BOA_MA_NHÃ, MAPUTO! EXPLORING THE WATER-ENERGY-FOOD NEXUS IN THE MAPUTO METROPOLITAN REGION AND PROVINCE

Laura Montedoro*, Maria Chiara Pastore*,
Alessandro Frigerio*, Alice Buoli*, Davide Danilo Chiarelli*

*Politecnico di Milano, laura.montedoro@polimi.it, mariachiara.pastore@polimi.it, alessandro.frigerio@polimi.it, alice.buoli@polimi.it, davidedanilo.chiarelli@polimi.it

Abstract

The paper presents the premises and some ongoing results from “Boa_Ma_Nhã, Maputo!”, a transdisciplinary research project based at Politecnico di Milano in partnership with Eduardo Mondlane University (Maputo, Mozambique) and the Italian Agency for Development Cooperation. The project is focused on the districts of Boane, Moamba, and Namaacha, questioning their role in consideration of the ongoing metropolisation of the Maputo Province, where the relation between urban and rural, national and transnational, local and global has become critical. Among the most pressing challenges, the main ones are related to the changing rural-urban socio-economic conditions and the local effects of climate change, including water competition, food insecurity, and access to energy. The research project embraces these challenging issues, mainly untackled by local planning tools, by proposing a multi- and inter-disciplinary approach to address the development of the growing peri-urban environment of Maputo in an integrated way and considering the interdependencies between internal/transnational migrations, demographic transitions, the increasing scarcity of natural resources, climate risks, natural hazards, local economic patterns (formal and informal). Particular attention is devoted to the Water-Energy-Food Nexus, considering the potential evolution of the agriculture sector, backbone economy of the region, in relation to the whole food system and its multiple environmental, economic, social, and cultural implications.

Il saggio presenta l’impostazione e alcuni risultati preliminari di "Boa_Ma_Nhã, Maputo!”, un progetto di ricerca interdisciplinare curato dal Politecnico di Milano in collaborazione con l'Università Eduardo Mondlane (Maputo, Mozambico) e l'Agenzia Italiana di Cooperazione allo Sviluppo (Aics). Il progetto ha come campo di ricerca i distretti di Boane, Moamba e Namaacha, e il loro ruolo rispetto al processo di metropolizzazione della Provincia di Maputo dove le relazioni tra urbano e rurale, nazionale e transnazionale, locale e globale pongono sfide rilevanti. Le più urgenti sono legate alle condizioni socio-economiche tra rurale e urbano, agli effetti locali dei cambiamenti climatici, tra cui la competizione per l’accesso e l’uso delle risorse idriche ed energetiche e l'insicurezza alimentare. Il progetto di ricerca affronta queste problematiche, trascurate dagli strumenti pianificatori vigenti, proponendo un approccio multi- e inter-disciplinare per leggere e immaginare uno sviluppo più sostenibile ed integrato del territorio peri-urbano della città di Maputo, considerando le interdipendenze tra migrazioni interne/transnazionali, trend demografici, sicurezza alimentare e idrica, rischio climatico e disastri naturali, e dinamiche economiche (formali ed informali). Particolare attenzione è dedicata al nesso Acqua-Energia-Cibo, considerando la potenziale evoluzione del settore agricolo come spina dorsale dell'economia locale, in relazione all'intero ciclo alimentare e alle sue molteplici implicazioni ambientali, economiche, sociali e culturali.

Keywords
Southern Africa, food security, water competition, transcalarity, interdisciplinary methods.

Premise: "Boa_Ma_Nhã, Maputo!" Project

"Boa_Ma_Nhã, Maputo!" (Polisocial Award 2018) is a research project based at Politecnico di Milano[1], carried out in partnership with the Eduardo Mondlane University (Maputo, Mozambique) and the Italian Agency for Development Cooperation (Aics, Maputo), with the support of the NGO Progetto Mondo MLAL, and the Faculty of Agricultural Sciences and Technologies at the University of Milano.[2] This papers aims at presenting the general framework of the project, its methodological approach and some preliminary results from a preparatory assessment phase. It highlights the need of setting a transdisciplinary and transcultural platform to deal with the challenges of local sustainable development when appropriate planning tools are lacking. This approach also aims at fostering cooperation for the co-production of knowledge and conditioning the metropolitan agenda towards a better awareness.[3]

The project is focused on the Maputo Province - and in particular on the western districts of Boane, Moamba, and Namaacha - and crossed by the "Maputo Corridor" (one of the most important infrastructures in the Southern African region, connecting Maputo with Johannesburg). More than 3,000,000 inhabitants live in this area, representing over 13% of the Mozambican population and over 40% of the urban population of the country. However, the lack of information regarding existing cross-scalar patterns that have been producing this territory in the past decades makes Maputo an "unknown Metropolis", fragmented in terms of administrative boundaries and governance (Andersen et al., 2015) and shaped by a complex tangle of informal or unmapped economic and spatial flows and systems. Among the main challenges that this territory has been facing, some are more evident and urgent, such as the changing rural-urban balance due to demographic growth, migrations and progressive urbanization, the local effects of climate change, deforestation, food and water insecurity, land grabbing, socio-economic and weak territorial governance. All these conditions make the peripheral districts of the fast-growing Maputo Metropolitan Region a fragile territory in need to be framed in a synergic inter-scalar vision for a more sustainable and integrated territorial development.

Due to the scarcity and inconsistency of the available statistical data and the lack of updated digital cartographies, a series of actions in terms of research methodologies and planning tools have been

[1] Four departments are involved: Architecture and Urban Studies (DAStU), Civil and Environmental Engineering (DICA), Electronics, Information and Bioengineering (DEIB), and Energy (DENG).
[2] See the "Acknowledgments" section for more details.
[3] The project has been completed in July 2020, almost a year after the presentation of this paper at CUCS Conference 2019. Due to the publication timeframe, this paper presents the early results (assessment stage) of the project as per the original aims of the authors, at the same time keeping as a references the final outcomes of the research.

designed and implemented in support of local actors to fill in the knowledge gaps, while coping with present urgent issues. "Boa_Ma_Nhã, Maputo!" research project embraced all these challenges by proposing a multi- and inter-disciplinary approach to tackle the development of the growing peri-urban environment of the City of Maputo in an integrated way, overcoming the traditional sectoral approach, and considering the interdependencies between issues such as migrations and demographic trends, unplanned urban growth, food and water security, climate change and natural hazards, local economic patterns (formal and informal), land tenure, cultural diversity, mobility and infrastructure.

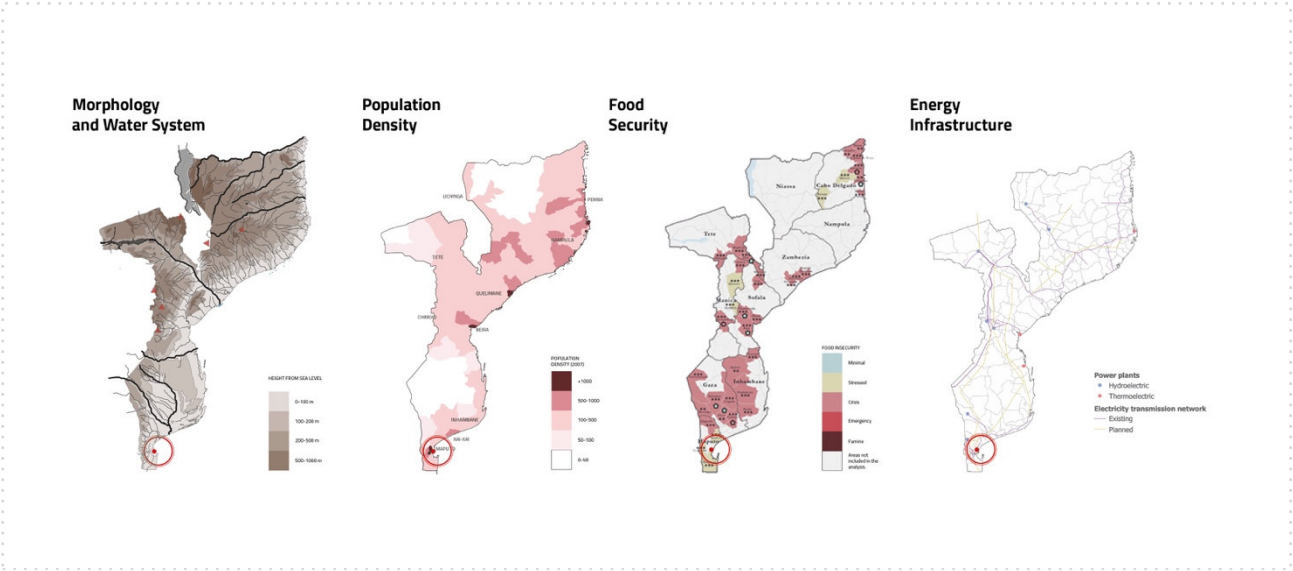

Figure 1. Locating Maputo. Main geographical framework in relation with national population density, climate and infrastructure networks. Source: Mo.N.G.U.E. Polisocial Award 2016.

More specifically the project aims to:

- Contributing to Pimi project[4], in order to fill the knowledge gaps and co-producing new knowledge in support of future research and planning activities, with the aim of overcoming rational-comprehensive/technocratic planning perspectives;
- Testing an integrated and replicable methodological approach to produce specific guidelines to support decision makers dealing with the challenges of sustainable development in fragile contexts of the Global South;
- Verifying the methodological approach through a locally relevant pilot project, involving local actors and investing in education and local rural entrepreneurship with the aim of producing measurable impacts.

[4] "Programa de Investigação Multisectorial Integrada (Pimi) Estudo para a Promoção do Desenvolvimento Territorial Integrado da Região de Boane, Moamba e Namaacha", a project initiated by FAFP, Mondlane University and Aics Maputo. See the "Acknowledgments" section for more details.

The project gives particular attention to the Water-Energy-Food (W-E-F) Nexus, considering the potential evolution of the agriculture sector, backbone economy of the area, and the whole food cycle and its multiple environmental, economic, social, and cultural implications. The project also assumed the UN Sustainable Development Goals (SDGs) (United Nations, 2015) and the UN-Habitat framework for urban-rural linkages as main cultural and policy-oriented framework and reference (UN-Habitat, 2017).

An Integrated Methodological Approach: Building a Common Research Ground

Since the early research operations performed by the "Boa_Ma_Nhã, Maputo!" team, multi- and inter-disciplinary methodological approaches have been specifically designed and implemented, with the aim to integrate a transcalar and multi-sectoral planning framework for the study area (Smith and Jenkins, 2015). The research team includes experts in physical planning and urban design, governance analysis, landscape design, sociology, civil, hydraulic and environmental engineering, energetic engineering, electronics and information engineering, combining hard and soft sciences. The general methodological approach proposed by the project includes both qualitative and quantitative multi- and inter-disciplinary methodological approaches, and it has been articulated in remote and on-site research activities. A key research operation has been the spatialization and representation of the collected data (i.e.: demographic trends and urban growth, land cover and land uses, food production patterns, climate data, hydrographic systems, energy networks and resources, etc.) into synthetic cartographies, which are presented in this essay, to be a common ground to visualize correlations among different phenomena and conceptualizations. The team initially worked mainly within a GIS environment, combining information from a variety of international (institutional or independent) databases - such as, among many, Global Forest Watch and WorldPop - and qualitative / quantitative data from national authorities such as the *Centro Nacional de Cartografia e Teledetectao* (Cenacarta), the *Instituto Nacional de Estatística* (INE), and local authorities. The project team also adopted Participatory Action Research methods, which emphasizes the co-generation of knowledge between researchers, the projects partners, interviewees and other actors to implement and assess the result of the research process with the academic / scientific community of reference and with the local stakeholders.

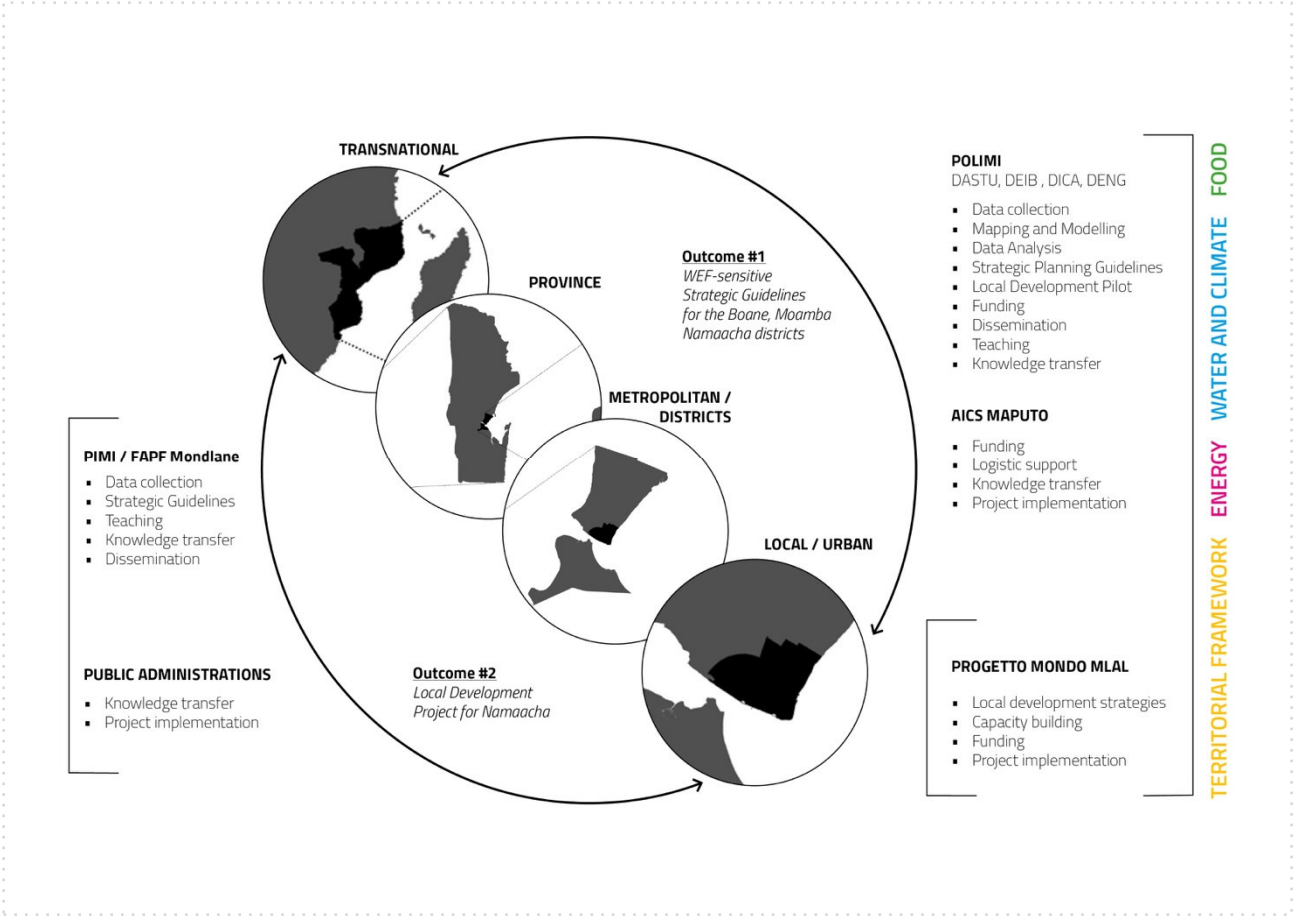

Figure 2. Research operations, actors and territorial scales. Source: Elaboration by "Boa_Ma_Nhã, Maputo!" team (A. Buoli), 2019.

Transcalarity: setting a telescopic framework of correlations

Along with the relevance of using an integrated methodological approach to deal with the complexity of the challenges mentioned above, the research project adopts a trans-scalar territorial perspective on the Maputo Metropolitan Region. In particular, it is relevant to stress the inconsistency of existing administrative boundaries in relation to the most important transcalar and cross-boundaries relational systems impacting the territory of study[5], and in particular the three districts of Boane, Moamba and Namaacha, such as:

- the transnational scale of the Umbeluzi, Incomati and Maputo water Basins, of the cross-border trade along the Maputo-Johannesburg Corridor, and of the existing and planned natural protected areas between Mozambique, South Africa and eSwatini;
- the national and macro-regional scale of mobility infrastructures and energy production and distribution networks;

[5] In administrative terms and for the purpose of demographic analysis, the Province of Maputo does not include the City of Maputo *(Cidade de Maputo),* that represents a different territorial unit.

- the administrative interplay between the provincial and district level at which the main public services and facilities are managed and provided to citizens, as well as the scale of the metropolitan region of Maputo;[6]
- the local and neighbourhood scale of everyday socio-spatial practices.

Working in this trans-scalar and fragmented territorial setting represents a main productive challenge both in methodological and epistemological terms, and a testbed for the development of innovative trans-disciplinary research tools. Among them, maps have a potential crucial role. Existing planning tools can rely on scarce, borders-limited and sectoral cartographies, unable to play a role as facilitating tools to assist decision making processes. "Boa_Ma_Nhã, Maputo!" includes an cartographic effort aims at re-composing the mosaic of the current planning tools in force in the study area, visualizing and investigating potential synergies, conflicts and emerging issues. Moreover, layering this mosaic with the transdisciplinary data-visualization produced within the assessment phase of the project, is meant to further improve the contribution to local territorial authorities and the definition of metropolitan frameworks of cooperation.

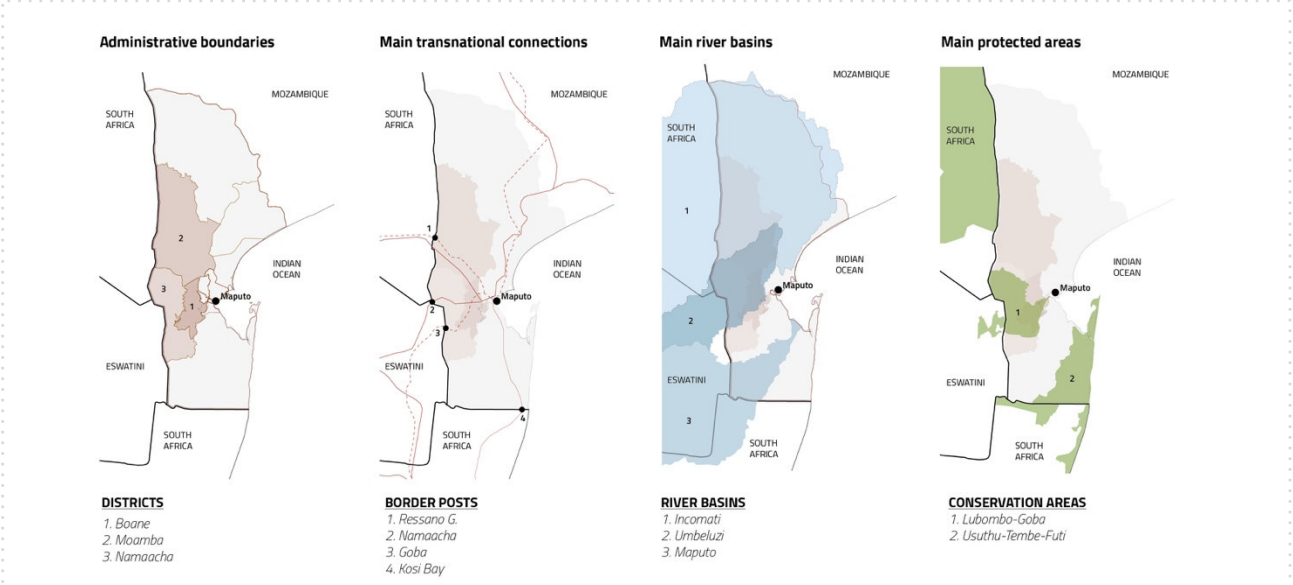

Figure 3. Transnational research framework: administrative boundaries, border posts and main connections, river basins and protected areas. Source: Elaboration by "Boa_Ma_Nhã, Maputo!" team (A. Frigerio), 2019.

[6] The so-called "Greater Maputo" is a still undefined territorial entity which includes Maputo City (excluding Inhaca), Matola City, the eastern portion of Boane City, and the southern half of Marracuene District (Jenkins, 2012; Macucule, 2016).

In accordance with the aim of overcoming the locally diffused rational-comprehensive/technocratic planning perspectives and their limits, the project roots its methodological approach in the systemic, metabolic and integrated framework proposed by the Water-Energy-Food (W-E-F) Nexus, keeping together different scales and disciplines. The W-E-F Nexus approach, embraced by Fao (Fao, 2014) and other important international organizations, has undergone different conceptualizations, according to scope, objectives and understanding of drivers. However, the conceptual framework that systematically links natural environment and human activities through trade-offs and synergies is a crucial lens to investigate the complexity of territories and to set more integrated and cost-effective decision-making and planning processes by challenging existing borders, policies and procedures at the various scales.

Looking at the Maputo Metropolitan Region and its Province and the urban-rural dynamics pushed by climate-change and socio-economic drivers, the W-E-F appears to be a crucial conceptual and methodological perspective to understand the current conditions of this territory and to properly plan its future development accordingly with local resource availability and needs. The increasing competition, observed in the study area, for resources such as water, energy, agriculture, fisheries, livestock, forestry, mining, transport and other sectors is determining impacts for livelihoods and the environment that are difficult to be predicted and controlled. In addition, the lack of a clear governance framework to implement effective W-E-F and sustainable development policies in the province appears to be one of the main obstacles towards an integrated vision for these territories.

Maputo Metropolitan Region: an unbalanced territorial growth

Mozambique's capital city, Maputo, and its province are located in the southern part of the country on the east coast of Africa. National boundaries overlap with geographical characters that shape the province and its landscape. In particular, the Lebombo Mountains, a long narrow mountain chain, range with volcanic origins, stretch north-south separating the Kaapvaal Craton (South Africa and eSwatini) from the sedimentary basin of Southern Mozambique, setting a natural border. Maputo Bay, where the three main rivers of the province (Umbeluzi, Incomati, Maputo) reach the ocean, is the most relevant geographic feature in the region. It forms a valuable harbour, accessible to large vessels at all seasons of the year, and was thus perfect for European traders to settle, kicking off Maputo urban history (Jenkins, 2012). The city has grown for two centuries as one of the most important port cities in Eastern Africa, especially thanks to the convenient connection with Johannesburg and the Gauteng's region mining industries. Today, the city has crossed its

administrative limits, merging with Matola, to host more than 2 million people, a number that has doubled in the last ten years (INE, 2018).

	2007	2017	Variation % (2007-2017)
Boane	102.457,00	210.498,00	**105,45%**
Moamba	56.746,00	83.879,00	**47,81%**
Namaacha	41.954,00	48.933,00	**16,63%**
Magude	54.252,00	63.691,00	17,40%
Manhiça	192.638,00	208 466,00	8,22%
Marracuene	157.642,00	230.530,00	46,24%
Matutuíne	37.239,00	44.834,00	20,40%
Matola	672.508,00	1.616.267,00	140,33%
Maputo Province	**1.205.709,00**	**2.507.098,00**	**107,94%**
Maputo City	1.120.360,00	1.080.277,00	- 3,6%

Table 1. Evolution of the population in the Maputo Province.
Source: Elaboration by "Boa_Ma_Nhã, Maputo!" team (A. Buoli and A. Frigerio) based on INE (2018), República de Mozambique / Ministério da Administração Estatal (2014a,b,c), Maputo Province (2017).

Available data from the WorldPop database for 2003 and 2013[7] show an increase of the urbanized areas along the northern axis between Maputo and Marracuene, southward close to Boane and along the main infrastructures and rivers in the province, towards the inlands and the borders with South Africa and eSwatini. Sprawling low density patterns are rapidly consuming land and the Greater Maputo is expanding over agricultural fields and forests, concentrating urbanization around the bay and along the main infrastructure lines and rivers, while the rest of the province is mostly non-urbanized nor cultivated and characterized by natural landscapes. Differentiated growth rates characterize the Greater Maputo Metropolitan Region and the rest of the province. Macucule (2016, p. 203) refers to this territory as "a continuous urbanization, a proto-metropolisation (...)" and synthesizes the main socio-economic dynamics which are shaping it: "the increase in the household income and in the use of cars, stimulating the option to increasingly live away from the centre (in Matola Rio, Boane and Maracuene), the large and multinational industries (Mozal, large retail and industrial markets), the increasingly strong connection of the local markets with South Africa" (*ibidem*). Additional factors of *metropolisation* are related to "international migration of people and capital linked to the advent of mineral resources in Mozambique and strong real estate investments (housing, commerce and services) in the centre which, together with the construction of the new ring road, are increasing the polarizing potential of the city of Maputo" (*ibidem*). Direct

[7] Data from: European Commission, Joint Research Centre (JRC); Columbia University, Centre for International Earth Science Information Network - CIESIN (2015).

observations in different areas of the province highlighted a punctual and discontinuous distribution of settlements and small villages along the main roads among small semi-urban centres, the railway lines, and the (major and minor) rivers of the province: a combination of dispersion and agglomeration factors of urban activities (*ibidem*, p. 205) seems to be at play with different degrees and outcomes.

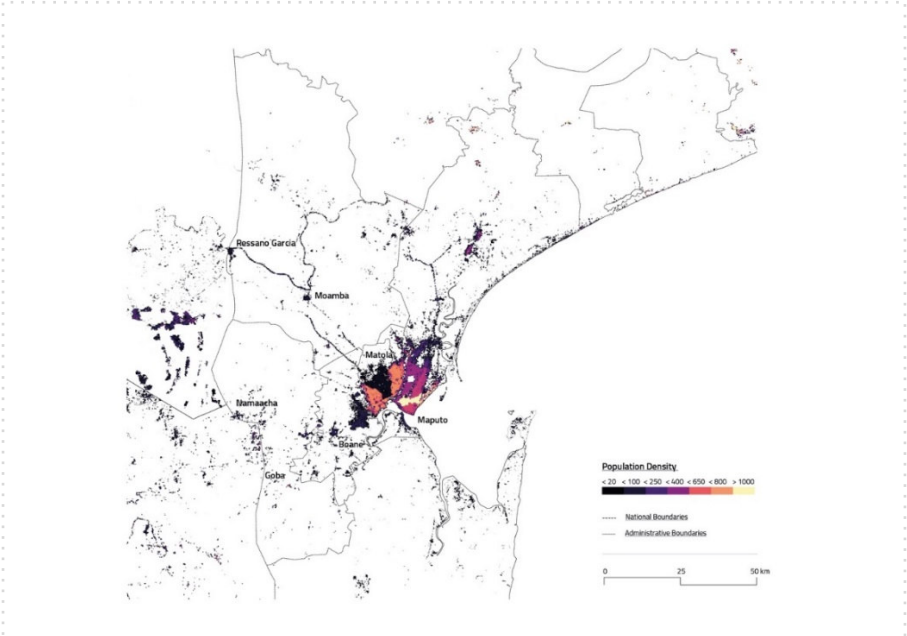

Figure 4. Density of Population (2015). Source: Elaboration by "Boa_Ma_Nhã, Maputo!" team (A. Buoli and A. Frigerio) based on European Commission, Joint Research Centre (JRC); Columbia University, Centre for International Earth Science Information Network - CIESIN (2015).

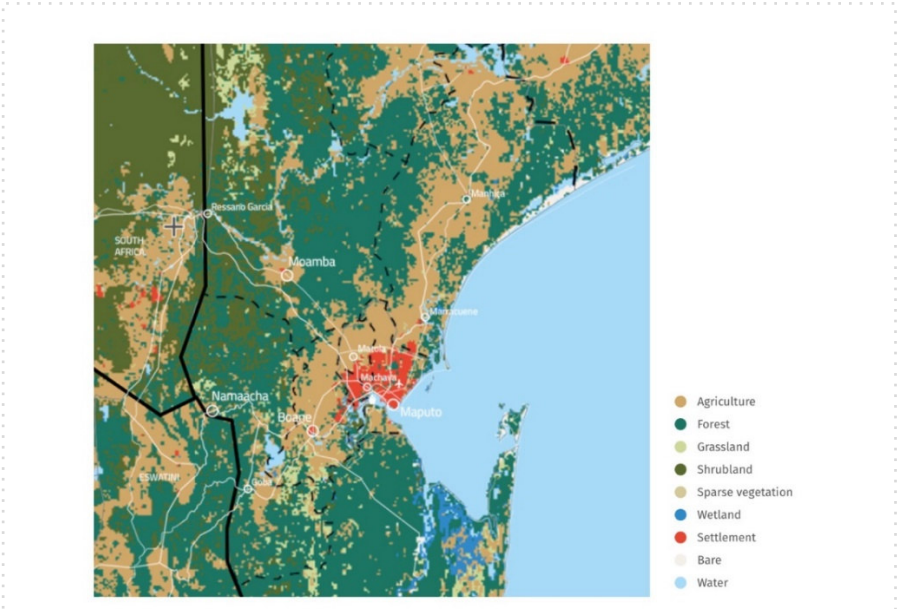

Figure 5. Land Use. Data © ESA Climate Change Initiative - Land Cover led by UCLouvain (2017). Source: Elaboration by "Boa_Ma_Nhã, Maputo!" team (A. Frigerio and A. Buoli) based on Global Forest Watch.

Processes of urban dispersion appear to be related to both structural conditions – also due to the administrative configurations and a (weak) territorial governance system in place – and the acceleration of demographic dynamics, especially in relation to the increase in the average income of households that has been promoting urban sprawl with consequent territorial fragmentation (*ibidem*, 206-207). At the same time, the main public (social and cultural) services and facilities – and therefore the highest degree of urbanity related to their concentration and interaction – are mainly localized in the city of Maputo (and especially in the *cidade de cimento,* the urban core of the city) or in the (medium and small) urban centres of the province (Jenkins, 2012, p. 24).

Moreover, rural-urban migrations are increasing. Most of the rural population rely on subsistence agriculture, but climate change and production costs are affecting the sustainability of traditional farming. Food security, in fact, is one of the most critical issues for Maputo's future, with most of the food consumed in the city being imported from abroad, according to more or less formal dynamics (Piscitelli, 2018). Growing food in the province is getting more and more difficult due to the scarce fertility of soils and to the lack of water caused by climate change, governance problems, water competition and absence of infrastructure.

The presence of foreign investors in agriculture is limited, but they get the best lands and the scarcely available water to grow water intensive cash-crops for export. Local entrepreneurship in agriculture, instead, is very limited, even because of the difficult accessibility of rural population to markets and services. Scarce connectivity across the province, depending on the limited density of its road network, isolates the majority of rural populations living further than 2 km away from any classified road. Fuel has a high cost, making mobility, mechanization and energy access another crucial challenge. In this framework, especially for the rapidly growing young generations, migrating from rural areas to the capital city seems to be the only choice, increasing the demand for the already critical offer of urban services and basic infrastructure, and thus abandoning rural and natural landscape to a socio-ecological desertification.

Food (In)Security, Water Competition, Energy Access and main Environmental Challenges in the Boane, Moamba and Namaacha region

Agricultural production between subsistence, intensive exploitation and the irrigation gap

Agriculture is the main economic activity in Mozambique providing income for more than 70% of the population, contributing by 31,8% to Mozambique's gross domestic product (GDP) and absorbing 81% of the total work force (World Bank, 2015). However, food security is a crucial issue for the development of the country.

The agricultural sector is mainly dominated by smallholder farmers, using family labour (99%), that practice subsistence rainfed agriculture in plots ranging from 0,5 to 1,5 ha (World Bank, 2015). They account for 95% of the country's agricultural production and produce mainly staple food crop production (maize, pigeon peas, cassava and rice) for household consumption. The remaining 5% of agricultural production is carried out by about 400 commercial farmers, mainly producing cotton, cashew, tobacco, sugar cane, coconut, sesame, soybean and fruit.

Mozambique is regarded as having great potential for agricultural production. In fact, even if the agricultural area covers 63,5% of the country area (78,6 Mha), less than 12% is used for a total of 5,7 Mha, mainly harvested with banana (31,8%), maize (18,6%) and groundnuts (6,9%). Furtherly, irrigation could potentially involve about 3 million hectares in the country, but currently only 90.000 ha are irrigated (De Sousa et al., 2017). Traditional irrigation system including furrow or surface irrigation are the most widespread thanks to the low input required in terms of energy compared to pressurized systems. Since the 60s the harvested area has doubled with a sharp increase after the year 2004 (Faostat, 2019). Current crop yields are much lower if compared to European countries and are also lower than the majority of sub-Saharan countries (Faostat, 2019). The highest increases in crop yields are registered for potatoes, onions and tomatoes, crops that also see a rapid increase in harvested areas (Faostat, 2019). Previous studies highlight how Mozambique's low yields are mainly due to a lack of irrigation water and to the fact that the country's soil is nutrient-poor (Muller et al., 2012). In the country less than 2% of total agriculture is currently (2010) irrigated (Aquastat, 2019), mainly with traditional irrigation systems. The majority of smallholders have limited inputs, and yields are generally low because of difficulties in accessing credit and markets. Furtherly, lack of refrigerated, logistic and infrastructure aggravated the low agricultural production.

The situation in the southern regions is furtherly worsened by a lack of nutrients in soils, reducing the crop yield even more. Thus, the agricultural sector is highly vulnerable to shocks, extreme events and market prices. Therefore, smallholder agriculture can be vulnerable and unsustainable in the long term due to low yields, labour-intensive technologies, and exposure to climate shocks (Silici et al., 2015).

Boane

About 35.000 ha are harvested in Boane district each year, mainly for vegetables, bananas and citrus of which 7.000 ha are irrigated (SDAE, 2011). Smallholder farmers usually have less than 1ha each and still practise subsidence agriculture with low inputs and consequently low yield. Farmers complain about scarce soil fertility and the too high cost of fuel, however the *Centro de*

Investigao e de trasferencia de tecnologias Agricola de Umbeluzi organizes courses for them, both devoted to agricultural practices and livestock. Furtherly, it is in the intention of the government to promote the use of local seeds and organic fertilizers and to provide the most potential areas for agriculture with electricity. Livestock in the district is mainly devoted to cattle, sheep, pork and poultry (egg and meat) (SDAE, 2011). In the last years, we are assisting to a restriction of livestock due to a reduction of rangelands due to city and villages expansion.

Figure 6. Irrigation system in Boane district. Red dots represent water withdrawal for irrigation purposes. Source: Elaboration by "Boa_Ma_Nhã, Maputo!" team (D. D. Chiarelli) based on information provided by the Instituto Nacional de Irrigação, Ministério da Agricultura e Segurança Alimentar.

Moamba

Out of about 200.000 hectares potentially suitable for agriculture, in Moamba only 20% are currently harvested mainly by smallholder farmers (<1,5 ha). Specifically, 21.630 ha are rainfed and 8.427 ha are irrigated (Cenacarta). Soil fertility in Moamba district is very low and the climate is dry with low precipitation. The main harvested crops are maize, nuts, beans, sugarcane and tubers (potatoes and cassava) (SDAE, 2011). Once a year there is a local peasant fair, while normally the production is sold in the capital market. More than for agriculture, the area of Moamba is very

exploited for livestock. In fact, more than 60.000 ha are used for livestock production: Moamba is the second most productive district in the Province of Maputo with 52.000 beasts.

Namaacha

Vegetables, maize, nuts, tubers and bananas are the main crops harvested on 14.792 ha rainfed and only 1.986 ha irrigated (SDAE, 2011). The district of Namaacha, however, sees in fruits, vegetables and poultry production a way forward for the next years. Every year, during the sowing period, courses to farmers are provided in order to help them in field managements and seeds choice. Farmers usually harvest small pieces of land (i.e. < 1 ha) and complain about aridity, but also for parasites that kill crop production. The extension services in the district have 4 extensionists and 1 supervisor who assist about 2.600 producers (836 men and 1.764 women) and 39 associations (1.015 members), of which about 29 are legalized. From 2011 the association Hanhane of Machauatimuca manages an irrigation system of 10 ha with the possibility to enlarge it in the future. The great potential of Namaacha agriculture is only limited explored by few farsighted entrepreneurs that recognize in organic fruit production and sophisticated irrigation systems (i.e. drip irrigation system in greenhouse) a way for running their business, as for the case of a strawberry farmer that is now covering the demand of three supermarkets in Maputo (Figure 7).

Figure 7. Strawberry production in Namaacha. Photo by A. Frigerio (2019)

Throughout the region, banana and sugarcane are the two main crops production carried out by foreign investors. Examples of those investments, mainly by South African companies are Bananalandia (located in Boane district) and Agrisol (located in Moamba district - data collected through fieldwork). Both sugarcane and bananas are crop intensive plants whose crop water requirement range around 12.000 – 13.000 m3/ha, and they require irrigation during the dry period. Specifically, our research shows how only about 50% of the water demand is supplied by rainfall, while the remaining is provided with irrigation, mainly sprinkler systems. Those fields are also receiving high input in terms of nutrients (i.e. fertilizers) and pesticides in order to maximize the profit and the production, mainly devoted to external markets.

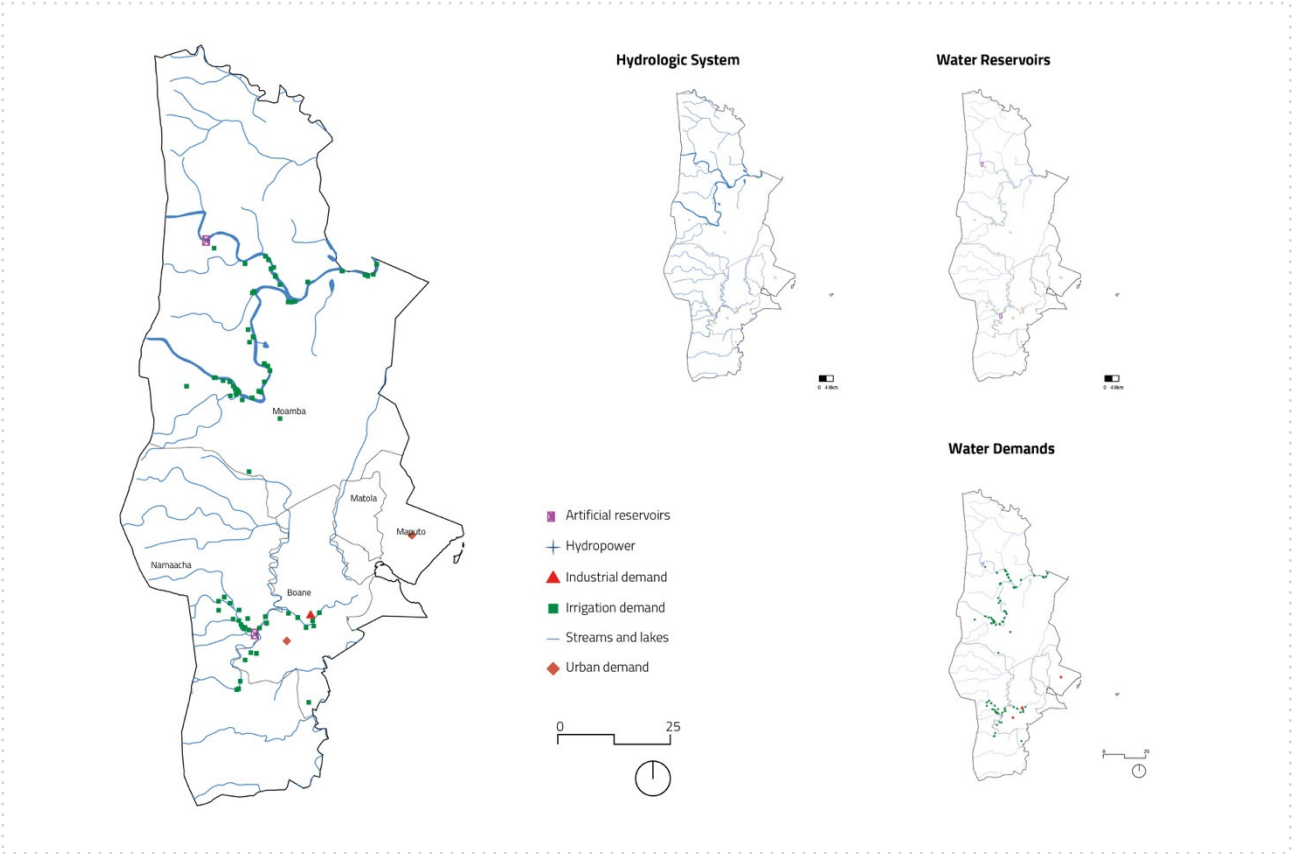

Figure 8. Hydrologic System, Water Reservoirs and Water Demands in the Boane, Moamba and Namaacha districts. Source: Elaboration by "Boa_Ma_Nhã, Maputo!" team (A. Amaranto), 2019.

Dealing with Water Competition: between Scarcity, Weak Management and Climate Crisis

The main source of water supply for urban, industrial and agricultural uses in the metropolitan area of Maputo, including the three districts of Boane, Moamba and Namaacha is the transnational Umbeluzi water Basin, extended across Mozambique, eSwatini and South Africa.

The main reservoir of the basin for the area is the Pequenos Libombos Dam, in Namaacha District but climate change and water competition are reducing water availability, threatening water

security. There are two major dams in the Umbeluzi river: the Mjnoli Dam (152 Mm3) and the Pequenos Libombos Dam (382 Mm3). Mjnoli was built in 1978 for securing water supply for the sugar-cane plantations in eastern eSwatini, while Pequenos Libombos was constructed in 1987 with the goal of ensuring urban water supply for the city of Maputo. A percentage of the releases from Pequenos Libombos is also used for agricultural and industrial purposes

The second relevant source of water in the province is the Incomati water Basin, that will soon contribute to Maputo's urban water supply thanks to new infrastructure developments on Corumana Dam, now exclusively used for energy production. The new dam Moamba Major, now under construction, will also provide water for agriculture and energy production. The *Administracão Regional de Ãgua* (ARA) *Sul* is the water agency responsible for the river basins in southern Mozambique. Considering the fundamental role covered by the Umbeluzi River for the Maputo domestic water supply, ARA-Sul is strongly involved in hydrological modelling, flood management and forecasting. It is also responsible for the operation of the Pequenos Libombos Dam.

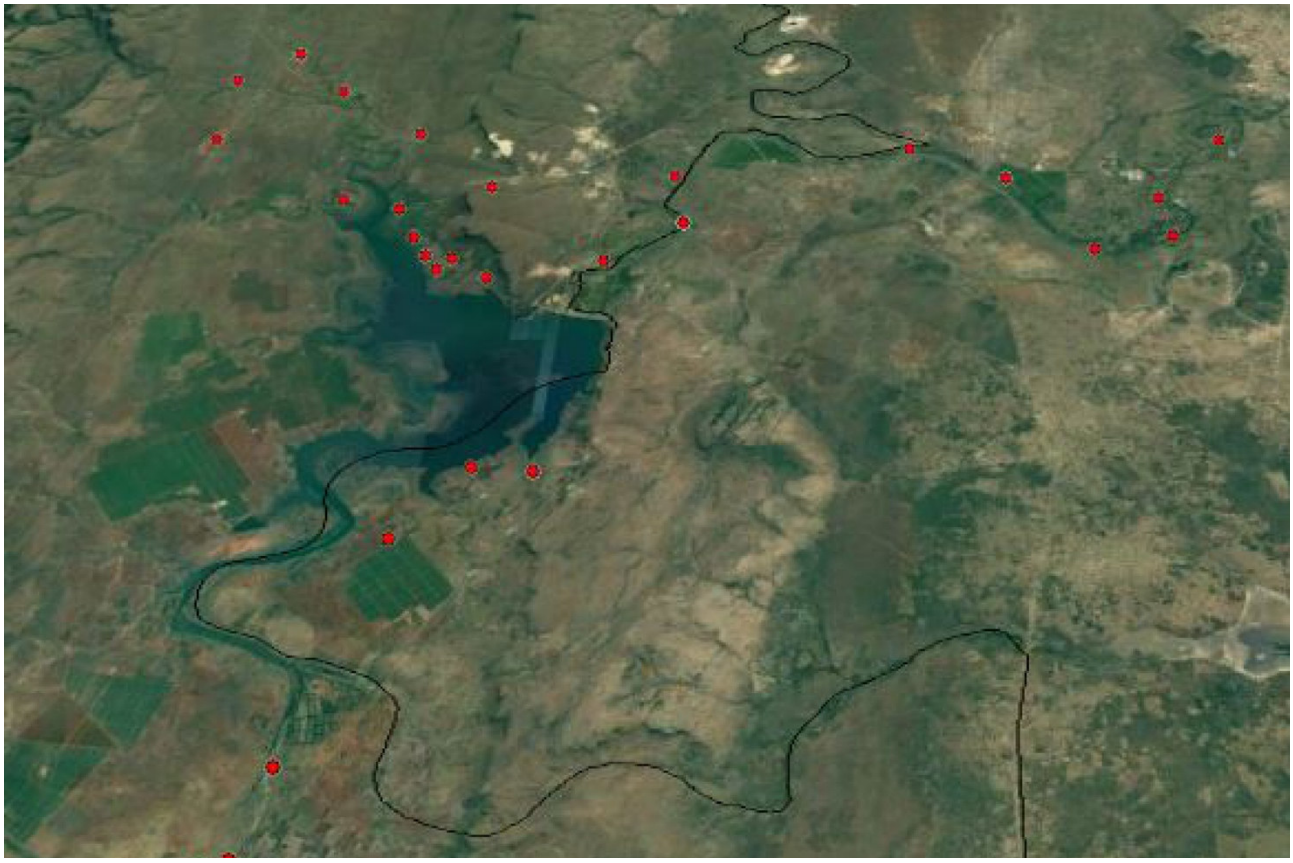

Figure 9. Pequenos Libombos dam water withdrawal for agricultural purposes. Source: Elaboration by "Boa_Ma_Nhã, Maputo!" team (D. D. Chiarelli), 2019.

Research conducted in remote and on-site revealed the persistence of a water-related crisis during the last 5 years that has driven local authorities (in particular the Maputo Regional Water Company - AdeM) to reduce "the water supply to the Greater Maputo Metropolitan Region, the satellite

industrial suburb of Matola and Boane district after a prolonged drought which started in March 2015 affecting Mozambique and other parts of southern Africa" (APANews, 2016)[8].

Namaacha is the only one among the district located upstream the dam. Therefore, the water supply for the district is not regulated by the management of the reservoir, but only depends on the Mjnoli Dam (which however usually releases enough water through the year). The main limitation for water distribution in the district is represented by technological developments: the pipeline network reaches only a small portion of households, and it is often required for people to walk to the city well or to the Umbeluzi river for water supply.

The three districts of Maputo, Boane and Moamba are the primary beneficiaries of the releases from the Pequenos Libombos dam, which was initially built solely for urban water supply. The development of agriculture and industries in the area did not change the water supply priorities: whenever a water shortage occurs, agriculture is the primary sector affected, followed by industry. In recent years, the World Bank founded a project for the expansion of the water distribution network in the city.

Focusing on agriculture, in the studied areas approximately 70% of the maize water requirement, the most widespread crop in the country, is satisfied by precipitation during the wet season. In the district of Moamba water gap is higher: only 67% of crop water demand is satisfied by rainfall, while in Namaacha we reached 72,3% (Figure 10).

A more detailed analysis at a monthly scale during the dry period is however necessary to assess impacts of water withdrawal on the ecosystem and water security of local population. Currently, there are almost 300 irrigation schemes in the three districts, covering more about 6.500 ha, mainly for horticultural, maize, sugarcane and banana. Irrigation schemes are mainly possible when local farmers organize themselves in cooperatives or associations, or in large-size fields of foreign investors, mainly devoted to banana and sugarcane plantations, while only a few are used by small-scale farmers. Detailed maps of irrigation are provided by the national irrigation service (INIR) (Figure 11).

[8] Retrieved from: http://apanews.net/en/pays/mozambique/news/mozambique-climate-change-drought (Last accessed 29.01.2020)

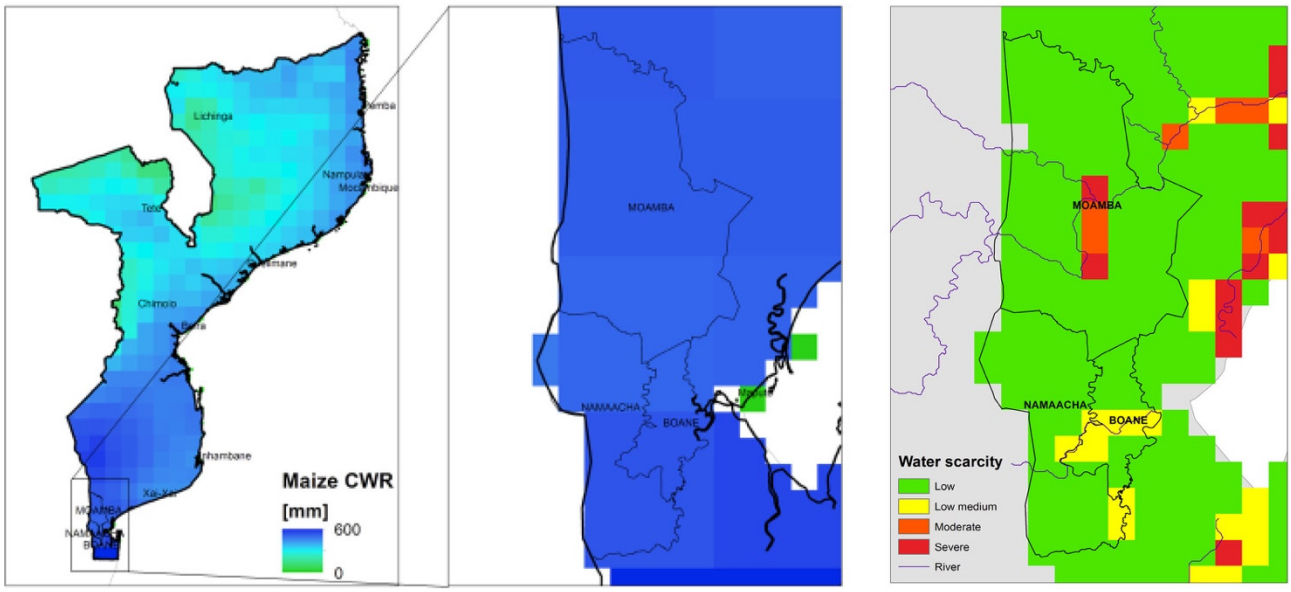

Figure 10. Crop water requirement and rainfall water required by maize production in the country and in the three districts / Water scarcity map. Source: Elaboration by "Boa_Ma_Nhã, Maputo!" team (D. D. Chiarelli), 2019.

Aside cash crops, as bananas and sugarcane mainly harvested by foreign investors for which water is properly and continuously provide, small farmers usually survive thanks to rainfed agriculture. Figure 11 reports the location of irrigation scheme in the three districts. They are mainly widespread in the area of Boane, along the Umbeluzi river, that represents an important area for the provision of food during the dry season. By conducting interviews with sellers at the local markets in Namaacha during the dry period (August-September) it was clear how products sold come from the area of Boane, where the closeness with the Umbeluzi river allows farmers to have a double cropping season, that is impossible otherwise. Thus, improving irrigation system is a necessary strategy in order to increase crop production of local farmer ensuring a double cropping during the year.

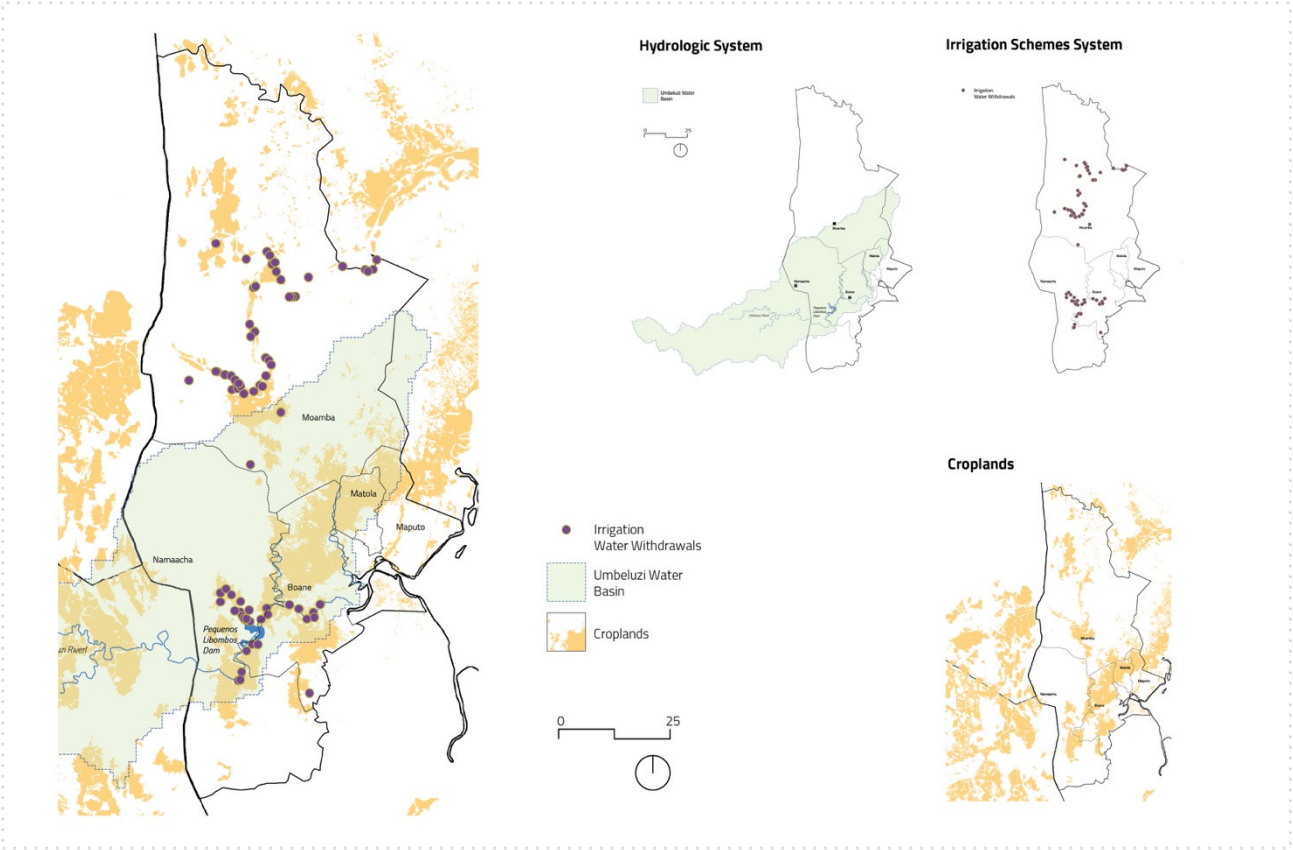

Figure 11. Agriculture and food production in the Maputo Province: a. hydrologic system, b. irrigation schemes and c. croplands in the Boane, Moamba and Namaacha districts. Source: Elaboration by D. D. Chiarelli based on high resolution cropland map (Thenkabail, 2013) and information provided by the Instituto Nacional de Irrigação, Ministério da Agricultura e Segurança Alimentar.

Energy Production and Access: Competing for Resources overlooking Self-Sufficiency and Renewables

More than 75% of the national population lacks access to electricity but this value dramatically increases in rural areas, reaching almost 95% (World Bank, 2016). Access to electricity is also strongly dependent on the region in Mozambique, with an alarming unbalance from northern and central provinces (around 17%) to southern (56%) (Electricidade de Mozambique, 2015). The Maputo area in particular is the most developed region in the country in terms of electricity access. According to the EDM data, 91% of the population living in the capital was connected to the national grid in 2015, while in the surrounding districts, this value decreases to 79%. These data suggest that 100% of the population in the Great Maputo will soon be reached by the national grid. According to the 2007 census data (INE, 2007) in the Maputo Province, 29% of the households reported electricity to be their main source of energy supply. In the same year though already more than 35% of the population was connected to the grid. If we compare this 6% difference with the absolute numbers in terms of population, this means that more than 15 thousand households in the

area preferred other energy sources to electricity. Reliability of the grid represents an issue in all sub-Saharan Africa, since it critically affects economic development. IEA (2014) reported that local SMEs may lose up to 25% of annual sales due to electricity outages. In terms of energy infrastructure, currently the major power station located in this territory is the Corumana Dam, in Moamba district, with a nominal capacity of 16 MW. The government though, is planning to deploy additional capacity with a diversified energy mix solution. According to Mireme master plan (Mireme, 2018), three 30 MW solar projects will start in Boane respectively in 2024, 2032 and 2038. In Moamba, the Government planned the construction of a 110/33 kV substation, interconnected with the existing network, while Moamba Major dam project (15 MW) is expected to be operative in 2020, and a 30 MW biomass plant is currently under feasibility study. In Namaacha, in the end, a 30 MW wind farm is expected to be operative in 2027. Waiting for these new developments, hydroelectric production is still the main source for electricity, with a relevant role in the water competition framework of the region. At the same time, the need for alternative energy sources pushes informal charcoal production worsening deforestation patterns and the ecological impoverishment of local landscapes.

Possible future trends and guidelines in the food production chain

Crop diversification and organic production has been highlighted by local experts as a way to enhance small-scale agriculture in the region, improving food security. These suggestions are identified in order to provide more resilient strategies for production that is less connected with the local market of a single product and could be at the same time competitive with the production coming from eSwatini and South Africa. Thanks to irrigation and cheaper production cost, products from South Africa are sold at a lower price than the same products harvested in Mozambique, where small farmers are only able to get one unique harvest during the wet season. Improving irrigation system is a necessary strategy in order to increase crop production of local farmer ensuring a double cropping during the year. Irrigation systems are usually possible when farmers organize themselves in associations or cooperatives in order to ensure their maintenance, while the initial financial input is anyhow provided by external private companies or associations. An example is represented by the “25 de Setembro” cooperative in Boane that is currently including more about 35 farmers mainly harvesting horticultural, vegetables and maize. Improving the knowledge of local farmers is another important key point to stress. Empirical research on-site showed that agrarian schools and universities are present in all the three districts, but usually

diplomats and graduate students found working position at the local institutions more than returning back to the field, thus without a return of acquired knowledge on the ground.

Figure 12. "25 de Setembro" Cooperative in Boane. Photo by Maria Chiara Pastore, 2019.

Openings and Conclusions

Research conducted by "Boa_Ma_Nhã, Maputo" team during the assessment stage of the project, and presented in this paper, allows to define the Maputo Province and the three districts of Boane, Moamba and Namaacha as relevant testbeds in the Water-Energy-Food nexus framework. Research results show, in fact, dynamics and conditions typical of a multi-stakeholder interdependent system, where different agents compete for the use of multiple resources, e.g.: (1) food needs to be provided for a constantly expanding city, but also needs to be produced for exporting and sustaining economy; (2) water is required for irrigation of local and transboundary crops, but also for hydropower production and urban supply. In this fragile context, the existing valuable ecosystems and high biodiversity of the region are threatened by climate change and anthropic pressure. In particular, deforestation, pushed by logging for valuable timber species and for charcoal or by "slash-and-burn" agriculture, has completely changed local landscapes. Community forestry and re-

afforestation programs are promoted by the government to save the socio-ecological value of forests as poverty reduction anchors, but the long-term perspective of these initiatives make them difficult to be accepted by local populations, that rather prefer fast return activities to face daily challenges.

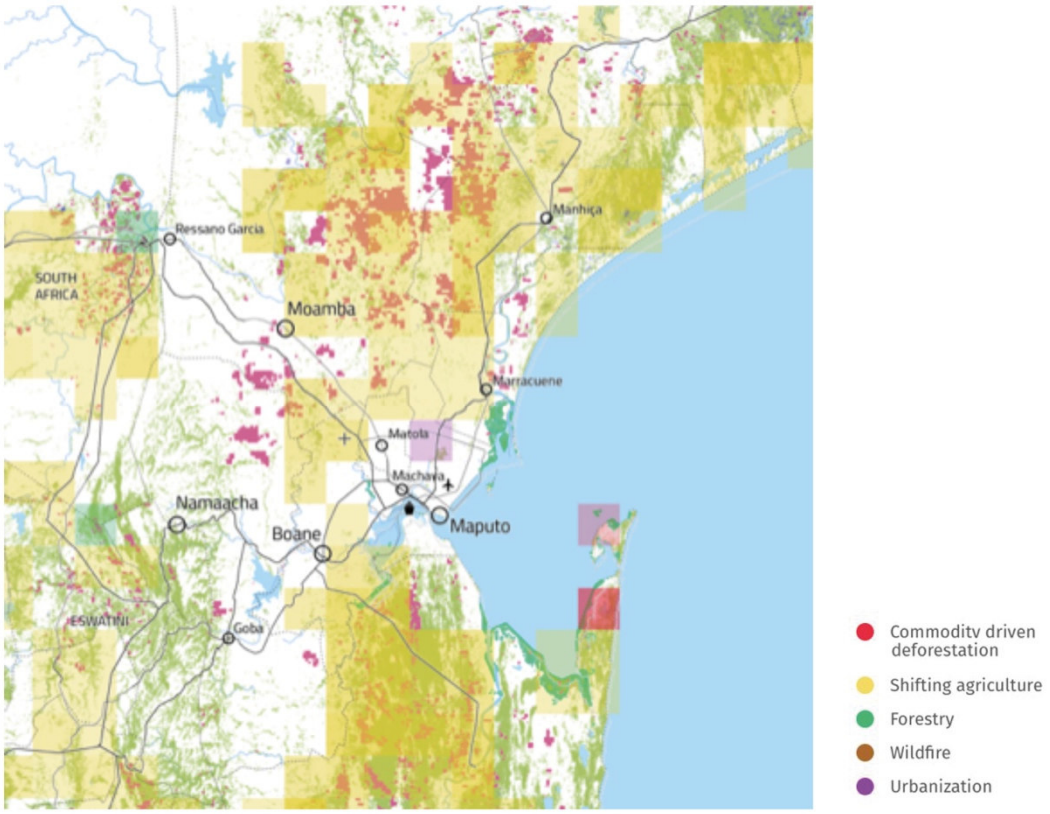

Figure 13. Deforestation. Tree cover loss by dominant driver (2001-2015). Elaboration by "Boa_Ma_Nhã, Maputo!" team (A. Frigerio and A. Buoli) based on Global Forest Watch.

At the same time, the three districts of Boane, Moamba and Namaacha are providing crucial services for the survival and growth of Maputo in terms of water, energy and food provision, as well as important educational services and ecological assets. Actions are required to increase awareness about such interdependencies and linkages among existing assets, processes and projects to facilitate sensitive decision making, people awareness and engagement into effective governance and planning tools.

The challenges and potentialities conditioning Maputo's growth and presented in this paper attest an unbalanced territorial development that needs a strategic reframing of the role of the districts neighbouring the capital's metropolitan area. The districts of Boane, Moamba, and Namaacha should understand their role and drive their future growth according to a balanced rural-urban cooperation performed in synergy among them, and in the larger framework of the Maputo

metropolitan region development, and in light of the integrated management of the basic agro and eco-systemic resources and assets in place.

Acknowledgements

The paper presents the early research results from the project "Boa_Ma_Nhã, Maputo! A study for the integrated development of the region Boane, Moamba, Namaacha". The project is funded by Polisocial Award 2018 and Aics Maputo, and has been developed with the support of the Faculty of Architecture and Urban Planning (FAPF), Eduardo Mondlane University, in the context of the "*Programa de Investigação Multissectorial Integrada (Pimi) Estudo para a Promoção do Desenvolvimento Territorial Integrado da Região de Boane, Moamba e Namaacha*" (Multidisciplinary and Integrated Research Project: Study for the Promotion of a Sustainable and Integrated Territorial Development for the Boane, Moamba and Namaacha Region). Texts and images in this paper have been developed for the purpose of an Assessment Report edited by "Boa_Ma_Nhã, Maputo!" team. In particular, the paragraph "*3.2 Water Competition and Climate Crisis*" is based on research and data analysis conducted by Alessandro Amaranto (Research Fellow at DEIB, Politecnico di Milano), while paragraph "*3.3 Energy Production and Access*" is based on research and data analysis conducted by Lorenzo Rinaldi (Research Fellow at DENG, Politecnico di Milano). The authors are grateful to the colleagues and partners in Milano and Maputo for their scientific and logistic support.

References

Andersen, J. E., Jenkins, P., Nielsen, M. (2015). "Who plans the African City? A case study of Maputo: part 1 - the structural context", IDPR, 37 (3), pp. 329-350.

Electricidade de Moçambique (2015). Annual statistical report, EdM, Maputo.

Fao (2014). The Water-Energy-Food Nexus. A new approach in support of food security and sustainable agriculture, Food and Agriculture Organization (Fao), Rome.

De Sousa, W., Ducrot, R., Munguambe, P., Bjornlund, H., Machava, A., Cheveia, E., & Faduco, J. (2017). "Irrigation and crop diversification in the 25 de Setembro irrigation scheme, Mozambique". International Journal of Water Resources Development, 33(5), pp. 705-724.

Instituto Nacional de Estatística (2008). Anuário Estatístico 2007- Moçambique. Maputo.

Instituto Nacional de Estatística (2018). Anuário Estatístico 2017- Moçambique. Maputo.

International Energy Agency (2014). WEO-2014 Special Report: Africa Energy Outlook. Retrieved from: www.iea.org

Jenkins, P. (2012). Home Space: Context Report. Danish Council for Independent Research, Copenhagen.
Macucule, D. A. (2016). Processo-forma urbana: Restruturação urbana e governança no Grande Maputo (PhD Thesis, Departamento de Geografia e Planeamento Regional). Retrieved from https://run.unl.pt/handle/10362/70410

Mueller, N. D., Gerber, J. S., Johnston, M., Ray, D. K., Ramankutty, N., & Foley, J. A. (2012). "Closing yield gaps through nutrient and water management". Nature, 490(7419), p. 254.

Piscitelli, P. (2018). Mobile Urbanity. Translocal Traders and City in Southern Africa, Planum Publisher, Rome-Milan.

Servicio Distrital de las Actividades Económicas / SDAE (2011). Relatório de Balanço das Actividades Desenvolvidas durante o Ano de 2011, SDAE, Maputo.

Silici, L., Bias, C., and Cavane, E. (2015). Sustainable agriculture for small-scale farmers in Mozambique. Country report, International Institute for Environment and Development, London.

Smith, H. and Jenkins, P. (2015). "Trans-disciplinary research and strategic urban expansion planning in a context of weak institutional capacity: Case study of Huambo, Angola", Habitat International, 46, pp. 244–251.

República de Mozambique / Ministério da Administração Estatal (2014a). Perfil do Distrito de Boane. Provincia de Maputo. Maputo.

República de Mozambique / Ministério da Administração Estatal (2014b). Perfil do Distrito de Moamba. Provincia de Maputo. Maputo.

República de Mozambique / Ministério da Administração Estatal (2014c). Perfil do Distrito de Namaacha. Provincia de Maputo. Maputo.

Republic of Mozambique / Ministry of Mineral Resources and Energy - Mireme (2018). Integrated Master Plan: Mozambique Power System Development. Final Report.

Rulli, M. C., Passera, C., Chiarelli, D. D., and D'Odorico, P. (2018). "Socio-Environmental Effects of Large-Scale Land Acquisition in Mozambique", in Petrillo and Bellaviti (2018), "Sustainable Urban Development and Globalization", Springer, Cham, pp. 377-389.

Thenkabail, P. S. (2013). Global Food Security-support data at 30 m (GFSAD30). In American Geophysical Union, Fall Meeting 2013, abstract.

United Nations (2015). A/RES/70/1 Transforming our World: The 2030 Agenda for Sustainable Development.

UN-Habitat (2017). Implementing the New Urban Agenda by strengthening Urban-Rural Linkages.

World Bank. International Economics Dept. Development Data Group (2015). World development indicators. World Bank.

World Bank. International Economics Dept. Development Data Group (2016). World development indicators. World Bank.

Websites

Aquastat / Fao (http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en) (last consultation 29.01.2020)

FAOSTAT (http://www.fao.org/faostat/en/) (last consultation 29.01.2020)

Global Forest Watch (www.globalforestwatch.org) (last consultation 29.01.2020)

INIR / Istituto National de Irrigacao (http://www.inir.gov.mz/) (last consultation 29.01.2020)

Mo.N.G.U.E. (www.mongue.org) (last consultation 29.01.2020)

Province of Maputo (https://www.pmaputo.gov.mz/) (last consultation 29.01.2020)

WorldPop (https://www.worldpop.org/) (last consultation 29.01.2020)

Acronyms

Aics	Agenzia Italiana di Cooperazione allo Sviluppo
Cenacarta	Centro Nacional de Cartografia e Teledetectao
Fao	Food and Agriculture Organization
FAPF	Faculdade de Arquitectura e Planeamento Físico
INE	Instituto Nacional de Estatística
Mo.N.G.U.E.	Mozambique.Nature.Growth.University.Education
Pimi	Programa de Investigação Multissectorial Integrada
W-E-F	Water-Energy-Food