NOVA IMS Information Management School

DOCTORAL PROGRAMME

Information Management

# Geospatial Data for Sustainable Development in Mozambique: Challenges on Spatial Data Infrastructure Development & Ecosystem Service Integration in Decision Making

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A thesis submitted in partial fulfillment of the requirements for the degree of Doctor in Information Management

**July, 2021**

**NOVA Information Management School**
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## Abstract

The Agenda 2030 challenges the countries to use and produce new spatial data to support the path to Sustainable Development (SD). This requires development and adoption of Spatial Data Infrastructure (SDI), and the production of new relevant spatial data to support implementation, monitoring and reporting the progress on the targets on Sustainable Development Goals (SDGs). The importance of access to spatial data for development and resource management is widely acknowledged worldwide. Unrestricted, reliable and efficient access to accurate, timely, and up-to-date spatial data may be achieved through a Spatial Data Infrastructure (SDI). Thus, most developed countries implemented and continue to develop their SDI. The Ecosystem Service (ES) is also crucially for SD and the concept needs to be expressed and communicated effectively to be successfully integrated into decision making. This study assessed the challenges and opportunities on SDI development and analyzed the documents relevant to LUP process and implementation. On the SDI, we identified and characterized through a survey the government institutions producing, sharing, and using spatial data in the country to estimate their potential contribution to the development of the Mozambican SDI. On the integration of ES into LUP, we conducted a review of relevant documents to Mozambique's spatial planning by performing a content analysis based on ES categories. Based on the possible contribution of the institutions producing and using spatial data, we proposed an SDI for Mozambique based on four pillars: i) organizational framework; ii) legal framework; iii) technical framework; and iv) accessibility. The periodical revision of tools and participatory approaches in LUP opens opportunities for integrating ES into LUP processes. This integration could be achieved by establishing a SEA legal framework based on LUP and Environment legal frameworks assisted by a set of common planning tools that consider ES as an additional indicator applied to spatial planning in Mozambique.


**Keywords**: Spatial Data Infrastructure; Geographical Information Systems; Strategic Environmental Assessment; SWOT; Participatory approaches; Ecosystem Services; Mozambique;

## Dedication

I would like to dedicate my work to my parents, Faustino Omar Atumane and Suhura Momade Jade

## Publications

## List of publication resulting from this dissertation

Title: *The Challenges and Opportunities for Spatial Data Development in Mozambique*

Journal: *Journal of Map and Geography Libraries* of Taylor and Francis. It is a Q2 journal at Scimago.

Link: . https://doi.org/10.1080/15420353.2019.1661932

Título: *Integration of Ecosystem Services into Land Use Planning in Mozambique*
Journal: *Ecosystem and People of* Taylor and Francis. It is a Q1 journal at Scimago.

Link: https://doi.org/10.1080/26395916.2021.1903081

## Other papers as co-author

Title: *Assessing Mozambique's exposure to coastal climate hazards and erosion*

Journal: *International Journal of Disaster Risk Reduction* of Elsevier Ltd. It is a Q1 journal at Scimago.

Link: http://dx.doi.org/10.1016/j.ijdrr.2017.04.002

Title: *Large-scale agricultural investments trigger direct and indirect land use change: New evidence from the Nacala corridor, Mozambique*

Journal: *Journal of Land Use Science* of Taylor and Francis. It is a Q1 journal at Scimago.

Link: https://doi.org/10.1080/1747423X.2018.1519605

Title: *Large-scale agricultural investments in Eastern Africa: consequences for small-scale farmers and the environment.*

Journal: *Ecosystem and People of* Taylor and Francis. It is a Q1 journal at Scimago.

Link: https://doi.org/10.1080/26395916.2021.1939789

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## Acknowledgments

I thank all the Mozambican government institutions that participated in the study, especially the Ministry of Science & Technology, Higher & Technical Professional Education (MCTESTP) for the credential to meet the other institutions; all the institutions that provided the required documents and information for the analysis, especially to the Ministry of Land & Environment, and to the NIRAS SEA Alumni group for their support.

## Curriculum Vitae

**1. Program**: Doctoral Programme in Information Management

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**6. Education**:

| Institution [Dates from – Date to] | Degree(s) or Diploma(s) obtained |
|---|---|
| Universidade Nova de Lisboa – NOVA Information Management School – Lisbon – Portugal (2014 -2021) | PhD Candidate in Information Management (GIS: Specialization)<br>Thesis title: Geospatial Data for Sustainable Development in Mozambique: Challenges on SDI Development & ES integration in Decision Making |
| Erasmus University Rotterdam, IHS - Rotterdam – Netherlands (2019) | Post graduate in Green Cities for Eco-Efficiency |
| NIRAS/Chalmers/University of Gothenburg – Gothenburg – Sweden (2017 – 2018) | Post graduate in Strategic Environmental Assessment |
| Catholic University of Mozambique (UCM) - Faculty of Economics and Management (FEG) – Beira – Mozambique (2008-2009) | Master in Regional Development Planning<br>*Main topic: Natural Resource Assessment, Land Use Planning, Regional Development Theories, Environment Impact Assessment, Database Management, GIS, Remote Sensing & Environmental Modeling.* |
| Catholic University of Mozambique (UCM) - Faculty of Economics and Management (FEG) – Beira – Mozambique (1999-2003) | BSc in Economics & Management<br>*Main topic: Economic, Development, Econometric, Accounting, and Management* |

**7. Membership of Professional Associations**:
YESS - Young Ecosystem Services Specialists

**8. Other Training**:

| Institution, Name of Training [Dates from – Date to] | Certificate(s) or Diploma(s) obtained |
|---|---|
| UNEP / WCMC – Regional Training of Trainers on Natural Capital Assessment - Addis –Ababa – Ethiopia (2015 -2015) | Natural Capital Assessment |
| UNEP - Regional Training of Trainers on Green Economy - Nairob- Kenya (2015-2015) | Green Economy |
| Rhodes University & NIRAS - Education for Sustainable Development - Grans town - Africa South (2012) | Education for Sustainable Development |
| CETRAD & CED University of Bern – Geographic Information System Nanyuki, Kenya (2008) | Geographic Information System |

| | |
|---|---|
| Mozambique Red Cross - Participatory Rural Assessment - Pemba, Mozambique (2005) | Participatory Rural Assessment |

**9. Languages:**

| Languages Level | Read | Written | Spoken |
|---|---|---|---|
| Portuguese | Excellent | Excellent | Excellent |
| English | Excellent | Excellent | Excellent |
| French | Basic | Basic | Basic |

**10. Employment Record**:

| | |
|---|---|
| From: _February 2017 To: Present | |
| | |
| Employer: | Catholic University of Mozambique (UCM): Management and Applied Economics Research Center (CIGEA) |
| Position Held: | Consultant and Research Coordinator |
| Main Responsibility | Coordination of Research and Community outreach activities<br>Coordination of preparation and evaluation of Research and Development projects<br>Conducting research and consulting in Rural Development, Sustainable Development, Land Use Planning, Green Cities, Strategic Environment Assessment, Application of GIS to Natural Resources<br>Implementation of projects funded by partners |
| | |
| From: _March 2012 To: January 2017 | |
| Employer: | Catholic University of Mozambique (UCM): Faculty of Agriculture (FAGRI) |
| Position Held: | Administrator, Consultant and Researcher |
| Main Responsibility | Faculty Administration<br>Financial and Asset Manager<br>Project Coordinator & Research Development |
| | |
| From: _March 2007 To: February 2012 | |
| Employer: | Catholic University of Mozambique (UCM): Center for Geographic Information (CIG) |
| Position Held: | GIS Technician, Consultant and Researcher |
| Main Responsibility | Resource Manager<br>Conducting research and consulting in Rural Development, Sustainable Development, Land Use Planning, Environment Management, Application of GIS to Natural Resources<br>Implementation of projects funded by partners |
| | |
| | |
| From: _July 2003 To: February 2007 | |

| | |
|---|---|
| Employer: | Catholic University of Mozambique (UCM): Faculty of Tourism Management and Information Technology (FGTI) |
| Position Held: | Coordinator & Lecturer |
| Main Responsibility | Coordinator of Tourism Management Program<br>Lecturer in the following courses: Project Management and Evaluation and the Applied Economics for Tourism<br>Conduct research & consultancy in Economics and Management<br>Implementation of touristic projects with partners |

**11. Projects**

| 01. Detailed Tasks Assigned | |
|---|---|
| Climate University | **Name of Assignment or Project**: Transforming Universities for Climate Change & Sustainable Development<br><br>**Year :** 2020-2023<br>**Location:** Mozambique, Kenya, Brazil, Fiji and UK<br>**Client:** Research project<br>**Main project features**: Practice, experience and attitudes toward Climate Change<br>**Positions held:** Research Associate<br>**Activities performed:** Research coordinator |
| Environmental Assessment | **Name of Assignment or Project**: Environment Impact Assessment -<br><br>**Year :** 2020<br>**Location:** Dondo - Sofala<br>**Client:** PROLER<br>**Main project features**: Environment scope for the renewable energy power generation project in Dondo – Sofala - Mozambique<br>**Positions held:** Team Member<br>**Activities performed:** Environment Scope |
| Green Economy | **Name of Assignment or Project**: Operationalizing Green Economy Transition in Africa<br><br>**Year :** 2016-2017<br>**Location:** Mozambique<br>**Client:** GIZ and UNEP<br>**Main project features**: a cooperation project between GIZ and UNEP to develop tools for use at sub national level, building capacity in local government and relevant stakeholders (public and private), support pilot demonstrations in selected districts and develop replica model to other districts<br>**Positions held:** Main Consultant working in collaboration with Ministry of Land, Environment and Development Rural (MITADER)<br>**Activities performed:** reorganizing the district development plans, particularly social economic plans (PESOD) for the Green Economy – the Fishing sectors, |

| | |
|---|---|
| | Agriculture, Water and Tourism - in the districts of Chokwe and Bilene, develop tools for use at sub national level, building capacity in local government and relevant stakeholders (public and private). |
| Aquaculture and Fisheries | **Name of Assignment or Project**: African Center of Excellence in Aquaculture and Fisheries (Aquafish ACE)<br><br>**Year :** 2016-2017<br>**Location:** Malawi & Mozambique<br>**Client:** Aquaculture & Fisheries Science Department, Bunda Campus, Lilongwe University of Agriculture and Natural Resources (LUANAR), Lilongwe, Malawi, with the partnership of the Faculty of Agriculture (FAGRI) - Catholic University of Mozambique (UCM) - Cuamba – Mozambique.<br>**Main project features**: developing a project to implement a African Center of Excellence in Aquaculture and Fisheries (Aquafish ACE)<br>**Positions held:** Team Member<br>**Activities performed:** Identify needs and contribute to develop a project to implement a African Center of Excellence in Aquaculture and Fisheries |
| small-scale farmers | **Name of Assignment or Project**: Market segmentation project for Financial Services with focus on small-scale farmers<br><br>**Year :** 2015<br>**Location:** Mozambique<br>**Client:** Financial Sector Deepening Mozambique (FSD Mozambique).<br>**Main project features**: Market segmentation project for Financial Services with focus on small-scale farmers<br>**Positions held:** Consultant<br>**Activities performed:** Market Segmentation for financial services with focus on small-scale farmer in North of Mozambique. Consultant hired by Centre for Financial Regulation and Inclusion (Cenfri) - The Vineyards Office Estate Farm, Farm 1, Block A Building - 99 Jip de Jager Drive, Bellville, Cape Town, South Africa – institution hired by The Financial Sector Deepening Moçambique (FSD Mozambique) - Av. Armando Tivane, 849. Maputo – Mozambique |
| Precision Farming & Information Management | **Name of Assignment or Project**: Agriculture Information Management and Precision Farming (AgIM)<br><br>**Year :** 2013-2017<br>**Location:** Mozambique, Cape Verde & Portugal<br>**Client:** European Development Fund (EDF)<br>**Main project features**: EDULINK Program – ACP-UE Cooperation Program for Advanced Teaching.<br>**Positions held:** National Coordinator for Mozambique<br>**Activities performed:** Coordinate the an institutional cooperation project on post-graduated teaching on Agriculture Information Management and Precision Farming |
| GIS | **Name of Assignment or Project**: Sustainable Geographic Information Knowledge Transfer for Post-Graduate Education (SuGIK)<br><br>**Year :** 2008-2011 |

| | |
|---|---|
| | **Location:** Mozambique, Cape Verde & Portugal<br>**Client:** European Development Fund (EDF)<br>**Main project features**: EDULINK Program – ACP-UE Cooperation Program for Advanced Teaching.<br>**Positions held:** Administrative and lecturer<br>**Activities performed:** Coordinate the administrative activities and assistant lecturer institutional cooperation project on post-graduated teaching on Geographic Information System |

## 12. Papers under review

- Title: Quantifying the Spatiotemporal Impacts of Floods on Cropland in Mozambique Using Multi-Satellite Data
  Corresponding Author: Professor Bingfang Wu
  Co-Authors: José Bofana; Mohsen Nabil; Miao Zang; Ning Zhang; Hongwei Zeng; José Marques da Silva; Anacleta Botão; Alí Atumane; Terence Darlington Mushore; Abdelrazek Elnashar; Nana Yan
  Under review in the Journal of Remote Sensing of Environment

## 13. Publications

- Ali Atumane & Pedro Cabral (2021) Integration of Ecosystem Services into Land Use Planning in Mozambique, Ecosystems and People, 17:1, 165-177, DOI: 10.1080/26395916.2021.1903081

- Julie Gwendolin Zaehringer, Peter Messerli, Markus Giger, Boniface Kiteme, Ali Atumane, Maya Da Silva, Lovasoa Rakotoasimbola & Sandra Eckert (2021) Large-scale agricultural investments in Eastern Africa: consequences for small-scale farmers and the environment, Ecosystems and People, 17:1, 342-357, DOI: 10.1080/26395916.2021.1939789

- Atumane, Ali; Cabral, Pedro (2019) Challenges and Opportunities for Spatial Data Infrastructure Development in Mozambique, Journal of Map & Geography Libraries, DOI: 10.1080/15420353.2019.1661932

- Zaehringer, Julie G.; Atumane, Ali; Berger, Sibylle & Eckert , Sandra (2018) Large-scale agricultural investments trigger direct and indirect land use change: New evidence from the Nacala corridor, Mozambique, Journal of Land Use Science, 13:3, 325-343, DOI: 10.1080/1747423X.2018.1519605

- Cabral, P., Augusto, G., Akande, A., Costa, A., Amade, N., Niquisse, S., Atumane, A., Cuna, A., Kazemi, K., Santha, R. (2017). Assessing Mozambique's exposure to coastal climate hazards and erosion. International Journal of Disaster Risk Reduction, 23, 45–52. https://doi.org/10.1016/j.ijdrr.2017.04.002

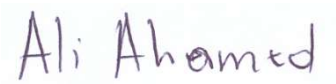
- Painho, Marco; Baptista, Alexandre; Atumane, Ali and Simões, Elsa. Blended Learning Education on Precision Farming in Developing Countries: The Example of Cape Verde and Mozambique. Proceedings of the 17th International Multidisciplinary Scientific

Conference - SGEM 2017 vol.17 - Ecology, Economics, Education and Legislation, Albena, Bulgaria. June 27 - July 6, 2017.

- Painho, Marco; Baptista, Alexandre; Atumane, Ali and Simões, Elsa. Including Geospatial Tools for Agriculture Education in Developing Countries: A Case for Cape Verde and Mozambique. Proceedings 6th International Conference on Cartography and GIS. Albena, Bulgaria, June 13 - 17, 2016.

- Painho, Marco, Alexandre Baptista, Judite Nascimento and Ali Atumane. AgIM - ensino Pós-graduado em Gestão de Informação Agricola e agricultura de Precisão em Cabo Verde e Moçambique. I Jornadas Lusófonas de Ciências e Tecnologias de Informação Geográfica - CTIG 2014 - Marco a Marcas Lusófonas. Coimbra, Portugal. September 11-13, 2014.

**14. Certification:**



29th of July 2021

[Signature ] Date:

# Chapter 1: Introduction

The 2030 Agenda for Sustainable Development adopted by United Nations urge all the countries and stakeholders to achieve social, economic and environmental sustainability (United Nations, 2015). The Agenda is a plan of action for people, planet and prosperity, that leads the world into a sustainable and resilient path through 17 Sustainable Development Goals (SDGs) and 169 targets around the sustainable development dimensions (United Nations, 2015). The challenges in achieving the SDGs are almost entirely geographic in nature, so geospatial information can play important role in addressing these challenges. However, the credit to the importance of geospatial information in sustainable development processes had been limited (Scott & Rajabifard, 2017). These led to a Group on Earth Observation (GEO) to ensure the actual use of Earth Observation (EO) and spatial information in support of the 2030 Agenda (Anderson, Ryan, Sonntag, Kavvada, & Friedl, 2017). This requires new data acquisition and exploitation, including geospatial data, to support implementation, monitoring and reporting the progress on the targets (Anderson et al., 2017). The connection and fusion between Sustainable Development and Spatial Information can be enhanced by enabling processes, data and institutional infrastructures such as the National Spatial Data Infrastructures (NSDIs) (Guigoz et al., 2017; Scott & Rajabifard, 2017).

The 2030 Agenda trigger the countries, especially the developing countries, to develop and adopt the Spatial Data Infrastructure (SDI) to provide high quality, timely and reliable geospatial data (Scott & Rajabifard, 2017). Europe is an example of a continental SDI through the INSPIRE directive, under which, the countries implemented a NSDI. Africa has no continental SDI body and an assessment on it revealed a weak status of SDI implementation in Africa, requiring efforts to improve the implementation in African countries (Guigoz et al., 2017).

The land use management and policy is also crucial for achieving the SDGs. It ensures that the region development approach consider natural capital, its stocks, flows and values. The natural capital concept also include Ecosystem Services (ES) (Tammi, Mustajärvi, & Rasinmäki, 2017), and both are inherently spatial by nature (Boyd and Banzhaf, 2007; Schägner et al., 2013). Therefore, geospatial data on natural capital and ES are essential in land management. The ES hotspot valid the need of ES in land use related decision making (Jäppinen and Heliölä, 2015; Vierikko and Niemelä, 2016) so there is a call for a need to integrated spatial ES data into planning, decision making and management (Tammi et al., 2017).

There are several Mozambican institutions producing and using geospatial data. However, the need for it at national and regional level to address the SD is continuously increasing. That rises the challenges to make high quality geospatial data available. The NSDIs is very important to resolve this challenges in country.

The land use management in Mozambique is based on the legal framework that states four levels. These are national level: national plan for territorial development and special plans for spatial planning; provincial level: provincial-territorial development plans and interprovincial territorial development plans; district level: district land use plans; and municipal level: urban structure plans, general urban development plans, partial urbanization plans, and details plans (Assembleia da República, 2007). The efforts to ensure sustainability of the process call for a need to enhance the production and use of geospatial data to address the SDGs. The integration of ES into Land Use Planning (LUP) is a mean to meet the need and ensure sustainability.

## 1.1. Hypotheses

The hypotheses under the research are the following:

- The production and sharing of spatial data is not coordinated among government institutions because of lack of SDI in Mozambique; and

- The ES information is not currently being considered in land use planning in Mozambique.

## 1.2. Objectives

The research aims to address the need to improve the use of spatial data in sustainable development in Mozambique, mainly the production, availability, share and use of spatial data among government institutions; and the integration of new geospatial data in decision making process. The specific objectives are the following:

i) Contributing to the beginning of Mozambique SDI by assessing the capabilities and insufficiencies of the main spatial data stakeholders in the country in what concerns their resources and policies.
ii) Assessing the current LUP documents regarding its suitability for mainstreaming the ES concepts in Mozambique, and propose a framework for ES integration in LUP processes

## 1.3. Methodology

The methodology applied to conduct the research is illustrated in figure1.

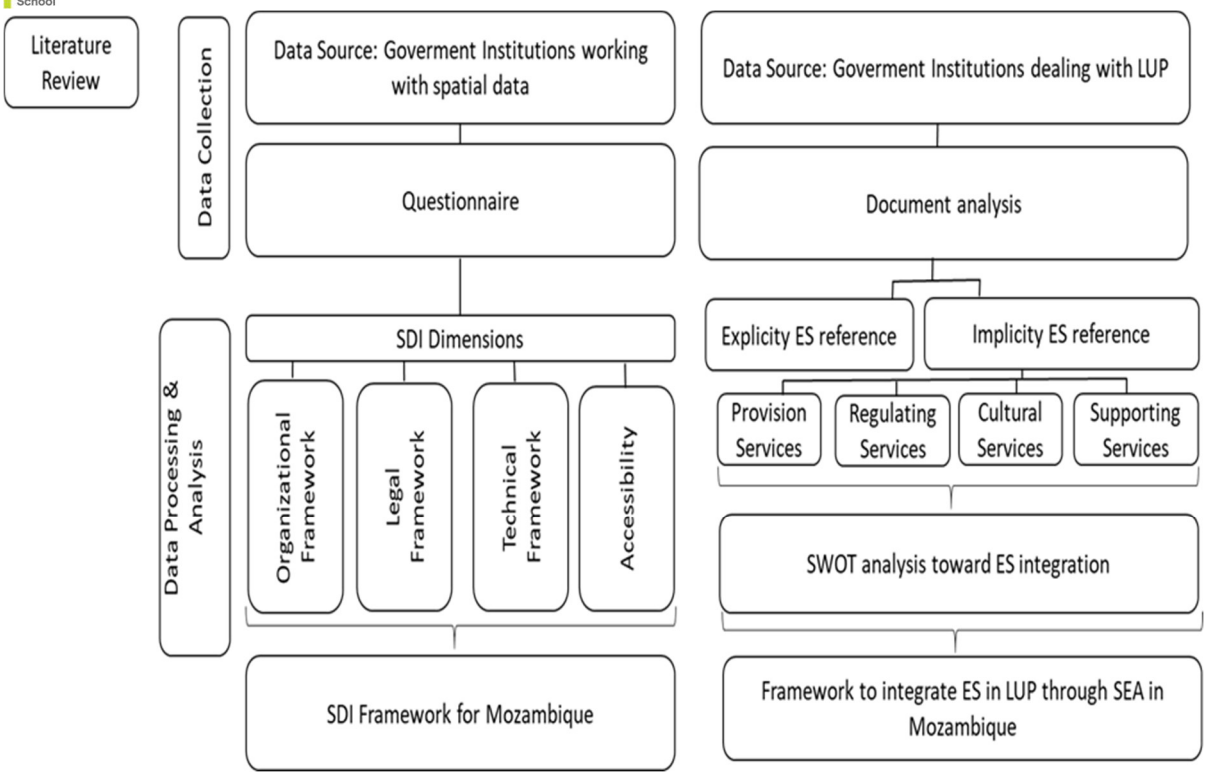



*Figure 1. 1: Methodology Diagram*

### 1.3.1. Literature review

The literature review was conducted to identify the state of the art on SDI in the world, particularly in Africa, and ES in decision making processing, mainly in the LUP. This was very useful to identify the gaps in the field, fine-tune the research objectives and methodology design. The SDI development process and procedures, types of integration of ES in LUP and the context of SEA in Mozambican LUP, and specific research methods were derived from the literature review using SCOPUS database, expert consultation, institutional websites and grey literature.

### 1.3.2. Data Collection

The data was collected through questionnaire and documents analysis. The questionnaire was used for the SDI framework, the data was collected from government institutions producing or using spatial data. The main collected was on SDI dimensions: organizational framework, legal framework, technical framework and accessibility. The documents analysis was used for the framework to integrated ES into LUP, the content in the documents were analysis based on the explicit and/or implicit ES reference.

### 1.3.3. Data processing and analysis

#### 1.3.3.1. SDI framework

The procedure to propose the SDI framework started from assessing the legal framework to support SDI, acquiring the spatial data availability within the government institutions, identifying data standards, skilled staff, and technology level and data accessibility. These were used to derive the potentiality of each of the government institutions to contribute to SDI development.

#### 1.3.3.2. Integration of ES in LUP

The integration was proposed through the content analysis based on the explicit reference to ES (direct reference to ES or its synonyms) and implicit reference to ES (different designations, e.g., measurement of biophysical values and benefits related to the ES). Then a Strengths, Weakness, Opportunities and Threats (SWOT) analysis was conducted. These were then, used to develop the proposed framework to integrate ES in LUP through SEA.

## 1.4. Thesis organization

The thesis is structured in 4 chapters. The first chapter is introduction, followed chapter two and three, the research papers, and the last chapter is conclusion. The research papers are the following:

- The first paper analysed the government institutions for SDI development and determine the contribution of each institution to SDI development. This paper was accepted and published in *Journal of Map & Geography Libraries* of Taylor & Francis. This journal is Q2 (SCOPUS) in Scimago.

- The second paper assessed the current LUP documents regarding its suitability for mainstreaming the ES concepts in Mozambique, and propose a framework for ES integration in LUP processes through an operational SEA which integrates ES information. It was accepted and publishedin the *Journal of Ecosystem & People* of Taylor and Francis. This journal is Q1 (SCOPUS) in Scimago.

There were also other papers in which I was co-author:

- Title: Assessing Mozambique's exposure to coastal climate hazards and erosion. It was published in the International Journal of Disaster Risk Reduction of Elsevier. It is a Q1 (SCOPUS) in Scimago. http://dx.doi.org/10.1016/j.ijdrr.2017.04.002

- Title: Large-scale agricultural investments trigger direct and indirect land use change: New evidence from the Nacala corridor, Mozambique. It was published in the Journal of Land Use Science of Taylor and Francis. It is a Q1 journal at Scimago. It is a Q1 (SCOPUS) in Scimago. https://doi.org/10.1080/1747423X.2018.1519605

# Chapter 2: Challenges and Opportunities for Spatial Data Infrastructure Development in Mozambique

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## 2.1. Introduction

The development of SDI in Africa has long been a concern of the United Nations Economic Commission for Africa (ECA, 2003). Successive Committees on Development Information, Science and Technology, have been promoting SDI initiatives in the continent including the publication of the African SDI Handbook by CODIST (ECA, 2003). The "African Action Plan on Global Geospatial Information Management 2016-2030" is now in effect with the mission of ensuring the African production and use of authoritative and evidence-based geospatial information to attain its sustainable development goals (United Nations. Economic Commission for Africa & UNECA, 2017). Other international initiatives, such as the "Network for Co-operative Management of Environment Information and Geospatial Data - EIS Africa", have been raising the awareness of geospatial data stakeholders to the advantages of using common data architectures, providing training and datasets to promote the capacity to generate, manage and disseminate geospatial data in Africa (EIS Africa, n.d.; UNECA, 2003).

The International Conference on Spatial Information for Sustainable Development published the Nairobi Statement, consisting of a set of recommendations for African governments, international organizations and market participants, to ensure the development of consistent and compatible SDI for Africa (Foster & Ryttersgaard, 2001). The first recommendation for African governments willing to develop an SDI is the

constitution of a Steering Group (SG) to promote the effective partnership and co-operation among the various spatial data stakeholders in the country (Foster & Ryttersgaard, 2001). SG have been instrumental in the successful implementation of SDI in South Africa and Namibia (Sinvula et al. 2017), two neighbouring countries of Mozambique. Both countries initiated their road to SDI by forming committees to address technical and institutional issues to allow for the efficient and effective share of spatial datasets among government organizations. This hands-on strategy, named "product-based" approach to SDI development, is the foundation of most of the thriving SDI now in force (Rajabifard et al. 2002). Sharing existing resources and building collaborations between institutions may sort out the basic technical questions and other barriers to data sharing (Akinyemi & Uwayezu, 2011), and ensure the SDI is responding to users' needs (Foster and Ryttersgaard 2001; Hendriks et al. 2012). Parallel to the "product-based" strategy, there is the "process-based" strategy focusing on the communication channels to foster awareness, knowledge, and alignment among spatial data stakeholders to promote the SDI (Rajabifard et al. 2002). These strategies are complementary and can be delivered by the SG which is composed by the main stakeholders of the spatial information community that will discuss the products and services to be delivered by the SDI (Rajabifard et al. 2006). The SG can also provide a forum for the development of communication channels, organization, leadership and inter-organizational cooperation, decisive to the success of the SDI initiative.

The importance of wide access to spatial data and geographical information for development and resources management is widely acknowledged by the scientific community and policymakers (Foster & Ryttersgaard, 2001; Makanga & Smit, 2010). The digitalization of spatial data and the advances in Information and Communication Technologies (ICT), led many non-specialised users to collect, use and replicate spatial data for their own purposes. However, inconsistencies and incompatibilities among spatial datasets impede their integration and re-use hindering the effective and efficient use of spatial data (Mwange et al. 2018). Kong (2015) while exploring the best management practices of geospatial data in academic libraries has reviewed the common challenges of spatial data management and curation, which includes the

application of big data, the emergence of web GIS, and the advancement of cyberinfrastructures, and conceptual framework (Schweers et al., 2016).

The role of a spatial data infrastructure (SDI) is "to provide an environment in which all stakeholders, both users, and producers, of spatial information, can cooperate with each other in a cost-efficient and cost-effective way to better achieve organizational goals" (Rajabifard et al. 2002). Several SDI definitions can be found depending on the context and type of organization (GSDI, 2012; OSGEO, n.d.; US President, 1994). In fact, there are so many definitions of SDI that Hendriks et al. (2012) classified them in two categories: those focusing in SDI components such as technology or human resources; and those listing SDI objectives to enable better utilization of spatial data and associated services. Still, for every SDI, the concepts of maximization of geographical information use, government coordination, user-driven, and the involvement of technical, organizational and financial issues, and human resources in the implementation should always be present (Masser, 2005).

The significant investment required for establishing an SDI can be readily recovered by the gains in efficiency and effectiveness for public servants alone (Lance & Bassolé, 2006). Other benefits include increased opportunities for qualified jobs in technology and research, and more resources made available for less wealthy users, such as small municipalities and small businesses. SDI can also contribute to a more efficient and transparent government due to the increasing availability of authoritative data for policy and decision makers (Yalcin, 2014).

Recently SDI emerged for social sciences (Schweers et al., 2016). However, environmental protection and natural resources management have been presented as one of the main reasons for implementing national and global SDI (Foster & Ryttersgaard, 2001; Guigoz, 2015). Environmental issues rarely conform with national, or even regional borders and their management often requires the integration of multiple data and sciences to be effective (UNECA 2017). The environment is clearly pointed as one of the main reasons for the legal enforcement of regional SDI (INSPIRE, 2004; US President, 1994).

SDI initiatives exist at regional and global levels to address technical issues and legal or administrative arrangements to promote spatial data sharing (GSDI, 2015; INSPIRE, 2004; PCGIAP, 2009; UNECA, 2003). In all cases, SDI is meant to provide users with complete, compatible, up-to-date, consistent and well documented spatial datasets, coming from different data providers. This requires not only the availability of those datasets, technologies, and skills for its production and dissemination but also the organization, cooperation, and coordination of all spatial data stakeholders, such as government agencies, the private sector, research institutions and other organizations (Coleman & McLaughlin, 1998).

In Africa, there is a fast-growing list of countries at an advanced stage of implementation of SDI such as South Africa, Senegal, Rwanda, Nigeria (Ayanlade et al. 2008), Cape Verde (República de Cabo Verde, 2010), Namibia, Ghana (Sinvula et al. 2017), with many others on their way. However, many African countries still have insufficient or inadequate infrastructures to manage and disseminate spatial data (Guigoz, 2015) as is the case of Mozambique.

This study aims at contributing to the beginning of Mozambique SDI by assessing the capabilities and insufficiencies of the main spatial data stakeholders in the country in what concerns their resources and policies. For this purpose, we surveyed all the Mozambique administrative institutions implied in spatial data production and use, from March to August 2016, to assess their communication and technologic capabilities (including skilled personnel), and the readiness of their data and policies concerning spatial data sharing. Other authors have acknowledged the importance of consulting spatial data stakeholders to identify the main obstacles to spatial data share and exchange at National level (Akinyemi and Uwayezu, 2011). In this study, we take one step further by conceptualising the development of the SDI for Mozambique. This conceptualization is carried out according to international recommendations (Foster & Ryttersgaard, 2001), and considering the experience of neighbouring countries and the particularities of Mozambique administration (Kisco et al., 2017). Specifically, the objectives of this paper are:

- Identify the level of potentially useful existing competencies within the government administration for the implementation of the SDI for Mozambique;
- Determine the possible contribution of each government institution; and
- Propose a framework for the initiation and the development of an SDI for Mozambique

## 2.2. Spatial Data Infrastructures in Africa: the case of Mozambique

Mozambique is a southern African country bordered by Tanzania in the North, Malawi, Zambia, Zimbabwe, and South Africa in the West, Swaziland, and South Africa in the south, and the Indian Ocean in the East (Figure 1). The country has 799.380km$^2$ with over 28 million inhabitants (INE, 2018), and a coastline of more than 2400 km.

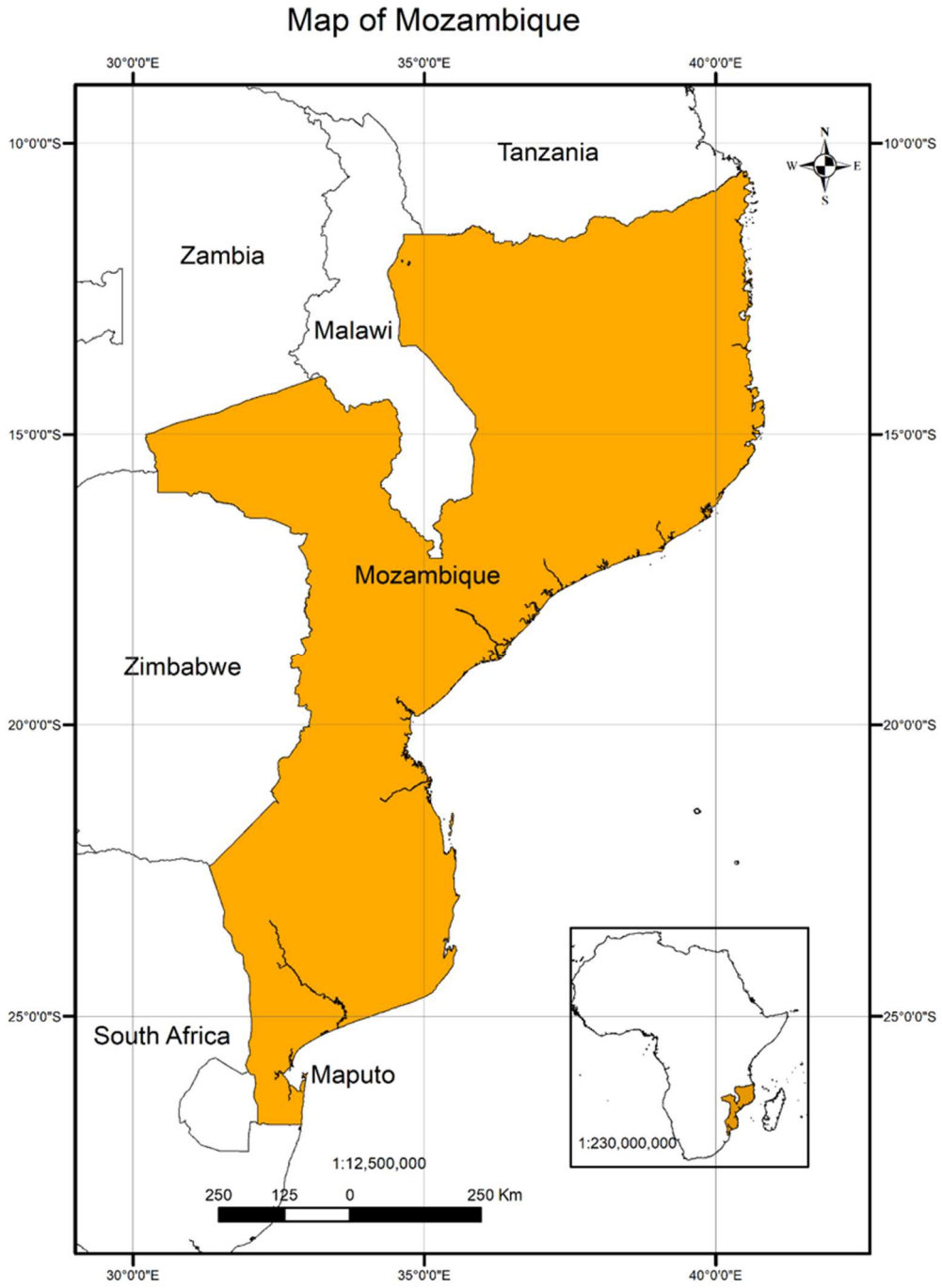


*Figure 2. 1: Map of Mozambique with surrounding countries. The inset shows the placement of Mozambique in Africa Continent*

The Republic of Mozambique is administered by the central government located in the capital Maputo. The country is hierarchically subdivided into 11 provinces, covering 53 municipalities containing 154 districts. Regional and local administrations have a minimal level of autonomy. Government agencies are also largely dependent on central government, and generally operate across the whole country, with little or no dependence to local administrations.

Mozambique is in the 180$^{th}$ position of the Human Development Index, of the 198 countries ranked (OECD, 2017). With a Gross Domestic Product per capita just above 100 USD, it is understandable that the development of an SDI has not been prioritized. Mozambique has been attracting foreign investment for its extractive industries and cash crops, both export oriented and with a strong territorial implementation (OECD, 2013). Its economic growth remains lower than expected to improve the living conditions of the growing population, also because of the poor state of its domestic physical infrastructures that are hindering the development of the internal market and regional development (OECD, 2013). On the other hand, the government is committed to the preservation of the valuable natural ecosystem services (Natural Capital Coalition 2018). The development of the Mozambican SDI must be brought to political attention to assist the government in negotiating among these important but sometimes conflicting objectives.

In Mozambique, there have been attempts to make spatial datasets available on the Internet, such as the "WebGIS Moçambique" prepared by the Brazilian state-owned Agriculture Research Corporation which brings together 14 spatial datasets from national and international institutions (Bolfe, Batistella, Custódio, Jalane, & Pugliero, 2011). Another initiative was the SDI for the Zambezi valley, in which a spatial and alphanumerical centralized database was made available to monitor sectoral activities using a WebGIS interface (PAINHO, ALMEIDA, MARTINS, ADELINO, & OLIVEIRA, 2015). However, these initiatives are no longer available on the Internet probably due to the end of project funding. The National Cartography and Remote Sensing Centre (CENACARTA) provides baseline GIS data, facilitates the purchase of satellite data, and provides topographic and thematic maps; these services are mainly online. However,

the website has regularly been offline due to unknown reasons. Finally, the Ministry of Transport launched the "Inter-agency GIS" for Mozambique through the spatial development program (PED) (Ministério dos Transportes e Comunicações, 2016). As far as the authors know, the "Inter-agency GIS" for Mozambique is the only initiative currently available on the Internet. The limited success of these initiatives may be due to the lack of commitment and follow-up by the main spatial data stakeholders in the country, and their loose political support and legal framework.

The lack of updated spatial data has been reported in several studies for Mozambique (Cabral et al., 2017; Niquisse, Cabral, Rodrigues, & Augusto, 2017). The existence of an SDI is of utmost importance to carry out reliable monitoring studies required for implementing national policies regarding climate change mitigation (República de Moçambique, 2015b), mangrove protection (República de Moçambique, 2015a), hydrology management (República de Moçambique, 2007), poverty management (República de Moçambique, 2011), agriculture (República de Moçambique, 2013a), and others. The existence of an SDI for Mozambique is also fundamental to unlock the full potential benefits from several Earth Observation programs in place, such as the Africa – EU Partnership of the Global Monitoring for Environment and Security (GMES, n.d.), the TIGER initiative (ESA, n.d.), among others.

## 2.3. Data and Methods

An early clarification of roles and responsibilities of the different institutions in the SDI initiation is important for the development of the project (Foster & Ryttersgaard, 2001). A total of 17 Ministries and 14 government agencies were identified as the main users and generators of spatial data in the Mozambican Administration (Annex 1). These institutions have responsibilities in defence, natural resources including energy, agriculture, mapping, disaster management, public infrastructure, and statistics in Mozambique.

To assess the potential contribution of these institutions for the development of the SDI in Mozambique, a questionnaire (Annex 2) was developed focusing on the existing capabilities of the different organizations concerning the main SDI components (Guigoz, 2015; Mansourian, Rajabifard, Valadan Zoej, & Williamson, 2006): organization, legal and technical frameworks and accessibility (Table 2.1).

*Table 2. 1: Survey categories and corresponding SDI (adapted from Mansourian et al. 2006, Rajabifard et al. 2006 and Rajabifard et al. 2002)*

| SDI Dimension (Mansourian et al., 2006) | Survey category/ SDI components (Abbas Rajabifard et al. (2002) |
|---|---|
| **Organization Framework** | Experience of the institution |
| **Legal framework** | Legal framework/ Policies concerning data sharing |
| **Technical framework** | Spatial data / Data: content (themes) |
| | Data Standards/ Standards: Data quality & metadata |
| | Skilled staff/ People working in the institution |
| | Technology level/ hardware & software for capture and database management |
| **Accessibility** | Data accessibility/ Accessing Network: communication system & network mechanism |

The "Organization framework" of the SDI proposed here, is meant to provide a conceptual model and a strategic plan for the process-based development of an SDI (Coleman & McLaughlin, 1998), to raise awareness of spatial data sharing, to promote partnerships among the organizations involved, and to ensure political and financial support for the SDI development and implementation (Mansourian et al., 2006). Whereas the SG of the Nairobi statement (Foster & Ryttersgaard, 2001) extends to all stakeholders in the spatial data community, including those not consulted in this survey,

such as academia and the private sector, we focused on the government agencies because those are the ones with potential to acquire the authority and political support to lead the initiation of the SDI.

We discriminated the experience of the institution as an indication of its potential contribution to the organization framework. The longer the institution has been involved in spatial data in the public administration the more likely its awareness is of the needs, challenges, and abilities of the spatial data stakeholders. Other infrastructural elements, such as recruitment, training and educational policies that would play an important role within and between organizations (Dessers, Hendriks, Crompvoets, & Van Hootegem, 2009) were not considered due to the lack of information.

The contributions for the Technical Framework and Accessibility of the SDI, or the "product-based" development strategy (Coleman & McLaughlin, 1998), are relatively straightforward, as it accounts for the in-house resources that each institution owns, allowing it to provide data and services to the spatial data community.

The data collection process took about 6 months and started with a formal request within the Ministries. The survey was only conducted upon approval of the Ministry which required considerable efforts (e.g., in some cases an appointment with the Permanent Secretary within the Ministries was required). Answers were analyzed and discussed with the institutions through follow-up phone calls and/or emails for further clarification, as well as website visits to complement the assessment.

## 2.4. Results

### 2.4.1. Survey results

From the 31 institutions invited to complete the survey, 10 declined or refused to participate (6 ministries and 4 government agencies), and 5 ministries appointed other government organizations already selected to represent them in the survey. Therefore, our questionnaire was completed by 16 institutions. However, 4 of them stated that spatial data is not of core relevance to their activities. Therefore, our analysis covered 12 governmental institutions of Mozambique involved with spatial data (Table 2.2).

*Table 2. 2: Surveyed institutions in this study*

| # | Ministry | Institutions | Department |
|---|---|---|---|
| 1 | Ministry of Agriculture and Food Security (MASA) | Agricultural Research Institute Mozambique (IIAM) | National Directorate of Documentation, Training and Technology Transfer |
| 2 | Ministry of Culture and Tourism (MICULTUR) | Human Resource Department (DRH) | Human Resource Department |
| 3 | Ministry of Economy and Finances (MEF) | National Statistics Institute (INE) | Cartography and Operations |
| 4 | Ministry of Foreign Affairs (MINEC) | Minister's office - Ministry of Foreign Affairs | Minister office |
| 5 | Ministry of Industry and Commerce (MIC) | Minister's office - Ministry of Industry and Commerce | Minister s office |
| 6 | Ministry of Justice and Religious Affairs (MINJUST) | Minister's office - Ministry of Justice and Religious Affairs | Minister office |
| 7 | Ministry of Land, Environment and Rural Development (MITADER) | National Directorate of Land (DNT) | Cadaster |
| | | National Center for Mapping and Remote Sensing (CENACARTA) | Studies and dissemination |
| 8 | Ministry of Mineral Resources and Energy (MIREME) | National Directorate of Mines (DNGM) | Cartography Department |
| | | National Institutes of Mines (INAMI) | Cartography Department |
| 9 | Ministry of State Administration and Civil Service (MAEFP) | National Department of Territory organization (land management) (DNOT) | Department of Geography and land Management |
| | | National Institute of Disaster Management (INGC) | Technical Department |

| | | | |
|---|---|---|---|
| 10 | Ministry of the Sea, Inland Water and Fisheries (MIMAIP) | Fisheries Research Institute IP | Aquatic Environment |
| 11 | Ministry of Transport and Communication (MCT) | National Institute of Meteorology (INAM) | Observation and Meteorological network |
| | | Spatial Development Program (PDE) | Information System |
| 12 | Ministry of Public Infrastructure, Housing and Water Resources (MOPHRH) | National Roads Administration (ANE) | Project Directorate |

*Organization framework*

The institutions CENACARTA, DNT, DNGM, and IIP have more than 15 years of experience with Geographic Information Systems (GIS). There are three institutions (INAMI, INE, and MAEFP-DNOT) with less than 15 years and more than six years of experience. There are five institutions (ANE, IIAM, INAM, INGC, and PDE) that have less than six years of experience with GIS (Figure 2.2).

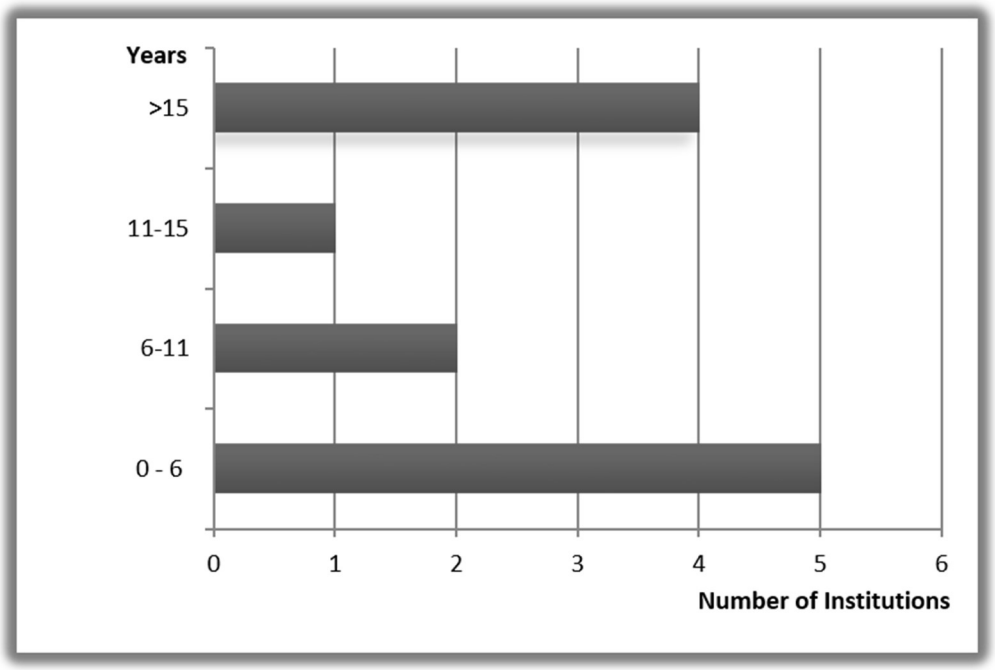


*Figure 2. 2: Experience in working with GIS*

*Legal framework*

Most of the surveyed institutions share spatial data with other public and private organizations (Figure 2.3). Only one institution does not share its spatial data due to regulations, four institutions only share spatial data with other public institutions, and the remainder (seven) share their spatial data with both public and private users. Most of the institutions have no price policy for data accessibility (ANE, DNT, INAMI, IIAM, INE, INGC, PDE). Three of the institutions have data pricing policy (CENACARTA, DNGM, INAM), some data are free of charge while access to other data requires users to pay for obtaining them. Some institutions (three) have no clear procedure for data sharing and require a formal request. Usually, spatial data are made available upon a formal reply to the request made in a long process.

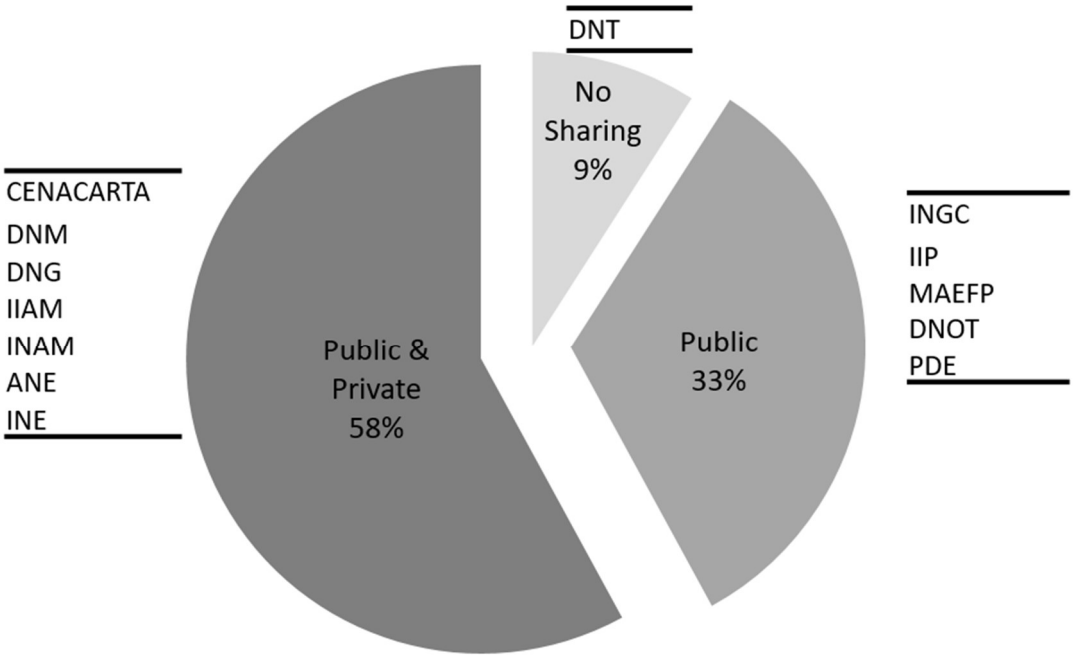


*Figure 2. 3: Spatial data sharing*

*Technical framework*

The 12 surveyed institutions produce 15 spatial data themes. The CENACARTA produces nine categories of spatial data equivalent to 60%. Most of the spatial data are being produced by more than one institution except statistics and mine resources by INE and INAMI, respectively (Table 2.3).

*Table 2. 3: Spatial data produced by each institution*

| Spatial Data | Institutions | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | K | L | |
| 1. Agro ecologic Zone | | X | | | | X | | | | | | | 2 |
| 2. Boundary | | X | | | | | | | | | X | | 2 |
| 3. Cadaster | | | X | X | | | | | | | | | 2 |
| 4. Climate | | | | | | X | X | | X | | | | 3 |
| 5. Geology | | | | | X | | | | | | X | | 2 |
| 6. Hydrology | | X | | | | | | | | X | | | 2 |
| 7. Infrastructure | | X | | | | | | | | | X | | 2 |
| 8. Land Use Land Cover | | X | | | | | | | | | X | X | 3 |
| 9. Mine Resources | | | | X | | | | | | | | | 1 |
| 10. Park & Reserves | | X | | | | | | | | X | | | 2 |
| 11. Soil | | X | | | | X | | | | | | | 2 |
| 12. Statistic | | | | | | | | X | | | | | 1 |
| 13. Transport | X | X | | | | | | | | | X | | 3 |
| 14. Vulnerability & Risk | | | | | | | | | X | | | X | 2 |
| 15. Others | | X | | | | | X | X | X | | X | | 5 |
| Total | 1 | 9 | 1 | 2 | 1 | 3 | 2 | 2 | 3 | 2 | 6 | 2 | |

Legend

A. National Roads Administration (ANE)
B. National Center for Mapping and Remote Sensing (CENACARTA)
C. National Directorate of Land (DNT)
D. National Institutes of Mines (INAMI)
E. National Directorate of Mines (DNGM)
F. Agricultural Research Institute Mozambique (IIAM)
G. National Institute of Meteorology (INAM)
H. National Statistics Institute (INE)

I. National Institute of Disaster Management (INGC)
J. Fisheries Research Institute (IP)
K. National Department of Territory organization (land management) (DNOT)
L. Spatial Development Program (PDE)

The category "Others" refers to varied spatial data themes, not included in any other category. Most institutions produce datasets with national coverage (eight), while others generate spatial data for specific parts of the country (four). This might mean that these institutions are working in different scales or coverage areas with a duplication of efforts in data production. Most institutions (ten) have their own standards to produce spatial data. These institutional standards are defined by each institution and differ from one institution to another. Only two institutions (IIP and INAM) follow international standards (ISO/TC 211) and use ISO 19115:2003 and ISO/TC 19139:2007 as a standard for metadata production. These institutions share data with international organizations and, for this reason, they use international standards.

The number of skilled GIS staff identified among the surveyed institutions were 220, most of them are found in CENACARTA and DNT (76%) (Figure 2.4).

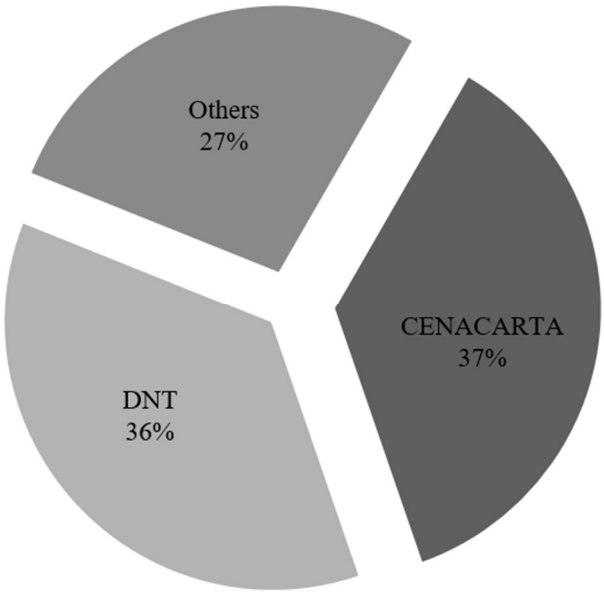


*Figure 2. 4: Skilled GIS staff*

The technology level is very good for two institutions: PDE and DNT. These have very good ICT infrastructure with a well-equipped GIS department, from data collection tools to easy online accessibility through SIGIT (land information system). Four other institutions were rated as good (CENACARTA, DNOT, INE, and INGC). These have very well-equipped GIS departments and are also well-equipped with ICT to make their data easily accessible online. The remainder are considered adequate due to some insufficiencies in the equipment for both ICT and GIS.

*Accessibility*

Spatial data is commonly made available for 11 of the 12 institutions. Seven of them make it available on the Internet, but CDs and pen drives are also regularly used. Figure 2.5 shows the means used to make the data available.

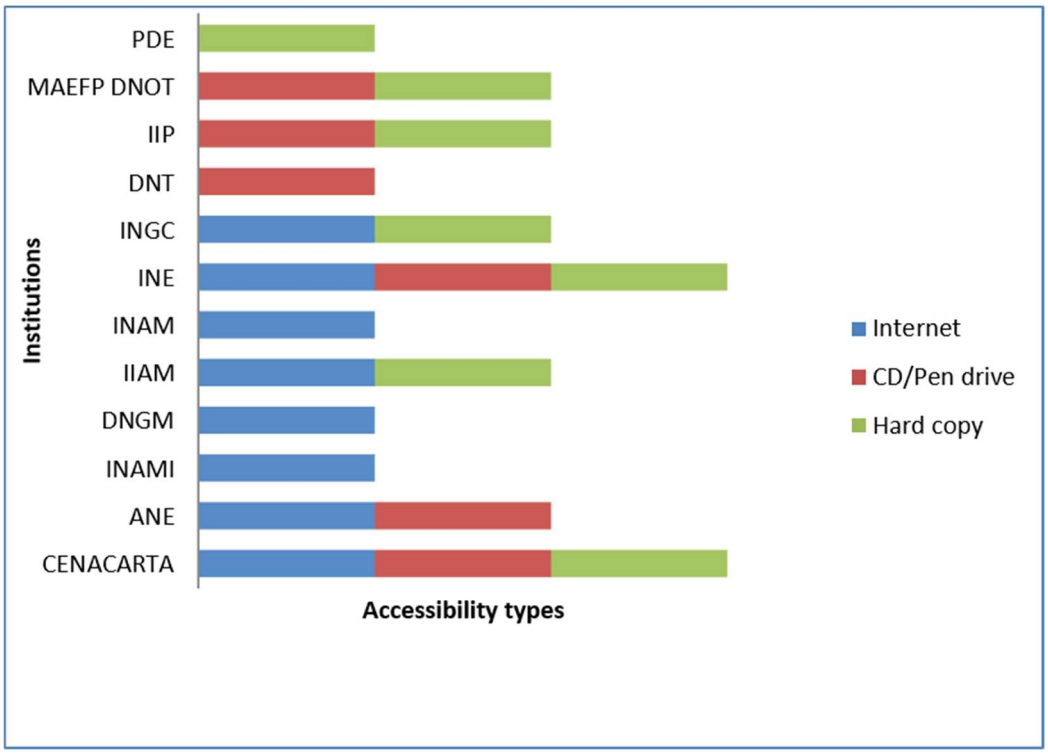


*Figure 2. 5: Accessibility types*

## 2.5. Discussion

### 2.5.1. Current status of spatial data sharing in Mozambique

The legal framework supporting spatial data is essential for SDI development. However, Mozambique has no policy, law or regulation concerning spatial data. African countries owning SDI have set up specific legislation (e.g., South Africa and Cape Verde for instance, have respectively, Act number 54 of 2003 (Republic of South Africa, 2004) and Decree-law 55/2010 of 6 of December (República de Cabo Verde, 2010).

The SDI's spatial data themes can differ from one country to another. Some African countries, such as South Africa, have ten spatial data themes (Siebritz & Fourie, 2015) and Cape Verde has 19 spatial data themes (Instituto Nacional de Gestão de Território 2014). The survey carried out in this study enabled the identification of 15 categories of spatial data themes within the Mozambican government institutions that can constitute the core datasets for the future SDI (Table 3). This set of geographical themes is quite diverse in nature and can be very useful, or even decisive, for setting up any successful GIS application in Mozambique. Two of the surveyed institutions, PDE and ITC, have the capabilities to host a WebGIS with the resources already in place. Particularly for Mozambique, organizations such as EIS Africa could provide a forum to stakeholders reach agreements and search guidance to reach a coherent set of common spatial themes and procedures like it has done successfully for other countries, such as Uganda, Benin, Madagascar, Ghana, among others (EIS Africa, n.d.).

The Mozambican institutions currently share spatial data in an environment where there are no common standards in producing the spatial data, no metadata regulations, no data custodianship nor sharing policies. This may also jeopardize future SDI implementation attempts.

### 2.5.2. An SDI framework for Mozambique

Experience from many countries (Sinvula et al. 2017) has shown that a successful SDI initiative must cover all the dimensions of the SDI conceptual model as adapted from (Mansourian et al., 2006), as well as the five components detailed by (Rajabifard et al. 2002). Whereas data, skills and technologies are necessary to connect people with the data (Rajabifard et al 2002), i.e., the “product-based” approach of the SDI development, these may not be enough to develop and sustain such a system. The “process-based” approach, involving awareness, communication organization, leadership and will, is very often decisive to the success of an SDI initiative and resides in the organization framework of the SDI model concept adapted from Mansourian et al. 2006.

The results of our survey highlight the potential contributions of 12 government institutions for the four dimensions of the SDI conceptual model: “Organization framework,” “Legal framework,” “Technical framework,” and “Accessibility.” Figure 2.6 shows the institutions that can better contribute to each dimension according to the referred criteria.

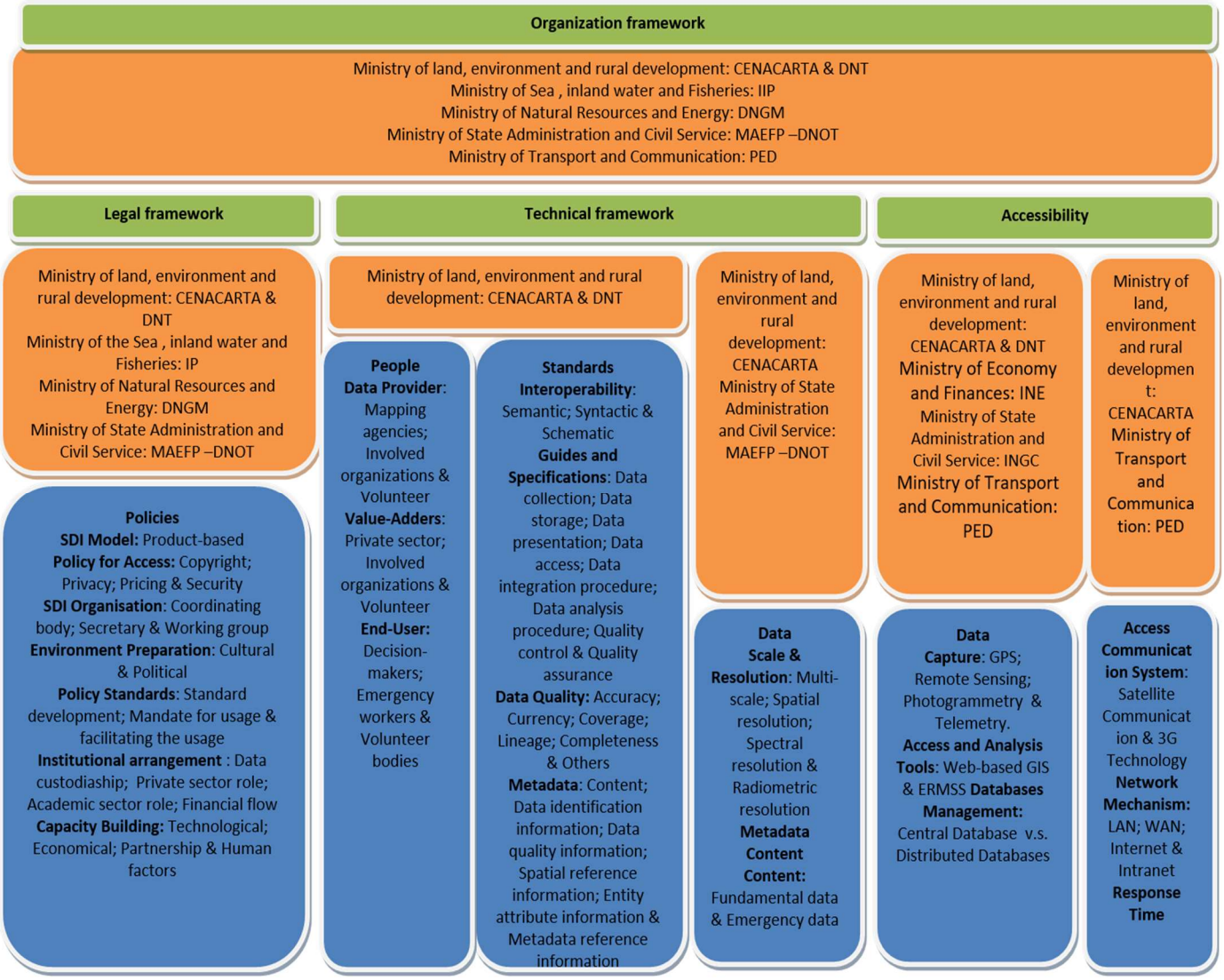


*Figure 2. 6: The proposed structure of SDI Framework for Mozambique*

*Figure 2. 7: The proposed structure of SDI Framework for Mozambique*

The green colour identifies the four SDI dimensions; the orange colour shows the best-placed institutions to contribute to the SDI respective dimension; and, the blue colour represents a schematic SDI conceptual model: guides and specifications required in each dimension (Mansourian et al., 2006). For the "Organization framework" the criteria used to identify the

institutions that can better contribute were the institution experience in producing and managing spatial data, and technology capability. The best-placed institutions in this criterion were the CENACARTA, DNT, DNGM, and IIP which had more than 15 years of experience, MAEFO-DNOT had 11-15 years of experience. Although PED had only six years of experience it had high technology capability and has been consistently promoting the use of spatial data through WebGIS (Ministério dos Transportes e Comunicações, 2016). The same institutions were also considered for the "Legal framework" due to the experience and the spatial data themes produced: CENACARTA produced nine data themes; MAEF-DNOT produced six; IIP three data themes; DNGM and DNT one data theme each but had more than 15 years of experience. The skilled staff and produced spatial data themes were used as a requirement for the "Technical framework." For these reasons, the selected institutions were CENACARTA, DNT, and MAEFO-DNOT. For the last dimension, "Accessibility", the selected institutions were according to technology capability and ICT infrastructure; these were CENACARTA, DNT, INE, INGC, and PED.

## 2.6. Conclusion

Mozambique has the potential to develop and implement an SDI in the short term. The government agencies have the technical capabilities and experience to put this project on the fast track. All the institutions producing or using spatial data can contribute to SDI development were identified: CENACARTA, DNT, IIP, DNGM, and DNOT for "Legal framework"; CENACARTA and DNOT for "Organization" and "Technical" frameworks; and CENACARTA and PDE for "Accessibility". This paper only addressed the government institutions; however other

stakeholders, such as private organizations and academia should also be involved to best contribute to the SDI development. We conclude that the country can develop SDI through "process-based" and "product-based" models. There is also a perceived need to expand and enrich the spatial datasets.

# Chapter 3: Integration of Ecosystem Services into Land Use Planning in Mozambique

## 3.1. Introduction

Ecosystem services (ES) provide benefits to people, fundamental for human well-being (Costanza et al., 2014; Mooney et al., 2005). The Millennium Ecosystem Assessment (MEA) conceptual framework formed a basis for the development of ES and decision-making (Baker, Sheate, Phillips, & Eales, 2013). Within this framework, many organizations developed guidance and other support forms to implement ES concepts into planning policies (OECD, 2010a). Changes in ES may impact human well-being requiring sustainable use and management of ecosystems (Millenium Assessment, 2003). These changes may be due to direct drivers (e.g., habitat changes, climate change, invasive species, overexploitation, and pollution) and/or indirect drivers (e.g., changes in the human population, economic activity, technology) (Millenium Assessment, 2003; Nelson et al., 2006; Syrbe & Grunewald, 2017). These drivers can be managed through Land Use Planning (LUP) frameworks (Greiber & Schiele, 2011; Sheate & Baker, 2012). The integration of ES concepts into decision-making is possible if aspects, such as common understanding of ES concept among the stakeholders, information availability and official guidelines are considered (Martinez-Harms et al. 2015). The ES concept must be expressed and communicated effectively (Sheate & Baker, 2012). This process requires knowledge about ES, which has been acquired through the development of biophysical, economic and social valuation of studies throughout the world (Boyd & Banzhaf, 2006; Costanza et al., 2014; Felipe-Lucia, Comín, & Escalera-Reyes, 2015; Frélichová et al., 2014; Naidoo et al., 2008; Turner & Daily, 2008). However, the use of ES information in planning is quite limited (Martinez-harms et al., 2015; Ruckelshaus et al., 2015), though incorporating ES in planning could advance planning goals (Bauler et al., 2017). This paucity could be due to institutional obstacles, such as the lack of standards in assessment protocols and target, lack of qualified personnel, lack of data, and others (Polasky, Tallis, & Reyers, 2015; Sousa & Alves, 2020). Therefore, there is the need to develop approaches that allow planners

to better incorporate ES into plan development and implementation (Bendor, Spurlock, Woodruff, & Olander, 2017; Bezák, Mederly, Izakovičová, Špulerová, & Schleyer, 2017).

The integration of ES into planning has mainly been debated at a theoretical level (Hansen & Pauleit, 2014), but there is less evidence on the efforts proposing the integration of ES into decisions made in land usage (Ashnani, Danehkar, Makhodoum, & Majed, 2018; Martinez-harms et al., 2015; Ruckelshaus et al., 2015). ES assessments increased in the last decade as shown by the European Union ecosystem assessment (Maes et al., 2020) and several countries, such as Mexico (Sarukhan et al., 2010), UK (Bateman et al., 2013), Czech Republic (Frélichová et al., 2014), China (Ouyang et al., 2016), among others. Some ES for spatial planning have also been studied in some regions, such as the Southeast Pampas of Argentina (María Paula & Néstor Oscar, 2012); Belize, the island of Oahu (Hawaii), Vancouver Island (Canada), (Mckenzie et al., 2014); and Bordeaux (France) (Cabral, Feger, Levrel, Chambolle, & Basque, 2016). However, there are still difficulties in defining and operationalizing ES within planning due to rigid regulatory frameworks and inadequate planning tools (Di Marino, Tiitu, Lapintie, Viinika, & Kopperoinen, 2019), which together with the lack of an consensual methodology for assessing ES in biophysical and economic terms, spatial representation of ES, interpretation and utilization at the normative level in plans and projects represent obstacles to the effective integration of ES in LUP.

It is evident that mainstreaming the ES concept into LUP has significantly increased in practice and research due to the growing scientific and political awareness on this topic (Egoh et al., 2008; Koschke et al., 2014; Rozas-Vásquez, Fürst, Geneletti, & Almendra, 2018). However, the understanding and the existence of a practical strategy for mainstreaming these concepts into LUP are still relatively new to many governments in Africa (Bauler et al., 2017). In the African context, South Africa is the country where most studies have been conducted (Cowling et al.,

2008; Egoh et al., 2008; Pierce et al., 2005; Wangai, Burkhard, & Müller, 2016). Some West African countries, such as Ghana and Nigeria, have also experienced studies to integrate ES into LUP (Bauler et al., 2017). Although Southern African countries, have, in general, experienced research in ES (Wangai et al., 2016), the lack of integration of ES into policy-making has been pointed as a gap between science and management processes (Byg et al., 2017; CEPSA, 2008; Fagerholm, Eilola, Kisanga, Arki, & Käyhkö, 2019).

Soon after the MEA synthesis report (MEA, 2005) was released, the International Institute for Sustainable Development (IISD) and the United Nations Environment Program (UNEP) assessed ES and poverty of seven countries under a series scoping studies: Kenya (Wong, Roy, & Duraiappah, 2005b), Mali (Wong, Roy, & Duraiappah, 2005a), Mauritania (Wong et al., 2005b), Rwanda (Wong et al., 2005b), Tanzania (Wong et al., 2005b), Uganda (Wong et al., 2005b), and Mozambique (Wong et al., 2005b). The assessment outcomes showed that, in five of the ten provinces of Mozambique, all ES were threatened, and improvement in the management of ES was recommended to go along with poverty alleviation (Wong et al., 2005b). Other assessments pointing to the need for improving LUP were carried out for Mozambique, such as environmental threats and opportunities assessment (Byers et al., 2013) and the state of forest ES and wellbeing (Norfolk & Cosijn, 2013). ES have also been assessed monetarily (Niquisse & Cabral, 2017) and through the impact of land cover changes on ES (Niquisse et al., 2017; von Maltitz, Gasparatos, Fabricius, Morris, & Willis, 2016). However, these ES assessments are far from filling the gap between science and management processes since none of these studies addressed integrating ES into existing decision-making processes. Developing a specific policy is one option to integrate ES in LUP, another option is integration through a Strategic Environmental Assessment (SEA) (Geneletti, 2011), which is a higher-level

structured approach for obtaining and evaluating environmental information (Abaza, Bisset, & Sadler, 2004). The environmental information obtained by a SEA includes social, economic, health, and environmental aspects, as well as the effects created by the implementation of policies, plans and other strategic instruments (Abaza et al., 2004; Rozas-vásquez, Fürst, & Geneletti, 2019). SEA can effectively enhance spatial planning processes' effectiveness in terms of sustainability by implementing the ES approach transparently through participatory approaches, scenario modeling, and trade-off analysis (Geneletti, 2015; Helming, Diehl, Geneletti, & Wiggering, 2013; Rozas-vásquez et al., 2019). There are general SEA guidelines, such as the ones defined by the World Bank (Kjörven & Lindhjem, 2002; The World Bank Group, 2012), and by the OECD (OECD, 2006). However, a SEA as a tool can differ depending on the context where it is applied, resulting in the need for specific guidelines to be developed to address the integration of ES into LUP, such as biodiversity (Brownlie & Treweek, 2018), climate change (Byer et al., 2018; OECD, 2008), and ES (Brownlie & Treweek, 2018; OECD, 2010b; Partidário, 2010).

Some early SEA were carried out in Mozambique since the late 1990's, for example, for the coastal area of the Inhambane province (Dalal-Clayton & Sadler, 2004), for the Mozambique Coastal Zone (República de Moçambique, 2013b), for the special planning of the Zambezi valley (Ministério de Planificação e Desenvolvimento - Agência de Desenvolvimento do Vale do Zambeze & Ministério para a Coordenação e Acção Ambiental, 2014) and, more recently, the SEA on the National Plan for Territorial Development (Ministério de Ambiente Terra e Desenvolvimento Rural, 2019). These initiatives have resulted in large quantities of environmental data being collected, updated, and systematized. It has also brought fruitful results for ecosystems, such as the special spatial planning for the Zambezi valley, where there

were areas identified with high natural value or high ecological sensibility. However, all these initiatives have been conducted without a clear mandate for coordinating SEA processes across sector ministries, making its implementation ineffective (NCEA, 2020). Setting the SEA legal framework, besides a local policy, could help to harmonize the process within the country and favor the integration of ES into LUP. This integration would benefit from the use of software tools which are being developed for ES assessment such as Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST), Artificial Intelligence for Ecosystem Services (ARIES), Multiscale Integrated Models of Ecosystem Services (MIMES), Social Values for Ecosystem Services (Solves), Land Utilisation Capability Indicator (LUCI), Integrated Model to Assess the Global Environment (IMAGE), Co$ting Nature, Ecosystem Valuation Toolkit, ESM-App and others (Palomo et al., 2017).

This paper aims to assess the current LUP documents regarding its suitability for mainstreaming the ES concepts in Mozambique, and propose a framework for ES integration in LUP processes through an operational SEA which integrates ES information. The study's outcomes will be useful for designing and implementing approaches mainstreaming ES into LUP the country. The results could also enhance the existing capabilities to produce, share and use spatial data among Mozambican government institutions (Atumane & Cabral, 2019), and help operationalize SEA legal framework.

## 3.2. Methodology

### 3.2.1. Study area

Mozambique is a country of southern Africa bordered by Tanzania in the north, Malawi, Zambia, Zimbabwe, and South Africa in the west, Swaziland and South Africa in the South, and the Indian Ocean in the east (República de Moçambique, n.d.) (Figure 3.1). The country spans 799,380km$^2$ with 27,909,798 population in 2017 (INE, 2019c), growing at an annual-rate of 2.8% and a population density of 35 inhabitants/km$^2$ (INE, 2019a). In 2017, the Gross Domestic Product (GDP) per capita was 466,18 USD (INE, 2019b). The country's GDP (current prices in $10^6$MT) in 2018 was 887.806 USD with the following top export products: mineral coal, aluminum bars and rods, electricity, natural gas, heavy sands, tobacco, sugar, bananas, prawns, and woods. The top import products were machinery, diesel, automobiles, petrol, medicines, food oil, hydraulic cement, and beer (INE, 2019a).

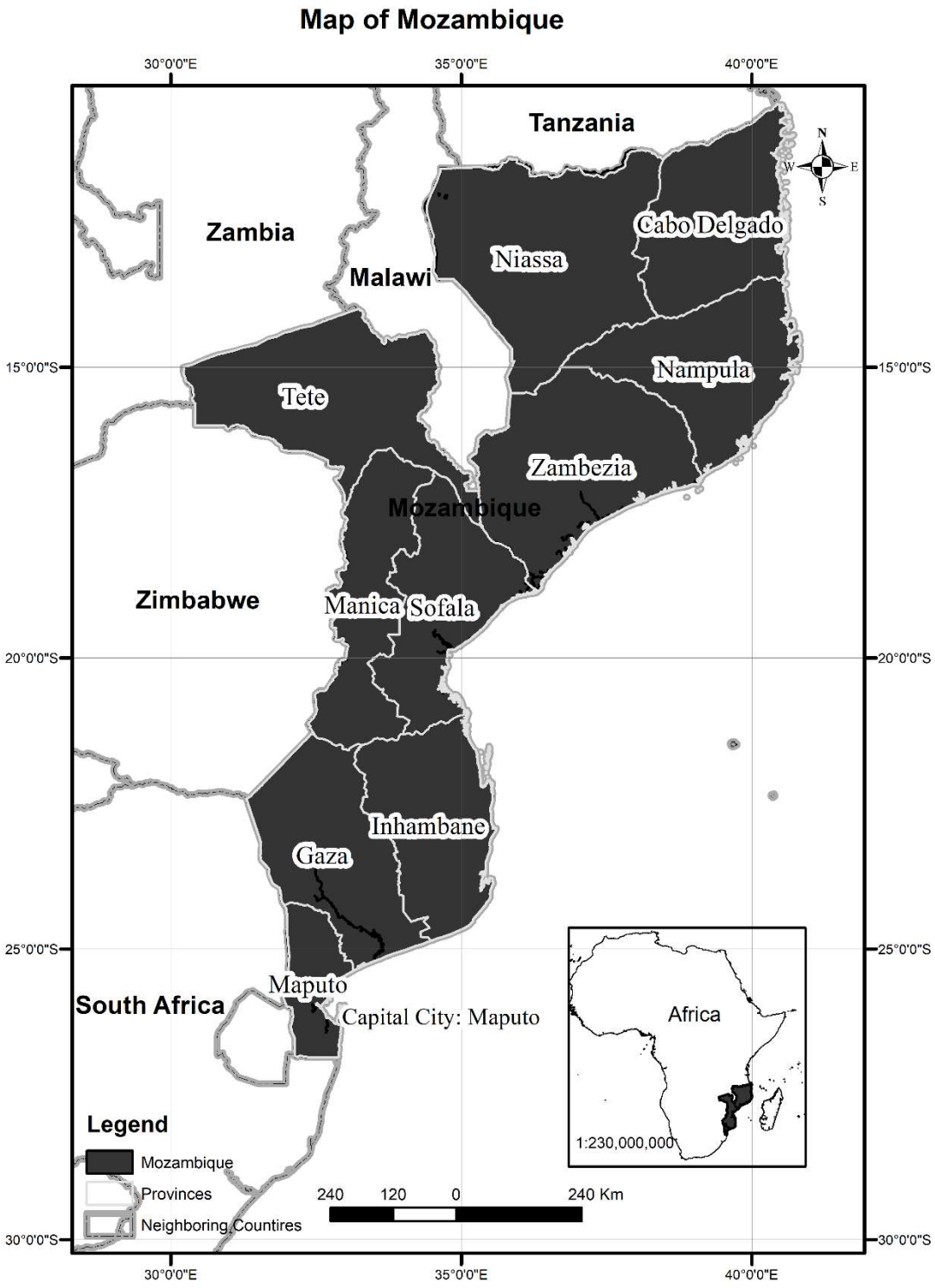


*Figure 3. 1: Study area*

### 3.2.2. Methods

The research was conducted through a review of documents relevant to LUP in Mozambique. The search and collection process of documents included a previous consultation of websites, email exchanges, and phone interviews with people from governmental institutions dealing with LUP, specifically the Ministry of Land, Environment and Rural Development through the National Directorate of Land and the National Directorate of Land Use Planning; the Ministry of State Administration and Civil Service through the National Department of Territory Organization; and the Ministry of Economy and Finances. All these institutions deal with LUP processes, except the last one, which deals with LUP implementation through development programs. The search for data and data collection process were carried out from February to August 2019. The objective was to understand the LUP context better and to learn about possible sources of information. After selecting the relevant documents for LUP processes and implementation, a content analysis (Hsieh & Shannon, 2005) based on ES categories defined by the Millenium Ecosystem Assessment (2003), i.e., provisioning, regulating, supporting, and cultural, was carried out. The analysis of the documents was made hierarchically in terms of importance, from the fundamental principles or objectives (policies or strategies) to official rules (laws and regulations). The content analysis was made by identifying any explicit or implicit match between the LUP documents content with the ES categories (Bauler & Pipart, 2013; Bauler et al., 2017; Mascarenhas, Ramos, Haase, & Santos, 2015). The explicit reference to ES in the documents was considered as a direct reference to ES or its synonyms, such as Environment Services or Ecological Services. The implicit reference to ES in the documents

consisted in looking for proxies representing the same concept but using different designations, e.g., measurement of biophysical values and benefits related to the ES.

Then, a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis was carried out to set up an ES framework. The experts who identified and judged the criteria of the SWOT analysis were the authors of this study. The aim of the SWOT analysis was to place in evidence the way internal and external factors affect the success of developing and implementing future strategies regarding the ES integration into LUP through a SEA (Bauler et al., 2017). Strengths were internal factors that could increase ES awareness and contribute to mainstream ES into planning goals. On the other hand, weaknesses were the opposite of strengths. Opportunities were external factors to policies, such as political, economic, and technical aspects, which could potentiate ES's mainstream into plans overcoming weaknesses. Threats were external factors to policies that made the mainstream of ES into LUP impossible. Finally, the information gathered from the SWOT analysis enabled the construction of a conceptual framework showing the possible strategies to mainstream ES into an LUP.

## 3.3. Results and Discussion

### 3.3.1. LUP documents retrieved for content analysis

A total of seven documents were retained for the content analysis: three policies, two laws, and two regulations were retained for analysis (Table 1).

*Table 3. 1: Reference to ES in the land use policy documents*

| Type | Description | Year | Source |
|---|---|---|---|
| Policy | Land Policy | 1996 | (Conselho de Ministro, 1996) |
| | Land Use Policy | 2007 | (Conselho de Ministro, 2007) |
| | National Development Strategy 2015-2035 | 2014 | (República de Moçambique, 2014) |
| Law | Land Law | 1997 | (Assembleia da República, 1997b) |
| | Land Use Law | 2007 | (Assembleia da República, 2007) |
| Regulation | Land Law Regulation | 1998 | (Conselho de Ministro, 1998) |
| | Land Use Law Regulation | 2008 | (Conselho de Ministro, 2008) |

The Land Policy (Conselho de Ministro, 1996) focuses on access and land use mechanisms while the Land Use Policy (Conselho de Ministro, 2007) focuses on LUP on a sectoral basis. The National Development Strategy (República de Moçambique, 2014) sets industrialization as the development path through economic diversification, research, and innovation. The National Development Strategy (República de Moçambique, 2014) is drawn based on the Land Use Policy (Conselho de Ministro, 2007) and deals with a sectoral strategy.

The Land Law (Assembleia da República, 1997b) focuses is on land rights while the Land Use Law (Assembleia da República, 2007) focuses is on the organization of national land and sustainable use of natural resources.

The Land Law Regulation (Conselho de Ministro, 1998) deals with cadaster, and the Land Use Law Regulation (Conselho de Ministro, 2008) focus concentrates on land use planning tools at national, provincial, district and municipal levels.

We found that all the documents referenced "sustainability," but only the National Development Strategy (República de Moçambique, 2014) made explicit reference to "Environmental Services," but without any further details. All the other documents did not

make any explicit reference to ES. The implicit reference analysis revealed that most of the LUP documents' content is related to provisioning ES (Table 3.2). All the analyzed LUP documents referred to at least one provisioning ES benefit. The Land Use Law Regulation (Conselho de Ministro, 2008) was the document that contained more implicit references to ES (four chapters). Five out of the seven LUP documents referred to regulating ES, the Land Use Law Regulation (Conselho de Ministro, 2008) being the one with more references. Both Land Law (Assembleia da República, 1997b) and Land Law Regulation (Conselho de Ministro, 1998) did not made reference cultural ES while all the other LUP instruments did, for instance, through references to the management of areas with high ecological value, landscape, and heritage. None of the LUP documents made any explicit or implicit references to supporting ES.

*Table 3. 2: Types of Ecosystem Service vs Land Use Planning Documents*

| Land Use Documents / Ecosystem Services | | Land Policy | Land Use Policy | National Development Strategy | Land Law | Land Use Law | Land Law Regulation | Land Use Law Regulation |
|---|---|---|---|---|---|---|---|---|
| **Provisioning** | Food, fuel, fiber, fresh water, biochemical & genetic resources | Chapter 3, nº 14<br>Chapter 4, nº 15 | Chapter 3, nº 3.2, line a)<br>Chapter 3, nº 3.3<br>Chapter 3, nº 3.4 | Chapter 3, nº 3.2.3.1<br>Chapter 3, nº 3.2.3.2 | Chapter 2, Article 8 | Chapter 3, Article 5, nº 1<br>Chapter 3, Article 7, nº 2 | Chapter 2, Article 5 & 6 | Chapter 3, Section II, Article 18, line a)<br>Chapter 3, Section III, Article 21<br>Chapter 4, Article 27 & 28<br>Chapter 5, Article 33 & 34<br>Chapter 6, Section II, Article 42 & Section III, Article 44 & Article 46 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Regulating** | Air quality maintenance, climate regulation, erosion control, regulation human diseases, water purification & pollination | Chapter 3, nº 14 | Chapter 3, nº 3.2, line a)<br>Chapter 3, nº 3.3<br>Chapter 3, nº 3.4 | | Chapter 2, Article 7 | Chapter3, Article 4, line d)<br>Chapter3, Article 5, nº 1<br>Chapter3, Article 5, nº 2 line d)<br>Chapter3, Article 7, nº 2 | | Chapter 3, Section III, Article 21<br>Chapter 4, Article 27 & 28<br>Chapter 5, Article 33 & 34<br>Chapter 6, Section II, Article 42 & Article 43 line c)<br>Chapter 6, Section IV, article 46 |
| **Cultural** | Spiritual & religions, education, recreation & ecotourism, aesthetic, inspirational & sense of place | Chapter 4, nº 15 | Chapter 3, nº 3.4 | Chapter 3, nº 3.2.3.3 | | Chapter3, Article 5, nº2, line e)<br>Chapter3, Article 7, nº2 | | Chapter 4, Article 28<br>Chapter 5, Article 34<br>Chapter 6, Section III, Article 44 & Section IV, Article 46 |
| **Supporting** | Primary production, production of oxygen, soil formation, nutrient cycle, water cycling & provision of habitat | | | | | | | |

### 3.3.2. SWOT analysis

#### 3.3.2.1 Strengths

The major strength found in the LUP documents is the common acknowledgement of the need to plan land use to ensure the sustainable use of ecosystems, i.e., the actual policies place sustainability as a fundamental aspect of LUP. The National Development Strategy (República de Moçambique, 2014) recommends planning the land use to guide a sustainable development strategy. The Land Policy (Conselho de Ministro, 1996) states the commitment to preserve natural resources, while the Land Use Policy (Conselho de Ministro, 2007)

addresses specific considerations for local populations. Both Land Policy (Conselho de Ministro, 1996) and Land Use Policy (Conselho de Ministro, 2007) have a strong orientation towards preserving the ecological equilibrium to ensure the sustainable use of natural resources.

#### 3.3.2.2 Weaknesses

The main weakness found was the lack of ES integration in the existing LUP documents. The existing LUP documents are old and/or ignore the ES concept making its mainstreaming into LUP difficult. LUP is developed according to what the Land Use Law (Assembleia da República, 2007) states at a national level (national plan for territorial development and special plans for spatial planning), provincial level (provincial-territorial development plans and interprovincial territorial development plans), district level (district land use plans) and, municipal level (urban structure plans, general urban development plans, partial urbanization plans, and details plans). However, regulations for implementing these plans are not yet in place. Another identified weakness was the shortage of trained staff in ES principles, which may compromise the existence and implementation of an ES integrative framework in LUP.

#### 3.3.2.3 Opportunities

The periodic and systematic revision of planning tools for land use within the timescale stated in the Land Use Law Regulation (Conselho de Ministro, 2008) is an opportunity to integrate new tools that may improve the LUP process and ensure sustainability. Other identified opportunities were the institutional development and the participatory approach recommended by the Land Policy (Conselho de Ministro, 1996), which might be useful towards

an ES integrative framework. The investment in information technologies and the existence of government institutions already working on spatial data (Atumane & Cabral, 2019) are also major opportunities towards a successful ES integrative framework.

#### 3.3.2.4. Threats

Negative political interference and/or lack of political willingness may threaten some initiatives and lead towards an ineffective ES integration in LUP. The lack of funds and technology to effectively monitor the natural resources exploitation may also cause existing LUP policies to be ignored or deficiently implemented.

Table 3 summarizes the SWOT results from the policy documents review and content analysis.

*Table 3. 3: SWOT analysis*

| **Strengths** | **Weaknesses** |
|---|---|
| • Strong orientation of LUP documents to preserve ecological equilibrium and ensure sustainable use of natural resources.<br>• Consideration for local populations.<br>• Recommendation to use LUP to guide the development strategy. | • No references to ES in LUP documents.<br>• Outdated LUP documents<br>• Lack of regulations for implementing lad use plans.<br>• Lack of trained staff in ES. |
| **Opportunities** | **Threats** |
| • Periodic and systematic revision of land use planning tools within the timescale stated in Land Use regulation.<br>• Participatory LUP processes.<br>• Investment in information technologies.<br>• Existence of Government institutions working with spatial data. | • Political interferences and influences contrary to ES integration in LUP processes.<br>• Lack of funds to invest in technology to monitor natural resources. |

### *3.3.3.* Integration of ES in Land Use Planning in Mozambique through a SEA

Based on the results of the content and SWOT analysis of LUP documents, a framework that can be adopted by governmental agencies and diverse stakeholders is proposed (Figure 3.2).

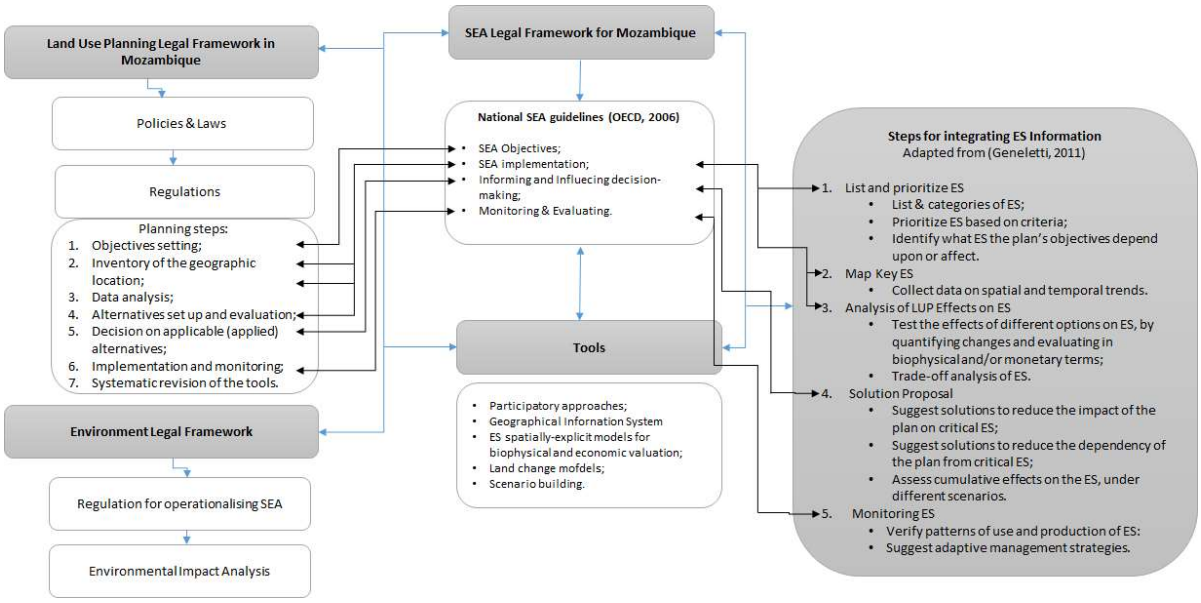


*Figure 3. 2: Framework to integrate ES in LUP through SEA in Mozambique*

This framework combines and adapts existing LUP and Environment legal frameworks to mainstream ES into LUP through an integrative SEA assisted by a set of common tools.

The Land Use Law regulation (2008) sets seven stages to be followed in the LUP process for Mozambique: (1) objectives setting; (2) inventory of geographic locations; (3) data analysis; (4) setting up alternatives and evaluation; (5) decision on applicable (applied) alternatives; (6) implementation and monitoring; and (7) systematic revision of the tools. However, as

mentioned before in the SWOT analysis, the tools for implementing plans at a national, provincial, and municipal level are not yet in place.

On the other side, the Environment Law (Assembleia da República, 1997a) which defines the legal basis for the correct use and management of the environment and its components, could also help in mainstreaming ES into LUP. The first decree–law regarding Environmental Impact Assessment (EIA) dates back from 1998 (Decree nº76/98). Its subsequent updates in 2004 (Decree nº45/2004), 2008 (Decree nº42/2008) and 2015 (Decree nº 54/2015) defined the EIA guidelines, i.e. "the necessary environmental studies, the public participation process, the review study process, the environmental feasibility decision process and the issuance of an environmental license for all public or private activities with direct or indirect influence on environmental components." Therefore, there are clear guidelines for environment assessment at an operational level.

At strategic level, several policies, plans, and programs in the country have gone through SEA, however, there are no regulations yet in place to help operationalising the SEA (NCEA, 2020) effectively. Therefore, one crucial step would be the creation of a new regulation under the Environmental Law (2007) to overcome this problem and update the Land Use Law regulation (2008) accordingly to create an effective SEA with ES information.

Under an operational SEA legal framework, the currently inexistent official SEA guidelines also need to be defined for Mozambique. The National SEA Guidelines should go through the following stages (OECD, 2006): (1) objectives definition; (2) implementation; (3) informing and influencing decision-making; and (4) monitoring and evaluation. The SEA stages within the country could be integrated into equivalent planning steps defined by the Land Use Law regulation (2008), and by the currently inexistent environment law regulation to

operationalize the SEA. This step would be beneficial since fitting SEA with other assessment systems would lead to efficiency and easy understanding (Therivel, 2010). Accordingly, five steps are proposed for mainstreaming ES into LUP in Mozambique under a SEA framework (Geneletti, 2011, 2015):

- *Prioritize ES based on criteria* (Rabe, Koellner, Marzelli, Schumacher, & Grêt-Regamey, 2016), such as the spatial importance, the importance of the ES for the population, rank in the ES concept (no overlap with other ES), comprehensibility, and origin of ES.
- *Map the key ES*: Ecosystems can be mapped by interpreting available land cover data, and ES can also be represented spatially through existing Land Use and Land Cover (LULC) data set (Sheate & Baker, 2012). Therefore significant ES can be matched with LULC within the spatial planning process in Mozambique. This process will require expert judgements about the different land cover types' capacities to provide various ES (Burkhard, Kroll, Müller, & Windhorst, 2009). The model can be used at various spatial and temporal scales. Some LULC data set are available through the Global Land Cover (Global Land Cover 2015), National Mapping Agency - CENACARTA (CENACARTA, 2012), and the planning area's inventory in the LUP process. The process must be completed through a participatory approach with stakeholders.
- *Analysis of LUP effects on ES*: The assessment of LUP impacts on ES can be carried out through the quantification of ES based on land cover using assumptions from literature reviews or process- based modeling (Altwegg & Grêt-regamey, 2011). Both approaches have limitations and require data beyond land cover. The required additional data is a challenge. However, process-based models use spatially explicit data, such as soil characteristics, geology, topography, etc. which is mostly available within LUP

processes and could facilitate the quantification of ES and analyze ES tradeoffs (Altwegg & Grêt-regamey, 2011).

- *Solution proposal:* The appropriate ways of presenting and communicating the findings from the analysis of LUP effects on ES are fundamental. For each scenario in LUP, assessing the cumulative effects on the ES and solution proposal to reduce the impact on critical ES and reducing the dependence of the plan from these ES is recommendable (Geneletti, 2011). This solution proposal model should lead to the response in securing and improving the continuous delivery of ES.
- *Monitoring ES:* Through the same information that informed the assessment for the potential effect of the plan on ES, data will be required to understand the actual effect and changes on ES.

The effective integration of ES in planning requires understanding the current planning tools (Albert, Aronson, Fürst, & Opdam, 2014; Di Marino et al., 2019). The LUP and Environment legal framework should be assisted by common tools necessary to implement the steps defined for integrating ES information into the SEA. These tools include, among others, found necessary, participatory approaches techniques, Geographical Information Systems, ES spatially explicit models for biophysical and economic valuation, land change models, and scenario building techniques. The use of common tools would facilitate communication among different stakeholders within the SEA framework.

The use of ES as a basis for land-use decisions requires information quantity and quality, stakeholder engagement, and tradeoff analysis (Bendor et al., 2017). It also requires measuring, visualizing and storytelling, and demonstrating impacts of decisions on ES supply (Brunet et al., 2018). The approach to integrate ES in Mozambique could consider ES, such as

water yield, water quality, erosion regulation, climate regulation, and biodiversity (Niquisse et al., 2017), or other judged relevant by stakeholders through a participatory approach.

The existence of opportunities to integrate ES could be shaped through established government agencies, such as the National Directorate of Territorial Planning and Resettlement and the National Sustainable Development Fund under the Ministry of Land, Environment and Rural Development. The agencies responsible for proposing to the government the national plan for territorial development have the responsibility and opportunity to plan the integration of ES and involve other relevant stakeholders, such as other government agencies, infrastructure companies, universities, civil society, and other organizations. This might lead to a greater importance of ES on the national agenda and to neutralize the threats detected by the SWOT analysis. In addition to the national plan for territorial development, the agencies could also develop guidelines for administrative subdivisions (subnational level) to overcome the identified weaknesses. These guidelines could include mandatory consultation of populations, and the systematic integration of ES into territorial development plans based on the principles of SEA. At the same time, it will be necessary to build capacity through training of technical staff to support regional and local authorities. Government agencies with capacity and universities could play an important role in capacity building. The universities can also be very important for research on the impacts of plans on ES to provide knowledge to optimize land use change plans while safeguarding ES. Some ES researches have been conducted at national level, such as modelling land cover changes and impacts on production and monetary value of ES (Niquisse & Cabral, 2017, 2018; Niquisse et al., 2017). We can also find some examples at sectoral level, such as the assessment of forest (Norfolk & Cosijn, 2013). Therefore, the universities can contribute to

wide and tailor the research on the integration of ES in land use plans and to make visible their relevance/contribution for achieving territorial development goals and welfare.

## 3.4. Conclusion

Integrating ES concepts into decision-making is crucial for achieving environmentally sustainable objectives. This paper assessed the current LUP documents regarding its suitability for mainstreaming the ES concepts in Mozambique. The content analysis and SWOT analysis show that current legal documents do not sufficiently support this country's integration process. To revert this situation, we propose a framework which integrates ES information in LUP under a legal SEA based on updated LUP and Environment regulations. We also suggest a set of actions assisted by common tools for mainstreaming ES into LUP. The proposed framework matches the requirements to include information on ES on LUP and can be used as a starting point by stakeholders to implement it through an operational legal SEA.

# Chapter 4: Conclusion

The Agenda 2030 challenges the countries to use and produce new spatial data to support the path to sustainable development. This requires development and adoption of Spatial Data Infrastructure, and the production of new relevant spatial data to support implementation, monitoring and reporting the progress on the targets on Sustainable Development Goals. This need was addressed through two research papers with the following objectives:

I. Contributing to the beginning of Mozambique SDI by assessing the capabilities and insufficiencies of the main spatial data stakeholders in the country in what concerns their resources and policies.

II. Assessing the current LUP documents regarding its suitability for mainstreaming the ES concepts in Mozambique, and propose a framework for ES integration in LUP processes

## 4.1. Summary of the results

This study assessed the challenges and opportunities on SDI development and analyzed the documents relevant to LUP process and implementation. On the SDI, we identified and characterized through a survey the government institutions producing, sharing, and using spatial data in the country to estimate their potential contribution to the development of the Mozambican SDI. On the integration of ES into LUP, we conducted a review of relevant documents to Mozambique's spatial planning by performing a content analysis based on ES categories.

The results revealed that 12 institutions produce 15 thematic datasets which can constitute the core of the SDI for Mozambique. Two government agencies have the technical skills and policies to make spatial data available to the public. Based on the possible contribution of these institutions, this paper proposes an SDI for Mozambique based on four pillars: i) organizational framework; ii) legal framework; iii) technical framework; and iv) accessibility.

The documents review results revealed that of the seven Land Use Planning (LUP) documents analyzed, only the National Development Strategy referenced ES explicitly. All documents made implicit references to provisioning ES. Five out of the seven LUP documents referred to regulating and cultural ES. None of the LUP documents made any explicit or implicit references to supporting ES. A SWOT analysis towards ES integration in LUP based on these documents showed that the major strength was acknowledging the need to preserve ecological equilibrium and ensure sustainability. The periodical revision of tools and participatory approaches in LUP opens opportunities for integrating ES into LUP processes. This integration could be achieved by establishing a SEA legal framework based on LUP and Environment legal frameworks assisted by a set of common planning tools that consider ES as an additional indicator applied to spatial planning in Mozambique.

### 4.2. Main contributions

The paper on SDI contributes with the identification of the potential stakeholders' roles to the development of the national SDI for Mozambique by assessing their capabilities to contribute to this task. Although the results are promising, the methodology presented in this article still needs to be tested in the field to verify its usefulness. Despite the lack of proof of concept, the methodology carried out can be a roadmap for other African nations within a similar context aspiring to develop their own SDI.

The paper on integration of ES in LUP assessed the current LUP documents regarding its suitability for mainstreaming the ES concepts in Mozambique, and propose a framework for ES integration in LUP processes through an operational SEA which integrates ES information. This is useful for designing and implementing approaches mainstreaming ES into Mozambican LUP, and could also enhance the existing capabilities to produce, share and use spatial data among Mozambican government institutions.

## 4.3. Limitations and future research

### 4.3.1. Future steps and risks for the Mozambican SDI

Experiences from other countries indicate that the best way to ensure the success of implementing an SDI is to constitute an SG to promote agreements among the main stakeholders. The SG has the immediate objective of making the existing spatial datasets with fully documented, coherent and compatible formats available, while promoting the communication among the data providers and the awareness of the whole community (Foster and Ryttersgaard 2001; Sinvula et al. 2017). The process of creating an SDI requires a harmonization effort by setting a technical and institutional framework, a clear legal framework, and easy spatial data accessibility. The main challenge is to raise awareness in the use and value of SDI within the stakeholders to endeavour on the SDI development journey. A strong coordination effort must be carried out to move forward successfully with this initiative considering the current political, social, and economic conditions of Mozambique.

The administration and regulation of the SDI should be based on a public mandate with the authority to ensure its efficient and effective use and public availability (United Nations, 2004). Government agencies are often among the main users and producers of geospatial data, and sharing spatial data avoids duplication of efforts in data production and avoids gaps, incoherencies, and incompatibilities among the spatial datasets (Akinyemi & Uwayezu, 2011). Therefore, the public administration should lead the implementation of SDI accessible through a reliable, up-to-date web site with information about the SDI associated to a WebGIS where users can easily access data in multiple ways (e.g., through downloads and/or web services).

The SG must be formed with a legal mandate to promote the project and formulate the draft legislation to institute the SDI and, therefore, government support must be found (Coleman & McLaughlin, 1998; Lance & Bassolé, 2006). The absence of political involvement has been identified as one of the main obstacles to spatial data sharing and SDI development, as was

the case in Rwanda (Akinyemi & Uwayezu, 2011) and, as experienced by other countries, the absence of an authoritative legal framework for SDI is a major drawback for the development, implementation, and maintenance of an SDI (Sinvula et al. 2017).

### 4.3.2. Limitations on Integration of ES in LUP

The experts who identified and judged the criteria of the SWOT analysis were the authors of this study as in a previous study (Inkoom et al. 2017). We are aware that it would have been preferable to use the approach by Bull et al. (2016) in which the information for the SWOT analysis was obtained from different people through a survey. However, this approach would not have been possible to implement in Mozambique because the number of people with knowledge about these instruments is very limited making difficult to use interviews/survey to collect this information. Nevertheless, the SWOT analysis provided an understanding of how LUP is developed to mainstream ES into decision making in Mozambique. Future developments of this study would benefit from the consultation of stakeholders to confirm the results of the SWOT analysis.

Regarding the proposed framework for integrating ES into LUP through a legal SEA, it should also be considered as a proposal and not as a definite guideline. In the construction of this framework, we used information from other studies carried out for Africa (Inkoom et al. 2017), together with published literature on how to integrate ES into LUP and SEA (Geneletti, 2011, 2015; Rozas-vásquez et al., 2019). The information from these studies helped us to look for relevant documentation and to adapt it to the Mozambique case. However, the framework proposed here would also benefit, as with the SWOT analysis, from stakeholder validation and discussion.

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# Annexure

## Annexure 1: The main users and generators of spatial data in Mozambique

***Annexure 1: The main users and generators of spatial data in Mozambique***

| No | Institutions | Mission /website |
|---|---|---|
| 1 | Interior Ministry (MINT) | ensure public order, security and tranquility, identification of national and foreign citizens, migration control and the prevention and combat of natural fires and disasters throughout the National Territory, contributing to a favorable environment for development. Website: www.mint.gov.mz |
| 2 | Ministry of Natural Resources and Energy (MIREME) | ensure the implementation of Government policy in geological research, exploitation of mineral and energy resources, and the development and expansion of infrastructures for the supply of electricity, natural gas and petroleum products Website: www.mireme.gov.mz |
| 3 | Ministry of Youth and Sports (MJD) | Boosting an Innovative and Intervening Youth and a Strong Sport Culture to Develop Mozambique Website: www.mjd.gov.mz |
| 4 | Ministry of Agriculture and Food Security (MASA) | Contribute to food and nutritional security and income of farmers in a competitive way, ensuring social and gender equity. Website: http://www.masa.gov.mz/ |
| 5 | Ministry of Culture and Tourism (MICULTUR) | coordinate, direct and plan the implementation of policies and strategies in the culture and tourism sectors Website: www.micultur.gov.mz |
| 6 | Ministry of Economics and Finances (MEF) | Formulate, implement and evaluate economic development policies, ensuring resource mobilization and criteria allocation as well as control on efficiency and efficacy of public resources utilization. Website: www.mef.gov.mz |
| 7 | Ministry of Education and Human Development (MINEDH) | Planning, coordinating, directing and develop educational activities Website: www.mined.gov.mz |
| 8 | Ministry of Foreign Affairs (MINEC) | To promote the defense of the interests of Mozambique and citizens at the external level, as a democratic state of law and social justice, based on the pluralism of expression and respect and guarantee of democratic rights and social justice; Contribute to the preservation of |

| | | |
|---|---|---|
| | | international peace and security and national efforts for the country's development through the promotion of friendship, cooperation and solidarity with other peoples, governments and international organizations<br>Website: www.minec.gov.mz |
| 9 | Ministry of Health (MISAU) | Provide better health services, universal accessible throughout decentralization system to maximize the health and wellbeing.<br>Website: www.misau.gov.mz |
| 10 | Ministry of Industry and Commerce (MIC) | To ensure the formulation, elaboration and implementation of sectorial policies and strategies to promote the growth of industrial production, trade, agricultural market and exports<br>Website: www.mic.gov.mz |
| 11 | Ministry of Land, Environment and Rural Development (MITADER) | Promote sustainable development with focus on reduction of socioeconomic inequality on rural areas throughout inclusive and diversify economy; dealing with land, environment and rural environment.<br>Website: www.mitader.gov.mz |
| 12 | Ministry of National Defense (MDN) | Implement national defense *policy*, ensure and supervise the administration of armed forces and other related services to be able to defend the country and national interests.<br>Website: www.mdn.gov.mz |
| 13 | Ministry of Public Infrastructure, Housing and Water Resources (MOPHRH) | Promote, build and preserve infrastructure that fosters socio-economic development by using available resources in sustainable manner for the planning and coordinated implementation of public water resources management programs, development of the construction industry, public buildings and road network, access to safe water, sanitation and decent housing.<br>Website: www.mophrh.gov.mz |
| 14 | Ministry of Science & Technology, High Education & Technical Professional (MCTESTP) | Promote scientific and technological solutions offers to the citizens in strategic development sectors defined in Government programs. Promote access, expansion of technical professional and high education in Mozambique<br><br>Website: www.mctestp.gov.mz |
| 15 | Ministry of State Administration and Civil Service (MAEFP) | Develop policies, strategies, regulations and implement actions on organization and work on public administration and ensure to provision of quality services to the citizens.<br>Website: www.maefp.gov.mz |

| | | |
|---|---|---|
| 16 | Ministry of the Sea , Inland Water and Fisheries | directs, coordinates, organize and ensures the implementation of the policies, strategies, and business plans in the sea areas, inland water and fisheries.<br>Website: www.mozpesca.gov.mz |
| 17 | Ministry of Transport and Communication (MCT) | To coordinate and supervise the development of means of transport and communication, consolidation and treatment of all economic, financial and social information related to the Transport and Communications sector; promotion, programming, registration and development of transport, communications and meteorological infrastructures.<br>Website: www.mtc.gov.mz/# |
| 18 | Agricultural Research Institute Mozambique – (IIAM) | Conduct research in various agrarian areas as well as the rationalization and complementarity of resources and actions regarding the research, development and dissemination of agricultural technologies in Mozambique<br>Website: http://www.iiam.gov.mz/ not available on 30th November 2018 |
| 19 | Fisheries Research Institute (IIP) | Conduct Fisheries Research and aquaculture studies that promote the Sustainable Development of Fisheries and Aquaculture in the country.<br>Website: http://www.iip.gov.mz/ |
| 20 | Mozambique Electricity (EDM) | Exploration of Generation, Transmission, Distribution and Sales of electrical services of good quality safeguarding the public interests for the benefit of the consumer, preserving the environment.<br>Website: https://portal.edm.co.mz/en |
| 21 | National Cartography and Remote Sensing Centre - CENACARTA | Coordinating and conducting geo-cartographic and remote sensing activities at national level, distributing remote sensing techniques in the country, acquiring, and processing image data from satellite.<br>Website: http://www.cenacarta.com/ |
| 22 | National Directorate of Geology & Mines (DNGM) | Implementation of Government policy on geological research and exploitation of mineral resources.<br>Website: not available on 30th November 2018 but mine cadaster available on: http://portals.flexicadastre.com/mozambique/pt/ |
| 23 | National Directorate of Land (DNT) (former DINAGECA) | Implementing laws and regulations related to the use of land: work related to Survey and Cadaster and with a Geodesy and Cartography<br><br>Website: not available on 30th November 2018 |

| | | |
|---|---|---|
| 24 | National Institute for Sports (INADE) | Promote uniform application of strategies, methods and techniques for the implementation of sport policies; and issue recommendations on policy and general strategies in the field of sport. Website: http://www.mjd.gov.mz/por/Instituicoes/Instituto-Nacional-do-Desporto-INADE |
| 25 | National Institute of Disaster Management - INGC | Coordinate Disaster Risk Reduction (DRR) actions in Mozambique through the implementation of measures such as: adequate communication and information system, Early Warning Systems, development of policies, strategies, legislation and operational plans aimed at prevention , mitigation, relief and rehabilitation of the economic and social structure Website: http://www.ingc.gov.mz/ |
| 26 | National Institute of Hydrography and Navigation (INAHINA) | Facilitate safe navigation in the coastal and inland waters of the country through hydrographic, oceanographic services as well as installation, rehabilitation and maintenance of navigation aids and calibrate magnetic needles. Website: https://www.inahina.gov.mz/index.php |
| 27 | National Institute of Meteorology - INAM | contribute to the preservation of lives and assets and to the Sustainable Development of Mozambique through the adequate use of weather and climate information and the generation of quality products for various applications. Website: http://www.inam.gov.mz/index.php/pt/ |
| 28 | National Mines Institute (INAMI) | Ensure that prospecting activities are carried out and research on mineral resources in the national territory and; conduct studies in the field of applied and global geophysics and manage the National Network of Seismographic Stations and the Magnetic Observatories. Website: www.inami.gov.mz (not available on 30th November 2018) |
| 29 | National Petroleum Institute (INP) | to carry out the petroleum operations in accordance with relevant legislation, ensuring the better practice with competence, technical capability and impartiality website: (http://www.inp.gov.mz/en) |
| 30 | National Roads Administration (ANE) | Guarantee the role and rough connection of persons, goods and services safely, economically and sustainable in contributing to economic, social and cultural development Website: http://ane.gov.mz/?page_id=457 |
| 31 | National Statistics Institute (INE) | Notation, tabulation, coordination and dissemination of statistical data Website: http://www.ine.gov.mz/ |

## *Annexure 2: Questionnaire to assess the contribution of Government institutions for the development of the national SDI in Mozambique*

**Introduction**

*Spatial Data Infrastructure (SDI***)** - is the collection of technologies, policies and institutional arrangements to facilitate the availability and access to spatial data. For its functionality it requires institutional arrangements to coordinate and manage.

*Spatial Data* – are data with geographic location (geographical coordinates). Example: location of a school / health unit / any infrastructure that is accompanied with a geographical coordinate, risk maps, agro ecological zones, etc.

*Purpose:* the questionnaire aims to identify the contribution of government institutions to the development of Spatial Data Infrastructure (SDI) as part of the doctoral thesis. This takes approximately 7 minutes to complete. Only one questionnaire per institution is sufficient. All information will be treated without identifying the respondent, thus preserving your privacy.

Thanks in advance for your cooperation.

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**Start of the Questionnaire**

**Identification**

1 Position
2 Department _____
3 Institution/ Company / organization _____
4 Responsible ministry _____

**Organization**

5 In general, how do you classify your institution in terms of Information and Communication Technologies (ICT)?

| | |
|---|---|
| ☐ | Very weak |
| ☐ | Weak |
| ☐ | Adequate |
| ☐ | Good |
| ☐ | Very Good |

6 How many people in your organization know how to work with Geographic Information Systems (GIS), geospatial data collection and processing? _____

7 Does your institution work with GIS / (spatial data), do you have a GIS unit or department, or do data collection?

- ☐ Yes
- ☐ No

**If you answered YES to question 7 you can continue to answer, if you answered NO you can dispense later questions, and thank you very much.**

The following questions are for institutions working with spatial data (GIS)

8 How long has your institution been working with GIS (spatial data), has a GIS unit or department, or does data collection?

- ☐ Less than 3 years
- ☐ 4 a 6 years
- ☐ 7-10 years
- ☐ 11-15 years
- ☐ More than 15 years

9 The GIS is well equipped in your institution

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly agree

**Legal Framework**

10 Do you know any law / decree / national law that mention the use of GIS? If so, which one?

_____

_____

_____

_____

_____

_____

**Data**

11 What is the category of data that your institution produces?

| | |
|---|---|
| | Administrative Bounderies |
| | Transport (roads network, railways, port, etc) |
| | Hydrology & Basin |
| | Parks and Reserves |
| | Land Use and Land Cover |
| | Soil |
| | Agro ecologic zones |
| | Statistics |
| | Geology |
| | Geomorphology |
| | Mine Resources |
| | Infrastructure (school location, health center, etc.) |
| | Climate (precipitation, temperature, solar radiation) |
| | Cadaser |
| | Vulnerability and Risk |
| | Water Caption Areas |
| | Forest |
| | Other. Which is? |

_____

12 The institution's geospatial database covers all national territory

| | |
|---|---|
| | Strongly disagree |
| | Disagree |
| | Neutral |
| | Agree |
| | Strongly agree |

13 If you answered completely disagree on question 12, say which area of territory covers

_____

**Standardization**

14 The data produced has metadata (Description of how, where, when, who produced the data)

- [ ] Strongly disagree
- [ ] Disagree
- [ ] Neutral
- [ ] Agree
- [ ] Strongly agree

15 If there are standards in the production of metadata what are they? (select from the options below)

- [ ] Institutional standards
- [ ] ISO 19115:2003
- [ ] ISO/TC 19139:2007
- [ ] ISO 19115-1:2014
- [ ] Other .Which?_____

16 There are standards used in data production.

- [ ] Strongly disagree
- [ ] Disagree
- [ ] Neutral
- [ ] Agree
- [ ] Strongly agree

17 If there are standards in data production what are they? (select from the options below)

- [ ] Institutional standards
- [ ] ISO 19115:2003
- [ ] ISO/TC 19139:2007
- [ ] ISO 19115-1:2014
- [ ] Other .Which?_____

**Access and Sharing of Data**

18 How the institution promotes the use of its products?

Internet
CD/pen drive
Hard copy
Others:_____

19 Which institutions share your data?

_____

_____

_____

_____

20 The institution has data distribution procedures

| | |
|---|---|
| | Strongly disagree |
| | Disagree |
| | Neutral |
| | Agree |
| | Strongly agree |

21 If you have completely agreed to the previous question, identify?

_____

22 Does the intuitions have a price policy (monetary rates) for public access to data

| | |
|---|---|
| | Strongly disagree |
| | Disagree |
| | Neutral |
| | Agree |
| | Strongly agree |

**Book Spine**


July
2021
[Geospatial Data for Sustainable Development in Mozambique: Challenges on Spatial Data Infrastructure Development & Ecosystem]
[Ali Atumane]
PhD