Chapter 2
Geoinformation Technologies in Land Use Monitoring of Fast-Growing Cities for Sustainable Urban Development:
Maputo as a Laboratory for Research and Action

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ABSTRACT

To understand the territory of fast-growing cities, where there are multiple stakeholders involved, the observation of such dynamics seems indispensable to formulate and implement policies and actions based on a better understanding of these territorial systems. This chapter offers a perspective on how urban territories should be observed through geoinformation technologies that can provide a means for creating monitoring indicators concerning land use of fast-growing cities. The city of Maputo was used as an experimental laboratory for the use of geoinformation technologies in the observation, discussion, and reflection on methods for sustainable urbanism. The discussion includes the implications of the case study and possible developments to take a step forward in land use planning processes to achieve the desired socio-spatial equality.

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INTRODUCTION

Despite countless good intentions and urban development agendas, there are still many persistent issues playing an important role in the urban expansion process in developing countries, which can lead to spatial inequities and social deprivation.

At the same time, emerging issues such as climate change and migration are extending this issue and hampering the process of reconciling urbanization and sustainable development.

The United Nations World Cities Report 2016 (United Nations Human Settlements Programme, 2016) refers to specific policies and actions that can drive transformation change to leverage a New Urban Agenda. Of particular note among these is a global monitoring framework to increase the availability and usefulness of data to support decision-making, accountability mechanisms, and the capacity of countries/cities to deliver and report on the New Urban Agenda and SDGs (Sustainable Development Goals).

Moreover, the New Urban Agenda supports

"the role and enhanced capacity of national, subnational and local governments in data collection, mapping, analysis and dissemination and in promoting evidence-based governance, building on a shared knowledge base using both globally comparable as well as locally generated data, including through censuses, household surveys, population registers, community-based monitoring processes and other relevant sources."

In addition, it fosters

"the creation, promotion and enhancement of open, user-friendly and participatory data platforms using technological and social tools available to transfer and share knowledge among national, subnational and local governments and relevant stakeholders, including non-State actors and people, to enhance effective urban planning and management, efficiency and transparency through e-governance, approaches assisted by information and communications technologies, and geospatial information management." (United Nations, 2017: 40).

Concerning urban territorial planning and policymaking in general, and in fast-growing cities in particular, spatial information management through geoinformation technologies is of vital importance in the monitoring and evaluation of the planning process. The determination of ratios and indicators through spatial data makes it possible, among other operations, to quantify needs and to understand

the transformation or evolution of certain phenomena, thereby contributing to the construction of an informed planning system and building evidence-based governance.

To understand the urban territory, where the stakeholders of its transformations are multiple, the observation of its dynamics seems indispensable to formulate and implement policies and actions based on a better understanding of these territorial systems. In short, observing to understand and understanding to act is an elementary element for promoting the sustainable development of cities.

Maputo, Mozambique's capital city, located in a coastal area of Southeast Africa, struggles from climate change effects, observable particularly during floods, land pressure, both from real estate investments and low-income families looking to settle where they can find a means of survival, and from the lack of effective integrated planning, based on a monitoring framework enabling public authorities to obtain periodic assessments of the various dimensions of urbanization and their impacts.

In this context, this chapter provides a perspective on how urban territories should be observed through geoinformation technologies that can provide the means for creating monitoring indicators concerning the land use of fast-growing cities. The city of Maputo has been used here as an experimental laboratory for the use of geoinformation technologies in the observation, discussion, and reflection on methods for sustainable urbanism.

The chapter is structured into two sections, as follows. The first section provides an overview on geoinformation technologies in urban land use monitoring processes, discussing: i) the concepts of geoinformation technologies, land use, and urban sustainability, as well as the methods that presently provide multitemporal information about their dynamics and the repercussions that these dynamics have on sustainable urban development; ii) the evolution of technology and data to monitor dynamics; iii) the most used methods to analyze and model the current land use situation and to simulate and/or create scenarios for future evolution. It also discusses monitoring and assessment as phases of the planning process, supported by geoinformation technologies, by providing an overview of progress in the field of technology and data acquisition. To this end, examples of the use of geoinformation technologies in monitoring and evaluation processes in very different development contexts will be analyzed. Special reference is made to the notion that geoinformation technologies facilitate the transparency of processes that should distinguish democratic societies. The second section uses Maputo city as a case study to illustrate the idea that geoinformation technologies are indispensable for the analysis of many spatial processes, and are fundamental in monitoring the rapid change of land use in urban areas. Through urban planning storytelling, the new land use planning paradigm that Mozambique is aiming to achieve does not deviate from public interest, social and spatial justice, environmental sustainability, and the transparency of processes. However, it needs to take full advantage of the opportunities created by geoinformation

technologies for sustainable urban development, for more informed urban policies, and ultimately to support a more just and resilient city.

The need for new evidence on urban territorial development to support the design of urban policies has long been advocated and the observation of land use dynamics has been one of the objects of research in many cities around the world, although this is less frequent for African cities. Framed by these ideas, the chapter concludes with a discussion of the implications of the case study, and possible developments to take a step forward in land use planning processes to achieve the desired socio-spatial equality.

GEOINFORMATION TECHNOLOGIES IN URBAN LAND USE MONITORING

Concepts and Methods

Urban areas are more than just a set of buildings, streets, and people living therein. They are systems of networks and flows (Batty, 2013) and, therefore, they are spatial systems characterized fundamentally by their structure and their functioning.

Regarding structure, urban areas and cities are systems which operate on two fundamental elements: i) networks, including roads and other infrastructures (basic sanitation, water supply, and energy), which guarantee flows and, therefore, allow for a balanced urban metabolism when they are sized to respond well to demand; ii) physical distribution of functions, that is, in the planned or self-organized allocation of land use, which, as the designation implies, associates a morphology and an arrangement to each area, territory or city, resulting from a social and economic vision at a given time. Regarding the function of each land parcel, this derives from the social use and is economically referenced by an agent or group of stakeholders that transform the territory and the city. These transformations (land use, social, housing, etc.) result in dynamics, and the functioning of the systems results from these dynamics.

Understanding the urban territory, at the same time both a living space and a managed space, mainly in terms of its functioning and the inequalities generated by growth, is of the utmost importance to present and support sustainable policies for spatial and social equity.

Land use planning of urban areas, besides being a process for regulating land use decisions and providing a framework to promote sustainable urbanism, also involves the systematic assessment of the physical, social, and economic transformations arising from the implementation of a plan and emerging urban development issues.

The transition from one land use status to another is an essential indicator of urban change. Focusing the evolution of a city on the geometric and semantic changes of the smallest parts that compose it, and that are (re)produced over time, it is possible to understand, albeit partially, the dominant model of this evolution. If it is true that the evolution of a city should not be reduced to just one of its tangible aspects (the land use), it is also true that ignorance of the speed of transitions, in an explanatory framework for the change that only considers the less tangible aspects (such as culture, policies, the degree of human development, information flows, capital flows, or migratory flows, among other factors), has consequences. Most developing countries, regardless of their individual histories, which necessarily have created their differences, are commonly characterized by high levels of poverty, low indexes of education and technical knowledge, fast-growing cities, lack of investment in social needs, considerable pressure on land and natural resources due to high population growth rates, and absence of physical planning – all of this coupled with other negative discourses that place almost all these countries at the bottom of any human development ranking. In short, there is a vast portion of territories in the world with basic social requirements and an absence of planning and management procedures for rational spatial organization and justice.

Cities in developing countries are diverse and difficult to conceptualize, like any other cities. However, most of them are undergoing a rapid pace of urbanization and land use change that imperatively need meaningful, available and up-to-date data and tools to understand trends, mitigate human impacts on the natural environment and simultaneously preserve social and economic structures, and ensure quality of life.

Rabinovitch (1996: 51) argues that the ultimate goal of any land use policy is to

"affect social environmental and economic aspects so as to benefit as many people as possible, especially the most vulnerable groups – which in the context of most developing countries, constitute the majority of the population anyway."

Land use planning is one of the basic instruments that leaders of fast-growing cities have to improve living conditions – by setting the terms of urbanization, especially policies targeted at using urban land and expanding basic infrastructures and public services – as well as managing the city's physical shape.

In a context of low financial resources, and, in most cases, a conflict between the interests and strategies of the private sector, local communities, and public administration, and the difficulties in harmonizing these interests, how can the spatial discourse be changed to respond affirmatively and critically and to achieve a desirable sustainable development regarding land use?

The monitoring and qualitative and quantitative assessment of spatial-temporal transformations of land use is a fundamental step in understanding the dynamics of

the processes that lead to the alteration of urban landscapes and consequently the geographical framework of the planning actions that are intended to be triggered (Henriques, 2008).

The use of geoinformation technologies "is, for many years now, embedded in many of the stages of the planning process, in particular for data collection, data visualization (in its many forms) and modeling and simulation of the spatial objects" (Pinto et al., 2014: xiv). They are, therefore, essential tools in the planning and monitoring of land use changes in any city in general and especially in those where such fast transformations are laborious to follow.

Data from remote sensing has been used for several decades now in the systematization and analysis of land use transformation processes. Whether by the use of conventional aerial photography, or by images from satellites, or more recently from unmanned aerial vehicles (UAVs), these types of location-based data play a critical role in the production of fundamental diachronic data sets and therefore in generating developing information. Achieving sustainable development goals goes beyond the representation of land use change. Measurable indicators based on geodata can provide a relational basis for the assessment of land use planning policies and in accomplishing progress and defined targets, and can also provide inputs for the modeling and simulation of future scenarios.

The utilization of land use transformation models dates back to the 1970s, having been developed with the aim of mathematically reproducing the nonlinear dynamic relationships that characterize the spatial evolution of cities. Its use made it possible to measure, recognize, interpret, and anticipate some of the sustainability problems in cities. The need to use these models remains today and their relevance in fast-growing urban areas is considerable, as they serve as an instrument to support integrated planning strategies that provide ways of understanding urban dynamics and their consequences at the human dimensional level (Henriques, 2008).

There are many approaches to the simulation of land use changes, most of them integrated, nowadays, in software packages. Cellular Automata, Markov chain algorithm, and Artificial Neural Networks, by themselves or combined, are common approaches for modeling land use changes. Mas et al. (2014) review and discuss several methods of some of these software packages.

Geoinformation technologies are widely used in contemporary decision-making processes and are unavoidable in planning and managing urban spatial development. Monitoring and evaluation through appropriate and affordable tools are ingredients for an effective and integrated perspective on the planning and management of fast-growing urban territories.

Monitoring and Assessment

Firstly, if the purpose of planning is to seek balance among competing interests in the use of land and guarantee a sustainable future, mechanisms to provide evidence on the progress of achieving stated goals should be assured. Secondly, if geoinformation technologies are appropriate tools for data collection, data visualization, and modeling, supporting an integrated view of the territory and the human activities that occur therein, advantage must be taken of them in providing such evidence.

Indicator frameworks based on geographic data and technologies can provide clear and direct information to support urban planning and policy-making activities. Various types of indicators are recommended in a process of planning and managing land use changes in fast-growing cities, but commonly they must ensure: i) monitoring of transformation trends; ii) benchmarking through the supplying of a set of time-lapse "images" of the territory; iii) referencing different life conditions to allocate the necessary infrastructures, social amenities and utilities in a balanced way; iv) evaluation of the success and impacts of the policies, measuring the distance between the existing situation and the stated goals.

Statistical capacity is an essential component of the monitoring and evaluation processes. Lack of reliable data on the territory and its inhabitants compromises planning and the evaluation of the planning process and undermines the transparency desirable in democratic systems. However, in many developing countries, statistical and cartographic data are not so readily available. Most of it is restricted to census data and to outdated maps undertaken as part of specific development projects which were not maintained after the project was completed.

Data from remote sensing, since the launch of the Landsat program, are an important source for building indicators of land cover status and the changes that occur therein. The ready availability, the convenient temporal resolutions, and the recently improved spatial resolution of several recent sensors, combined with free and open-source software packages for data processing, have enabled a turnaround in the acquisition of land cover data. Taking the example of the Sentinel 2 MultiSpectral Instrument (MSI) data, which are open data associated with ESA open software, can be a strong argument for deciding to use Vegetation, Soil, and Water indicators, as well as land use as basic information to observe the cities at a macro-scale. These indicators are biophysical but may be used with indicators of a different nature to improve the analysis of urban territories. At the scale of the neighborhoods and of the urban fabric, the ability to discern urban features (that may include soil, concrete, asphalt, plastic, metal, wood, water, vegetation…) and their use (residential, industrial, agricultural, educational…) from satellite images requires high spatial and spectral resolution and image processing software that accounts for spectral and contextual information. However, remote sensors from satellites that supply images with sub-

meter spatial resolutions and spectral resolutions beyond the panchromatic, the three bands of visible, and near infrared, such as WorldView-3, are commercial programs and still have high acquisition costs. Images freely provided by Google, Bing, ESRI, Maxar, among others, are not suited for automated remote sensing analysis of any kind. What is extracted from the satellite image is a mere photo, which does not contain the various spectral bands of multispectral resolution satellite data. Nonetheless, when incorporated as a base map in several Geographic Information Systems (GIS) packages, this can contribute with highly detailed information on the complexity of the urban landscape inferred by visual image interpretation. Several crowdsourcing and Volunteer Geographic Information initiatives have contributed to enhancing geospatial databases around the world based on these images where OpenStreetMap and Collect Earth stand out. In Maputo, "#MapeandoMeuBairro" is an example of a non-governmental organization (NGO) that has been contributing to acquiring data on self-produced neighborhoods.

The widespread use of UAVs, due to their affordable cost and ease of handling, is also becoming an important source of urban data. "… data obtained using UAVs are useful for 3D urban modeling, i.e., buildings and urban areas, with a view intending to support large scale urbanism and urban planning studies" (Tenedório et al, 2016). Although more limited in the extent of the covered area, the assessment of the impact of a given occurrence or the obtaining of 3D information for a better understanding of a specific urban context, have much to benefit from the information collected through this technology.

According to Sawicki and Flynn (1996), the development and use of urban indicators is not always a consensual process. They argue that on the planners' and policy-makers' side, the idea of "straightforward, easily understood, and applicable to a specific program or policy" indicators opposes the academics' will for "innovative methodologies, models, theories, and complex indices for publication" not in line with the "repetitive exercise of updating yearly reports." However, if an urban observatory is preconized for a city, within the context of the functions of a university (building capacity, research, and social extension), the scope and applicability of urban research are considered and both types of indicators can be incorporated thereby contributing to the improvement of the quality of life.

Land Use Change Observatories: Tools For Spatial Planning

The need to record, analyze, and interpret the cumulative results of human action, translated into the physical expansion of cities and the emergence of new forms of urbanization and urbanity, has long been advocated (Atkinson, 2005; United Nations Development Program, 2016) and recently emphasized by the emergence of climate

change challenges (Bai et al., 2018). Means for the effective implementation of the New Urban Agenda also refer to the

"use of digital platforms and tools, including geospatial information systems (…) to improve long-term integrated urban and territorial planning and design, land administration and management, and access to urban and metropolitan services"

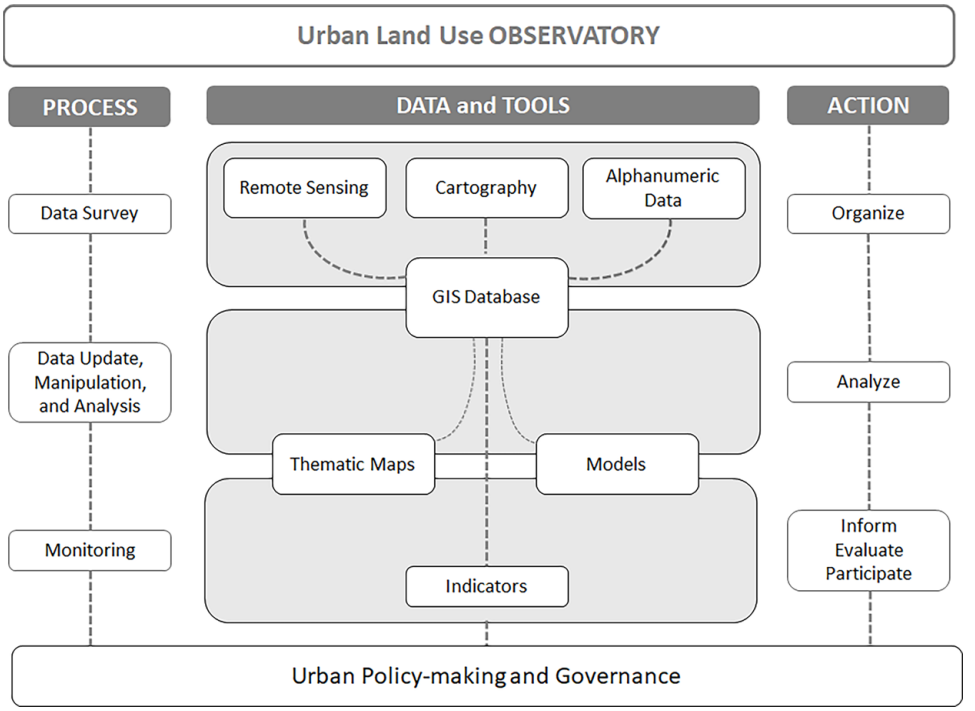
and which fosters

"the creation, promotion and enhancement of open, user-friendly and participatory data platforms using technological and social tools available to transfer and share knowledge among national, subnational and local governments and relevant stakeholders, including non-State actors and people, to enhance effective urban planning and management, efficiency and transparency through e-governance, approaches assisted by information and communications technologies, and geospatial information management." (United Nations, 2017)

Developing the city dynamics of countries often leads to irreversible consequences such as the geographical and social impact of many construction projects carried out in unsuitable areas or the generation of conflicts concerning sustainable nature between urban land uses and the various stakeholders (Jenkins, 2013). The development of observation methods, structured around geographic information, either to map the global change of territories and human settlements or to carry out spatial analysis on land use oriented towards the management of urban territories, are necessary and desirable, but should be tailored to each local reality: the availability of data and equipment, and technical capacities must be checked, in order to guarantee its usefulness, continuity, and appropriation by users.

An urban observatory implemented through the modeling of phenomena and guided by a set of indicators can show the evolution trends of the urban system over time, space, and in relation to specific objectives, thereby guiding local development (*Figure 1*).

Figure 1. Urban land use observatory model (adapted from Henriques, 2008)



The process and means of gathering and analyzing geographical information within a monitoring frame can be guided by the following questions: 1) observe why?; 2) observe what?; 3) observe how? (Henriques, 2008).

1. The urban territory is a space with different levels of organization. Understanding the city, at the same time a lived in and an administered space, mainly with regard to its functioning and the inequalities generated by growth, is an element of the greatest importance to show and support democratic policies involving spatial and social equity, in this way observing to understand and understanding to act;
2. The question of "observe what" leads us to land use as a tangible part of urban growth and the basis for deciding on the preferential guidelines for future expansions, of the conditions to be established, and of the actors within the urban economy to be elected, considering that they will be promoters of the sustainable development of the territory;
3. Urban observation currently requires technically simple means to implement, but difficult to maintain in view of the scarce resources of many developing countries. Geoinformation technologies are barely replaceable in urban contexts

where the rates of change in land use are large and very often irreversible. Local policymakers and organizations from civil society (Universities, local NGOs, national and international institutions, and other stakeholders), if working together, can share costs and knowledge to develop such an observatory. The promotion and enhancement of open, user-friendly, and participatory data platforms using technological and social tools available to transfer and share knowledge should also be considered in this context.

An urban observatory can be a cross-disciplinary project strengthening ties between different urban stakeholders (researchers, policymakers, planners, residents), producing knowledge together for different purposes.

LAND USE PLANNING AND PATTERNS OF CHANGE IN MAPUTO

Maputo city, the capital of Mozambique, is one of the fast-changing urban areas of Southeast Africa. The extremely high population growth and the consequent accelerated variation in land use, are problems of great importance in this city, due to the human and environmental repercussions that they entail.

The surrounding territory of the colonial city's core is an enormous coalescent urban area based on self-produced residential land use, which originally was not structured by any master plan. The urban growth was 'organic' and very dependent on the social and economic population conditions (migration from rural areas to Maputo) and on the political system both before and after Independence in 1975. According to Henriques & Tenedório (2010), the most important transition of land use between 1964 and 2008 was from Natural, Semi-natural, and Leisure Areas to Residential Areas (Periphery).

The territory of Maputo has been recorded by remote sensing images (aerial photographs and satellite images) since the 1960s. This has enabled the acquisition of knowledge on developing trends at a macro scale, the observation of the different urban fabrics produced over time (planed, organic, self-produced, imposed), and the modeling of the urban expansion for the near future. The spatial and temporal aspects of land use throughout five decades, as well as the model of urban development for 2011, was carried out by Henriques (2008) and was used for drawing up the municipality's master plan.

From Urban Planning In The Colonial Period To The Explosion of Self-Produced Settlements

In the early 1940s, the Municipal Council of Lourenço Marques (the former name of Maputo) started to face an effective occupation of the city surroundings with self-produced settlements compromising the expansion of the colonial city. Therefore, the idea of having a Plan for the city and its suburbs began to emerge. However, it was only in 1947 that the process of drawing up an urbanization plan started, under the coordination of João Aguiar, and in 1952 that plan was approved. Notwithstanding the distance between its proposals and real needs, the "General Urbanization Plan for Lourenço Marques" (*Plano Geral de Urbanização de Lourenço Marques*) had some of its proposals implemented, especially concerning the road network, and stressed the differences between the solutions presented and the actual situation. This plan was used until 1969 when a new plan was proposed.

During the 1960s, the city was confronted with a process of fast growth and strong pressure from the private sector, and the Urbanization Plan of 1952 was inadequate to regulate those forces. In an attempt to fill this gap, two documents were produced: an urbanization study in 1965, and the Regulation Plan of Land Occupation for Lourenço Marques Surroundings (*Plano Regulador da Ocupação do Solo nos Arredores de Lourenço Marques* – PROSALM) in 1966. Both studies tried to zone the city's expansion by defining the location for different land uses.

Under the coordination of Mário de Azevedo, the works leading to the Master Urbanization Plan of Lourenço Marques (*Plano Director de Urbanização de Lourenço Marques*) started in 1967 and were delivered in 1969. Only in 1972 was it formally approved by the Municipal Council. This plan, consisting of twenty-three volumes, was intended to be a tool for the framing and coordination of land use in the urban area and its surroundings in a malleable and dynamic manner according to the urban reality and to the perspectives that would progressively be defined, but always supported by permanent natural constraints and by the main options determining the development framework proposed (Azevedo, 1969). In respect to the definition of the land use, the Master Plan defined and mapped six main classes: i) Residential, ii) Traditional Residential, iii) Industry, iv) Retail and Services, v) Regional Equipment, vi) Tourism and Recreational Equipment, Regeneration Areas and Green Areas. Additionally, it identified twenty-two subclasses.

The Master Urbanization Plan of Lourenço Marques has been the only legal document able to regulate the urbanization processes of the whole region under the influence of the city almost down to the present day. In fact, after Independence, in 1975, several attempts were made to address urban land issues. Between 1979 and 1985, the National Institute of Physical Planning carried out a planning action that culminated in the Maputo Structure Plan. Facing serious difficulties with the

ongoing civil war, high levels of demographic growth (immigration and high natural growth rates), and a shortage of financial resources, such physical planning activity was urgent. The Structure Plan intended to be a legal tool for regulating the location of human activities and stopping informal land supply activity. It proposed three different scenarios for the city's development. However, its implementation was doomed from the start. At that time, the Maputo Council had very little awareness of the importance of urban planning. The political and administrative culture of centralization did not help. Moreover, there was no legal framework for its approval by the municipal council. This was aggravated by the absence of mechanisms for the implementation and control of development proposals. The Structure Plan was therefore never put into practice.

Later, in 1999, another attempt was made concerning land use planning in the Maputo metropolitan area. The Greater Maputo Metropolitan Structure

"covered the two municipalities of Maputo and its satellite Matola, and areas between these and the two nearest towns in Maputo province to the north and south. It hence involved three administrations, namely, two autonomous municipalities, newly elected during the course of the project, and one appointed provincial government of long standing. (…) Hence, while the structure plan proposal called for metropolitan functions to be developed for certain activities (e.g., land management and development, infrastructure planning and environmental protection), there was no way that this could be implemented for all three administrations, and only possibly for the two municipalities if they choose to form an association. In practice, it is quite likely that they will compete rather than collaborate." (Jenkins, 2000)

These failed attempts to have an instrument for urban land use management during a long period, when urban demographic growth and its consequent demand for land was critical, led to an explosion of self-produced settlements on the peripheries. In fact, this 13% of residential areas of the Maputo municipality in 1973, two years before Independence, corresponded to 41% in 2008, when the new structure plan was approved (Henriques, 2008).

The Urban Structure Plan of Maputo Municipality of 2008 was the first practical consequence of the approval of a set of regulations concerning the definition of land use strategies in urban areas of Mozambique. For the first time after Independence, the citizens of Maputo had an instrument which had been subjected to a democratic process of approval, debate, and public participation which was able to support procedures for rational spatial organization. This plan intended to be a document that illustrated the locations and the relations between geographical, natural, and infrastructural features in order to manage the evolution of the city as required and to provide a framework for decisions regarding its future development. It was not

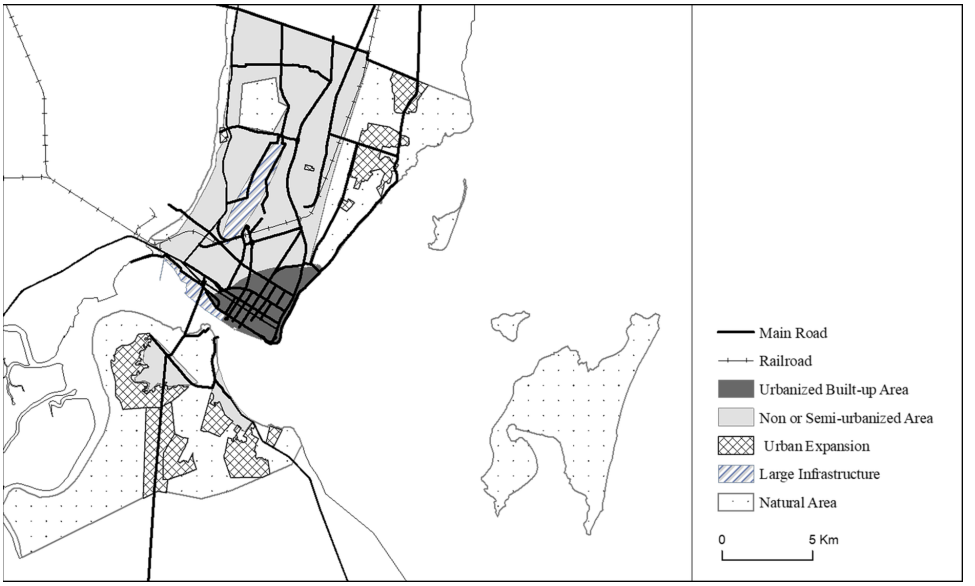
only a necessary document but a mandatory one since the legislation at that time concerning territorial planning required the preparation and the approval of spatial planning instruments by the local administration under municipal jurisdiction.

The Urban Structure Plan of Maputo was designed with the following principles of urban development in mind (consistent with the Constitution): i) the right to the city; ii) the right to urbanized land; iii) the right to adequate housing; iv) the right to environmental sanitation; v) the right to infrastructures, utilities, and urban amenities for education, health, information, and culture, sport, leisure, and safety; vi) the right to participation. In addition, with the establishment of the following priorities to achieve those principles: i) reordering of informal neighborhoods; ii) recuperation of land for social activities, services, and public amenities; iii) adequate city occupation densification; iv) reservation of areas to restore the ecological balance and to ensure environmental quality; v) establishment of the necessary conditions for mobility; vi) support for social housing construction; vii) encouragement of urban agricultural activities; viii) carrying out the diversification of urban activities to avoid suburbanization and spatial and environmental segregation of low-income households; ix) reduction of inequalities and privileges concerning the selection of sites for network infrastructures and social amenities (Conselho Municipal de Maputo, 2008).

The principles and priorities listed above aimed at achieving three main objectives: qualification of land, the control of environmental impacts, and the correction of social inequalities manifested through the existing urban land use. Urban qualification involves land use classification and the definition of its indexes and densities for present and future urban development. The control of environmental impacts is supported by the definition of *non aedificandi* areas in relation to the ecological structure of the city, such as water bodies, mangrove and humid areas, beaches, green spots and others, and the definition of partially protected areas with specific regulation concerning their use. The correction of social inequalities implies, among other interventions, the renewal of neighborhoods and the improvement of accessibility from each neighborhood to the city center and within the geographical region.

Maputo's growth during recent decades has been an extensive one with a densification process only in the neighborhoods close to the city center and therefore leading to a nearly complete occupation of the municipal territory. The exceptions are: the green belt along the river Infulene and along the Eastern coast (consisting here of urban agriculture, mangrove, and other flooded areas), Catembe on the south bank of the estuary, and Inhaca island (*Figure 2*).

Figure 2. Main land use classes in Maputo Municipality in 2018



Given this scenario, the Urban Structure Plan proposed a densification of the more peripheral areas as well as some new areas for urban expansion (30% more than the current residential areas), either along the coastal area or in Catembe. These new areas for urban expansion have meanwhile been subjected to Partial Urbanization Plans. As Catembe is located on the south bank, improvement of fluvial transportation is foreseen as well as the construction of a bridge. Besides the expansion and densification of the residential areas, the Urban Structure Plan also proposes eleven multipurpose Urban Centers throughout the municipal territory and therefore reversing the polarization of activities in the prior city center, structuring the territory in a balanced way and with principles of spatial justice.

To achieve the inclusion of the different parts of the municipality and to incorporate the new multipurpose centers, a new accessibility and mobility structure is planned. This Plan proposes a consolidation of the existing road network through improving its infrastructure and the creation of new major circulation infrastructures.

From what was said, it is clear that Mozambique has made significant progress regarding the practice and culture of land use planning and has the legal framework necessary to implement different planning processes. However, some problems remain and still pose some challenges when it comes to enhancing the promotion of the territory as a more attractive, sustainable, and fair one. The great pressure on land has led to the need to establish new areas for expansion. However, suitable land use practices should be tailored, especially in places sensitive to flooding and

erosion. The experience of the past (notably in 2000) proved that the occupation of these sites, although in that case involving unplanned and precarious situations, can be catastrophic.

Regarding technical issues and in order to track and monitor the implementation, and now to review the Urban Structure Plan, a different organizational structure is needed. However, in spite of the major investment made by the Municipal Council concerning the creation of a georeferenced database and tools for spatial analysis, the Urban Structure Plan of Maputo was not designed to be manipulated and tracked by a Geographical Information System. Its regulation also sustains the need to disseminate and to ensure public consultation, but there is no platform to ensure this process. The technical departments of the municipality, namely the ones related to urban management and planning, still work in a gated way. Most of the information produced therein is not shared with other institutions that produce relevant data for the planning process and therefore duplicate and generate inconsistent datasets. A need to take a step forward in the land use planning processes is obvious and necessary to achieve the desired spatial and social justice, but it will have to face the game of competing interests from the different stakeholders that play a major role in this process. The creation of open, user-friendly, and participatory platforms supported by geoinformation and technological tools for sharing knowledge among different stakeholders can enhance effective urban planning and management and promote a sustainable future for the Maputo territory.

Land Use Change In Maputo Between 1964 and 2018: Changing Patterns and Their Consequences

Analysis of the change in land use between 1964 and 1973, before Independence, provides for the identification of the main change: almost 30% of the total land use change corresponds to an alteration from "Other Natural, semi-natural and Leisure Areas" to "Peripheral Residential Area," leading to an occupation that is mainly residential made through the appropriation of "Bush Areas" (Table 1). The period coincided with the implementation of strategic policies intended to maintain the Portuguese presence in the colonies as a response to nationalistic movements, resulting in a migration wave from the metropolis to the colonized territories and a certain level of investment in industry and infrastructures.

The years between 1973 and 1982 were years of political change in Mozambique. The Independence brought changes to the territorial administration systems, particularly due to the nationalization of land and built property. The rural exodus had reflexes in the urban landscape especially in the growth of the periphery. The incentives given to agricultural production and the stimulus to create cooperatives had its main impact in the landscape of the utilization of the best soil areas for agricultural production.

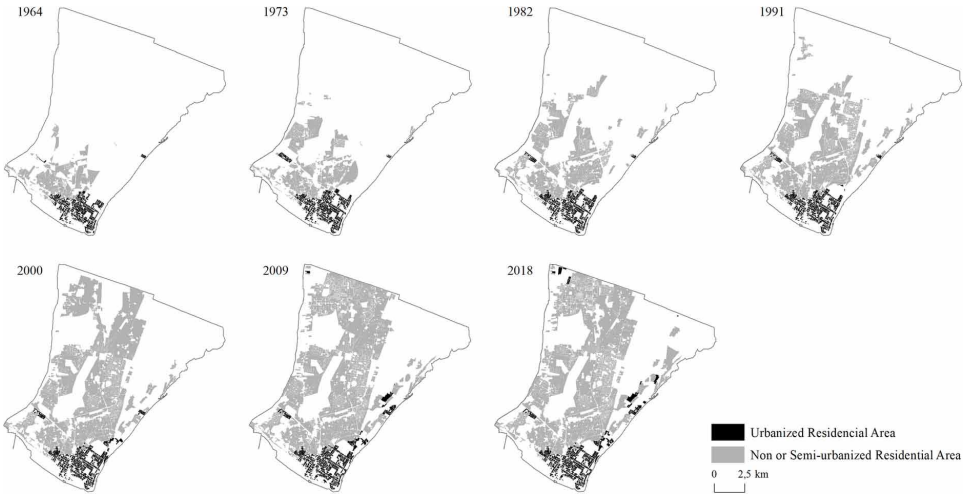
Table 1. Land use rate of change (%) between 1964 and 2010 in Maputo City[1]

Land Use Classes	1964 -1973	1973 -1982	1982 -1991	1991 -2000	2000 -2009	2009-2018
Residential Areas (Urbanized)	17.1	-0.9	1.6	13.2	16.1	10.1
Residential Areas (non- or semi-urbanized)	70.0	45.6	48.0	53.2	13.0	0.8
Social Amenities, Infrastructure and Public Services Areas	24.3	12.0	6.2	2.7	14.0	3.8
Agricultural and other Economic Activity Areas	5.3	81.9	80.3	-23.8	26.6	-4.1
Vacant and Derelict Urban Areas	24.9	-10.4	-0.9	-41.3	38.8	-9.3
Water Bodies and Floodable Areas	13.2	-13.8	-45.5	86.9	-56.4	-7.1
Other Natural, Semi-natural and Leisure Areas	-18.5	-24.5	-41.1	-60.5	-72.3	-0.5

[1] Does not include Catembe and Inhaca.

Source: Author's aerial image interpretation and field work.

Figure 3. Residential Area in Maputo between 1964 and 2018



Between 1982 and 1991, the civil war was still devastating Mozambique. As a consequence, the rural exodus to Maputo city intensified, stressing the accelerated

growth of the periphery. Many areas that were rejected for residential purposes were occupied with houses during this period.

During the next decade, the Peace Agreement and the democratization of the political system influenced the process of urban development. In terms of land use change, these years were clearly marked by the expansion of the periphery to remote areas (Figure 3). Until 2008 there was no legal framework and no planning instruments to control urban expansion. Several *ad-hoc* measures were taken by different authorities and carried out in specific areas (such as the Maxaquene Pilot-Project), in an attempt to eliminate the contrasts between the formal colonial city and the self-produced neighborhoods through reordering its precarious residential areas, but still lacking a global policy for land use within the municipal territory of Maputo that could change the pattern of spatial decisions.

The considerable rate of change in the territory, in a short time followed by the outgrowing of financial and management capacity, left scars that were not possible to heal and which actually compromised the future: vast areas with precarious settlements, lack of security of tenure, considerable environmental sensitivity are obvious in the landscape of the city of Maputo. Desirable resilience should imply, among other things, political strategies based on thorough knowledge about the functioning of the interactions that take place among the various stakeholders that shape the territory.

The great pressure on land has led to the need to establish new areas for expansion. However, suitable land use practices should be tailor made, especially in places sensitive to flooding and erosion. The experience of the past (notably with the floods of 2000 and 2001) showed that the occupation of these sites, although in that case referring to informal and precarious situations, can be catastrophic. Moreover, the lack of an environmental impact assessment, concerning the new large infrastructures already under construction, has been pointed out and criticized by various groups of citizens concerned with the sustainable development of the region.

At the social level, the issues relating to the resettlement of the population as a consequence of the construction of the new infrastructures foreseen in the plan are worthy of note. Despite the recent regulation on the resettlement process resulting from economic activities (Decree-law 31/2012 of 8 August) trying to protect the rights of affected populations, in practice, the displacement of families to more peripheral areas, most of which being without basic infrastructures was a widespread occurrence. A conflict of interests by stakeholders and the high illiteracy level in communities offers a difficult scenario for the effective performance and transparency of a praxis process.

Many other examples of political, technical, environmental, and social issues could be addressed in this context. Perhaps what is most important to emphasize here is the importance that the new land use planning paradigm that Mozambique is

aiming to draw up does not deviate from public interest, social, and spatial justice, environmental sustainability and transparency of processes, taking full advantage of the opportunities created by the growing demand for this territory.

Census data from 1997, 2007, and 2017 provide a demographic and socio-economic picture of the city and combining this with geometric and semantic data supplied by aerial images are basic elements for the creation of monitoring and evaluation indicators for an urban development model, as well as supporting the definition of policies that should guide the future of the territory. The idea of "socializing the pixel" and "pixelizing the social", as discussed by Geoghegan, et al. (1998) is a potential area of research and action here if framed by an urban observatory laboratory.

FUTURE RESEARCH DIRECTIONS

Land use monitoring for planning and management purposes in fast-growing cities can greatly benefit from currently available geoinformation technologies that provide an integrated view of the environment and the agents that intervene in it.

However, to enhance the advantages that these technologies may bring in improving the quality of life and sustainability in adverse contexts with a strong transformational dynamic, certain steps forward should be considered and evaluated:

1. Developing and integrating effective methodologies for obtaining and providing data from remote sensors within planning and management processes;
2. Providing technological means to add and show significant geographic information to promote a debate around urban issues among researchers, practitioners, decision-makers, citizens, and other stakeholders, and to strengthen partnerships, while improving knowledge and action methodologies;
3. Revitalizing urban planning education, introducing diverse forms of reading the territory, particularly through the use of geoinformation technologies, and encouraging universities to embrace long-term research programs concerning emerging urban issues of their cities;

CONCLUSION

Land is the resource that populations can use to express their culture. Planning land use – by understanding and clarifying the complex relations between the different components that produce space – is an indispensable step towards providing a framework for decisions regarding the future development of any country.

Urban planning processes should incorporate monitoring and assessment phases that can be supported by geoinformation technologies. Geographic data supported by these technologies enables the definition and use of indicator systems to evaluate contexts, realities, and trends; in other words, permanent monitoring by detecting deviations or variations in previous situations and by identifying the progress already achieved compared to the intended or expected final results.

The city of Maputo was set up as a laboratory to show the relation between territories with a large population concentration and functions and the technology that describes and should monitor this concentration in urbanistic, economic, social, and geographic terms. At the technical level, there are already several conditions in place for it to become a methodological case study for action. If framed by a strong link between research and urban policy and practice (as was already started through collaborating with the municipality in the developing of land use plans), it can have a stronger role in urban planning activities.

Availability of up-to-date data is the most important bottleneck in preventing geoinformation technologies from being used effectively in developing countries, but current free or low-cost data from remote sensing platforms can help to overcome these difficulties. Moreover, several crowdsourcing programs led by civil society organizations have begun to play a significant role in the construction of information on the territory. Geoinformation technologies anchored within a land use observatory of fast-growing cities could be a groundbreaking project to engage researchers, planners, policymakers in promoting a better understanding of the urban phenomena and their impacts and, therefore, in achieving the desired sustainability goals.

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KEY TERMS AND DEFINITIONS

Geoinformation Technologies: Technological tools used for measuring, mapping, modeling, and visualizing features from human and natural environments.

Land Use: The functional use of land units based on human activity.

Self-Produced Settlements: Non- or semi-urbanized areas produced more or less autonomously in relation to state order and control by the resident population.

Spatial Justice: When social resources are adequately distributed in space promoting equitable opportunities to benefit from them.

Urban Indicators: Tools that can provide a comprehensive means for the monitoring and assessment of urban conditions, trends, and policies.

Urban Observatory: Infrastructure element to record, analyze and interpret the cumulative results of human action, translated into the physical transformation of cities and enabling the monitoring and assessing of changes and policies, through a set of dedicated indicators.

Urban Structure Plan: Land use normative planning instrument, also known as master plan.