Rural-urban Moatize: water harvesting design strategies to enable community-driven development

Moatize rural e urbano: estratégias projetuais para a captação de água como forma de promover desenvolvimento comunitário

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Abstract

This paper presents design research on Moatize rural-urban area, located in the Zambezi river basin, Mozambique. The design research intended to find measures of conserving available resources, supporting reforestation and taking advantage of the riverscape to enlarge the landscape capacity. Starting with a vision of creating resilience through landscape design, the project worked within dualities of extremes: wet versus dry; rural versus urban; endogenous versus exogenous processes. This area is in a fast transformation process, mostly driven by foreign companies that negatively impact the environment and socio-economical dynamics. From an interdisciplinary analysis, problems related to water were identified as key issues to reduce community vulnerability and therefore, community's reliance on outside interference. The design research proposes a water capture and distribution system, with small scale elements and a scattered management. As a result, the system can be better integrated with the landscape occupation, facilitating efficient community maintenance. The design process was a result of learning from local knowledge and applying it to infrastructural solutions, a soft-engineering project that can be built integrated to natural cycles. Since the project follows the principles of community driven development, it is not a final result, but the starting point of a discussion.

Keywords: Water harvesting. Vulnerability. Community driven development. Zambezi basin. Mozambique.

Resumo

Esta pesquisa foi feita a partir de um projeto na área rural-urbana de Moatize, bacia do Zambeze, Moçambique. Pretendia-se encontrar medidas de conservação dos recursos naturais, apoiando o reflorestamento e aproveitando a paisagem ribeirinha para potencializar recursos naturais disponíveis. Buscou-se criar resiliência por meio de um projeto paisagístico, que trabalhou dentro de dualidades de extremos: chuvas intensas-seca;

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rural-urbano; processos endógenos-exógenos. Esta área está em constante processo de mudança, impulsionado principalmente por empresas estrangeiras que impactam negativamente o meio ambiente e a dinâmica socioeconômica. Com base em uma análise interdisciplinar, os problemas relacionados à água foram identificados como questões-chave para reduzir a vulnerabilidade da comunidade e, portanto, sua dependência de interferências externas. O projeto propõe um sistema de captação e distribuição de água com elementos de pequena escala e gestão descentralizada. Assim, o sistema pode se integrar melhor à ocupação do território, facilitando uma manutenção eficiente pela comunidade. O processo de projeto resultou da aplicação de conhecimentos locais em soluções de infraestrutura, um projeto de engenharia leve que pode ser construído integrado a ciclos naturais. Uma vez que o projeto segue os princípios do desenvolvimento voltado à comunidade, não é um resultado final, mas o ponto de partida de uma discussão.

Palavras-chave: *Captação de água. Vulnerabilidade. Desenvolvimento comunitário. Bacia do Zambeze. Moçambique.*

Introduction

Mozambique presents extensive natural resources, among which is the Zambezi River, the fourth biggest of its continent. Zambezi river (figure 1) is enormous and diverse.

The present article presents an exercise made under the frame of a landscape urbanism studio, which applied research by design methodology to discuss resilient solutions for the Zambezi river's development, focusing on the Tete District Region. The methodology involved a collective fifteen-day fieldwork, as an immersion in the local conditions, essential for understanding the spatial dynamics of the researched territory. The fieldwork occurred in February 2018, summer and rainy season in Mozambique. During the collective fieldwork, the researchers visited and observed multiple sites, carried photographic surveys, worked with interpretative mapping, interacted and discussed with local authorities, scholars and local inhabitants, observed the quotidian life of rural and urban areas and carried out multiple non-structured interviews. After the fieldwork, the team focused on desk research based on secondary sources, investigating the physical, geological, botanical and hydrological aspects of the site, to further comprehend the local conditions. Desk research was elaborated in parallel with individual and group analytical cartography, evolving to a design exercise in a multi-scalar approach[1].

To understand the regional scale, the group explored the landscape characteristics of a transect, which comprehends a 140 by 10 km section of the Zambezi River basin (represented in Figure 2). The characteristics of the landscape were further explored in four sites (squares of 5 by 5 km), each one as a representative situation of the transect´s landscape and existing urban-rural conditions. Each specific site was further explored in collective designs that were detailed in fifteen local projects, with detailed specific design strategies in 150 by 750 m sections.

The transect encompasses approximately 450,000 people, mainly concentrated in Tete city and its surroundings. In this region, the rural territory´s occupation is determined by the distance from the river and, therefore, its fertile margins, except for Tete and Moatize cities. These cities are points of attraction, due to the increasing coal mining activity that brings external settlers.

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[1] The Studio was part of the Research project called "Resilient Zambeze - Restoring the productive ecosystem of the lower Zambeze, Mozambique", coordinated by prof. Bruno De Meulder and Wim Wambecq at the Department of Architecture of KU Leuven (Belgium) in cooperation with the Faculty of Architecture of Universidade Vale do Zambeze (Mozambique). The project was developed between 2017-2019, under a South Initiative call, funded by the Flemish agency VLIR -IOS. The project involved several workshops with local stakeholders, one design studio (from which this design-research presented in this paper derived), 7 undergraduate master thesis. More information about the studio and its goals can be found at De Meulder &Shannon (2018) and De Meulder, Shannon & Wambecq (2019).

Figure 1 – Site location and transect framework. Source: De Meulder; Wambecq (2018), p. 21; 281.

An important part of Zambezi river lies over a carboniferous basin, an area that holds wide reserves of coal, an object of interest for international mining companies, that gained concessions to exploit the area. The design exercise presented is in Moatize, a city of Tete's district, with most of its population living in rural areas, presenting a scattered occupation pattern. Its traditional settlements have a close relationship with the Moatize River and its fertile margins. The rural dynamics suffered drastic transformation when the mining activity started in the area, introducing new flows and infrastructures.

On this design exercise, the proposals aimed to find measures for the conservation of available resources and the enlargement of landscape capacity. To create resilience through landscape design, the studio worked within dualities of extremes - wet versus dry; rural versus urban; endogenous versus exogenous processes. With the vision to find better territorial responses to continuous changes imposed on the landscape, water was identified as a key element to activate the landscape, both as a resource and as a habitat. (De Meulder, Shannon & Wambecq, 2019).

The first section presents a literature review on development initiates and projects in sub-Saharan Africa, showing how vulnerability is being accessed in such areas. This review is complemented by Mungoi's application in the Mozambican context of the concepts of vertical and horizontal actions and the vulnerability indicators of Antwi et al. (2015). Both studies demonstrate that vertical actions, prevailing on the region, are not effective to reduce community vulnerability. The next sessions describe the object of this design research. In the second session we present the socio-economic context of Mozambique, specifically the Tete-Moatize conurbation region, as the basis for the design research exercise. The third section, by means of a commented photographic essay, describes the physical characteristics of the site explored, located in Moatize´s rural area. Finally, the authors detail the elaborated individual project, a water harvesting system, based on a community-driven development approach. The final part of the paper is a reflection on the potentials of community-driven approaches on rapidly transforming traditional areas.

Less vulnerability, less dependency

The project discussed here was designed for a fastly changing rural context in central Mozambique. In this section, we present a literature review on vulnerability-mitigation in rural areas of sub-Saharan African sites. We considered papers published from 2017 to 2021, pointing the most recent research that can inform how this thematic is currently being addressed both in academia and in the development sector[2]. This exercise led to the need of investigating further project-based criteria that could guide the design exercise, which is presented at the end of this section.

Mngumi (2020), when analyzing the resilience of ecosystems services in peri-urban areas of Sub-Saharan Africa, identifies research gaps on this theme, particularly concerning limited knowledge on peri-urban ecosystems services in Sub-Saharan Africa, highlighting three reasons for increasing research on rural-urban areas: (i) these areas converge many forces and functions, working as a transitional space, (ii) their multifunction nature, receiving both housing and agriculture production, and (iii) their severe ecosystem degradation. Mngumi (2020) concludes by identifying the need for developing case studies that can contextualize and downscale the concept of peri-urban to enhance resilience of vulnerable communities highlighting that, when well-managed, these areas can potentially reduce physical exposure to floods and droughts.

Makate (2019) highlights the importance of embracing local knowledge systems and using a participatory approach for the success of climate smart agriculture innovations in African smallholder agriculture, especially when considering scaling it up. When considering scaling up agroecological initiatives, Le Coq et al. (2019) suggest that the most successful experiences combine local organization, collective learning, experimentation carried out by the farmers themselves, which put a strong emphasis on the local level, and the engagement with and of the farming community in the projects.

Mfitumukiza et al. (2020) discuss community-based adaptation to climate change, focusing on projects that tackle directly what they identify as the context-specific socio-economic and ecological drivers of vulnerability. The paper focuses on cases by which rural and isolated communities that are largely dependent on natural resources are undertaking local adaptation strategies and promoting collective actions to address climate-change risks, with cost-effective and socially accepted solutions, based on indigenous and experiential knowledge that can sustain resilience and enable bottom-up adaptation and collective learning. The authors identify as key success factors for such projects: being locally led, to ensure that adaptation addresses the priorities and needs of the most vulnerable, encouraging equity, promoting "decision-making that promotes ownership of the adaptation processes and outcomes at household and community levels" (p. 2).

Yéo et al. (2016) also tackled the problems of vulnerability and rural development, when analyzing adaptation to climate change in the Comoe River Basin, West Africa. The authors describe that the communities experience "reduced water level in rivers, crop failure, delay in cropping season, new pests and diseases, food insecurity, drop in income and decline in crop yield" (p. 12). Among the adaptation strategies to overcome these conditions is new irrigation systems.

Additionally, concerning community-based projects, Mustalahti et al (2020) emphasize the need for a bottom-up approach to empowerment and "responsibilization". With case studies on natural resources governance, the article discusses multiple overlapping claims and power structures when dealing with natural resources, concluding that the existence of different stakeholders worked to enhance decentralization.

Still on governance and the proper scale for action in such contexts, Gibbens & Schoeman (2020) focusing on planning for sustainable livelihood development in Rural South Africa focus on the need to deal with the appropriate scale concerning rural development, highlighting the importance of understanding what constitutes the local scale. Making a case of a micro-level development that focuses on enhancing rural livelihoods specific to each context, the author emphasizes the need to acknowledge the complexity of these spaces and their different typologies when aiming to diminish their vulnerability. Their conclusion points to focus on livelihood strategies when dealing with rural development in Africa, increasing the importance

[2] The literature review was based on a Google Scholar search with the key words: vulnerability, rural, Mozambique, water, community-driven, landscape, encompassing articles written between 2017 and 2021.

of micro-scale planning and action, which enables citizen active participation in their development and the achievement of "livelihoods they want and need" (p. 25)

The literature review presented above points to the matter of finding the right scale of intervention, when dealing with contexts such as Moatize. Literature shows that there are difficulties when aiming to scale up local initiatives, however there are multiple case studies that were locally successful on improving landscape capacity and peri-urban ecosystems services, increasing resilience and enhancing local livelihoods. This review points to the importance of reaching out to local indigenous knowledge, mobilizing local forces, increasing a diversified project governance, focusing on micro-level initiatives of development that have the potential to decrease vulnerability and reduce climate-change impacts. Finally, Williams et al (2018) indicates that "evaluation of adaptation capacity as a critical aspect of vulnerability assessment" (p. 1). The authors point out that vulnerability assessment, when linked to adaptation policy and measures that consider the end-user, are the best practices. Moreover, the future of vulnerability assessment needs to be comprehensive enough to understand the human -environment system relationship better.

While searching for vulnerability assessment criteria elaborated to contexts such as rural-Moatize, Antwi et al. (2015) proposed a range of vulnerability interrelated indicators, applicable for semi-arid African areas, according to their mode of production and water availability. These indicators for community vulnerability were divided into four interconnected categories: socio-economic, ecological, engineering, and political ones. The following table describes indicators in the engineering category, the most relevant for this project.

Table 1 – Community vulnerability indicators

Vulnerability category	Indicator	Indicator description
Engineering	**Access to irrigation system**	**Access to irrigation mostly in the form of small dams including dug outs allows a community to plant in the dry and wet season**
	Improved crop variety	Improved crop variety which could mean early maturing variety, late maturing variety, **drought**, high yielding or pest resistant variety
	Access to potable drinking water	**Potable drinking water could mean access to protected dug well, borehole, protected spring and rainwater collection**
	Involvement in dry season farming	Involvement in **dry season farming** by a community either lying closer to water body or having access to a small dugout community dam
	Soil improvement technologies	Use of soil improvement technologies include all organic and inorganic amendments such as chemical fertilizer available to community and applied to soil

Source: based on Antwi et al. (2015, p. 60).

In semi-arid contexts such as Moatize, water resilience is a critical matter, as shown in the indicators above. During the fieldwork, described in more detail in the following section, we identified that the community does not have access to irrigation systems, the crop variety is low and the access to potable water is unreliable. Moreover, there is almost no farming during the dry season and no soil improvement technologies are used. Therefore, the community presents a high level of vulnerability.

Focusing on the specificities of Mozambican vulnerability, Mungói (2008) analyzes the different historical stages that determine the ways of political and economic use of the territory in the Zambezi Valley, as well as the participation of private sector, civil society and rural families in promoting the community development in the region. He describes the ongoing dynamics of family-based agriculture, to explain how different multiscale actors promote development projects in the region.

His central hypothesis is based on two concepts, given by Santos (1996)[3]: vertical and horizontal actions. The vertical actions

> are those that characterize the spaces in which a single temporality and particular objectives are considered: the use of the territory as a resource to enable actions of interests outside the region. They are, therefore, centrifugal forces that (...) remove or displace elements of their own command that are then sought out and far away. Horizontal actions are those that characterize the spaces in which daily life encompasses various temporalities, considering the existence and interest of each and every one, emphasizing interdependencies and networks of solidarity among people, groups, social and economic organizations located in the region. (Mungói, 2008, p. 24-25).

Mungói advocates that "verticalization of the actions are more expressive and dominant in the region. The horizontalities, when eventually imprinting specific forms of land use, still manifest in a rather timid way" (Mungói, 2008, p. 24). According to this reading, Mozambique's population does not drive its country's development process, as exemplified in the Moatize region.

It is important to understand the meaning of development to propose suitable alternatives and better projects. Mungói (2008, p. 28) revised various definitions and found that in most of them, development "designates a process of gradual social change". However, he highlights the fact that development usually is used as a tool of westernization.

In the case of Mozambique, a substantial GDP growth occurred after policies to open the market to external enterprises. However, it was not converted into a reduction of poverty indexes. Examples can be seen in projects such as: Cahora Bassa Dam in Tete region, the sugar mills in Marromeu, the cotton exploitation in Morrumbala, the Coal Mines in Moatize, the tobacco production in the Báruè. In the case of Cahora Bassa dam, for example, even though it is responsible for the largest production of electrical energy in Mozambique, only 3% of Tete's district population has electrical power in their houses. Therefore, Mozambique became merely a "spectator or passive receiver of the decisions' chain concerning projects" (Mungói, 2008, p.227). In this context, vertical actions have proven ineffective to reduce vulnerability.

Moreover, to revert the process that continues the structural inequities in social and economic relations, it is necessary to build within a community their "capacity of aspire" (Appadurai, 2004, apud Mansuri and Rao, 2004, p.27). With collective organization, it can be achieved what individuals cannot do alone. Appadurai (2004[4] apud Mansuri and Rao, 2004, p.27) says that this is "a way out of the culture of domination and poverty". This organization can create "environments to equalize the relational and group-based structures that influence individual aspirations, capabilities, and agency. This is the kind of empowerment that advocates of community-based development envisage" (Rao & Walton, 2004[5], apud Mansuri and Rao, 2004, p. 27).

The reflection about vertical and horizontal actions and community-driven development, allied to the vulnerability indicators, suggested by Antwi et al. (2015), indicates that initiatives that promotes community-driven irrigation systems, accessibility of potable drinking water, enabling multi-season farming activities and the increase of crop variety can dimmish community vulnerability in semi-arid areas, therefore amplifying its landscape capacity and resilience. These were the guidelines for the design exercise presented in the next sections, starting with the description of the area.

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[3] Santos, M. (1996). *A natureza do espaço. Técnica e tempo. Razão e emoção.* São Paulo, Hucitec.

[4] Appadurai, A. (2004). The Capacity to Aspire: Culture and the Terms of Recognition. In V. Rao, & M. Walton (eds.), *Culture and Public Action: A Cross-Disciplinary Dialogue on Development Policy.* Palo Alto, Calif.: Stanford University Press.

[5] Rao, V., & Walton, M. (2004). Culture and Public Action: An Introduction. In V. Rao, & M. Walton (eds.), *Culture and Public Action: A Cross-Disciplinary Dialogue on Development Policy.* Palo Alto, Calif.: Stanford University Press.

Describing the area

The focus of the present design research is Moatize, the center of the coal mining activity of Vale do Rio Doce, a Brazilian multinational company (figure 2). Moatize was a traditional settlement that presents the original occupation in close relationship with the Moatize river, a tributary of Revuboe river. The semi-arid biome and the contrasting water availability during the year marks profoundly how the inhabitants interact and depend on their environment.

The dynamics of occupation suffered drastic changes when the mining activity started in the area, in 2007[6], introducing new flows and infrastructures.

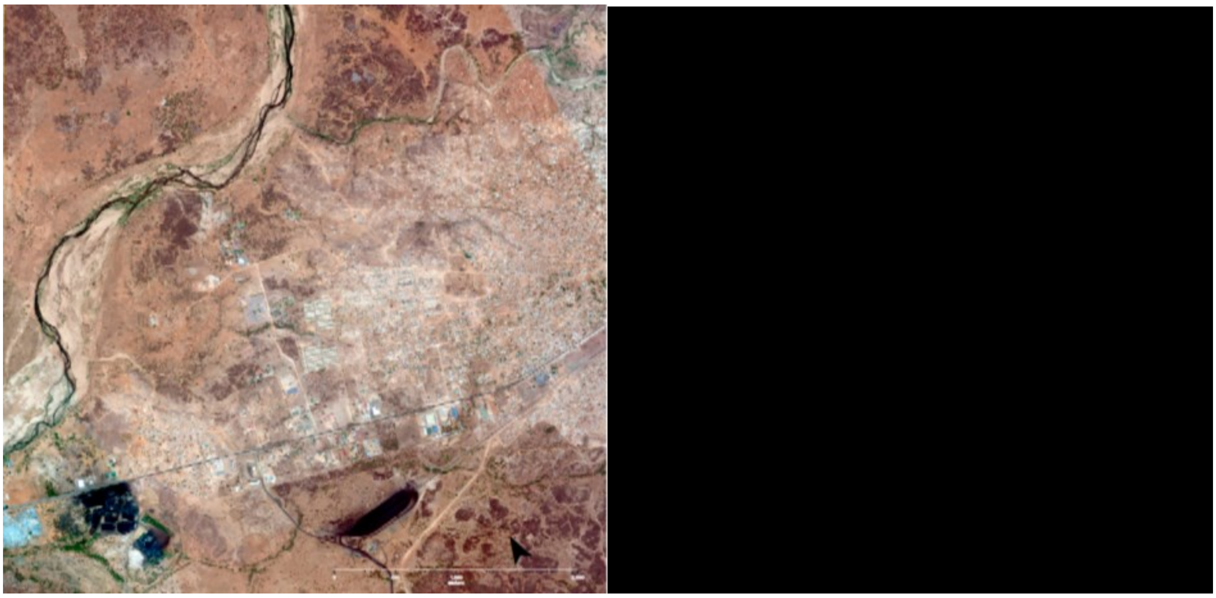


Figure 2 – The city of Moatize: the national road (1), the new gridded settlement pattern (2), the Moatize river (4), the traditional occupation (3) and the mining exploration (5). Source: Personally devised by the authors, based on Google Earth aerial view, extracted in 2018.

First, there was the construction of a national road (1), bringing new markets and occupation patterns. Additionally, a gridded settlement was built on the plateau (2), where gated condominiums were constructed for mining workers, disregarding the surrounding communities and landscape (3) and the Moatize river (4). Thus, exogenous urban characteristics were added to what was previously a rural area, differing completely from the traditional ways of occupying the landscape. Simultaneous to this new pattern of occupation, there was a migration flow to Moatize, with newcomers seeking new economic opportunities.

In this region, the availability of water changes drastically during the year, with severe droughts in the winter, and strong storms over the summer, causing erosion and landslides (figure 3). The winter presents a quite different scenario, with little vegetation due to lack of rain (figure 4). The pictures that follow depict the above-mentioned contrast: not only is the number of green patches different, but also the width of Revuboe river.

[6] Underground mining activity occurred since colonial times.

Figure 3 – Wet season - Moatize rural area. Source: Google Earth aerial view from February 2019 (accessed on 30/03/2021)

Figure 4 – Dry season - Moatize rural area. Source: Google Earth aerial view from June 2018 (accessed on 30/03/2021)

In 2007, Vale obtained a 35-year mining concession to explore coal in 25,000 hectares of Moatize district. It spent over US$8 billion to explore the coal and create its supporting infrastructure. Such an amount is considerably impacting a country which GDP was US$11,1 billion in 2010, according to the World Bank (2021a). Despite these investments, there was no sensible increase in employment in the country: the total labor force in Mozambique varied 6%, from 10,113,187 (2008) to 10,733,467 (2011), according to World Bank (2021b). Moreover, the presence and activities of foreign companies was not followed by any significant social advance, like reduction of poverty or health improvement. More than half of the population is still under the poverty line. World Bank, apud Human Rights Watch (2013, p. 33), outlines that "the limited progress in poverty reduction while the economy continued to grow at substantially high rates suggests that growth has become less inclusive than in previous years." Finally, due to mining activity, Vale resettled more than 5 thousand people between November 2009 and Abril 2010 (Mosca & Selemane, 2011).

Figure 5 – One of Vale's open pits of coal exploration, exemplifying the companies' mining activity in the Moatize region. Source: Personal Archive of Júlia Paiva, February 2018.

The open pits have a considerable impact on the landscape (figure 5). According to Vale's employees, they can be more than 30 meters deep and there is no limit for its width. Several civil society groups and scholars in Mozambique criticized such concessions, mostly because of the lack of transparency about the terms of the contracts, the limited information concerning the use of revenues and the lack of government control, to guarantee that companies would comply with the environmental and social commitments they made. Their concern also refers to the difficulty of the Mozambican government to manage the scale and speed of these investments (Human Rights Watch, 2013).

The expectation of rapid growth brought by the implementation of large-scale projects, such as this one, lead to migration. However, the job market did not absorb the mostly unskilled workforce involved and public services failed to meet the growing demands that it caused (Mosca & Selemane, 2011).

Fieldwork observations and interviews with local stakeholders provided further understanding of ongoing local dynamics. The livelihood of the inhabitants in the region is mainly based on family agriculture and livestock. The enlargement of mining activities introducing large scale open pits is negatively impacting the environment and disrupting existing socio and economical dynamics: communities' resettlement, air and water pollution and production of dust, noise and vibration. Moreover, this activity is expanding the erosion process, modifying topography and water regimes, lowering the water table level, increasing average temperature, and reducing the volume of rain. Furthermore, this exploration endangers biodiversity and causes acid-mine drainage. Additionally, there is an increase of deforestation rates in this territory, mainly through illegal logging.

The analysis of fieldwork materials suggests that when intervening in such an area, it is important to come up with alternatives that enhance subsistence economies, contributing to local communities' livelihood. To do so, it is necessary not only to understand the socio-economic and cultural aspects of the region, but also its physical conditions in detail, presented as follows.

Different water regimes

As previously discussed, the rural-urban area of Moatize is a place that was rural but received exogenous urban characteristics due to mining activity. In the scenario of fast changes, a key issue was identified: there is a disparity in water availability throughout the year. In the rainy season, the huge amount of water provokes problems of floods, erosion and landslides; thus endangers the local population. During the dry season, the lack of water diminishes agricultural production. Focusing on the traditional patterns of occupation, this session will use a photographic essay to present the physical consequences of these dynamics. The following photographic survey depicts the site during the wet season, showing an abundance of agriculture and vegetation.

The rural traditional settlements in Moatize are composed by scattered isolated brick houses, surrounded green areas, many characterized as *Machambas*[7]. While walking around this context, there were many places where it was not possible to differentiate the public and the private spaces. It was common to be walking in what we thought was a public pathway and end up in the middle of a house. Closer to the new gridded settlements, there were different patterns of occupation, influenced by the newcomers. In those areas, a remarkable characteristic is that many houses are fenced by bushes, an application of an urban condition in an organic and natural way. With the green fences, it appeared a path, almost a street to walk in, resembling the patterns of an urban environment.

Figure 6 – House built in bricks in Moatize rural area and landslide after rainstorm. Source: Personal Archive of Clara Medina, February 2018.

Figure 6 shows a popular house in the rural area of Moatize. After a strong storm, it is visible the landslide close to the house, threatening its structure. The house is constructed with bricks, a material locally produced, as it will be further explained. Moreover, it is noticeable that the occupation of the territory is scattered, as there are no houses close to these one.

After strong storms, the landscape is reshaped due to erosion and landslides. In stepper areas, ditches are created by the waterflow, and afterwards, plants grow in this wetter land. This process is visible in Figure 7, which shows a creek with plants growing on it.

[7] Machamba – local term used for plantation and crop production.

Figure 7 – Plants growing in a creek. Source: Personal Archive of Júlia Paiva, February 2018.

As it gets closer to the Moatize river, the declivity gets higher, as well as the erosion, exposing huge steps. Figure 8 illustrates this process, showing a step bigger than a person. The National Institute of Agronomical Investigation produced an erosion hazard index and classified Moatize region's propensity to soil erosion as high (Van Wambeke, 1986, p. 3).

Figure 8 – Erosion and landslides in Moatize riverbed. Source: Personal Archive of Clara Medina, February 2018.

However, during the dry season, agricultural activities tend to decrease in central Mozambique. According to Macie (2016, p. 56), the probability of having thirty days in a roll without rain can be higher than 80%. However, the majority of Moatize have its main economic activity based on agriculture, silviculture and fishing. In Tete's province, it reaches 84.6%, according to Census 2007.

The water retention capacity is good due to the soil composition, which is "grayish brown soils, shallow reddish brown on limestone and basaltic rocks may be red, brown reddish or black" (Macie, 2015, p.13).

According to field work observation, the topsoil is graduated thick sand with low amounts of gravel, as shown in Figure 9. This image also shows that in the wet season, the landscape is green, but mainly composed of bushes. The big trees are scattered and represent important marks on the territory. Fieldwork observation showed the importance of these trees, as a place of reunion and social activities.

Figure 9 – Topsoil and vegetation in Moatize rural area. Source: Personal Archive of Júlia Paiva, February 2018.

Inside the meanders of Moatize river, there is clay soil which is exploited to produce brick. This process alters the landscape by producing a sequence of holes and piles. This is a common process, seen in many places. Figure 10 shows the availability of this material.

Moreover, some of these holes are afterwards used for agriculture since they are closer to the water table and above the saturation level of the soil. Bricks are also produced on a smaller scale, inside the house plots. The square holes have an average size of 3 to 4 meters wide and 1-to-1.5-meter depth. Figure 11 shows a brick hole close to a house used for plantation.

Figure 10 and 11 – Brick extraction causing landscape alteration (on the left) and agriculture inside the brick hole (on the right). Source: Personal Archive of Clara Medina, February 2018.

Moatize river is the main source of water in the rural area. During the fieldwork, it was common to see people carrying water in buckets above their heads from the river to their houses. There is a public institution responsible for the water supply in the whole region, FIPAG (Investment and Heritage Fund of Water Supply), that installed taps outside houses (figure 13) as well as pumps (figure 12) to allow inhabitants to reach underground water. Each one of these pumps and taps is responsible for supplying water for many households. However, during interviews conducted in the fieldwork, the residents complained about constantly present operational problems which resulted in the absence of water provision.

The water supply of the Moatize city is ensured through underground water. The recent growth of the city imposes an expansion of the system. Nevertheless, there is a problem in enlarging the amount of pumped underground water. It can provoke fall of the water table level or the piezometric surface, requiring greater pumping, as well as an aggravation of aquifer contamination and increasing thickening of underground layering. Moreover, it can also result in soil settlements and slippages.

Figures 12 and 13 – Water pump (on the left) and Water tap (on the right). Source: Personal Archive of Júlia Paiva and Clara Medina, February 2018.

In the traditional patterns of occupation there is no irrigation system. *Machambas* are made where plants can naturally grow, fed by rainwater, surface runoff or groundwater. Among the houses, the most fertile areas are the ones naturally irrigated by creeks. Therefore, water availability, both potable and irrigation water is a crucial issue in Moatize.

There are scattered houses constructed in the proximity of Moatize riverbed, but the majority is settled approximately 300 meters away. This in-between space is used for brick-making activities and agriculture, depending on the season. Therefore, most of the population does not suffer risk of flooding due to changes in the Moatize river level. However, erosion problems related to soil and topography are seen among the settlement in steep areas (figure 14).

Figure 14 – House settled in a high erosion-risk area. Source: Personal Archive of Júlia Paiva, February 2018.

Regarding soil and agriculture activity, there is a low variety of crops. The main plantation in the area is corn, which is further milled to produce flour. There are small markets and selling tends among the houses. Corn, tomatoes and potatoes are the main vegetable available, there are hardly more than five different types of vegetables.

Each plantation species needs a different amount of water to grow. Thus, having soil with different moisture content can increase crop variety. It is important to notice that not only water is necessary, but also different nutrients to guarantee fertility, as nitrogen, phosphorus and potassium. Nonetheless, during fieldwork, it was possible to observe that there is no use of fertilizers in the soil, neither organic nor inorganic. The maintenance of nutrients in the soil results from natural decomposing processes. However, the mixture of plantations and the increase of crop variety will enhance the fertility of the soil.

The photographic survey presented the local conditions as the basis for the explorative design, presenting the pitfalls and the potentials of such landscape conditions. When dealing with water in such a context, design strategies should assure water resilience throughout the year, strengthening local agricultural livelihoods, as well as mitigating the main water related hazards: the absence of water or erosion and landslides. These two main guidelines oriented the explorative design presented in the following section.

Design strategies towards improving landscape capacity

Given the conditions described in the previous section, and the Antwi et al.'s (2015) vulnerability indicators' mitigation, based on community-driven strategies, the design-research exploration aimed to address the needs of the local population while making the landscape more productive and resilient to exogenous forces. Therefore, any model proposed should use landscape features and ecosystem services as the means to mitigate the dichotomies present on the territory. Thus, the project´s premise was to decrease dependency on exogenous forces, which are determined by a western model of development, many times relying on economic resources that this territory lacks.

Using an integrated approach, based on the local knowledge that derived from the fieldwork and the interaction with local inhabitants, the conceived infrastructural proposal intends to improve spatial organizations. There are seasonal creeks in the region, interpreted as green cores and natural collectors of water. Thus, these creeks were redefined as the elements to protect the rural-urban tissue against natural hazards, strengthen local resources and to introduce a more resilient water management. The aim was to enhance the ongoing relations of social-economic and ecological systems and create new economic opportunities. This manipulation of natural rhythms and fluctuations could reinforce the natural potentials and intensify resilience of ecosystems. Furthermore, it could reduce unsustainable use of the territory, as well as prevent human and ecosystem exploitation.

Understanding the creek system: runoff influential area

The creek chosen for this design exploration is in the west side of Moatize, starting in the plateau where Moatize city is located (southwest of the image) and running in the interface between the urban and the rural settlements until Moatize river (northwest of the image). The creek is in an intermediary position in relation to the Moatize river, exemplifying a location that deals with scarcity of water in the dry seasons and intermediate level of erosion in the wet season. To calculate its hydraulic potential, we started analyzing its basin, tracing its 3500 m extension (figure 16).

For this creek, the design proposed four tanks feeding, each one, its corresponding canal and irrigating plantations among the settlements. The storage tank was designed to be introduced in less steep areas, where the water naturally has a lower speed. Thus, the proposal for this creek was the introduction of a series of Small Retention Obstacles (SRO), four storage tanks and four small canals.

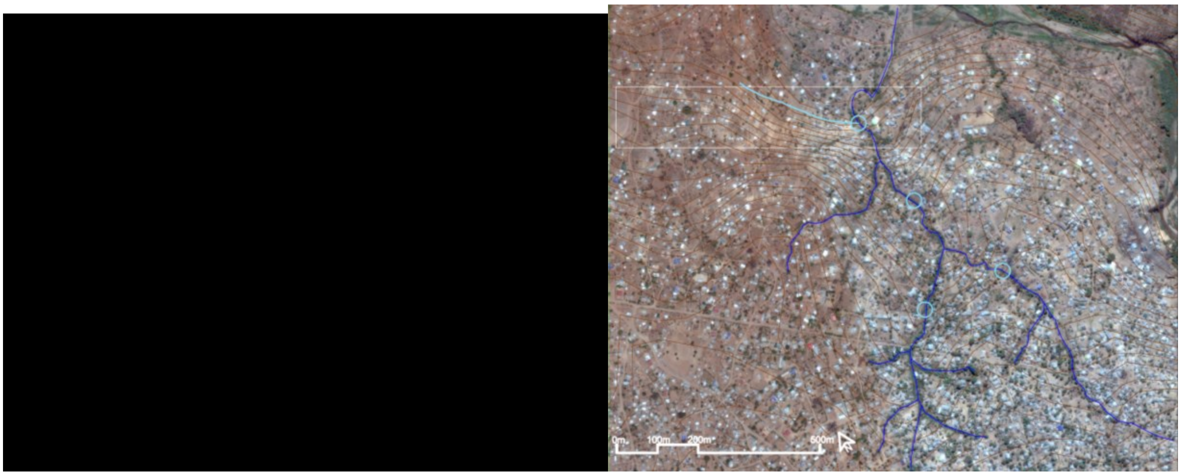
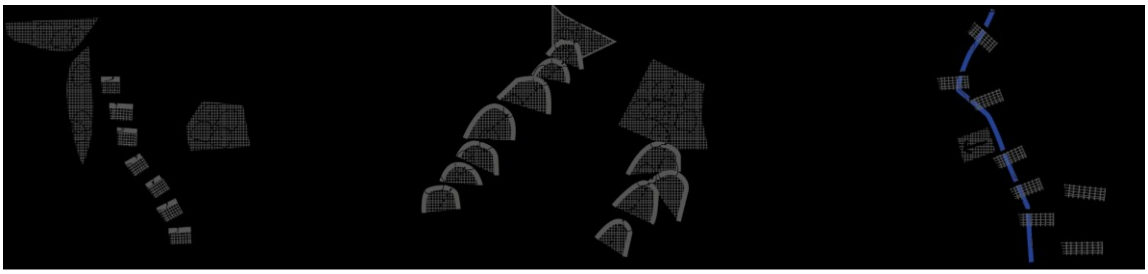


Figure 16 – Project´s location in rural Moatize. Source: Personally devised by the authors based on Google Earth Aerial view, 2018.

Given the detailed problems in the previous section, the present research by design exercise emerged. The project was framed in an exploratory site of 150 m x 750 m chosen by the analysis of the creeks in the area, as described before. The project consists of the manipulation of the water that naturally flows in creeks by introducing small dams and obstacles, increasing water infiltration and water harvesting. The creeks are interpreted as potential green cores that can enhance landscape productivity.

The model of the project and the schematic representation show the different creeks (a,b,c,d) and its proposed integration (e), which is a canal, designed to be responsible for connecting adjacent creeks, as well as a retention tank (f), that feeds the canal. The existing trees in the model are represented in white, while the proposed planted ones in yellow and green, respectively dealing with landscape production and soil retention. In each existing creek, we designed small retention obstacles, varying by size and distance according to the availability of water. In the next section, we present the detailed dimensions of the elements, designed to be introduced in the chosen creek (d) (Figures 16 and 17, in blue).

(a)



(b)

Figure 17 – (a) The physical model of the project; (b) a schematic representation of the design strategies. Source: Personally devised by the authors, 2018.

The system is designed to mainly deal with runoff water, slowing it down, reducing its erosion potential and increasing infiltration and could generate a change in the creek path, diverting the water and enlarging the runoff width.

However, slowing down the water also provokes a lower availability of water to be stored. It is not possible to count that most of the runoff can be collected by the structures once they function also as diverting obstacles. The system was designed to collect half of the runoff, while the other half can infiltrate or evaporate. Nevertheless, since the surface runoff width is larger, its contribution area can increase as well as the contribution of the rainwater in the surface runoff.

The proposed system has the capacity of storing water, in the strategic points of confluence (g). In the creek chosen for this design exploration[8] (Figure 16 and 17, in blue) we introduced 6 SROs, separated by 25 meters: a storage tank and an irrigation canal. During the dry season, when the elements are not filled with water, the infiltrated water allows plantation growth on them or their surroundings. The size and quantity of elements suit the rural condition of the settlements, the landscape topography and the security for the local population, as will be further explained.

The fieldwork observation of the brick making activity was important to determine the soil profile. The depth of the holes made by the local population among the houses vary from 1 to 1.5 meters. Consequently, the sand layer has approximately the same thickness.

For the construction of this project, for each constructed SRO, it would be necessary to determine the exact thickness of the sand layer. This can be made during the construction process, measuring the sand level while digging as the soil. Since no soil has an equal distribution of its components, nor the same length of its layers, the general calculus must be made with average layer thicknesses. The sand layer is considered to be located at a 1.2-meter depth, therefore the holes can have an average 1.5 meter depth, 30 centimeter deeper than the sand layer. The water level is lower than the hole´s depth.

Detailing the elements

The first elements to be detailed are the SRO (Small Retention Obstacles). The SRO system is composed of three elements: one planted tree, a catchment water hole and a pile of soil covered with broken bricks. In the sides of the catchment hole, there can be small holes, following the principles of zay technique[9]. A schematic drawing of the SRO system below (figure 18). The depth of the catchment hole is 1.5 m for security reasons and its base has dimensions of 3 m x 3 m with a ramp of 45°. This measure gives the structure a modular size, facilitating its construction.

[8] The complete calculation is shown in Paiva (2018).

[9] Zay, or tassa, is a micro water catchment system based in a sequence of holes dug approximately 80 cm apart from each other. Their depth varies from 5 to 15 cm, with a diameter of between 15 and 50 cm . It can be used where the land is not very permeable or where the runoff can be collected, improving infiltration. This technique is used in Mali, Burkina Faso, Niger and Sudan. (Thornton, 1998)

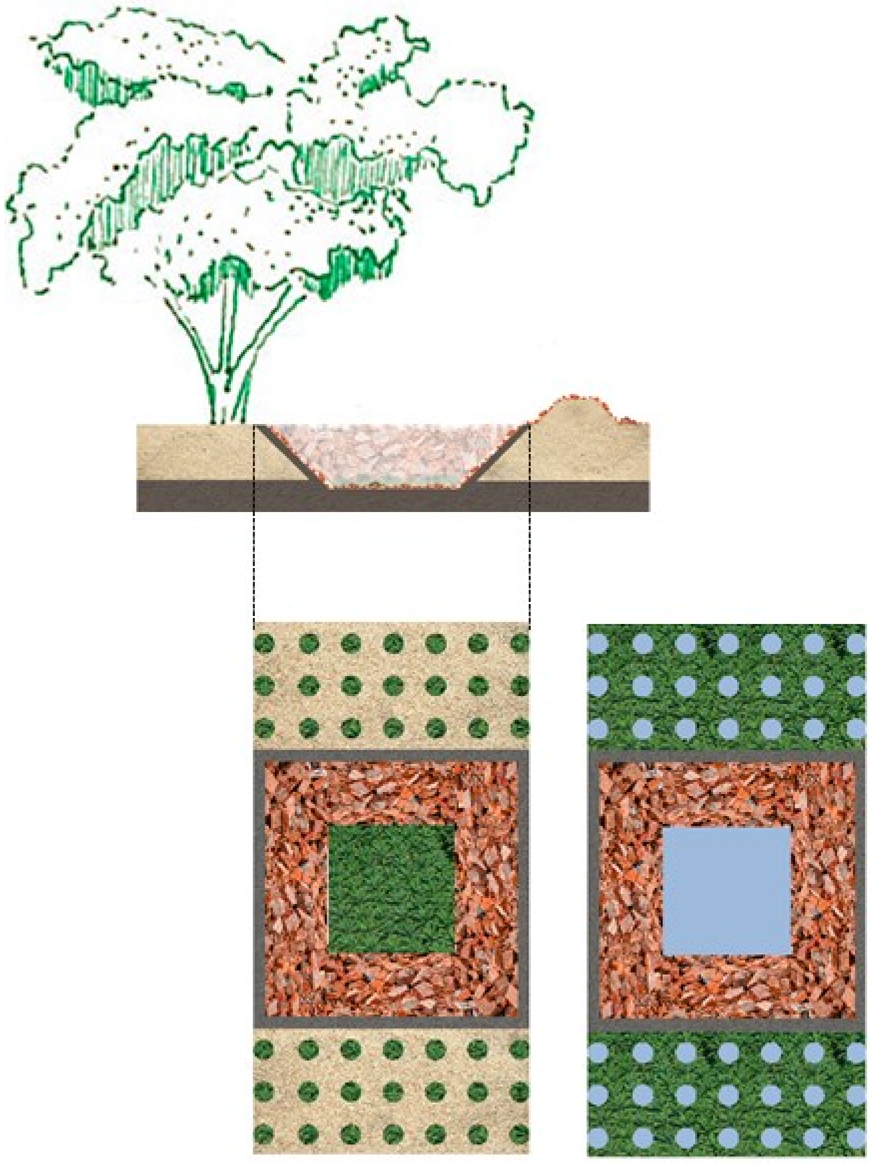


Figure 18 – Small retention obstacles – general scheme. Source: Personally devised by the authors, 2018

Firstly, the existence of a planted tree in front of the entrance ramp can slow down the water speed before it reaches the ramp. Additionally, its roots can give more stability to the soil and increase its resistance against shear stress. Moreover, the water can enter the catchment hole. In events of heavy rain, the water can overflow and irrigate the zay system on the ramps. The pile of sand in the opposite direction of the tree is the accumulation of the dug upper layer from the catchment hole. It functions as a small dam, diverting the water flow. It will be permeable, thus some of the water can flow through it, while the rest can flow on its sides and over its top. The broken bricks on top of the pile will exert a force that avoids the destruction of the sand pile.

During the wet season, the crops can grow around the catchment hole and surrounding the small zay holes. These elements can be currently refilled with water, being able to irrigate -by water infiltration or eventual overflow- its environs. In the dry season, the situation is reversed: inside the catchment hole and the small zay holes it can be possible to grow crops, once these would be the wetter soils.

Secondly, the canals, as described before, enlarge the irrigation area and connect adjacent creeks, by being fed simultaneously by both creeks. The available water in the analyzed creek allows the irrigation of four canals of 0.5 x 0.5 x 30 meters. Moreover, the reduced depth and width of the canals foster a better integration with the existing landscape occupation, as well as facilitate manual water catchment by the population. In such a context, it is preferable to make longer and thinner canals, spreading water in the territory.

Thirdly, each tank was dimensioned to feed its canal with a reduced runoff, avoiding problems of margin erosion in the canal, as well as making the water available for longer periods. Once the canal is filled, it is expected that the local population can collect this water, or that it can evaporate. With these dimensions, the eventual overflow of the canal does not constitute a problem or a risk for the surrounding area, but a possibility of irrigation.

The second element of the system is the catchment tank. The dimensions of the tank were defined by calculating the difference of input and output flow. According to the difference of topography and to have a natural outflow, the tank can have a depth of 1.5 m, with width and length of 5 x 6 m.

Harvested water could be used for agriculture or domestic purposes, such as washing clothes or cleaning the houses, but this system also has the potential to distribute potable water. In this case, it would be necessary to account for water quality and implement additional filtering or other water treatments.

As explained before, the water harvesting system was estimated for one creek. With the integration of other creeks, the potential of this strategy becomes more significant.

These design strategies compose a decentralized water retention system, to better relate to the scattered occupation of the territory, as well as to the decentralized social-political organizations. In that sense, the family-based decentralized agriculture production and the average size of plantations and the fences of the plots were considered as ordering elements in the design. In addition, the maintenance and management of the system can be facilitated if its structures are dispersed and better integrated on the communities' settlements.

In this context, in the locations where the availability of water is wider, it can be collected in storage tanks and distributed in small canals. The small canals propitiate the connection between adjacent creeks. By slowing down the runoff flows, enlarging its reachability and storing water in strategic points, the proposed project can increase infiltration and make water available in longer periods of the year, also mitigating erosion, landslides and food production problems. Consequently, even with small scale elements, this water harvesting system proposes an integration of water flows in a much bigger range, allowing its implementation in different parts of Moatize rural area.

With the aim of investigating models for community-driven development, the project was designed in a way that could be implemented directly by the local population, with as little external interference as possible. Its implementation would not require the use of external mechanical processes, taking advantage of the existing and already available local resources and materials.

Final remarks

This paper, while focused on exploring design strategies that can trigger a community-driven water harvesting project, defined to reduce vulnerabilities, as an alternative development scenario for traditional rural areas of Moatize, in Mozambique.

Rural Moatize is in a process of fast changes, mostly driven by foreign companies that negatively impact the environment, as well as socio and economical dynamics. From an interdisciplinary analysis, it was possible to identify the problems related to water as a key issue to reduce community vulnerability and therefore, reliance on outside interference.

The fieldwork provided a broader interpretation of these dynamics and its complexity, from social-cultural, to economical and infrastructural points of view. The different stakeholders are interfering in the area, prevailing actions of exogenous character, increasing social vulnerability of traditional communities. Therefore, a vicious circle was identified: the more vulnerable the community is, the more it will rely on external interventions, with fewer capacity of questioning or claiming. Additionally, the external companies impose a model of economic development that does not integrate with the ongoing dynamics and, therefore, enlarge socio-economic inequalities.

The project proposes an alternative solution to the vicious cycle identified, describing design strategies that mitigate the harsh climate conditions the territory faces, both in the dry and wet season. While investigating in depth the creek system and its potentials, the project introduces small scale elements, here called Small Retention Obstacles, that increase this landscape´s resilience, decreasing its population vulnerability.

Since 2018, when the project was defined, we observe a rapid transformation and, consequently, the increased densification in the occupation pattern of rural Moatize, which shows the urgency in developing community-driven projects that can increase landscape resilience towards change. These fast transformations show the necessity of more design-based research focusing on the problematic of vulnerable rural areas, such as this case study. The project shows that design-based research can be a tool for exploring alternative development models in the region. A next step would be to submit these results to the inhabitant´s appreciation, enabling improvements and working towards co-production initiatives that ally soft engineering solutions and local social knowledge[10].

The design exercise was the result of learning from local knowledge and applying it to decentralized infrastructure solutions, proposing an alternative development model that increases landscape resilience. However, since the project follows the principles of community driven development, it is not a final result, but as a starting point for a discussion regarding alternative models for development. It should be read as technical guidance that can be adapted in accordance with community response and implementation results.

Data availability statement

The dataset that supports the results of this paper is available at SciELO Data and can be accessed via https://doi.org/10.48331/scielodata.C5OLYQ.

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