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João Carrilho
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Resumo

O nexo entre água, energia e alimentos (AEA) é um desafio para a sustentabilidade nas áreas periurbanas devido aos factores institucionais inerentes e práticas correspondentes. Sugere-se uma estrutura participativa multissectorial e multinível para impulsionar a mudança estrutural e formalização do regime sociotécnico, ligando reguladores, fornecedores e consumidores. Com base num estudo de caso em assentamentos periurbanos informais em Moçambique, identificam-se questões e potenciais pontos-de-entrada a considerar na promoção de inovações institucionais locais. A associação local de fornecedores privados de água é sugerida como ponto de entrada, por ser semiestruturada e equidistante entre utilizadores e criadores de ciência e tecnologia.

Palavras-chave: inovação institucional; regime sociotécnico; nexo AEA; água subterrânea; periurbano; Moçambique.

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Abstract

The water-energy-food (W.E.F.) nexus is a challenging sustainability issue in peri-urban areas due to their inherent institutional drivers and corresponding practices. A multilevel and multisector participatory framework is suggested to drive the structuration change and sociotechnical regime formalization linking regulators, suppliers, and consumers. Based on a case-study on informal peri-urban settlements in Mozambique, issues and potential entry-points are identified to consider when promoting local institutional innovations. The local private water suppliers' association is suggested as the entry-point, as they are semi-structured and equidistant between the users and the science and technology creators.

Keywords: institutional innovation; sociotechnical regime; groundwater; peri-urban; Mozambique.

Introduction

In twenty five years, it is expected that two-thirds of the world increasing population will be urbanized (Ritchie, Samborska, and Roser 2024). This shall happen through urban expansion or sprawl, leap-frogging and in-situ urbanization from short distance rural exodus (Liu et al. 2014; OECD and Sahel and West Africa Club 2020), Such process includes peri-urbanization. All dimensions of sustainability relate to the resource management in varying degrees, depending on the physical and socio-cultural characteristics of the peri-urban domain in addressing the transition and change.(Adell 1999; Dadashpoor and Ahani 2021; Iaquinta and Drescher 2000; Romero-Lankao, Bruns, and Wiegleb 2018; Sahana et al. 2023)social, economic, and environmental consequences in these areas. Such a process converts the peri-urban areas into a challenging part, the guidance of which requires a comprehensive understanding of them in all its dimensions. The most important of these dimensions are effective forces and mechanisms in the formation and expansion of peri-urban areas around metropolises. With this in mind, this paper, using a critical realism approach and a systematic review, explains first the effective objective forces in the formation and expansion of peri-urban areas in the form of different patterns of peri-urbanization. Then, the driving forces affecting these patterns are examined. Finally, the underlying causal structures and mechanisms affecting these forces are explained. The results indicate a three-level framework including (a.

This study follows previous research on land use planning priorities in outer peri-urban village-type informal settlements north of Maputo, Mozambique. The research identified the need for institutional innovation to address the provision of public goods such as water sources, sanitation, and energy. It also emphasized the importance of interconnectedness related to (food) market hubs, roads, and railways.

The water-energy-food (WEF) nexus revealed to be an issue deserving a fresh look.

The water-centricity in this study and the attraction to the groundwater management was in part motivated by considering it as a typical common-pool resource, which so much influenced the Östrom theorization of the governance of commons (Ostrom 1990), and her rules of boundaries, authority and power, information and aggregation, always to be considered in institutional innovations applied to any setting, in this case of peri-urban areas. Frequent interaction of actors in hybrid, temporary or circumstantial institutions and rules, both formal and informal, under a set of social preferences and values, affects power relations, improve cooperation, and make social participation relevant in avoiding a “tragedy of commons”.

The WEF nexus, as topic of (peri-)urban sustainability studies and as related to institutions with a role in land use planning, has been, over more than thirty years, the subject of differing conceptual and operational debate on their completeness and relevance. Geels (2004), Fuenfschilling and Tuffer (2014), and Narain et al. (2023) address the structuration of socio-technical regimes based on hydraulic, market, and knowledge logics, as well as the formal-informal dialogue and policy and political implications. While Smajgl et al. (2016) question the water-centricity of the nexus, Zhang et al. (2019) provide a more flexible choice based on a comprehensive review of a range of mostly context and scale responsive methods of modelling, assessment, and management of the sectors, their relevant combination in pairs, addressing integration and interdependence, collaboration and inter-connectedness, and suggests research in characterization, connection mechanisms, collaborative decision, and governance. Törnqvist (2007) systematizes approaches and frameworks of planning support and adoption of technological systems, based on broadly common sets of goals and objectives, indicators, degrees of participation, and external factors.

The research question

The study questions how to identify the entry point for innovations that local institutions could enact to improve the sustainability of common water resources under the WEF nexus approach in outer peri-urban village-type informal settlements. This question assumes that the institutions themselves have to identify their boundaries of action, the areas and levels of authority of actors, the rules for decision and their enforcement, and mechanisms to resolve conflicts and incoherences (Ostrom 1990).

Socio-geographic context

The reference settlements are located in inland sand dunes at altitudes between 20 and 70 m, and crossed by streams of a 2nd order watershed (Bobole River) of the Nkomati River basin (Cendón et al. 2020). There is no meteorological station in the study area and information is regional: the average annual precipitation is 768 mm, lower than evapotranspiration (annual average of 1,190 mm), only higher from December to March; the average temperature is 22.9 °C (Impacto 2012). A biodiversity reserve is present. The area is located along a major road linking the hinterland to the capital and is served by three mobile telecommunication operators. The settlements are of village type (Iaquinta and Drescher 2000), with an estimated total population of 20,000 inhabitants, organized into a cluster of neighborhoods, three levels below the district level, where some administrative sector representations exist, but are understaffed and under-resourced. Formal private operators provide most of the drinking water locally. The area is crossed by high and medium voltage power lines originating in distant hydropower plants serving the capital of the country, with a local substation and a still underdeveloped local distribution network. A small furrow irrigation system was built in the settlement and a variety of irrigation systems, from sprinkler to gravity, and water management practices are well established and used upstream the main basin.

Access to resources of land and water is generally viewed as easy and equitable, but tensions remain between formal and informal rules, the former used for securing tenure and conflict settlement with external actors, and the latter more frequently used for record and local conflict resolution. Social organization is based on occupation, religion, and place and idiom of origin. Young commuters bring urban values and behavior as well as information and participate in local meetings. Long term residents also commute daily to the cities and are thus exposed to urban values and information on innovations. These data justify the qualification of the settlements as transitional village-type, as argued above.

Figure 1 provides information on the occupation of settlements, groundwater bores, secondary and tertiary surface water streams, used for horticulture, and wastewater disposal. The inclusion of health centers is justified by the fact that these are the institutions in charge of ensuring water quality and promotion of sanitation standards. The inclusion of the dike is justified by the fact that farms along the Nkomati (Incomáti) River are exposed to elevated risk of floods and cyclones.

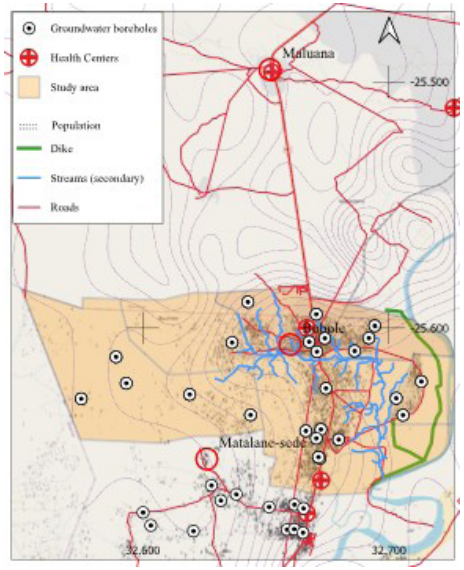

Figure 1. Groundwater sources location relative to residential areas.

Groundwater sources were located within densely populated quarters where septic tanks and pit latrines are common, and close to horticulture gardens, where wastewater collection or control of use of fertilizers are absent.

Local social institutions are hybrid of traditional and statutory, their leaderships are not elected and there is a relationship between traditional and appointed officials, including at kinship level. Local and external notable economic actors also sometimes exercise power. Apart from the agricultural private sector, a beverage industry is also located in the settlements cluster.

Conceptual framework for WEF responsive institutional innovations

A framework is suggested to assist in identifying at which institution and at what level it is more likely that innovations contribute more effectively to advance the sustainability of groundwater management, considering the context.

Based on the literature review, it is conceived that the nexus in peri-urban areas goes beyond water, energy, and food, connecting at least to climate and technology (e.g. Echeverry, Marques, and Pereira 2024), which are increasingly viewed and organized as sectors in their own right. It is also conceived that a component of one sector is more relevant in the intersectoral connections. For instance, in the climate sector, rainfall is more related to food production than other climate components.

The multi-sector coordination is of a horizontal nature, i.e., the actors are working at the same institutional level. These include formal and informal actors from the public, private, and social sectors.

Figure 2 represents intersectoral linkages and components within the sectors. The positions of water, energy, and food are interchangeable and depend on the context.

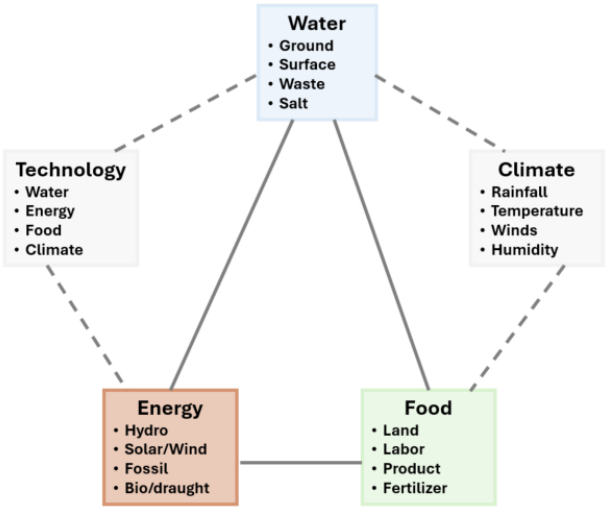

Figure 2. WEF governance: inter-sectoral framework

Similarly, some processes, like the management of groundwater, are more scientific-technically intensive with corresponding higher needs of vertical collaboration. For instance, there is a limited impact of local-traditional knowledge in hydrogeology research and deep groundwater abstraction technologies, compared with shallow wells and wastewater management practices. Within each sector, there are regimes, such as the scientific-technological regime, the policy-regulatory regime, the market operator regime, the consumption and user regime, and the socio-cultural regime (Geels 2004) which need coordination, including vertical, and combine into a wider socio-technical regime. The assessment of their level of structuration and the resolution of potential incoherences between them is context dependent (Fuenfschilling and Truffer 2014) . At the local level, it is suggested that their position in the formal-informal dialogue and their social recognition, legitimacy, and interaction are base criteria to determine the preferred entry point to mobilize responsive institutional innovations.

Methodology and Limitations

The case study from which this study derived used a mixed method qualitative approach, including expert opinion, focus groups, interviews, participatory GIS and basic spatial analysis. A supplementary literature review was undertaken to shed new light on the qualitative and geographic information collected for the above mentioned case study. Relevant national legislation was also studied and opportunistic interviews with experts on water supply, including private water suppliers. Information on the social composition and organization, the difficulty of accessing water, energy, and land, as well as on local social groups, was retrieved for analysis. The mean distance to nearest water point was calculated for the groundwater sources, for the study area and overlaid on the medium-sized rural clusters with densities between 750 and 1,500 inhabitants per km^2 (Commission et al. 2020). The mentioned institutions with a role in the water supply by-laws were located.

The analysis followed the suggested framework and developed a vertical collaboration map to identify the entry point for institutional development.

This study faced limitations such as lack of information on local hydrogeology, meteorology, and hydrometry due to lack of local geological studies and meteorology stations in the study area. Regional data were used to mitigate this limitation. Local point-by-point study was not possible because of unsafe conditions of access because of social unrest. Open ended interviews were conducted with key informants, two farmers, and water consumers, both in the risky low areas, the sandy medium altitude of the study area.

Results and Discussion

Case study information retrieval

The main sources of drinking water are 24 standalone microsystems based each serving up to 500 client households. The systems rely on groundwater abstraction from bores equipped with solar powered pumps or connected to the local power grid, under nationwide quantity and quality regulations (GoM 2015). The groundwater bores have a depth of up to 90 m and reach where the water is semi-confined between aquitard layers. This semi-confined water may be polluted by sanitation practices, as 70% use septic tanks and pit latrines and 20% dispose of their waste directly on surface streams. Although none of the bores in the region registered levels of nitrites and nitrate above the international guidelines, the location of the bores within the most densely populated areas of the settlement raises the need for regular monitoring of water quality. The regulated control period is five years, to renew the abstraction and supply license. Given the climatological context and the significant annual precipitation received, along with the substantial recharge of at least 1 million m^3 per year, it can be concluded that there are likely more concerns related to water quality (pollution) than to water quantity (availability). The level of precipitation supports a stable water supply, yet anthropic activities could pose risks to the overall water quality.

More than 50% of the population derives their livelihood from agriculture, in both subsistence farming and as wage-laborers in medium to large food crops farms. Some farms in the lowlands along the Nkomati River are periodically affected by floods and salinization following drought events. The sluice gates of the rivers and dikes are not functional and do not contribute to controlling the water flow. Less than five percent spend more than half an hour accessing some source of power, including wood fuel or charcoal. No schools other than primary schools are present in the area. Long-term residents are 41% of the total population.

But more than thirty percent are newcomers with less than five years of residence, two thirds of which are young. The origin of the population is either local or coming from a nearby rural district, pointing to a more rural traditional overall values and behaviors. However, 21% come from a neighboring urban area.

Table 1. presents the mean distance between the bores for the whole study area and for the more densely populated neighborhoods.

Boroughs	Bore Points	Mean distance (m) to nearest	Max. pop. density in EA ppl/km²
All 5 boroughs	24	1055	1684
Bobole	8	973	1420
Matalane-sede	7	613	1684
Note: EA = enumeration Area			

Table 1. Mean distance to the nearest point, in meters, and maximum associated population density.

Research institutions, universities, colleges, and high schools are absent in the area, but within commuting distance in neighboring urban centers. At primary schools, a basic emergency plan was disseminated and originated from the establishment of committees for disaster risk management. Sector specialist staff are present at province and district level and may have a trained focal point at lower level. These do not exist in the study area. There are two health centers in the area. These centers have the mandate to monitor and certify the quality of drinking water. Figure 3 presents the levels of coordination within each sector under the regimes, logics, and structuration frameworks (Geels 2004; Fuenfschilling and Truffer 2014).

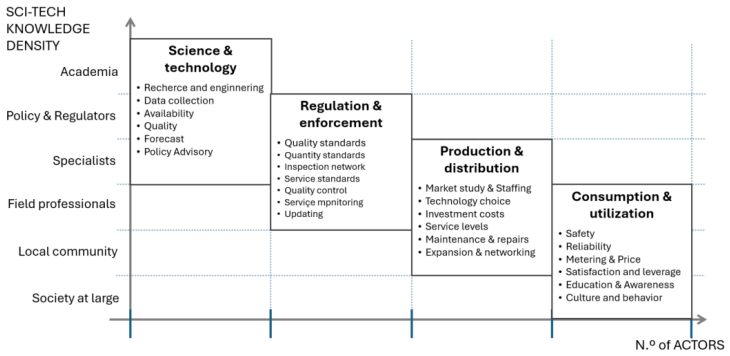

Figure 3. Socio-technical regimes and levels of coordination within each sector

With reference to production and distribution (Figure 3), the private operators are organized into an association, which have statutory mandate under the national legislation and where some incoherence may occur because of market interests, but they have regular interaction and boundary rules. The licenses have a period of five years. The operators interact monthly with the consumers for tax collection purposes and eventually for evaluation of satisfaction.

Consumers are informally grouped by occupation, focusing mainly on the quantity and price of drinking water. They also cooperate during floods and droughts, exchange seeds and seedlings, and share knowledge about farm management.

The land use planning priority actions obtained from the case study attribute high priority to register and regularize rights, waste management, dikes maintenance and to collaboration between informal and formal authorities. Definition of baseline standards for service levels to access public goods and services. There were not, however, specific references to groundwater quality and protection.

These results indicate that the actors occupying the best position in terms of equidistance between formal and informal institutions and their social recognition, legitimacy, and interaction by both the upper and lower levels are the associations of private water suppliers. From this, specific working groups may emerge to coordinate the water-land pair of the nexus, and the water-energy pair, gradually involving local primary schools and specialists.

Setting rules of entry and exit, managing power relations, and a set of incentives and penalties within the national legislation are of key importance to enable an environment for institutional innovations and progressive structuration.

Conclusion

The fieldwork for the case study has shown that sustainability is related to social cohesion, with its dimensions of inclusion, participation, and trust in institutions, which is, in turn, related to the formal-informal power relation dialogue, the effectiveness and competence of addressing equality in access, and management of resources. The legitimacy of institutions in hybrid contexts is challenging and depends on the local institutional culture. Sustainable management of groundwater within the Water-Energy-Food nexus requires institutional innovations that improve social cohesion, enabling global changes to be addressed locally. Institutions should be structured to facilitate horizontal and vertical cooperation, making the resource of groundwater accessible to common knowledge, action, and awareness. In the same way that a researcher brings to the table information and forecast on availability and quality of groundwater and its relationship to surface water and climate, or to land for food production, the knowledgeable consumer may provide hints to assess quality, help in data collection, and make adequate use and disposal of a scarce common resource. The operators consistently engage with researchers and regulators, as well as consumers. Therefore, the operators' association serves as an appropriate entry point to establish a sustainable collaboration that leverages universal knowledge alongside local culture and values.

After identifying this entry point, working groups can be set up to use existing groundwater management data and enhance participatory land and energy management practices.

Future measurements in densely populated areas like Bobole and Matalane-sede are crucial to monitor water availability and quality. Selecting boreholes, technical solutions for water cycle and hydrogeologic measurements, and the development data protocols should involve all relevant stakeholders of the socio-technical regime.

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