsidized nature of the previous implementation process (SORIS); where CARITAS appeared to residents as a central actor when it comes to the financing intermediation of the system - as well as the watchdog for the delivery of this initiative. In the current implementation lead by UFPA, note the brokerage from SEASTER, AMAE, and CARITAS, evidenced by their intermediation in the network “connecting” funding agencies and recipient communities. In this case, the SNA facilitate the identification of both, actual and potential competitive behavior. These tensions were expressed by the academic experts during the focus group discussion, where it was highlighted that the competence for resources exists and is expected to become more aggressive under the new economic situation of the

country:

"We have seen, and we expect to see under the actual economic circumstances more intense competition for resources between the delivery agencies, and it will have big impacts on the communities" (Academic expert No.2 - currently working on rainwear systems)

- Education: This issue is connected to providers (UFPA, CARITAS, Forum das Ilhas) and the recipient communities (either directly or via several community organizations: Unions, community associations). In general, the education-related with the rainwater systems and its implementation is technically adequate, however, it is sensible to the level of education and the social dynamic of the recipient communities (e.g. peer pressure, perception of wealth; isolation, levels of scholarly). Nevertheless, education related to the functioning of the system does not contemplate the solution of collective action dilemmas resulting from the shared access to, and use of rainwater (e.g. maintenance, operation cost). When the supply system does not arise from the community but the action of external actors, as in this case, the learning processes may not meet the needs of political education so that all stakeholders, from within their organization, develop some type of systems' governance. At ground level, the delivery of education proves resilient as the involved organizations have structural equivalence in the network: similar levels of connectivity and similar connections.

  " ... different organizations visited the community a couple of times after the delivery of the (rain) water system. I remember an instructor from the University, but later, there was other related to the church. We all know how to use and do the maintenance of the system, but we struggled to define who is responsible for it – in our case the solutions was easy because we are all family, but on the other side of the river the system is not used because the people there have no education, they think different". (Community leader - user of the system – Ilha de Combu)

- Relationships: In general, the issue relates to the brokerage function between delivery organizations and recipient communities. The common perception of experts is that the relationship between delivery organizations - at different governmental levels (e.g.: MDSA - Federal government; SEASTER - County

government; AMAE - Municipal government) must improve and be more efficient. This perception points out to the behaviour of street-level bureaucracies and the capture of resources while being responsible for the intermediation of financing in the federative bodies. It should be noted that the AMAE, SEASTER, and MDSA are connected and present themselves as bureaucracies that are in dispute for resources. This seems to be particularly true for the AMAE's intermediation with the communities and CARITAS.

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"... you can't find corruption here. Yes, there were various agencies involved in the funding of the (rainwater) systems, interacting with the communities - and among themselves. It takes time and we must be patient, but I believe we learned how to speak with all them to ask for and receive the (financial) resources we needed. "
(Community leader of Ilha Cotijuba; former official of the local government – section clean water and sanitation of Belem)

- Conflict: This issue was connected mainly to the different organizations acting in representation of the recipient communities and funding bodies. Community organization is a complex issue itself as in the region is possible to find more than 100 different community organizations with different agendas and political interests. It is noticeable that the issue was not raised concerning the multiplicity of government agencies involved - in many cases with overlapping functions. It is important to note that most of the time the conflicts are revealed at the stage of ownership of the system by the residents. However, the conflict is latent in all phases of the implementation of the rainwater supply system. From the disclosure of funds for the construction to the delivery of the system, the dispute over power resources in system governance is established on a growing and more complex scale as the number of stakeholders increases. However, it becomes more visible in the moments of establishing the rules of access and use. As pointed out, the system presents characteristics of a commons and the literature points out that conflict is one of the constituent elements in the processes of construction and maintenance of this type of system. Concerning the governance system, tools are needed for these conflicts to be settled. These tools should be (ideally) emergent and/or co-created during the education regarding the use of the system. Conflict is also evident when it comes to funding and can directly identify itself with the AMAE and indirectly

appears in the federative levels of the nation through the conflicts it establishes with community associations. However, from the community perspective, the conflict is more perceived as frictions among users rather than between the institutions involved and competing for resources, as expressed by social leaders in the islands visited:

"...the problem is to bring together the different community associations in the island, and when the (rainwater) system is built there is conflict defining who does what; for instance, to share the water or at the time of taking care of the (rainwater) system" (Community leader No. 5 - Ilha Grande)

- Monitoring & infrastructure: As detected in the interactions with experts and the communities, the monitoring and infrastructure maintenance is deficient and not connected in any form with governmental agencies. I the present time, just the UFPA performs limited observations on the functioning and condition of a limited number of rainwater systems in the region - aiming to develop a systematic approach to collect information to inform policy. This result is consistent with the separation between education and training. The training process, by not being more comprehensive, establishes ex-ante a distinction between the stakeholders, with loss of autonomy of the recipient communities and consequently, dilemmas of collective action. This, in turn, causes that an external actor is identified as the person in charge of the maintenance of the infrastructure and system monitoring. The limited connections of this issue with other relevant actors suggests that the residents and other collective actors that will be responsible for this stage have not been inserted in the processes of construction of the required social infrastructure for the adequate functioning of the rainwater systems.

*"So far, I am the only person who regularly visits the communities **to do the maintenance** of the units and the monitoring of their use near the campus of the university. From my knowledge, since the delivery to the communities, there has not been any visit from any governmental office to check the condition or use of the units delivered" (Academic expert No. 1 - currently working on rainwater systems)*

4. Discussion and Conclusions

The key actors identified in this study where the residents, UFPA, SEASTER, and CARITAS. Their importance in the network is related with the fact that most of them are local to Belem (residents, UFPA SEASTER) and are key brokers for the design and implementation of the rainwater system, as well as for the bidding for public funds (UFPA, SEASTER, CARITAS); implying brokerage with other public agencies at different administrative levels (state, federal, national).

The case of CARITAS and the UFPA, with high levels of connectivity, can also be explained by their role in the operationalization and maintenance of the system. From this role, an important effect is noticed regarding the relationship with the communities, linking with the issue of education: The education provided seems not to contemplate the totality of the system's governance. In consequence, stablishing an unintended relationship of dependency from the local communities.

Additionally, in the network the issues infrastructure and monitoring present few connections, since these two components of the system end up being identified as an attribution of religious actors (mostly CARITAS) and UFPA; reinforcing the process of technical and social dependency generated at times of construction and delivery of the rainwater systems.

The study suggests also that the overlapping functions of governmental agencies at different levels (Federal, county, municipality, local) is not an issue at a practical level - due perhaps to accumulated knowhow by delivery agencies at (the local) community level. However, this fact has the potential to be a major issue for the communities at the time to claim ownership and autonomy in the implementation process, particularly under the current economic environment and the budget limitations of the multiple agencies involved - presiding of delivery/broker agencies. In this respect, this study suggests that more transparency in the local administration and more autonomy at a community level, with more direct access to funding sources, could simplify and reduce the administrative complexity and cost of the implementation process. In this context, the adoption of private or autonomously funded initiatives could bypass and/or simplify the complexity and bureaucratic cost of the multiple overlapping agencies involved, making relevant just the local agencies that could regulate locally the implementation of rainwater systems; providing that local communities will have a more active role in the definition and delivery of the

project. At this stage, and considering the forthcoming economic constraints in the Brazilian economy, the major threat for the sustainability of the systems is related to funding. In terms of governance, this study would like to suggest the strong brokerage of UFPA and CARITAS to transfer knowledge to the communities to provide them with better elements to improve the ownership of both, the implementation and use of the rainwater systems.

Supporting the previous argument, from the interviews and the SNA, it became evident that the implementation of rainwater systems is highly dependent on public funding where the NGOs (e.g. CARITAS) act mostly as delivery partners. In this sense, to increase the use of rainwater in the region - given the current and forthcoming economic situation of the country - this study highlights the need to explore new sources of funding based on private capital and/or autonomously funded by the local communities (for instance via social entrepreneurship and/or social banking). In consequence, further research would be recommended to better understand the role and impact of new external actors in the event of privately funded implementation for rainwater systems.

The other major issue at the community level is the complexity and variety of community associations (generalized in this study but with more than 100 in the Belem area). Yet playing an important role in the recipient end of the implementation process, by facilitating issues such ownership and management of the rainwater systems; the existence of unions with structural equivalence in the network may suggest that such unions could assume the agency (role/function) of the community associations to deliver rainwater systems and reduce their complexity. It is also noticeable the local influence of CARITAS as a key player with influence in local communities derived from their history of engagement in the region, the religious affiliation (catholic charity), their contacts with different agencies at different administrative levels and their capacity to mobilize financial resources. Consequently, new studies are recommended to improve the design of the complex networks paying attention to the detail of the role/function of CARITAS, the unions and other significant religious groups that could simplify the approach and eventual inclusion of communities at the time of implementing new rainwater systems – and/or to enhance the use and maintenance of the existing ones.

In terms of design, is concerning the fact that not all the economic/social groups to be affected by the implementation of the rainwater systems have been involved in the different stages of development and implementation of rainwater systems in the region. Particularly the ones who can potentially be negatively affected by this initiative (e.g. water and building materials traders) For further expansion on the implementation of the system in the region it would be key to include these actors, particularly if exploring forms to expand the adoption of the system not depending (exclusively) on public funding. As these stakeholders may either act as key partners or competitors if a market-based implementation process is adopted (however, rainwater has proved to be more economically efficient than the distribution of bottled water). In this sense, it would be desirable to provide autonomy to each community supporting the funding/development of their own business model for the implementation of RTRWH. In this context, the support to be provided must contemplate the autonomous definition or local rules of access to the use of the shared RTRWH, as well as the autonomous identification of key players and stakeholders. Therefore, and as mentioned previously, in a more autonomous scenario, issues such as maintenance and further expansion in the use of the rainwater system will be less dependent on UFPA, CARITAS, and SEASTER.

Concerning the methodology used in this exploration, SNA offers the possibility to map and understand better the functions and relationships of the different agents involved in this initiative. The main limitation to explore the full potential of this method was related to the nature of the dataset and the data collection. Limitations to access information, public records and availability of data and time affected the depth of this exploration. The use of more complete datasets including interviews (for instance, a cascade model) involving all the agents identified as well as a comprehensive review of previous documented process of implementation could provide a more detailed view of issues affecting the implementation of rainwater systems in the region by offering a better understanding of institutional aspects affecting the development of this initiative. At ground level, the use of interviews and advanced SNA techniques can accurately identify key actors in the communities playing enabling roles that could be used in the exploration of other forms of funding.

Conceptually, the framework created using the Strategic Niche Management (Niche

Governance) and the "Safe and SuRe" provided a useful tool for the understanding of the relations expressed in the network. Particularly, the reflection on the behaviour of the regime - and the local communities - towards the generation of governance mechanisms for sustainability and resilience. Also, it offers a clear framework to inform (public) policymakers and stakeholders on how to direct their efforts to serve the needs of the niches conforming the regime. In this sense, the combination with the SNA offers a more comprehensive understanding of the interdependencies between stakeholders, and key links (existent or required) necessary for the sustainability and resilience of the implementation of rainwater systems.

However, clearer links with the SNA are in need to be developed to provide better evidence and more robust evaluation of the factors affecting governance described both in the Niche management and the Safe and SuRe model; perhaps with the use of advanced SNA techniques involving meta-matrices escribing connections between individuals, institutions, issues, knowledge and access to resources/skills; to better detect (structurally) organisational risks to the resilience and sustainability of the social construct surrounding the implementation of the rainwater systems

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Conflict of interest

None

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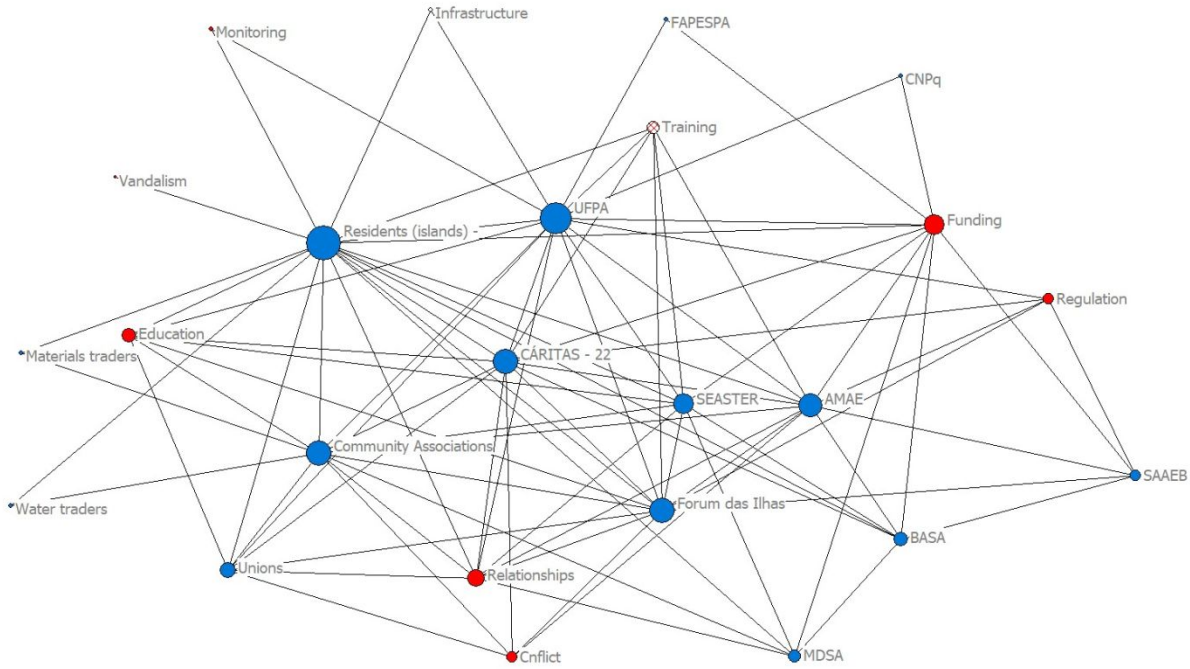
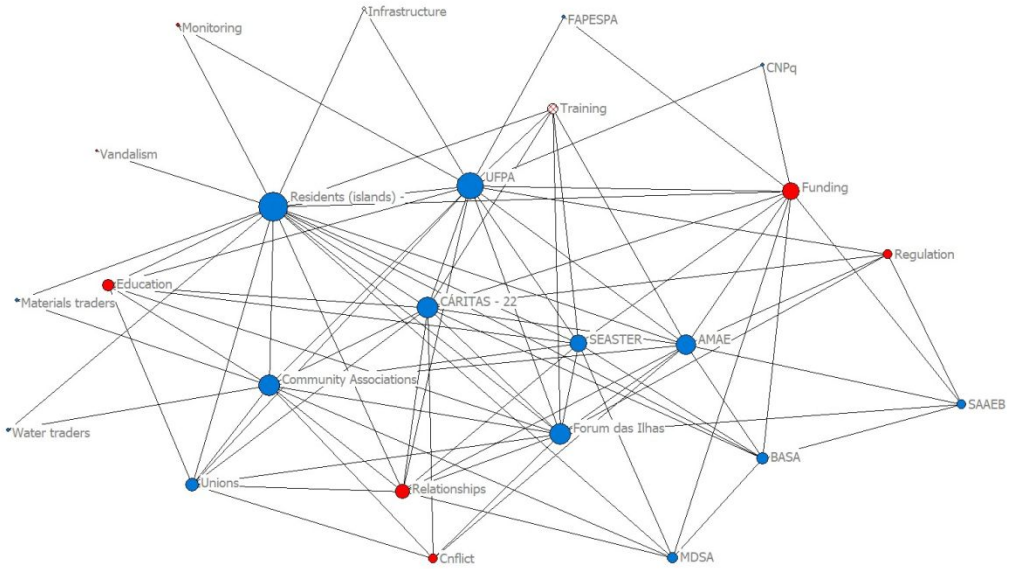
Stakeholders	Role/Function
BASA- Bank of Amazonia SA	Canalize financial resources from the federal government to local delivery partners
MDSA- Ministry of Social and Agrarian Development	Funding and monitoring sustainable development projects at federal level
AMAE - Municipal Agency of Water and Sewage Services	Local (district) regulatory agency for the monitoring of services related with clean water and sanitation
SAAEB - Autonomous Water and Sewage Service of Brotas	Local agency that implement, manage and delivery projects of clean water and sanitation services at local level - they also participate in the implementation of RTRWH systems.
SEASTER- Secretaria de Estado de Assistência Social, Trabalho, Emprego e Renda	Regional social assistance agency acting as the watchdog of resources used for other agencies for the provision of clean water and sanitation services
CNPq-National Council for Scientific and Technological Development	National funding of R&D in Higher academic institutions
FAPESPA - Amazonia Research Foundation.	Regional funding of R&D in Higher academic institutions.
UFPA- Federal University of Para	Research and higher Education in Para
CARITAS	Catholic NGO (international) - alleviation of poverty. Delivery of projects related with the improvement of access to water and sanitation in vulnerable communities
FORUM DAS ILHAS	Local NGO - alleviation of poverty. Delivery of projects related with the improvement of access to water and sanitation in vulnerable communities (Belem)
COMMUNITY ASSOCIATIONS (30+)	Local organizations distributed in the islands. Social activism and lobby to different public and private organizations to access resources/projects related with social development.
RESIDENTS	Local residents of the islands - ultimate recipient of sanitation and clean water services.
UNIONS	Local trade unions linked to commercial activities in the area (agriculture, fishing, fluvial transport, etc)
WATER TRADERS	Local commercialization of clean water in the islands
MATERIALS TRADERS	Local commercialization of building materials





NICHE FEATURE	APPLICATION TO THE RTRWH
Niche Creation	
Selection of candidate technology	UFPA determined the parameters of design and then transferred to communities.
Selection of settings for the project	As result of the influence if the catholic church, UFPA and local/regional delivery and control agencies.
Define local project	CARITAS, UFPA, SEASTER, Forum das Ilhas
Scale-up local project	Not made by lack of public funding and feedback on the effectiveness of the project (watchdogs and controllers)
Dismantle protection mechanism to facilitate independence	RTRWH designs are public patent/ therefore in public domain under the administration of the county in partnership with UFPA.
Availability of sheltered spaces for incubation	Islands around Belem where UFPA and CARITAS has strong presence
Possibility for continuous evaluation and improvement	Influenced by the political agenda of CARITAS and SEASTER; and limited to the constrained budget of UFPA.
Exhibition of possibilities for capturing increasing returns or learning economies	R&D is currently made via international cooperation but limited to pilot tests in campus.
Openness to develop in different directions	Not evidenced
Favoured in certain applications so that advantages outweigh disadvantages	Not evidenced
Strategic Niche Management	
Expectations (promises, actions)	Limited to public funding and changes in public policy
Learning	Current new R&D using international aid, limited to technical related developments (e.g. UFPA).
Networks (interactions)	Managed by influential stakeholders, mostly via activation on convenience by delivery partners (UFPA, CARITAS, Forum das Ilhas).
Conceptual Niche Management	
Define a concept	Defined as an adaptation of the national cisterns project to fit the requirements of the Amazonian environment (RTRWH)
Explore its social embedding	Just recently included multidisciplinary studies as R&D - co- creation with participation of local communities

Start talks with 'new' actors	Just recently, as results of R&D with international partners
Set up experiments	Ongoing - technical improvements - R&D outcomes
Evaluation and learning	Ongoing in the technical side. Not registered in the communities and non-academic actors
Social Niche Management	
Values-niche-regime differences and interactions expressed	Customization in the implementation of the system in each community/territory
Existence in the social economy	Impact is evident in the change of consumption behaviour (markets) and social interactions, but it has not been technically assessed
Pluralistic resource base	No, totally dependent on public resources
Communities of Interest (CoI) or Location (CoL)	Profiles are now being identified as results of the implementation and new ongoing R&D
Conventional and alternative innovations are permitted to combine	UFPA and partnerships with external (international) bodies.

SAFE SuRE			
Concept	**Definition**	**Feature**	**Evidence**
Safe	Ability to meet public health (or equivalent) concerns of the existing regime	Public acceptance for using non-potable water for diverse uses and rainwater for human consumption	Safe - low/none reports of disease related with the use of RTRWH
Sustainable	The degree to which the system maintains levels of service in the long-term whilst maximising social, economic and environmental goals	RTRWH use have a competitive cost-benefit and are socially acceptable. However, limitations in the learning process related with the approbation of the system by some communities	In path to sustainability
Resilience	The degree to which the system minimises level of service failure magnitude and duration over its design life when subject to exceptional events in response to the lack	At operative level the issue of ownership, community based use and maintenance is critical with several events of failure. Institutionally, the regime	Currently no resilient

	of dedicated protection mechanisms and imposition of threats (see row below), the RTRWH niche innovates quickly to maintain its ability to respond to emerging market conditions (extremes)	for rainwater has structural equivalents at the delivery level, but not at the R&D and funding.	
Threat	Any internal or external actual and/or likely event with the potential to reduce the degree to which the system delivers a defined level of service	Threats the RTRWH niche has experienced include regime pressures (changes in policy aims; funding), which reduced its ability to demonstrate advantages over centralised infrastructure	Public patent. Regime aims changing due to economic and political turmoil. Total dependence on public funding.
Impact	The degree of non-compliance with the defined level of service (results from a threat)	The proportion of RTRWH that do not meet regime aims or market needs.	Uncovered expectations in terms of number of installations, monitoring and support.
Consequence	Any outcomes and effects of the impacts (i.e., non-compliance with a level of service) on each pillar of sustainability	Inability to respond to sustainability-related regime aims	Social learning process hindered; uncovered expectations in terms of number of units implemented; failure / abandonment of several installed units; unnoticeable new improvements on public health and economic performance in the communities
Intervention: mitigate, adapt, cope, learn	Reduce the threat; increase reliability and resilience; reduce the frequency, magnitude or duration of impact; embed experience in new knowledge and best practice	Use of lobby intermediaries to understand the policy aims/influence the regime Learning should be used to demonstrate attainment of regime-imposed (new) aims and better represent end-users	Intermediaries influencing the regime; Fluidity, dynamism and reflexivity in learning type combinations at operative level. Evident with the structural equivalences of the delivery partners (UFPA, CARITAS, Forum das

			ilhas)
Recover	Regain the ability to deliver and comply with a defined level of service	How RTRWH innovators meet the needs of the regime and markets	CARITAS, UFPA and SEASTER influence internal niche process and trajectories to meet regime aims