Master's Thesis – Water Science and Management

Social Cost-Benefit Analysis of Mangrove Restoration in Mozambique

A Case Study of Icidua: Community Engagement and Alternative Livelihoods

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Utrecht University

Van Oord
Marine ingenuity

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Abstract

The people of Icidua, a neighbourhood of Quelimane (Mozambique), rely on logging their local mangrove population for their livelihood to survive. Unfortunately, these same practises are causing environmental degradation, the erosion of their natural riverbanks, resulting in floods which wash away their homes. 50% of the community suffers from damage to their property caused by floods and erosion. The main reason is exploitation of the mangrove forest due to the lack of alternative means to generate income. Van Oord aims to restore the depleted mangroves in the area following the nature-based solution approach. An integral factor in this methodology is community engagement. To promote an increase in community participation of mangrove restoration efforts, this study assessed potential alternative livelihoods. These were derived from existing literature and narrowed down by the local community and relevant stakeholders. Two policy plans were compared: 1) Business as Usual (BaU), and 2) Alternative Livelihood Development (ALD), both composed after a field visit in June 2022. The BaU alternative was designed based on current data of mangrove-related practices obtained from a baseline survey and community consultations. This scenario forecasted the collapse of the bridge connecting Icidua to the rest of Quelimane, and a total disappearance of all adult mangrove trees. These combined events would be sure to devastate the community and are guaranteed if current erosion trends of up to 6.5 m per year continue. The ALD policy was co-created with community members and stakeholders based on their self-selected top three preferred livelihoods: 1) aquaculture, 2) agriculture, and 3) chicken farming. This research further assessed the long-term Net Present Value (NPV) of the economic benefit of the current practices and implementing alternative livelihoods using a Social Cost-Benefit Analysis (SCBA) over a 20-year timeframe. Results showed a net positive economic impact of the ALD policy (NPV = 8,500,000 MZN (Mozambican Metical) per ha), as opposed to a net negative outcome of the BaU policy (NPV = -1,000 MZN per ha). A sensitivity analysis showed that BaU would lead Benefit to Cost Ratio (BCR) smaller than 1 for discount rates of 5% and 10%. On the contrary, the ALD policy resulted in BCR larger than 1 for discount rates of 5%, 10% and 15%. Therefore, this thesis shows Van Oord the necessity and positive viability of including alternative livelihoods in their mangrove restoration project plan.

Keywords: Community Engagement, Mangrove Restoration, Alternative Livelihoods, Social Cost-Benefit Analysis.

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LIST OF ABBREVIATIONS

AJCD	Community aquaculture association
ALD	Alternative Livelihood Development
BaU	Business as Usual
BCR	Benefit and Cost Ratio
BwN	Building with Nature
CBA	Cost-Benefit Analysis
GDPR	General Data Protection Regulation
IDH	Sustainable Trade Initiative
IFAD	International Fund for Agricultural Development
INOM	Mozambican Oceanographic Institute
IUCN	International Union for Conservation of Nature
MoU	Memorandum of Understanding
MZN	Mozambican Metical
NPV	Net Present Value
PES	Payment for Ecosystem Services
SCBA	Social Cost-Benefit Analysis
UEM	University Eduardo Mondlane
USD	U.S. Dollar
WUR	Wageningen University & Research
WWF	World Wide Fund for Nature

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1. Introduction

1.1 Background and Problem Description

Mangrove forests are one of the most productive and biodiverse ecosystems on the planet (Donato et al., 2011). They provide comprehensive protection to the coast which reduces coastal populations' exposure to extreme weather events (Arkema et al., 2013). Mangroves function as natural barriers, providing shoreline protection during both normal sea conditions and extreme weather events. Around 70-90% of the energy from wind-generated waves is absorbed by healthy mangroves. In addition, mangroves are a source of food and building materials and spiritual significance, while supporting the nutrient cycle and habitats of fish nurseries (UNEP-WCMC, 2006). Mangroves provide valuable ecosystems, contributing to the livelihoods, security, and well-being of coastal communities (FAO, 2020). The total economic value generated by mangrove forests ranges between 200,000 and 900,000 USD per km^2 USD (UNEP-WCMC, 2006). According to the Global Mangrove Watch, the global mangrove area is estimated at approximately 140,000 km^2, distributed across (sub-) tropical coastal and riverine regions (Figure 1A) (FAO, 2020). This results in an economic value of an estimated 80 billion USD average.

Despite the numerous benefits that mangroves offer, they are among the most vulnerable and threatened ecosystems worldwide (FAO, 2020). The total global area of mangroves has been reduced by 30-50% over the past decades due to overharvesting, land use change (e.g. into aquaculture and salt-pans), and coastal development (Donato et al., 2011). The decrease in mangrove area, caused largely by anthropogenic activities, is partially compensated by locations where mangroves are expanding (Spalding & Leal, 2021). According to a global map produced by the Global Mangrove Watch, the world's mangrove area shows a net loss of 4.3% from 1996-2016 (Bunting et al., 2018).

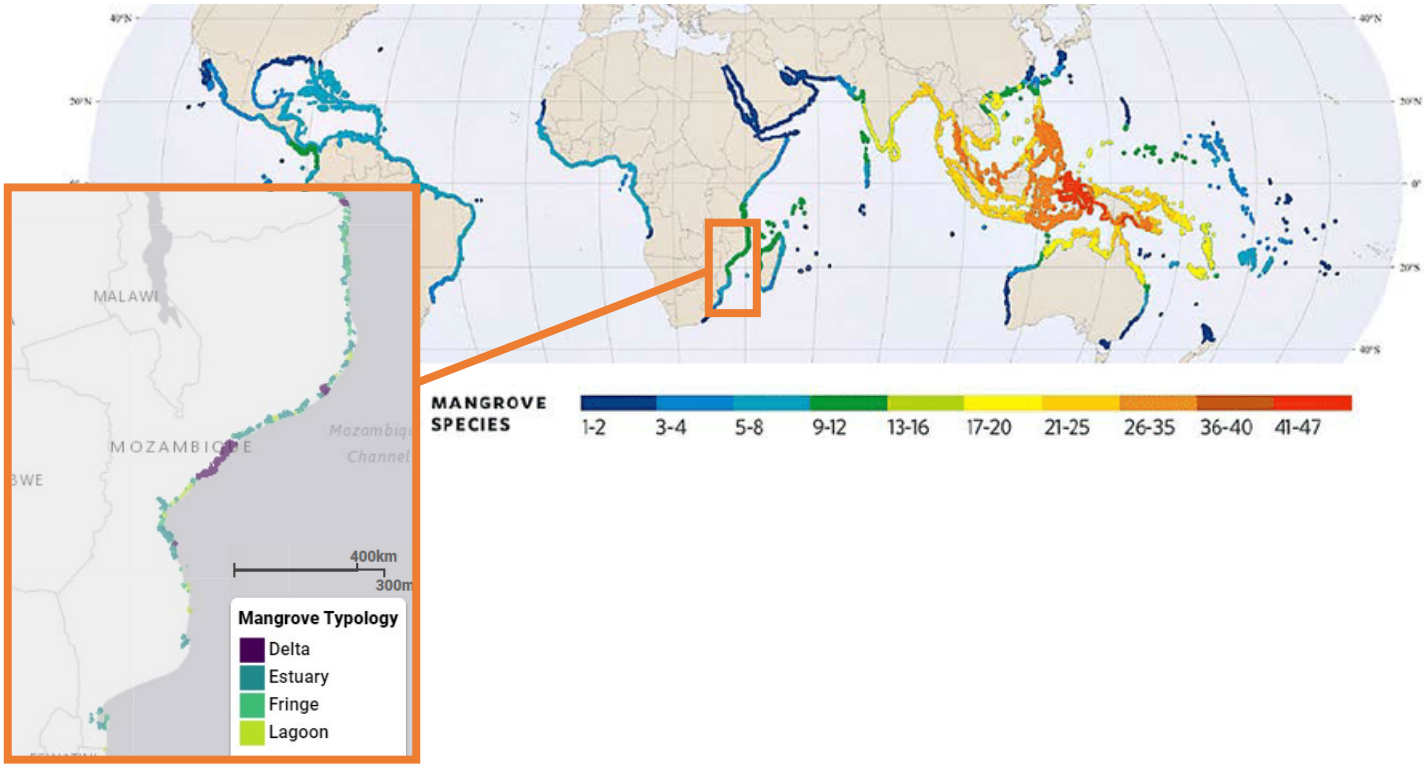

Figure 1, A) Global mangrove cover and number of species. This figure is taken from Hoff & Michel, 2014 (their figure 1.1, page 2). B) Extent of delta, estuary, fringe, and lagoon mangroves along the coastline of Mozambique (Figure modified from: Ocean Wealth Global Database, 2021).

One of the countries with rich mangrove forests is Mozambique, where the coastline extends for about 4,700 km (Figure 1B). With more than 3000 km^2, the mangroves of Mozambique are ranked the 13th biggest worldwide, representing approximately 2% of the global mangrove area (Western Indian Ocean Mangrove Network, 2022). The large extent of the coastline of Mozambique makes the country vulnerable to tropical cyclones, floods, and strong winds. The total population of Mozambique consists of approx. 32 million people (The World Bank Group, 2022a). About 60% of the Mozambican population lives in coastal areas, in particular in Maputo, Quelimane, Beira and Pemba (Instituto Nacional de Estatística, 2017). Between 2000 and 2015, floods in Mozambique affected over 4.6 million people, damaging about 1.2 million houses of which over 600,000 were destroyed, and caused 1,204 deaths (MITADER, 2015). In 2019, Cyclone Idai severely affected coastal provinces Sofala and Zambezia, causing thousands of deaths and damaging over 715,000 ha of crops (Castiano, 2020). In the face of the projected climate change causing more intense storms, nature-based coastal protection afforded by mangroves becomes increasingly important. Around the year 2000, Mozambique had the second largest mangrove forest in Africa with a cover of almost 400,000 ha (FAO, 2005). However, in 2016 Mozambique had lost over 20,000 ha of mangroves (Bunting et al., 2018). Figure 2 shows the change in mangrove cover in the provinces of Mozambique from 1995 to 2018. Many local communities in Mozambique depend on mangrove forests for their income. They harvest mangroves for firewood or charcoal production, and use them for religious rituals and other practices (Chevallier, 2013). Further decline of mangrove forests will affect communities' livelihood, stressing the importance of sustainable use of mangroves.

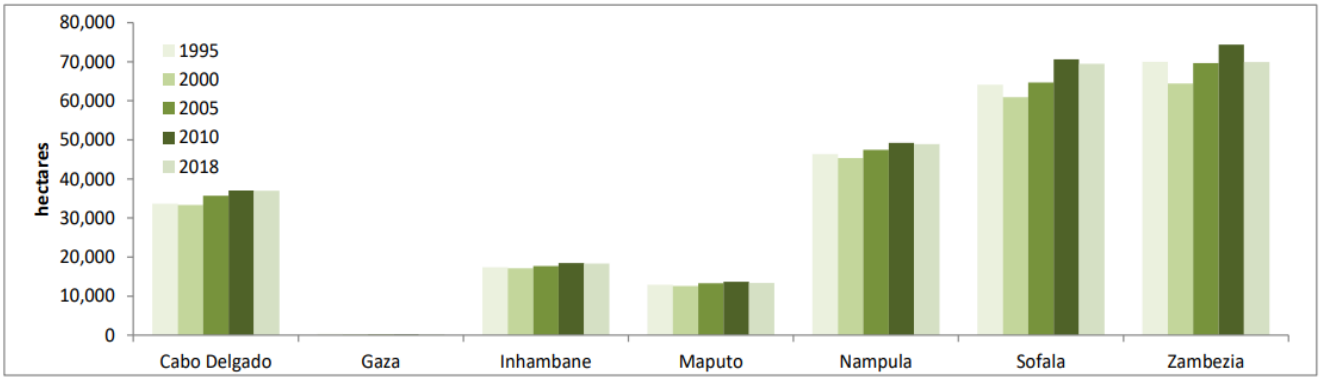

Figure 2, Mangrove cover per province (Mozambique) in hectare from 1994 to 2018 determined from Landsat imagery. This figure is taken from Shapiro, 2018 (their Figure 5, page 6).

Causes of Mangrove Deterioration

Mangroves depend on certain natural conditions such as water availability and sediment supply. A change in these natural conditions can cause mangrove deterioration. However, in Mozambique the main reason for a decrease in mangrove cover is because of anthropogenic causes. A decrease in mangrove cover is, among other factors, induced by the construction of river dams, urban development, and water contamination caused for example by oil spills and pesticides (Mitra, 2013). Loss of mangroves is, in a large part of the world's tropics as well as in Mozambique, attributed to the actions of local communities, which live in poverty and rely on mangroves for their livelihoods and have been exploiting them unsustainably (Debrot et al., 2020). Mangroves provide local populations with timber, fuelwood, construction material, food from fisheries and medicine (Aheto et al., 2016; Charrua et al., 2020). Moreover, activities such as shrimp farming, salt extraction, agriculture, forestry, and tourist development lead to a decline in mangroves. According to Debrot et al. (2020), poverty amongst rural mangrove communities often results from economic setbacks because of environmental exhaustion, or natural hazards such as cyclones and tsunamis. The options for local livelihoods are reduced which often results in failure of mangrove restoration, as due to the lack of

feasible alternatives, local populations may be forced back to their unsustainable practices which caused mangrove depletion and increased vulnerability to hazards. This negative feedback cycle can only be broken by introducing sustainable alternative livelihoods and engaging local communities in the restoration process (Adeel & Safriel, 2008; Debrot et al., 2020).

Mozambique Mangrove Regulations

The long term socio-economic and environmental impacts of mangrove deterioration are now seriously emerging, and the need for restoration of degraded mangrove forests and proper management of remaining forests are being recognised (Bandeira & Badily, 2016; Charrua et al., 2020; Quinn et al., 2018; Su et al., 2021; Zhongming et al., 2020). Mangrove degradation is rising to be high on the agenda of the Mozambican government (Castiano, 2020). In 2015, a national strategy and action plan for mangrove protection and rehabilitation was adopted which turned out to be highly ineffective. In an IUCN-WWF report on the fragmented and ineffective management of mangroves in Mozambique, it is stated that without the identification of alternative livelihoods and fuel sources to address the dependency of local communities on firewood, laws on mangrove protection will not be effective (Castiano, 2020). Even though cutting of mangroves is prohibited, mangrove wood and charcoal are openly sold on the streets. The Government of Mozambique launched a mangrove restoration programme on the 26th of July 2021, on World Mangrove Day, to restore thousands of hectares of mangroves along the Mozambican coast. In February 2022, Blue Forest announced a plan to plant mangroves across 185,000 ha in Mozambique, with the goal to capture 200,000 tonnes CO_2 per year (Friess et al., 2022).

Community Mangrove Restoration

Economic benefits and livelihoods are the primary factors to motivate local stakeholder participation in mangrove restoration and management (Aheto et al., 2016). Socio-economic development, monetary benefits from non-consumptive uses, and the provision of economic alternatives to forest resources help to generate local community support for mangrove restoration (Roy, 2016). The ecosystem services that are provided by mangrove forests are key to integrating both economic considerations and ecological perspectives in tackling overharvesting. A cooperation of governmental agencies, civil society organizations, the private sector and local communities is necessary for successful mangrove restoration (Barbier et al., 2011). Even if the conditions are right for mangroves to regrow naturally, mangrove restoration projects may fail. Success of mangrove restoration is limited which can often be derived from the lack of local community involvement (Erftmeijer & Bualuang, 2002). By integrating human livelihood needs into mangrove conservation, community engagement can be pursued, which is key to achieving long-term sustainability of mangrove forests (Romañach et al., 2018; Debrot et al., 2020). Therefore, local community engagement is crucial for, among others, mangrove restoration execution, leveraging of local knowledge, mangrove management, and for educational and awareness raising on the importance of mangroves.

Van Oord and Mangrove Restoration

This thesis was written as part of an internship at the Environmental Engineering department of Van Oord. Van Oord has the ambition to add mangrove restoration to its portfolio of environmental, social, and economic solutions. Van Oord selected Mozambique to develop and demonstrate their capabilities in mangrove restoration. Considering the large scale of mangrove deterioration due to human impacts in Mozambique, it is critical to strongly involve local communities in the mangrove restoration project. Important aspects of Van Oord's mangrove restoration project are community engagement and the development of a business case. Therefore, this research aims to conduct a Social Cost-Benefit Analysis of mangrove restoration in Mozambique. Van Oord sought advice on how to

gain local community support, which was obtained through community consultations on potential alternative livelihoods. In July 2021, Van Oord signed a Memorandum of Understanding (MoU) with the Mozambican Oceanographic Institute (INOM), which is a public institution of the Ministry of the Sea, Inland Waters and Fisheries. In this MoU, Van Oord aids the National Mangrove Restoration Programme of the Mozambiquan Government by finding a suitable location for a new mangrove restoration project and by developing a plan for implementation. After an extensive scoping study, the location of Icidua, which is a neighbourhood of Quelimane, was chosen as the project location.

Van Oord aims to follow the Building with Nature (BwN) approach in this mangrove restoration project. BwN is a design approach to develop sustainable water-related infrastructure to benefit economy, society, and the environment (Ecoshape, 2022). The approach uses natural processes and system understanding to develop nature-based solutions. BwN solutions work with the dynamics of nature rather than fighting them, they are climate-adaptive and often are cheaper to construct and maintain than hard-infrastructure solutions. Local stakeholders including the local communities are involved in the process of designing, constructing, and maintaining the measures, resulting in the shortening of permitting procedures and lower concerns related to human rights (Winterwerp et al., 2016).

1.2 Previous Work Done

The vulnerability of coastal mangrove ecosystems in Mozambique has been assessed in previous studies. Cabral et al. (2017) assessed the exposure of Mozambique to coastal climate hazards and erosion, in which mangroves play an important role. It was established that nine species of mangrove forests in Mozambican's estuaries and deltas reach dozens of kilometres inland and hundreds of kilometres along the coast. Figure 3 shows the exposure index as was calculated by Cabral et al. (2017)

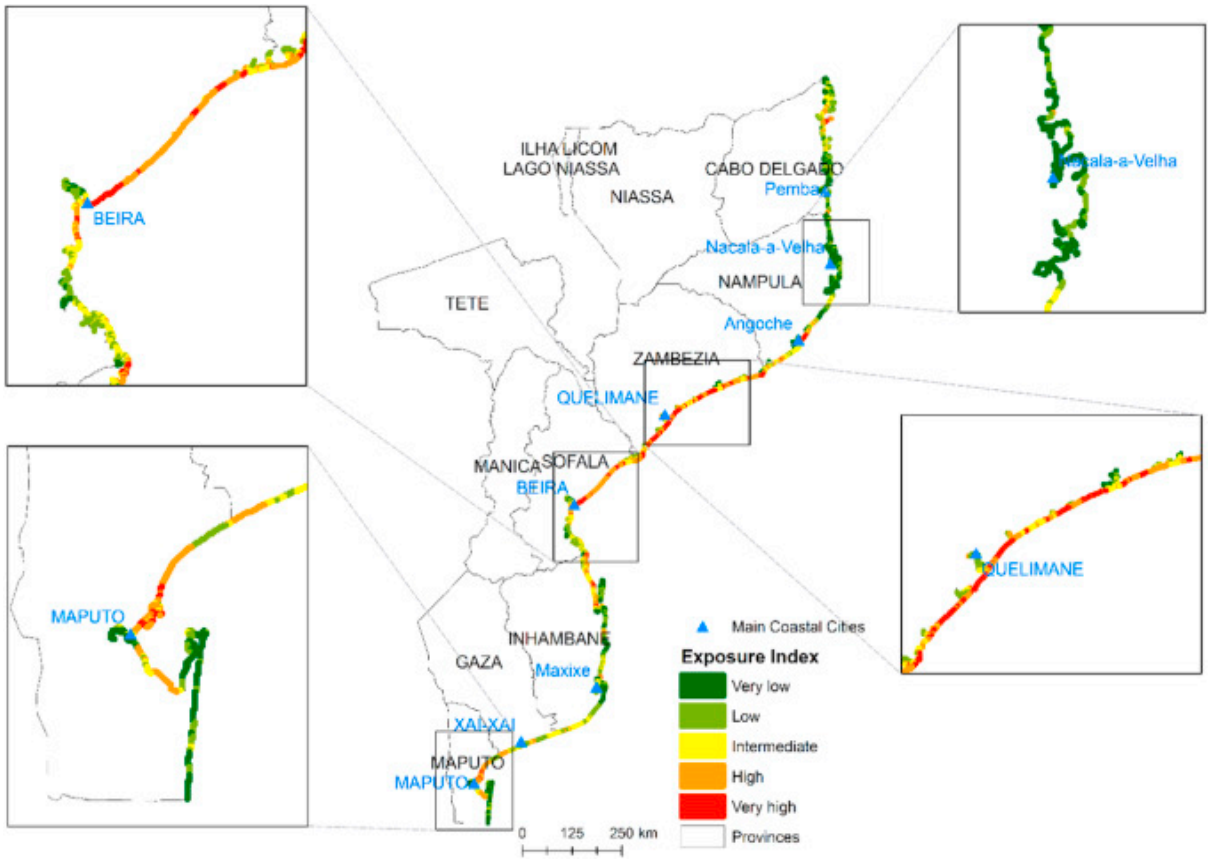

Figure 3, Exposure Index for Mozambique based on the presence of mangroves, coral reefs, and sand dunes to protect the coastline from natural hazards. The provinces of Mozambique are shown, and the coastline nearby the cities Beira, Maputo, Nacala-a-Velha, and Quelimane are highlighted in the panels. Green colours indicate a low exposure index, with dark green being the lowest. Yellow to red indicates intermediate to very high exposure, respectively. This figure is taken from Cabral et al., 2017 (their Figure 2, page 48).

for Mozambique taking the current protection provided by mangroves, coral reefs, and sand dunes into account. As can be seen from this figure, according to the estimations, the coastal zone around Quelimane faces an intermediate to high exposure to climate hazards.

Community Engagement in Mangrove Restoration

It has been widely assessed that failure of conservation approaches can often be devoted to a lack of community engagement (Golebie et al., 2022; Hai et al., 2020; Holl, 2020; Le et al., 2012; Lovelock & Brown, 2019; Primavera & Esteban, 2008; Ranjan, 2019; Romañach et al., 2018). A 2020 study (Shackelton et al.) established that local communities often poorly understand the purpose of mangrove conservation and may feel that they are being excluded from access to their resources. This has been described by Romañach et al. (2018) as the so-called science-community-policy gap which is often identified in failed conservation projects. In the Philippines, Valenzuela et al. (2020) conducted a study to assess the impact of local community participation in mangrove restoration and concluded that their participation can improve their livelihoods and increase the social capital. Bandeira & Balidy (2016) have analysed the Limpopo estuary mangrove rehabilitation and management in South Africa and Mozambique, and state that local communities were strongly engaged which led to a better understanding of the relation between the community and their surroundings. The Limpopo mangrove restoration project has provided local communities with new livelihoods after the river's flooding in 2000 (Bandeira & Balidy, 2016). In Demak in Indonesia, Van Oord has previously conducted mangrove restoration under the flag of EcoShape. Here, sustainable aquaculture provided space for mangrove restoration through a higher productivity and a lower use of chemicals. As a result, vulnerable communities became more self-reliant and their hazard-resilience increased (EcoShape, 2021).

Narayan et al. (2017) performed a Cost-Benefit Analysis (CBA) of mangrove restoration for coastal protection in Mozambique near Quelimane (Icidua and Mirazane communities), in which they compared 22 ha of mangrove restoration with the construction of an earthen dike. They concluded that mangrove restoration would be more economically viable than constructing an earthen dike. However, their research also showed that local communities in the area have been cutting mangroves due to a lack of alternative livelihoods. Hence, there is a low chance of success for mangrove restoration without involvement of the local community in a restoration project. This study therefore aimed to bridge the gap between the local community who depends on mangroves, and mangrove restoration which depends on the community's commitment to stop logging mangroves. Ultimately, the needs of the local community need to be fulfilled to allow for viable mangrove restoration.

1.3 Aim, Rationale & Approach

Mangroves are a key asset for both climate mitigation (through sequestering carbon from the atmosphere and permanently locking away into biomass and soils) and adaptation (reducing hydrodynamic forces through wave and current attenuation), and are therefore highly relevant in a world where climate change and global warming are the key scientific topics of today. Unsustainable coastal development is globally one of the key drivers of loss of mangrove habitat. Therefore, creating a framework for development projects that consider opportunities for symbiosis between economic development and nature are very important to protecting mangrove ecosystems, and more widely, mitigating and increasing coastal resilience in areas that are likely to be placed increased risk under future climate scenarios.

The purpose of this research was to provide recommendations for Van Oord's community engagement plan for mangrove restoration in Icidua, Mozambique, with a focus on alternative livelihoods. The research was split up into three objectives in order to reach this goal. The first

objective was to identify the state-of-the-science of alternative livelihoods from previous mangrove restoration projects around the world, through a literature review. The second goal was to narrow down these globally implemented alternative livelihoods towards a selection suitable for Icidua. The third goal was to design a policy plan for mangrove restoration in Icidua, based on alternative livelihoods. In order to achieve this goal, a Social Cost-Benefit Analysis (SCBA) was conducted for two different policy options: 1) Business as Usual, and 2) Alternative Livelihood Development. Recommendations for the community engagement plan were based on the outcome of the SCBA. The following research questions were formulated:

1. Which cases of mangrove restorations worldwide have been implemented with explicit considerations of identifying alternative livelihoods for affected communities?
    a. Which alternative livelihoods have been implemented in these projects and how often?
2. Which of the identified livelihoods from literature would be relevant to the Icidua community and which alternative has the best potential according to them?
    a. What is the current use of the mangroves in Icidua?
    b. Which non-mangrove related livelihoods currently exist in Icidua?
    c. Which of the selected livelihoods from literature would be relevant to adopt in Icidua?
    d. Which of these livelihoods have the best potential (top three) according to the community and relevant stakeholders?
3. Which policy alternative would be most beneficial to the Icidua community following a Social Cost-Benefit Analysis?
    a. What is the net present value of the economic benefit of investments of alternative livelihoods corresponding with a restored mangrove ecosystem for the Icidua community?
    b. What is the net present value of the current mangrove related livelihoods?

2. Conceptual Framework

The following sections touch upon the main concepts used in this study. First, mangrove restoration is defined. Next, the valuation of mangrove ecosystem goods and services is explained. Lastly, the concept of SCBA is introduced.

2.1 Restoration, Rehabilitation or Replanting

The terms restoration, rehabilitation and replanting are often used intertwined even though they do not have the same meaning. The term rehabilitation can be defined as the act of partially or completely replacing essential ecosystem structures and functions that have been diminished or lost (Field, 1999). Rehabilitation is aimed to return to achievable similarities of prior conditions, without the aim of accomplishing absolute authenticity (Cooke, 2005). Restoration is a special case of rehabilitation with the goal of bringing an ecosystem back into its original condition as nearly as possible (Field, 1999). Planting, on the contrary, does not look at restoring any ecologic conditions. Even though mangrove planting has become highly popular and seems to be a quick method to increase mangrove area, a great part of planting efforts fail (Wetlands International, 2016). Planting practices generally entail the planting of seedlings which have low survival rates due to inappropriate species selection and/or poor site selection (van Bijsterveldt et al., 2022). The aim of Van Oord is to assist the natural regeneration of mangroves through mangrove habitat restoration following a BwN strategy.

2.2 Valuation of Mangrove Ecosystem Goods and Services

Ecosystem goods and services are components of nature resulting from natural processes and functions which can be consumed, used, or enjoyed by humans (Boyd & Banzhaf, 2007). Mangrove ecosystems provide raw materials and foods and play a role in coastal protection. Furthermore, mangroves sequester carbon and act as water purifiers, and they help maintain fisheries, tourism, education, and culture (Barbier et al., 2011).

The valuation of mangrove ecosystem services is based on the Total Economic Value framework, which categorises ecosystem services into use and non-use values. Use-values are divided into direct and indirect use, and optional values (DEFRA, 2007) (Table 1). Direct-use values of mangroves could involve commercial or non-commercial activities such as collecting fuelwood, harvesting fish, or recreational use of a mangrove forest. Indirect-use values are values provided by mangroves which protect and maintain natural and human systems through services such as flood control, water quality maintenance and nutrient retention. The third category of use values is the option value, which compasses the future value of a mangrove ecosystem (i.e., the possible future use). Non-use values are related to benefits which are derived from maintaining the mangrove resources, such as biodiversity and cultural heritage. Whereas non-use values generally do not include human interactions with a resource, use values do involve some human interaction (Barbier et al., 1997).

2.3 Social Cost-Benefit Analysis for Decision Making

SCBA is a widely accepted and used tool to support decision making in policy planning (Mouter et al., 2013). SCBA for social decision- and policy-making requires valuating future benefits and costs of environmental goods and services (de Zeeuw et al., 2008). In this research, the SCBA was implemented to evaluate the economic effect of policy alternatives which impact ecosystem services. The net annual benefit was estimated to evaluate economic efficiency of the policy alternatives, and the impact per year could be measured via the Net Present Value (NPV) which is the value of all future cash flows at the discount of economic benefit (de Zeeuw et al., 2008).

Table 1, Total economic value of mangrove forests, divided over use values (direct-, indirect- and option values) and non-use values. (Source: modified from Barbier et al., 1997)

Use values			
Direct use value	**Indirect use value**	**Option value**	**Non-use values**
Aquaculture support	Saline intrusion control	Potential future uses	Biodiversity
Fishing	Erosion control		Cultural heritage
Timber	Flood control		
Firewood	Storm protection		
Charcoal	Nutrient retention		
Medicines	Groundwater recharge		
Agriculture	External ecosystem support		
	Carbon sequestration		

The mangrove ecosystem goods and services which are of use for the local community were determined during the community consultations. Following a market based valuation approach, the total economic value is the sum of the consumer surplus and the producer surplus of the net benefits of a service. However, in this case only the producer surplus was estimated considering that this study aims at identifying the benefits of mangroves to local people. The producer surplus is the surplus which local communities obtain from the mangrove ecosystem and provide to the market. Calculations for the SCBA in this thesis will deal with MZN (Mozambican Metical) only, due to its local residency.

The Benefit Transfer Method is a popular method to valuate ecosystem services without primary site-specific data as this can be too expensive or simply unavailable (Plummer, 2009). The benefit transfer method is a way to apply economic value estimates from one location to a similar site elsewhere (Plummer, 2009). Via this way, the lack of data is omitted, and costs and benefits can be obtained from mangroves nearby where aquaculture is being practiced. The Benefit Transfer Method was conducted to assess the monetary values of ecosystem goods and services for the Alternative Livelihood Development policy plan of which the livelihoods are currently not implemented in Icidua.

Analytical Framework

The SCBA was carried out following 5 steps: 1) Design of policy alternatives; 2) Cost and benefit estimations; 3) Calculating the NPV per alternative; 4) Sensitivity analysis; and 5) Recommendations based on the NPV and sensitivity analysis (Figure 4). These steps are described in more detail in Stage 3: Social Cost-Benefit Analysis.

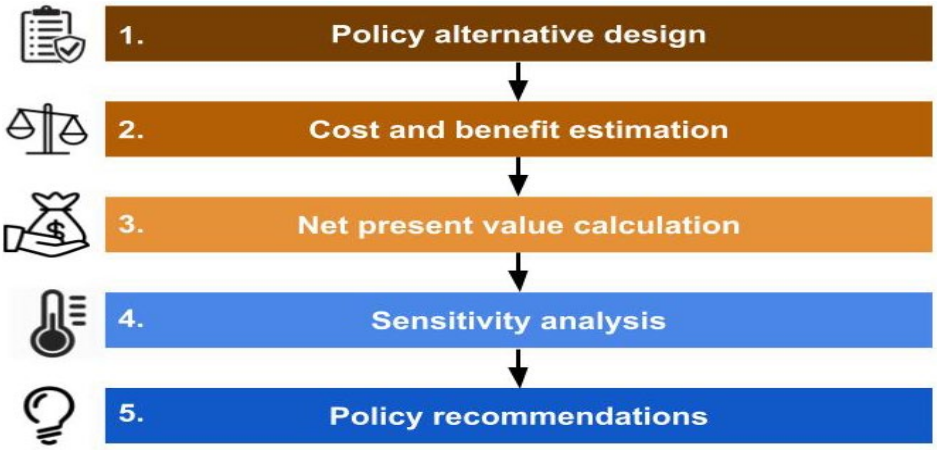

Figure 4, Analytical framework of the Social Cost-Benefit Analysis.

3. Methodology

3.1 General Methods

3.1.1 Objectives, Rationale & Approach

Table 2 below covers the main description of the methodology for the three questions in this research, covering the objectives derived from the research questions and the rationale for their function within the research. Furthermore, the approach for each objective is included, divided into data collection and data analysis.

Table 2, Brief overview of the methodology for the research questions.

***Objective 1:** Identifying previous mangrove restoration projects focused on alternative livelihoods.*	Literature on previous mangrove restoration projects can help in gaining an understanding of restoration strategies in relation to alternative sources of income. Analysing previous projects will help in determining alternative livelihoods related to community engagement.
Approach/Method: I performed a systematic literature review on mangrove restoration projects worldwide in which local communities were provided with alternative livelihoods. (Qualitative) Data collection: literature obtained from Scopus, Web of Science and WUR Library.	
***Objective 2:** Determining potential alternative livelihoods for the local community of Icidua.*	Community consultations were held to select alternative livelihoods together with the community members, considering the alternative livelihoods obtained from Research Question 1.
Approach/Method: Community consultations and stakeholder meetings were organized to identify alternative livelihoods which would be beneficial to the Icidua community. Two policy plans were designed based on these alternative livelihoods. (Qualitative)	
***Objective 3:** Economic valuation of mangrove ecosystem services and alternative livelihoods of the policy alternatives.*	An overview of the costs and benefits of each of the policy alternatives was made to perform a Social Cost-Benefit Analysis of both policy alternatives.
Approach/Method: I conducted a baseline survey and community consultations to gather input data for the Social Cost-Benefit Analysis to assess the most beneficial policy alternative. (Qualitative)	

3.1.2 Ethical Issues

Community consultations were important aspect of this study. The general opinion of the community was perceived through community consultations. It is important to think together with the community representatives about which alternative livelihoods would be suitable for them to adopt. The community representatives should at no times have the feeling that we try to force our opinion on them. They should feel as if they are part of the creation of this project and that their vision is truly valuable and will be considered. Before the community consultations took part, respondents were asked to sign the informed consent form (APPENDIX A). The form was translated into Chuabo, and read out loud by the interviewee if needed, to make sure the community members understood what they signed for. Respondents to the survey and participants of the community consultations remain anonymous, and personal data was handled with care following the General Data Protection Regulation (GDPR). Data provided by Van Oord which is marked as confidential is not shared with external parties and was merely used with the purpose of writing this thesis.

3.1.3 Study Area

The project area selected by Van Oord is Icidua, which is a neighbourhood east of Quelimane. Icidua is located slightly inland off the Mozambican coast and borders the Cuacua river (Figure 5). According to the community leader of Icidua, the area contains approximately 13,000 inhabitants. Icidua is located in province Zambezia, which is the province with the largest delta mangrove area in Mozambique. Zambezia has lost over 8,000 ha of mangrove forest from 1996-2016, of which over 7,000 ha could be restored at a restorability potential of 65-94% according to the Ocean Wealth Global Database.

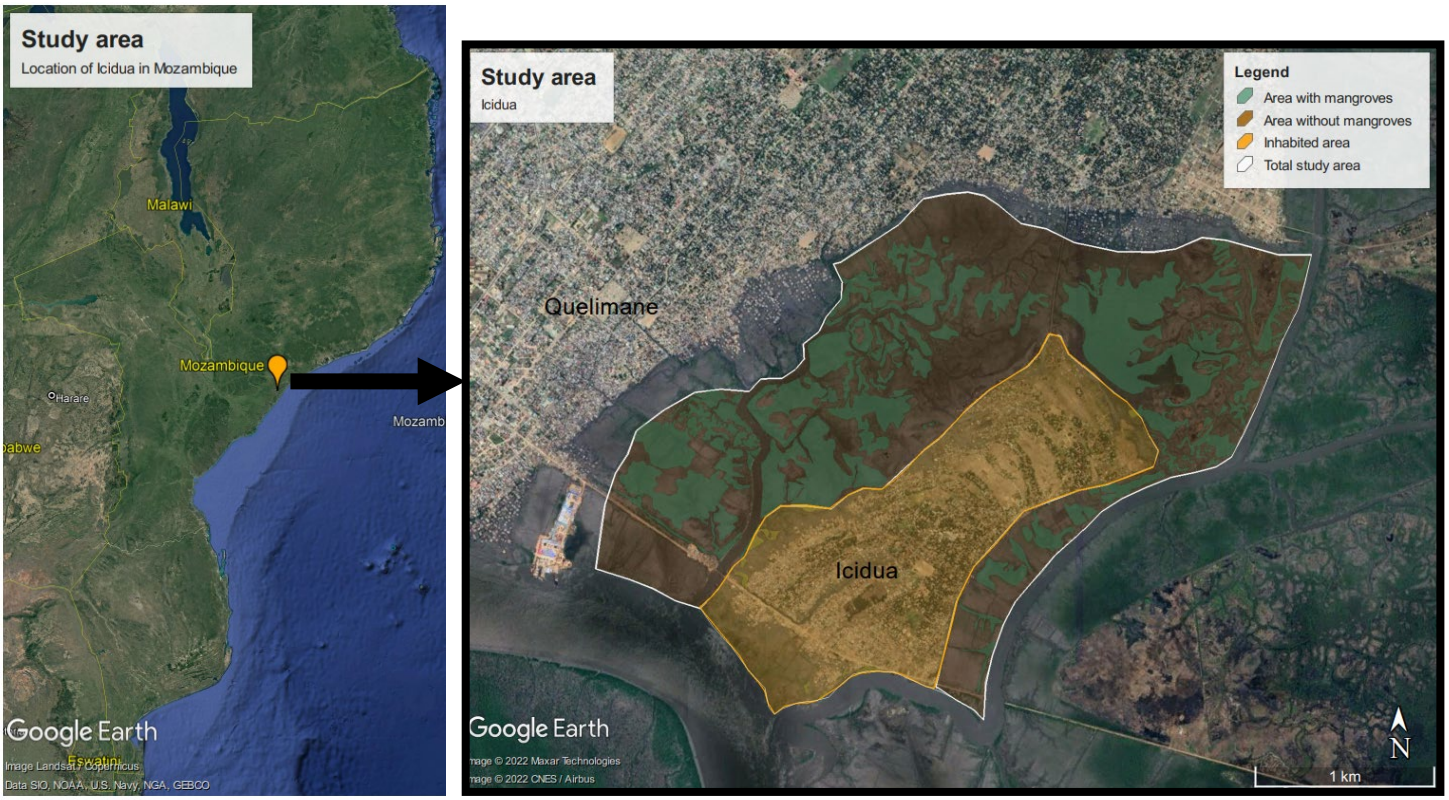

Figure 5, A) Location of study area Icidua in Mozambique, and B) Map of the study area of Icidua, located east of Quelimane city. The orange area indicates the inhabited area of Icidua. The mangrove cover is indicated in green, and the area without mangroves is coloured brown. The Cuacua river passes south of Icidua.

Mozambique contains a sub-tropical to tropical climate, with more rainfall along the coast. Annual rainfall varies from 800 to 1200 mm. The mean annual temperature in Mozambique between 1991 and 2020 was 24.3 degrees Celsius, and the mean annual precipitation in this period was 977 mm (The World Bank Group, 2021).

The central coast of Mozambique is located on the Sofala Bank, which is a wide, shallow shelf in the Mozambique Channel (Figure 6) (Chevane et al., 2016). The Sofala Bank is characterized by semi-diurnal tides, varying from 0.6 m up to 6.6 m during spring tide (Da Silva et al., 2009). The Sofala Bank receives sediment from the Zambezi River. The coastal contour of Mozambique and shelter from Madagascar allow sediment accumulation on the bank. As the Zambezi River carries nutrients, the Sofala Bank contains a high productivity (Huggett & Kyewalyanga, 2017). Mangroves prefer organic and muddy environments (Ecoshape, 2021), explaining the rich initial abundance of mangroves along the coast of Mozambique.

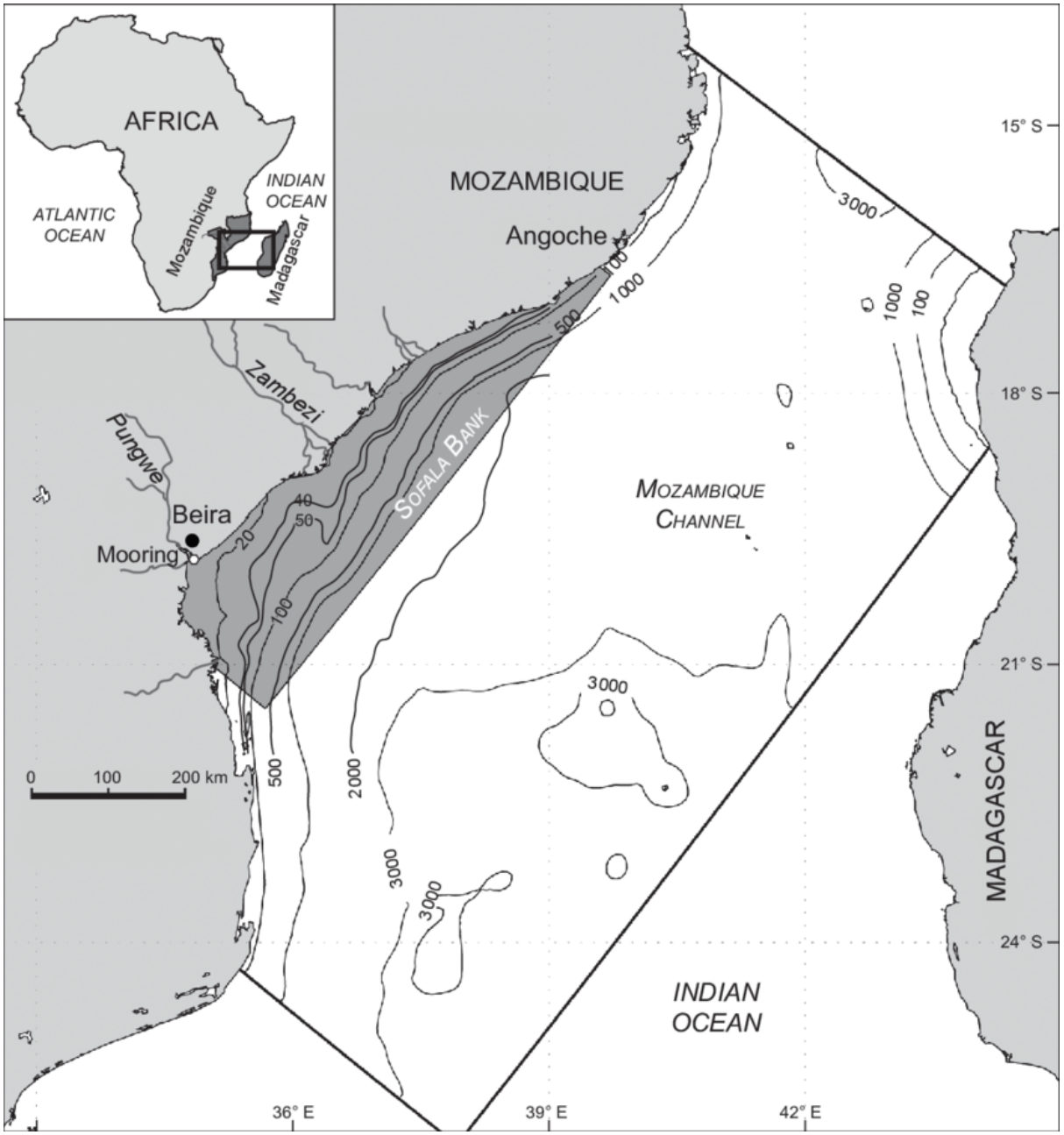

Figure 6, Geographic location of the Sofala Bank. Contours represent sea bottom topology (m). This figure is taken from Chevane et al. (2016) (their Figure 1, page 2).

3.1.4 General Approach/Setup: Research framework

This research includes three stages: 1) Identifying the state-of-the-science of alternative livelihoods related to mangrove restoration; 2) Community and stakeholder consultations to determine site-specific alternative livelihoods; and 3) Economic valuation of mangrove ecosystem services and alternative livelihoods (Figure 7). The coming sections each deal with one of the stages. First, the systematic literature review approach is described. Then, the step of selecting alternative livelihoods for Icidua is presented, followed by the method of the SCBA.

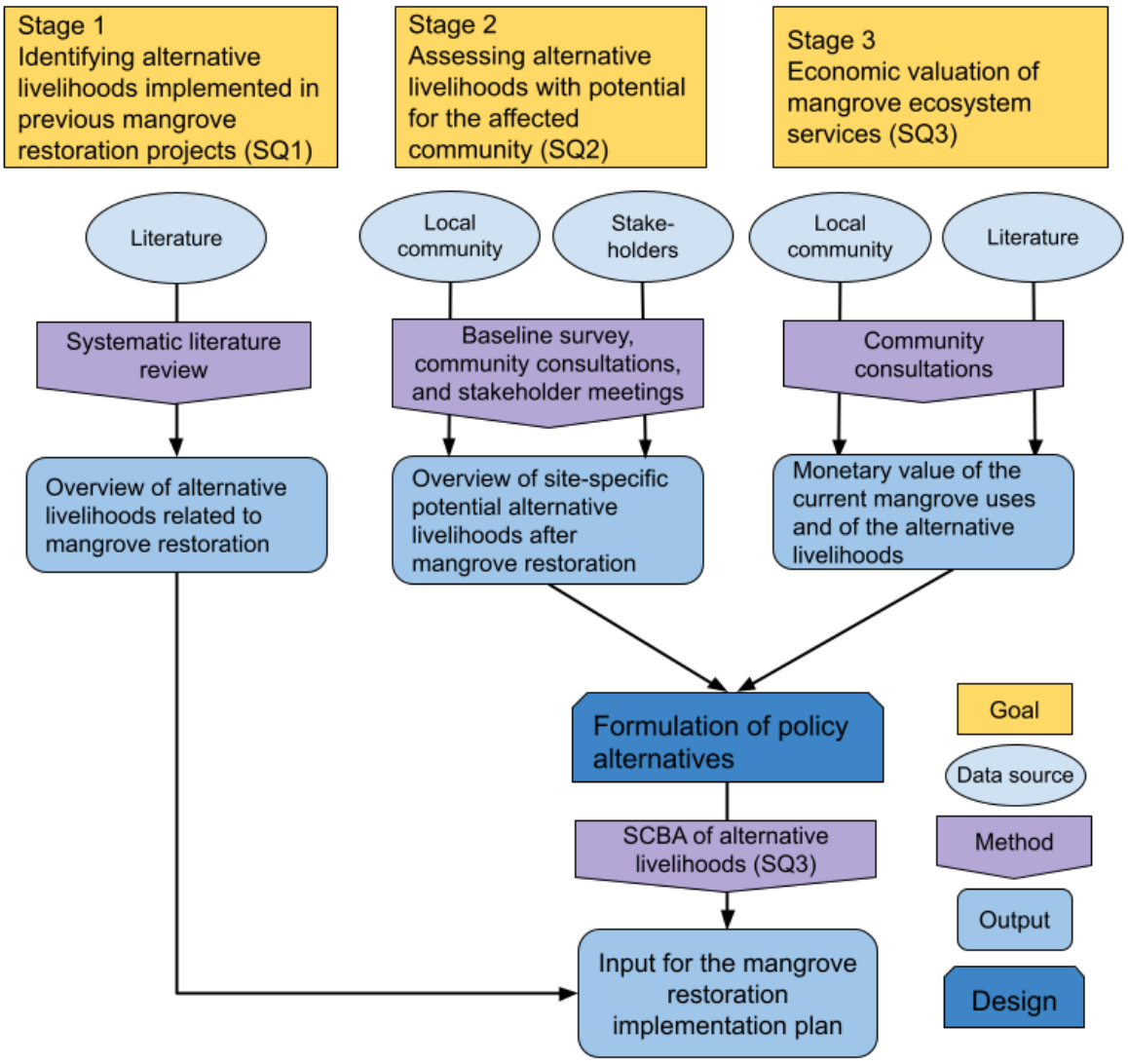

Figure 7, Overview of the research design framework showing the goal and intermittent steps including the methods, data sources and outputs that were obtained in this research.

3.2 Stage 1: Systematic Literature Review

A Systematic Literature Review (SLR) was performed to answer Research Question 1. The SLR aimed to establish a comprehensive state-of-the-science inventory of alternative livelihoods in relation to mangrove restoration projects. The main keywords used in the search strings were: "mangrove restoration", "alternative livelihoods", "local communities", and "community engagement". The synonyms mangrove rehabilitation (synonym for mangrove restoration) and alternative income (synonym for alternative livelihoods) were also included in the database searches. Mangrove restoration namely is a form of mangrove rehabilitation (see: Restoration, Rehabilitation or Replanting). Alternative income is used as synonym for alternative livelihood as the goal of this study was to search for money generating practices without the need to log mangroves. The search strings were entered in the databases Scopus, Web of Science and the WUR (Wageningen University & Research) Library, and they were adapted to the number of results from each of the database searches. Due to the limited number of results from the Scopus database, "conservation" was also added as a keyword to look at a slightly wider variety of sources. Similarly, it was aimed to increase

the number of results in the Web of Science database by excluding the restriction of the term restoration. This resulted in the following search strings:

Scopus

1. In title, abstract, or keywords: Mangrove AND restoration OR rehabilitation OR conservation AND alternative AND livelihood OR income (43 results)
2. In title, abstract, or keywords: Mangrove AND restoration OR rehabilitation OR conservation AND community AND engagement (21 results)

Web of Science

1. Search in keywords: mangrove AND livelihoods (35 results)

WUR Library search

1. In keywords: kw:(Mangrove restoration) AND kw:(livelihood) (232 results)
2. In keywords: kw:(Mangrove restoration) AND kw:(livelihood) (121 results)

First, a literature search of the three databases was performed and duplicates were removed, after which the abstracts were briefly reviewed to exclude non-related mangrove restoration articles. The inclusion and exclusion criteria are provided in Table 3. It had to be clear from reading the abstracts that the article dealt with mangrove restoration (or rehabilitation) and that the article also included some information on livelihoods, community engagement, or other social aspects of mangrove restoration. Research papers in which the term 'livelihood' was not mentioned specifically in the abstract were not directly eliminated, because it could still be possible that the full text contained information on livelihoods. Second, all articles related to mangrove restoration and some form of community engagement were thoroughly reviewed to identify alternative livelihoods. Articles which did not mention livelihoods or means of income generation from mangroves were excluded. Selected case studies had to describe whether local communities were engaged in the restoration process, and if at all, which alternative livelihoods were created for local communities. Figure 8 provides a schematic overview of the steps taken in the SLR. Results of the SLR were used to identify the alternative livelihoods that were most frequently adopted in past restoration projects, thereby, informing the design and execution of the subsequent research objective.

Table 3, Inclusion and exclusion criteria for the systematic literature review of mangrove restoration projects and livelihoods.

1. Inclusion criteria	2. Exclusion criteria
English language	Not in English
Full text available	No full text available
Scientific papers	Not a scientific work
Book chapters	Not on mangroves
Describes mangrove restoration	Not on mangrove restoration
Describes a change of livelihoods	Not on livelihoods
Describes a specific project on a certain location	Global studies

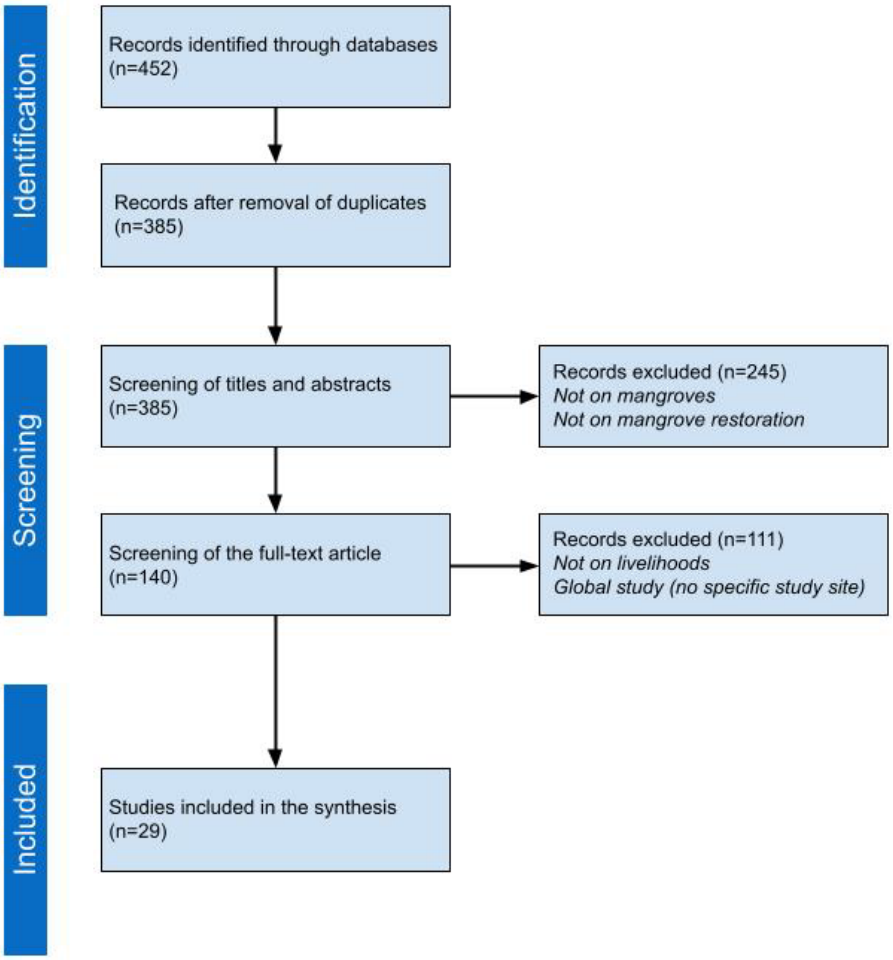

Figure 8, Schematic overview of the steps taken in the systematic literature review on mangrove restoration projects which created alternative livelihoods for the local communities following the PRISMA protocol for transparent reporting of systematic reviews.

Of each of the included research papers, the following data was documented in Excel:

- Year of publication
- Article title
- Country
- Location
- Latitude and longitude coordinates
- Size of the project area [ha]
- Time till the area was restored [year]
- Soil type
- Plant species
- Local community involvement [yes/no]
- Management strategy
- Livelihood prior to restoration
- Alternative livelihood
- Other benefits of the restoration project

The outcome of the SLR was aggregated into an overview showing how often each of the livelihood alternatives and other mangrove ecosystem services were generated in previous restoration projects. Through this methodology it became clear which livelihoods are implemented most frequently and may therefore be a potential good solution in Mozambique. The alternative livelihoods which were mentioned in the research articles were divided into direct-use values,

indirect-use values, non-use values (i.e. following the total economic value framework of Barbier et al. (1997)). Other benefits to the local community (i.e., mangrove ecosystem services) described in the research articles were also included, because this could be valuable information to take to the community consultations. Eventually, the overview of livelihoods related to mangrove restoration projects was used as input for second research question.

3.3 Stage 2: Community and Stakeholder Consultations

After the SLR had been completed, a field trip to Icidua took place in June 2022. The purpose of the field trip was to conduct a baseline household survey, community consultations, stakeholder meetings, and field measurements. The baseline household survey and community consultations were organized to verify which of the identified livelihoods from literature would be relevant to the Icidua community. First, the current use of the mangroves in Icidua and other current livelihoods were identified through the household baseline survey. Second, a selection of the livelihoods identified from the SLR (Stage 1) with high potential to be adopted in Icidua was made based on certain selection criteria detailed later. Next, these livelihoods were presented to the community leaders and the local government to make a final selection. The final selection of livelihoods was tested amongst the community members through community consultations and amongst the relevant stakeholders, which led to a top three alternative livelihoods to be included in the SCBA. Each of the steps are described in more detail in the coming sections.

3.3.1 Baseline Household Survey

Based on the literature review and on a first field visit by two colleagues in December 2021, a baseline household survey was designed and pre-tested with the community leaders to make sure that all questions were answerable. The baseline survey was designed as a door-to-door household questionnaire and was held to obtain a general overview of the local awareness and current use of mangroves (APPENDIX B). The baseline survey included three main sections, of which the first section was used to collect demographic information of the respondents. The second section was designed with questions related to community awareness on mangrove forests and the willingness to participate in mangrove restoration. The third section was developed to collect information on current livelihoods and energy uses related to mangroves. The latter section was of highest importance to this study.

The sample size *n* needed for a statistically viable result was calculated through the following formula:

$$n = \frac{N}{1 + Ne^2}$$

In which N is the total number of households in the area, and e is the design margin of error. The total population of Icidua contained approx. 13,000 inhabitants, with an estimated number of 1,900 households (based on an average of 4.9 births per woman in Mozambique) (World Population Review, 2022). With a margin of error of 6%, the minimum sample size needed was 241 households. The targeted number of respondents was set to 300 households considering an anticipated number of incomplete questionnaires due to complexity of the topic for community members. The baseline survey was conducted by 10 students from the local Eduardo Mondlane University (UEM), accompanied by community representatives. Prior to conducting the survey, the students were briefed and given the opportunity to practice through a roleplay. The students were provided with an instruction leaflet (APPENDIX C) and the printed baseline surveys in both Portuguese and Chuabo (I.e., the native language of Icidua). The students were instructed to actively include women. The surveys were conducted door-to-door using pen and paper. The minimum age to participate in the baseline

survey was set at 15 years, which is the age at which employment commonly starts according to the community leader. The survey was conducted over three days in central Icidua, Bairro Sangariveira and Bairro Thorrone (Figure 9). The latter two are neighbourhoods which are expanding into the mangrove area surrounding Icidua.

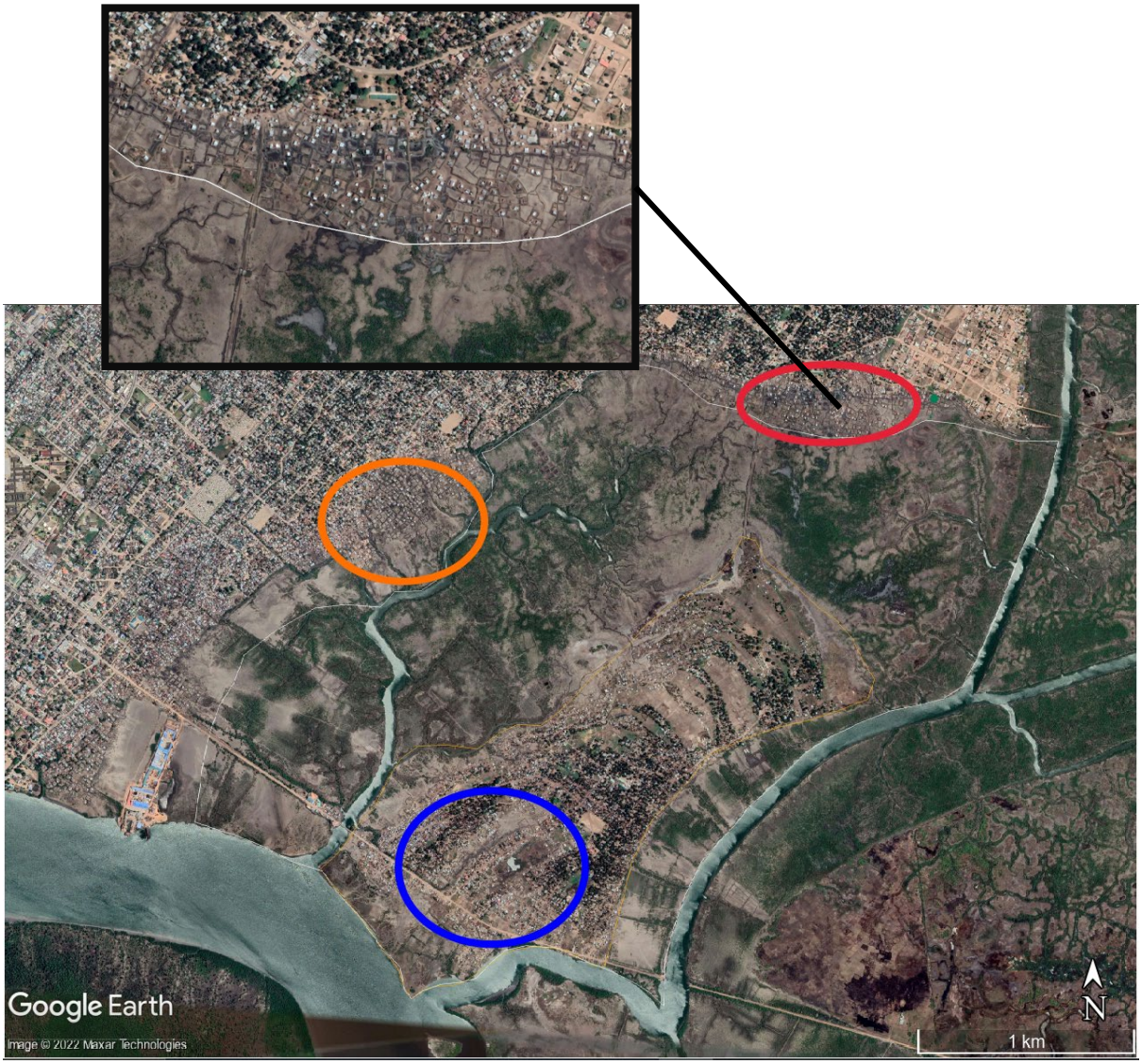

Figure 9, Areas in which the baseline survey was conducted. Blue colour indicates central Icidua, and orange and red indicate two neighbourhoods of Quelimane which are expanding into the mangrove area surrounding Icidua (Thorrone and Sangariveira, respectively). Sangariveira is highlighted to show urban expansion into the mangrove area.

3.3.2 Livelihood Selection

Some of the livelihoods which were identified in the SLR (Research Question 1) to be tested during the community consultations, were eliminated based on the following criteria:

1. The livelihood should not obstruct growth of new mangrove seedlings.
2. The livelihood should not entail systematic logging of mangrove trees.
3. The livelihood should be feasible to implement in Icidua.
4. The livelihood can possibly be implemented without external funding (i.e., there is a local market for the product).

After applying these selection criteria, the selection of livelihoods which remained was presented to the community representatives and to the local government (Table 4; Figure 10). This was done to make a final selection of livelihoods to present at the community consultations with the approval of the community leaders and local government.

Table 4, Community and local government stakeholders included in the selection process through expert judgement of the alternative livelihoods to be presented during the community consultations and stakeholder meetings.

Stakeholder type		
Community stakeholders	Community leader of Icidua	Manuel Joaquim Bronge
	Community leader of Sangariveira	Artur Adimao
	Community leader of Thorrone Velho	Mendes amade Lourenco
	Community leader of Ivagalane	Marques Egidio Xavier
Local government stakeholders	Provincial Delegate INOM	Daniel Oliveira
	Environmental technician INOM	Celso Billy Montanha
	District economic services (SDAE)	Aderito Augusto Goncalves

Figure 10, Meeting with INOM and 4 community representatives to prepare the community consultations; Posters of the livelihoods were shown (background) to discuss the livelihood selection for the community consultations.

3.3.3 Community Consultations

Community consultations were held to provide qualitative input for this study (Figure 11). The Van Oord team was split up over three tables, one of which hosted a discussion on community awareness and support of mangrove restoration, the second table discussed livelihood and energy use, and the third table covered environmental and technical topics. Participants for the community consultations were selected by the community leader, who was instructed to select a representative group of the community of Icidua. In total, 66 community members joined the community consultations.

The aim of the community consultations was to present the selection of livelihoods to the community members. Posters were created to visualize these livelihoods for the community members (APPENDIX D). Community members were asked to vote for each of the livelihoods to identify their interest. Considering the language barrier, the UEM students were used to translate from Portuguese and Chuabo to English. The community consultations were guided by a set of questions (APPENDIX E) which were prepared, translated, and previously discussed with the students. One UEM student per table was asked to take notes in Portuguese to be able to verify information later.

Figure 11, A) Setting with the 3 discussion tables for the community consultations in Icidua. B) Community consultations on different livelihood activities in Icidua and communication of potential alternative livelihoods through posters (on the wall in the back).

3.3.4 Stakeholder meetings

The set of alternative livelihoods was also tested amongst the relevant stakeholders. The stakeholders which were consulted are listed in Table 5. Together with project leader Nathalie Strookman and social expert Sanne Vermeulen it was decided how much weight was put to the vote of each of the stakeholders (Table 6). The alternative livelihoods were ranked based on the votes of the stakeholders and of the community members, and an SCBA was performed for the top three alternative livelihoods, as is described in the next section.

Table 5, List of stakeholders which were included in the stakeholder consultations.

Stakeholder type	Name	Description
National government	INOM	Public Institution of Oceanography, subordinate to Ministry of the Sea, Inland Water and Fisheries
Local government	Community leaders	The community representatives of Icidua and surrounding neighbourhoods
Community associations	CCP	Community fishing association
	ASSOPEZA	Community fishing association
	AAUNZ	Community aquaculture association (Nhanhibua neighbourhood)
	ANAICIDUA	Community mangrove restoration through seedlings plantation
	AJCD	Community aquaculture association
Non-Governmental Organisation	Manitese	Mangrove restoration through seedlings plantation, sustainable stoves donations, funds for alternative income development
	Eden Reforestation	Environmental conservation through planting of mangrove seeds
	FDC	Community development fund with a focus on the empowerment of communities to avoid poverty
	CCM	Catholic Council Mozambique
Knowledge institute and experts	UEM	Eduardo Mondlane University
	Jan de Moor	Irrigation expert who has lived and worked in Quelimane for 34 years on several irrigation projects.
Business & industry	Aquapesca	Shrimp, tilapia and crab farm, aquaculture training for UEM students, and mangrove protection

Table 6, Scoring system for the stakeholder ranking of livelihoods.

Scoring system	Weight
Community leaders (local government)	1
National government	0,75
Community associations	0,4
Academic or knowledge institutions	0,3
NGO	0,25
Business & Industry	0,25

Stage 3: Social Cost-Benefit Analysis

The final research question was aimed at finding the most beneficial policy alternative for Icidua following an SCBA. In order to conduct the SCBA, two policy alternatives were designed of which the first policy describes business as usual, and the second policy is based on alternative livelihood development (i.e. including the top three livelihoods resulting from Stage 2). For both policies, the NPV was calculated as input for the SCBA, and the benefit to cost ratio was determined. The coming sections describe the step-by-step approach of the process.

Step 1: Policy Alternative Design

Two policy alternatives were designed based on information derived from the community consultations. The first alternative is the Business as Usual (BaU) alternative, which analyses the

current situation. The second alternative includes the top three alternative livelihoods which were selected by the community and stakeholders.

Policy 1: Business as Usual

In the BaU alternative, nothing changes to the current situation regarding the use of the mangrove forests. The community consultations, the baseline household survey, and the field measurements were used to establish the current mangrove use and cover, as will be further elaborated in step 2.

Policy 2: Alternative Livelihood Development

The second policy alternative consisted of the top three alternative livelihoods which were selected by the local community and relevant stakeholders (Research Question 2). The aim of implementing alternative livelihoods was to conserve biodiversity by substituting one livelihood activity that is causing harm to a species or habitat (such logging mangroves for construction materials) with another activity, or resource, that will cause less harm. The Alternative Livelihood Development (ALD) policy was designed to provide an alternative to the local community with potential for the mangroves to be restored.

Step 2: Cost and Benefit Estimation

Business as Usual

The most common mangrove uses were identified during the field trip. The costs and benefits of the use values were established through the market-based valuation approach. For each of the use values, the production costs, transport costs, and selling prices were established through the community consultations and by consulting market prices. Furthermore, the damage related to floods was estimated based on information from the community consultations and the baseline household survey. The community members stressed the difficulties of expressing their income as it is often highly variable. Therefore, they were asked to give a range of which the mean was taken as input for the SCBA.

Furthermore, environmental measurements were used as input to estimate the consequences of the BaU scenario for 2022 to 2041. At the time of the field trip, there was 155 ha of mangroves left in Icidua, and there was 272 ha of mangroves with the potential to be restored (Figure 12). During the field visit, the team took measurements along 10 transects in Icidua of 50 m long and 10 m wide (Figure 12). Along these transects, the number of adult trees were counted (i.e., all trees above chest hight), of which the diameter and height was measured. To compare the BaU alternative to the ALD policy, the input values for the SCBA for BaU were divided by 155 to obtain values per ha.

Alternative Livelihood Development

Costs and benefits of the ALD policy were determined based on both the Marked Based Valuation Method, and the Benefit Transfer Method. The costs include the initial investment costs to implement the alternative livelihoods, and the yearly costs made to sustain a livelihood. Benefits of the alternative livelihoods were derived from selling prices on markets in Quelimane and through the community consultations. The costs and benefits of ALD were also calculated per hectare to compare them to the BaU policy.

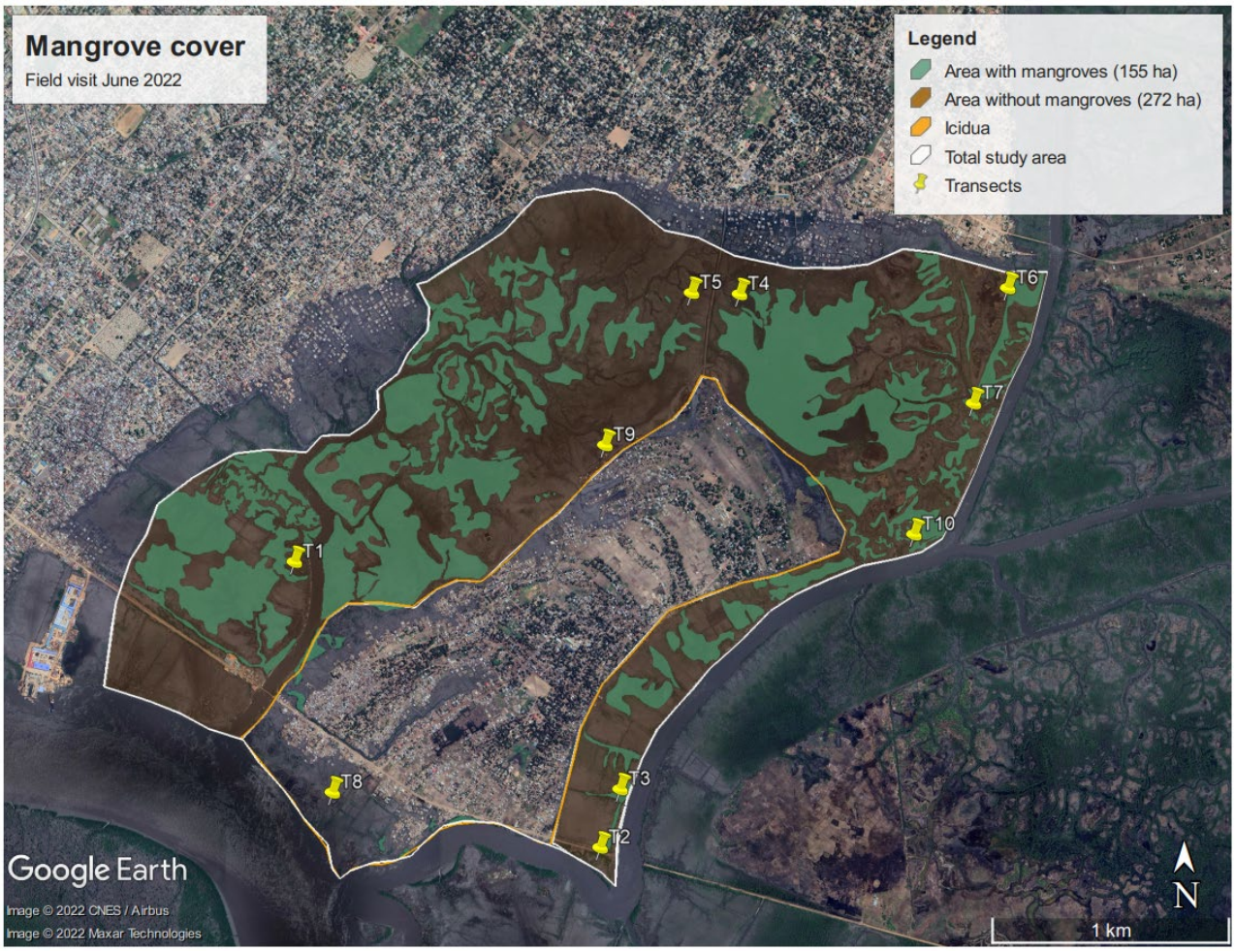

Figure 12, Study area of Icidua including the locations of the transects for the field measurements. All transects were 50 m long. Along the transects, the number of adult trees were counted, and their height and diameter was measured. The area containing mangroves is indicated in green (155 ha), and the area without mangroves is Indicated in brown (272 ha). The inhabited area of Icidua is outlined in orange.

Step 3: Net Present Value Calculation

The NPV was calculated for the different policy alternatives according to the formula:

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t}$$ with time (t) = 1,2,3 … n

Where B_t is the total benefit and C_t are the total costs over time t, n is the time span, r is the discount rate, and $\frac{1}{(1+r)^t}$ is the discount factor. The discount rate of Mozambique has been constant at a rate of 9.95% since 1998 (African Development Bank Group, 2019). Therefore, the NPV was calculated for a discount rate of 10% over a time horizon of 20 years to see long term effects.

Step 4: Sensitivity Analysis

The sensitivity analysis accounts for uncertainty of the input values of the SCBA (Saint-Geours, 2012). The sensitivity analysis was an important step in this research, as the benefits and costs are based on estimations and depend on the discount rate. Previous CBAs of mangrove restoration projects contained a timespan varying from 10 to 30 years (Hakim, 2017; Karanja & Saito, 2018; Nguyen, 2015; Tuan & Tinh, 2013; van Zanten et al., 2021). Together with the Van Oord team it was decided to conduct the SCBA over a period of 20 years after the start of the project (i.e. 2022-2041).

A small difference in discount rate could lead to a significant different outcome in benefit of the policy over 20 years, which demonstrates the importance of a sensitivity analysis. Furthermore, the estimation of mangrove ecosystem goods and services such as charcoal or construction material, and the coastal protection against flood may lead to an overestimation or underestimation of the SCBA result. The sensitivity analysis was carried out on the input parameters to assess the effect of a change in the net estimated project benefits on the NPV. The analysis was carried out in Excel by increasing and decreasing the revenue of the input parameters by 50%. In addition, a discount rate of 5% and a discount rate of 15% was applied for the sensitivity analysis. A discount rate of 5% was chosen to account for mangrove restoration leading to social welfare development. The discount rate of 15% was applied to describe a scenario of economic crisis and the current rise of fuel and gas prices due to the war between Russia and Ukraine.

Step 5: Recommendations Based on the NPV and Sensitivity Analysis

The Benefit and Cost Ratio (BCR) was calculated by dividing all benefits by all cost. For a BCR > 1, benefits exceed the costs which indicates that the scenario would be economically beneficial. BCR < 1 signifies costs exceed the benefits and thus the scenario would lead to an economic loss. Based on the results of the SCBA and the BCR with a sensitivity analysis, this study provided policy recommendations for Van Oord's restoration project and the local government of Icidua.

4. Results

4.1 Systematic Literature Review

The search strings in Web of Science, WUR Library and Scopus resulted in 452 research articles in total, of which 29 research papers describing 35 restoration projects were included (APPENDIX H). The studies spanned a total of 31 countries and regions, mostly in Southeast Asia (Figure 15). Studies generally increased over time until 2019 (Figure 13).

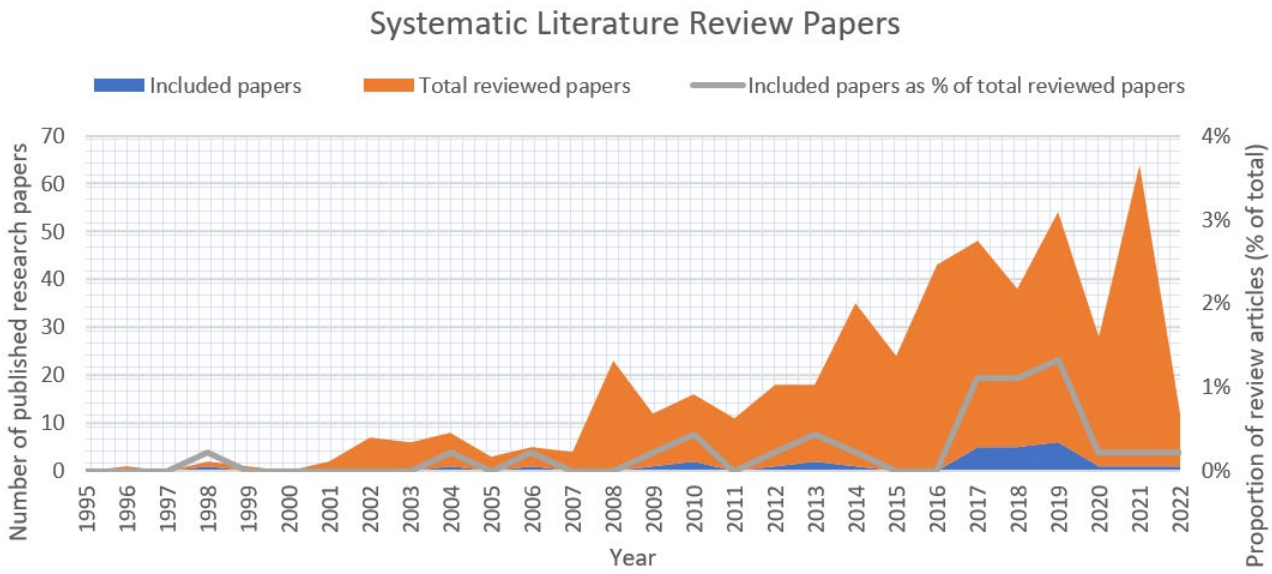

Figure 13, Year of publication of the studies included in the systematic literature review on mangrove restoration and livelihoods. Orange represents the total reviewed papers of the database searches, and blue represents the papers which met the inclusion criteria. The latter are represented as percentage of the total reviewed papers by the grey line.

Results per use value (i.e. including both mangrove ecosystem values and livelihoods) are provided in Figure 14. Indirect-use values have been mentioned most frequently (N=67), followed by direct-use values (N=56), and non-use values (N=42). The top five livelihoods which were implemented most frequently in mangrove restoration projects (N_{tot}=35) are: 1) fishing (referring to the increased fishery productivity resulting from a restored mangrove forest) (48.5%, N=17); 2) eco-tourism (34.3%, N=12); 3) food provisioning (i.e., fruit, herbs, sugar, honey, mangrove drinks and cookies) (25.7%, N=9); 4) aquaculture (20%, N=7); and 5) mangrove management and nurseries (20%, N=7) (NB: one project may have provided multiple alternative livelihoods). Figure 15 shows how often and in which areas the livelihoods were implemented.

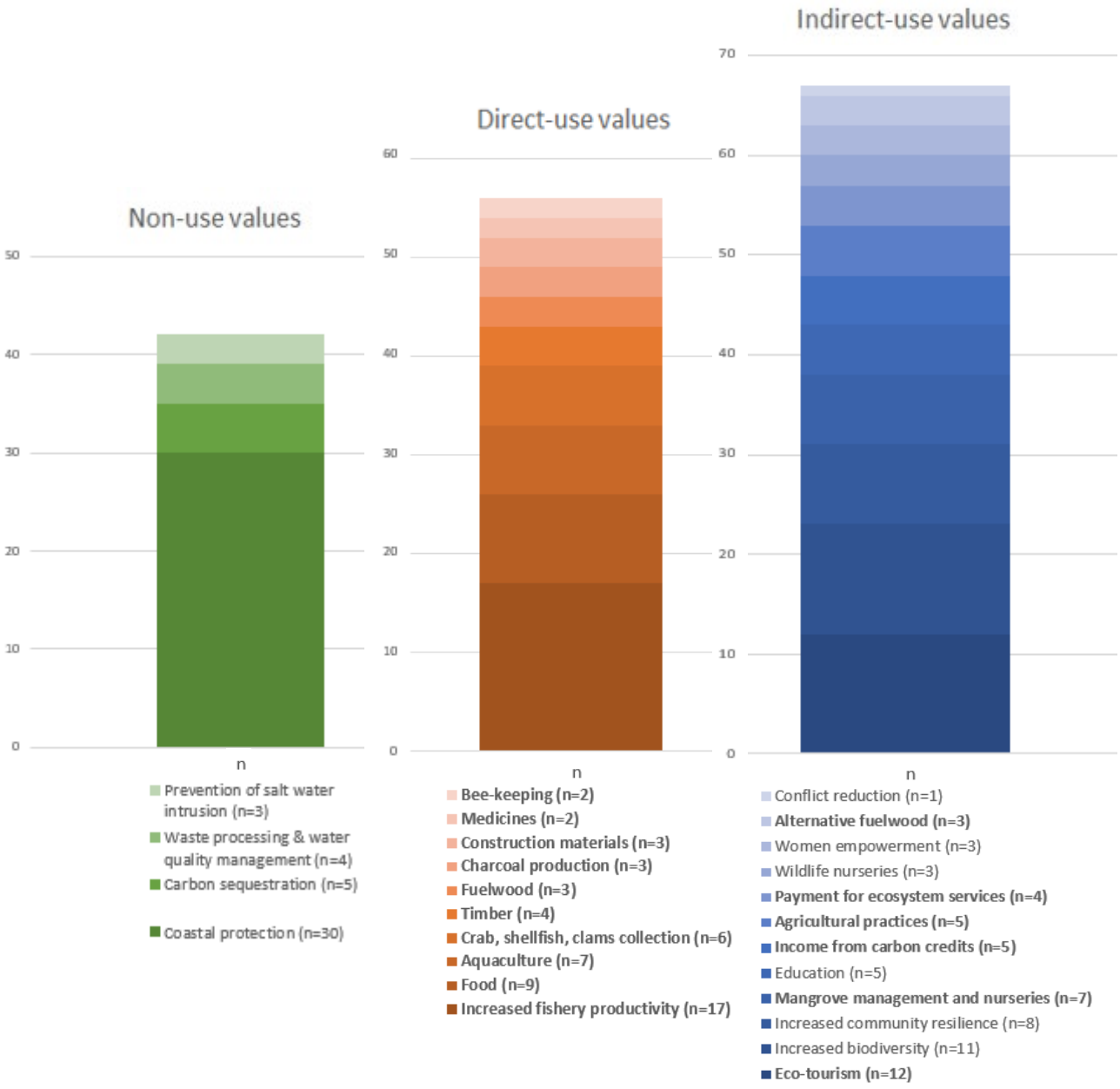

Figure 14, Overview of the amount at which livelihoods (bold) and other mangrove ecosystem values were mentioned in the projects included in the Systematic Literature Review (N_{tot}=35), divided into direct-use values, indirect-use values, and non-use values (following the total economic value framework of Barbier et al. (1997)) (N.B.: Some projects contain more than 1 livelihood or ecosystem value). Agricultural practices also include livestock. No option values were identified from the research papers.

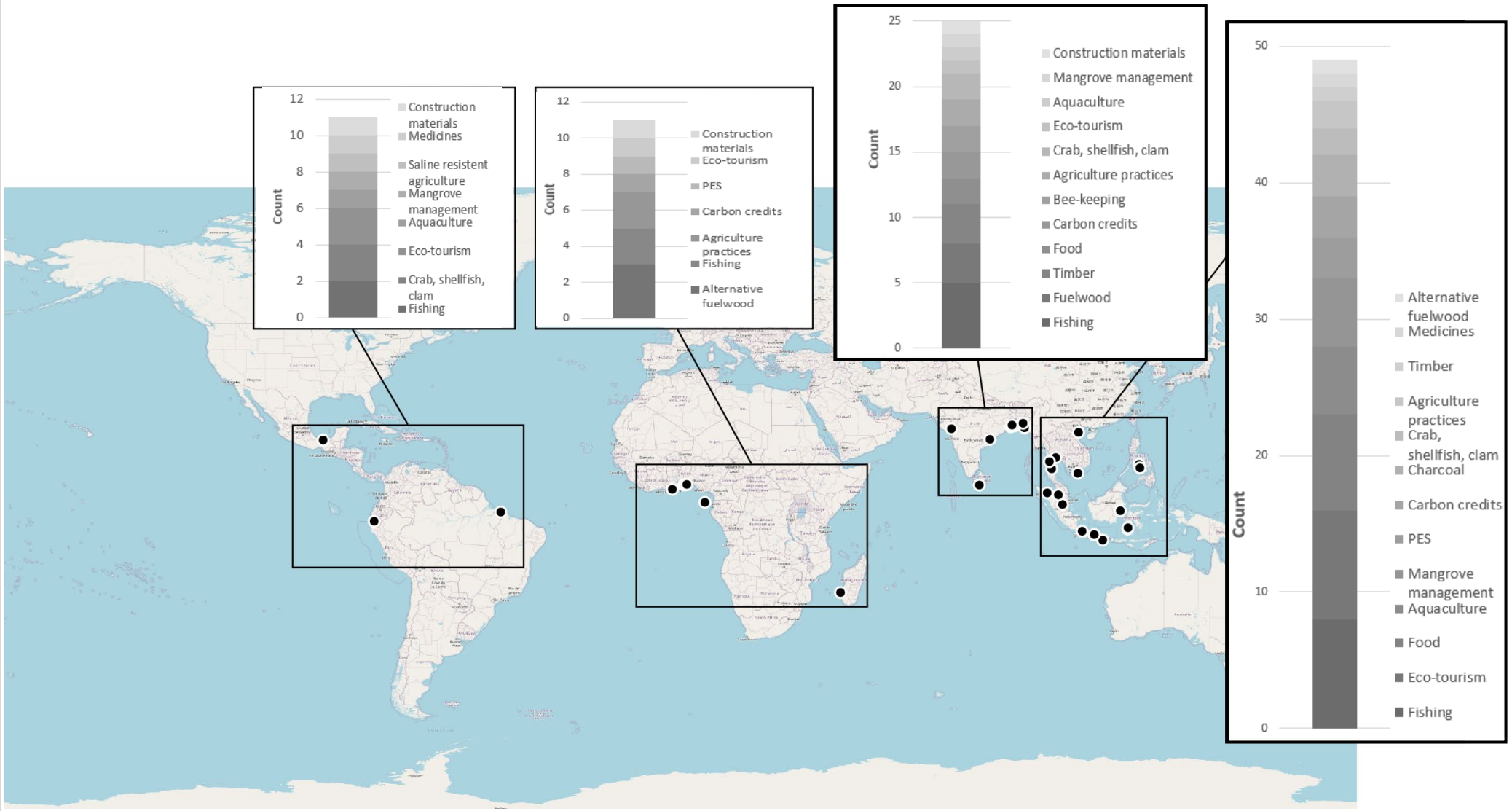

Figure 15, Map showing the locations of the mangrove restoration projects and the alternative livelihoods which were created for the local communities in these projects. The map shows how often the livelihoods were implemented in Latin America, Africa, West-Asia, and Southeast-Asia. 'PES' stands for Payment for Ecosystem Services. 'Food' includes mangrove cookies and drinks, and herbs. 'Fuelwood' means the use of mangrove wood for fire making, whereas 'alternative fuelwood' means planting other wood sources than mangroves for fire production. Agriculture practices also include livestock.

4.2 Community and Stakeholder Consultations

4.2.1 Baseline Survey

Demographic Information

The baseline survey was conducted amongst 290 respondents in total, of which 286 surveys were filled in completely (1.4% dropout rate). The total sample included for analysis consisted of 286 respondents, which is more than the required sample size ($N_{required}$ = 241). A slight majority of the respondents was female (52.8%, N=151), as opposed to male (47.2%, N=135). Most of the respondents were aged 15-25 years (38.8%, N=111), followed by 26-35 years (30.4%, N=87), 36-45 years (19.2%, N=55), and finally 46 years or older (11.5%, N=33). Respondents were mostly smallholder farmers (30.0%, N=86), had their own businesses (e.g., street sales or bicycle taxi) (22.7%, N=65), or were unemployed (21.7%, N=62). About half of the respondents completed their primary school (44.7%, N=128), and slightly smaller amount finished secondary school (33.2%, N=95). About a fifth of the total sample did not receive any level of education (20.2%, N=58) (Figure 16).

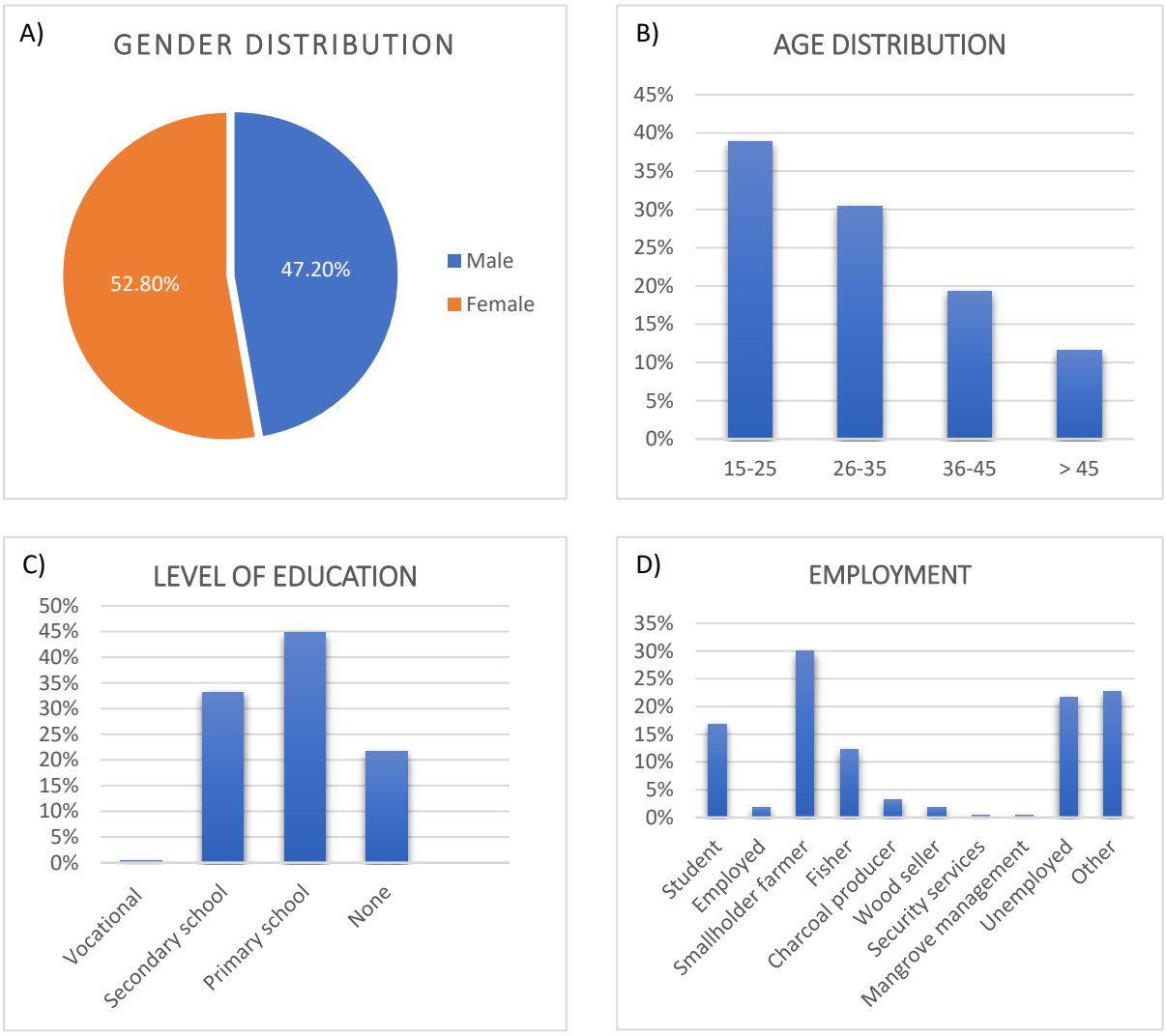

Figure 16, Demographic information of the respondents to the baseline survey: A) Gender distribution, B) Age distribution, C) Level of education (highest degree received), and D) Employment, (respondents were asked to fill in their major occupation) in which 'employed' involves public servant/private or non-profit sector employees. Respondents who selected 'other' mostly stated to have their own small, unregistered businesses such as street seller or bicycle taxi. The percentage on the y-axis describes the percentage of the total surveyed population.

Current Mangrove Use in Icidua

The current use of the mangroves in Icidua was determined based on the baseline survey and the community consultations. From the survey it appeared that the main uses of mangrove resources are charcoal production, firewood collection and house construction (Figure 17). The same question was asked during the community consultations (round 1 and 2 contained 18 and 24 community members respectively). During the community consultations the answers from the baseline survey were confirmed: mangroves in Icidua are mainly used for firewood, charcoal and to construct houses.

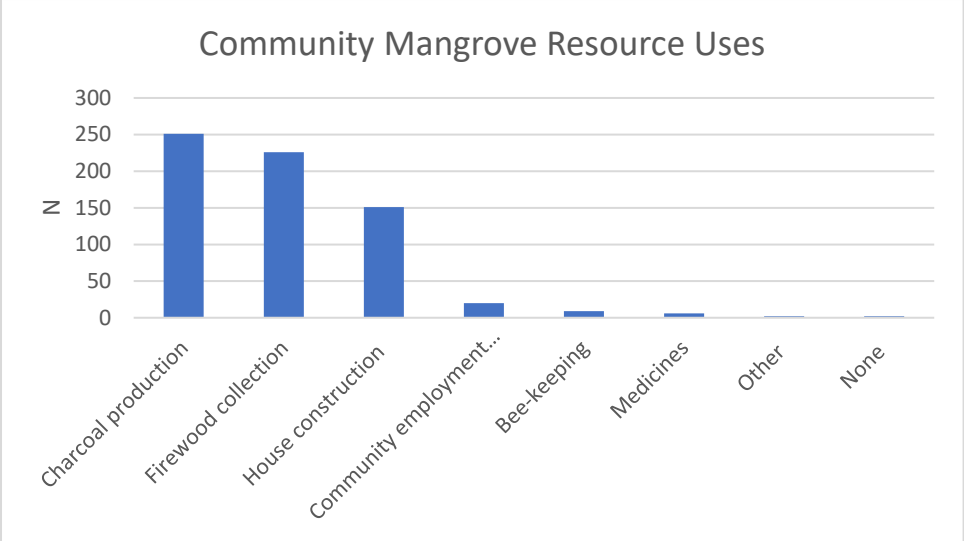

Figure 17, Current use of the mangroves in Icidua identified in the baseline survey which was conducted amongst 286 respondents. The 4th column stands for 'community employment for mangrove restoration'. N stands for the number of times a mangrove use value was mentioned. N.B.: respondents were allowed to select multiple answers.

Non or Indirect Mangrove Related Livelihoods in Icidua

The baseline survey was also used to identify other livelihood activities making the community less dependent on mangroves. Fishing and agriculture were mentioned the most frequently (Figure 18). During the community consultations, fishing and crab catching were mentioned as the most common livelihoods which are not directly related to mangroves. Furthermore, saltpans, sales of fish feed (i.e., corn flower), fish trading and small business such as beauty salons and barber shops were mentioned as common alternatives.

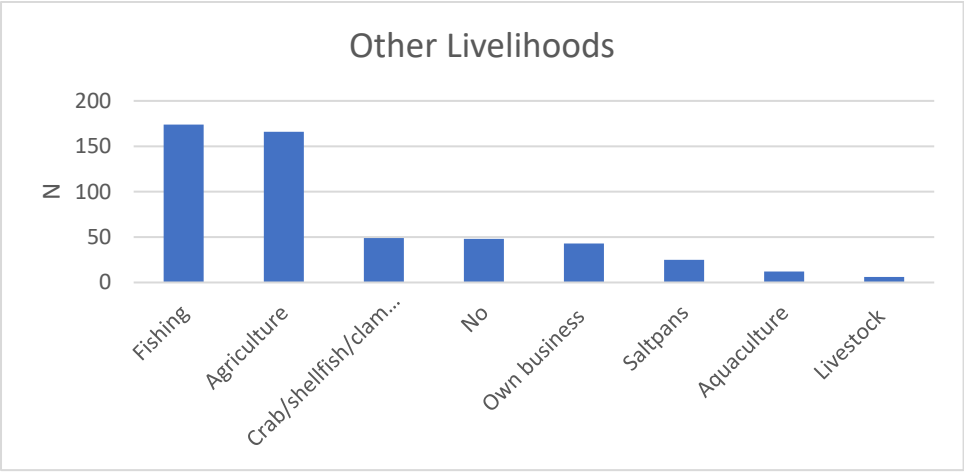

Figure 18, Other livelihoods making the community less dependent on mangrove resources. 'Own business' mostly refers to street sales or bicycle taxi. 48 respondents answered 'No', stating there are no livelihoods which are not related to mangroves.

Selection of Alternative Livelihoods

The result of the first selection of the alternative livelihoods based on the selection criteria is provided in Table 7. The livelihoods which were included after selection are 1) fishing, 2) aquaculture, 3) crab, shellfish, and clam collection, 4) beekeeping, 5) agriculture and 6) livestock. This selection of livelihoods was presented to the community leaders and INOM, who advised to exclude fishing due to the ongoing problems of overfishing. Furthermore, together with the community leaders and INOM, it was decided to include goats and chicken, but to exclude cows due to the lack of fodder and space in Icidua.

Table 7, Livelihoods obtained from the systematic literature review assessed based on the following inclusion criteria: 1) The livelihood does not obstruct growth of new mangrove seedlings; 2) The livelihood does not entail systematic logging of mangrove trees; 3) The livelihood is feasible to implement in Icidua, and 4) the livelihood can be sustained within the local context (i.e. the product is used on the local market).

		Suitable?	Excl. criterium	Explanation
Direct use values	Fishing (increased productivity)	Yes	-	-
	Food (fruits, herbs, medicines)	No	1	Eating mangrove fruits impedes spread of mangrove seedlings
	Charcoal, fuelwood	No	2	Cause of deforestation
	Aquaculture	Yes	-	-
	Fuelwood	No	2	Cause of deforestation
	Crab, shellfish, clam collection	Yes	-	-
	Timber	No	2	Cause of deforestation
	Livestock fodder	No	1	Seedlings used as livestock fodder impedes growth of new mangroves
	Construction materials	No	2	Cause of deforestation
	Beekeeping	Yes	-	-
Indirect use values	Eco-tourism	No	3	There is currently no tourism in Icidua
	Mangrove management and nurseries	No	4	Absence of local market for mangrove nurseries
	Income from carbon credits	No	4	Cannot be arranged without external funding
	Agriculture and livestock	Yes	-	-
	Payment for Ecosystem Services	No	4	Cannot be arranged without external funding

The alternative livelihood options have been presented and discussed during the community consultations. The result of the community consultations is a list of rank ordered alternative livelihoods based on the discussions with the community members and the governmental and non-governmental stakeholders (Figure 19). The top three livelihoods selected by the community members are: 1) agriculture, 2) livestock (chicken), and 3) aquaculture. The top three livelihoods selected by the stakeholders are: 1) aquaculture, 2) livestock (chicken), and 3) agriculture. These three livelihoods were therefore included in the SCBA. For agriculture, with both the stakeholders and the community members it was decided to select salt resistant crops.

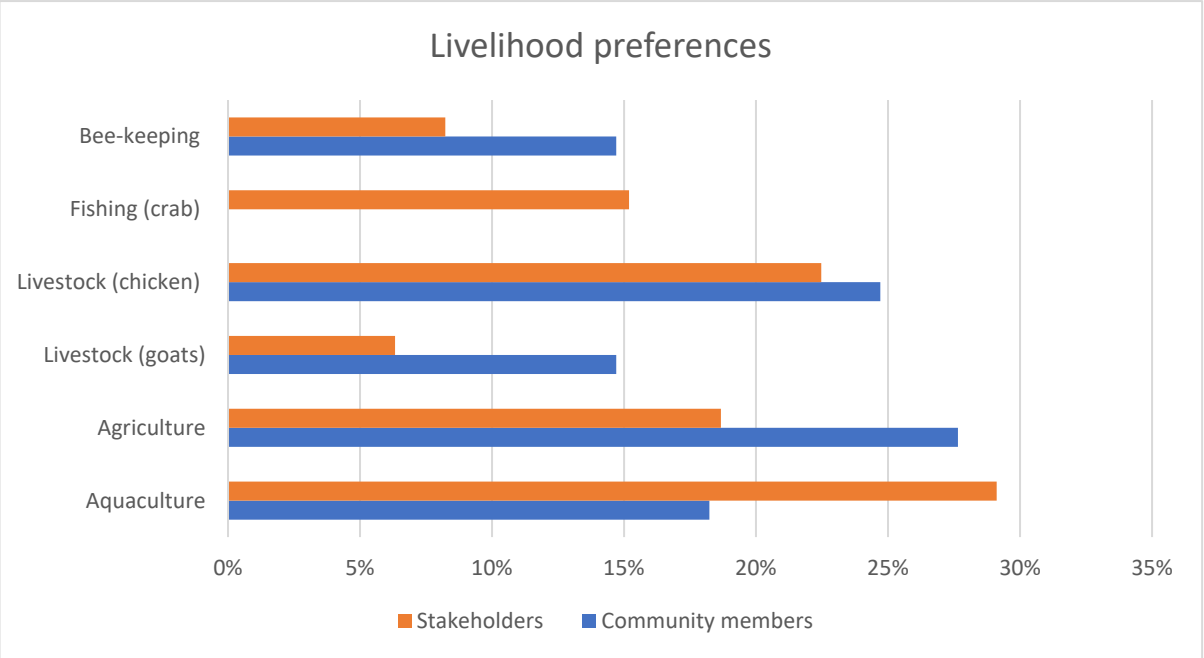

Figure 19, Livelihood preferences of the community members and the stakeholders, identified during the community and stakeholder consultations. The stakeholder preferences are ranked according to importance through a weighting system.

4.3 Social Cost-Benefit Analysis

Step 1: Policy Design

Policy 1: Business as Usual

The full BaU policy alternative was designed based on the field trip; the community consultations showed that mangroves were mainly exploited for charcoal and firewood production and construction material for houses (Figure 20). Figure 21 shows the erosion process which is amplified by mangrove logging. Based on satellite imagery, the coastal engineer of the team (Elly Diamantidou) calculated that along the main river (Cuacua), erosion occurs at a rates up to 6.5 m/y.

Figure 20, House constructed with mangrove wood in Icidua.

Figure 21, Bundles of mangrove wood ready to be transported by canoe and sold at a market, and B) signs of riverbank erosion. On both pictures there used to be houses where the land has been eroded. Erosion rates at this location are about 6,5 m per year.

Flooding of houses is common, and several houses have vanished into the river due to riverbank erosion (Figure 22). Furthermore, the ongoing mangrove logging has caused river erosion which has led to a collapse of the bridge connecting Icidua to Mirazane (east of Icidua) (Figure 23).

Figure 22, Houses on the riverbank of Icidua from 2002-2022 and the signs of erosion. The coloured boxes on the map show the year in which houses were built corresponding with the colours in the legend. By 2022, 32 houses have been destroyed due to erosion.

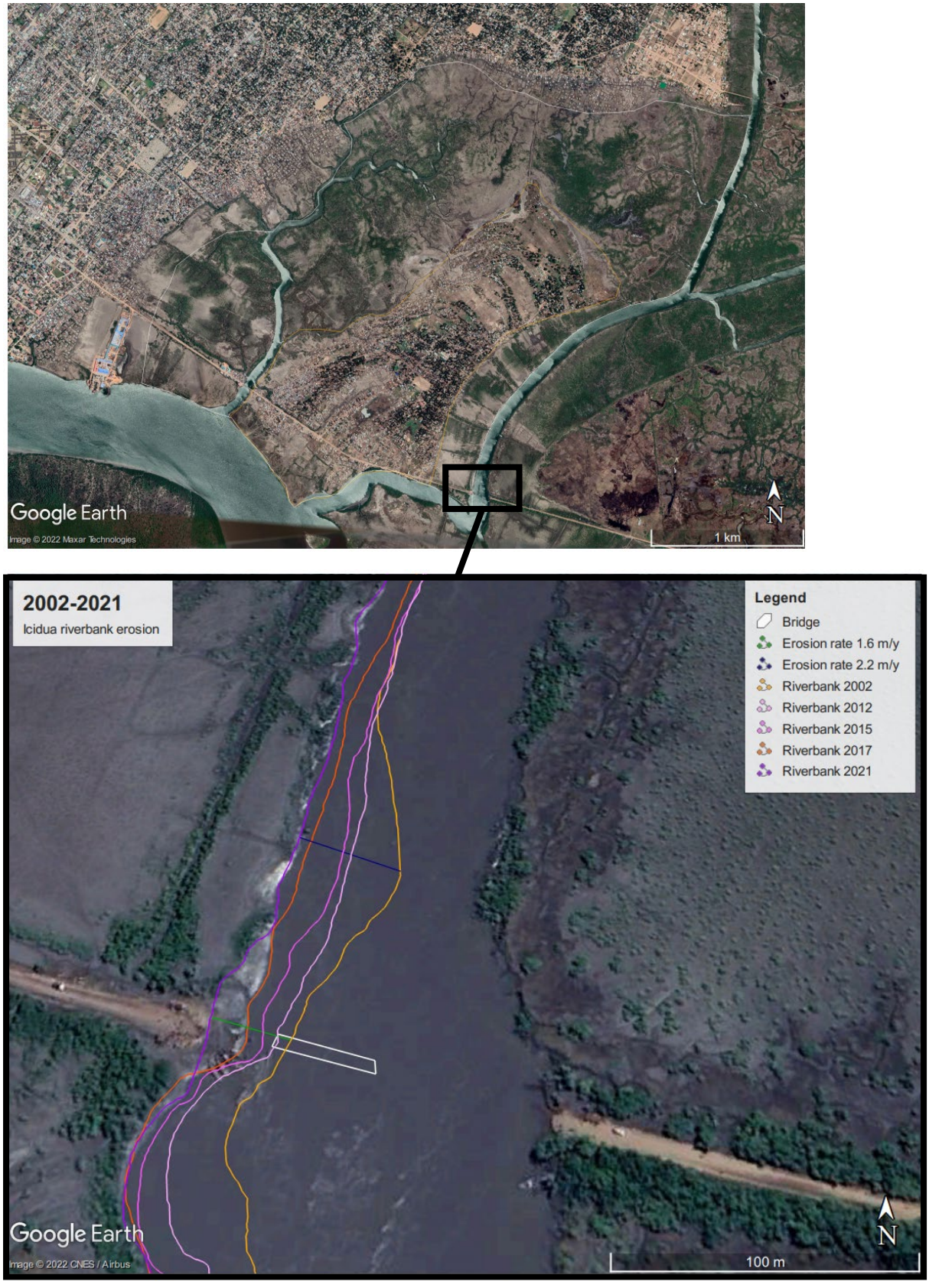

Figure 23, Rates of erosion at the riverbank east of Icidua, and the bridge which has collapsed in 2013 (indicated by the white box). The coloured lines indicate the change in riverbank from 2002 until 2021. The green and the blue line indicate points at which erosion rates were measured; 1.6 m/y and 2.2 m/y, respectively. (N.B.: a change in riverbank is not indicated on the eastern side of the river due to too large spatial resolutions (the western and eastern riverbanks were namely split up over two separate satellite images).

Policy 2: Alternative Livelihood Development

The second policy design includes the top three alternative livelihoods which were selected through the community and stakeholder consultations, namely: 1) aquaculture, 2) agriculture, and 3) chicken farming. The three livelihoods were all included into one policy alternative as they are interrelated: agricultural and chicken by-products can be used as fish feed, and agriculture by-products can also be used as chicken feed.

Step 2: Cost and Benefit Estimation

Cost and Benefits of Policy 1

The field measurements showed a mangrove density of 371 adult trees per ha, with an average height of 2.26 m, and an average diameter of 6.8 cm. 14 out of 286 households stated to log mangroves (4.9%), for either charcoal production (N=9), or to sell the wood (N=5). River erosion occurs at rates up to 6.5 m per year along the main river (Cuacua). According to the baseline survey results, half of the households (50%, N=143) have experienced damage from floods to their house property. The Costs and Benefits for the Business as Usual policy are listed in Table 8. More detail on the calculations made in the costs and benefit estimation can be found in APPENDIX I.

Table 8, Costs and benefits [MZN] estimation of policy option 1: Business as Usual (for 155 ha and for 1 ha). The costs consist of all materials which are needed to produce charcoal, firewood, and construction material, and damage from floods. Benefits consists of revenue generated from charcoal, firewood, and construction material sales.

Costs and Benefits for policy Option 1: Business as Usual									
			155 ha				1 ha			
			Year 1	Year 2	Year 3-10	Year 11-20	Year 1	Year 2	Year 3-10	Year 11-20
Revenue										
	Charcoal/firewood/construction material		1,890,000	1,890,000	1,890,000	0		12,194	12,194	12,194
Input										
	Matches		3,456	3,456	3,456	0	22	22	22	0
	Metal drum		90,000	0	0	0	581	0	0	0
	Shovel		27,000	0	0	0	174	0	0	0
	Bags (50kg)		31,672	31,672	31,672	0	204	204	204	0
	Saw		113,400	0	0	0	732	0	0	0
	Rope		45,000	45,000	45,000	0	290	290	290	0
Others										
	Bridge east	10 MZN per trip	648,000	648,000	648,000	648,000	4,181	4,181	4,181	4,181
	Bridge west	11 MZN per trip	0	0	648,000	648,000	0	0	4,181	4,181
Flooding hazard	Damage from floods		135,000	135,000	135,000	135,000		871	871	871
	Total costs		**1,093,528**	**863,128**	**1,511,128**	**1,431,000**	**7,055**	**5,569**	**9,749**	**9,232**
	Total revenue		**1,890,000**	**1,890,000**	**1,890,000**	0	**12,194**	**12,194**	**12,194**	**0**
	Net revenue		**796,472**	**1,026,872**	**378,872**	**- 1,431,000**	**5,139**	**6,625**	**2,444**	**- 9,232**

Costs and Benefits of Policy 2

Costs and Benefits of the ALD policy are displayed in Table 9. Costs are displayed for 1.38 ha (i.e. the sum of the agriculture field, aquaculture pond, and chicken farm area), and were converted to 1 ha. Calculations made for the cost and benefit estimation for ALD are listed in APPENDIX I.

Table 9, Costs and Benefits [MZN] estimation for policy option 2: Alternative Livelihood Development (for 1.38 ha and 1 ha).

Costs and Benefits for policy Option 2: Alternative Livelihood Development										
				1.38 ha			1 ha			
		Amount	Size	Year 1	Year 2	Year 3-20	Year 1	Year 2	Year 3-20	
Productivity pond				0.8	0.9	1	0.8	0.9	1	
Chicken mortality				0.1	0.075	0.05	0.1	0.075	0.05	
Revenue										
Aquaculture		6	Pond 400 m2	2,300,950	2,588,568	2,876,187	1,667,355	1,875,774	2,084,193	
		2	Pond 660 m2	1,265,522	1,423,713	1,581,903	917,045	1,031,676	1,146,306	
Agriculture	Cabbage		0.5 ha	450,000	450,000	450,000	326,087	326,087	326,087	
	Maize		0.25 ha	87,609	87,609	87,609	63,485	63,485	63,485	
	Potato		0.25 ha	240,000	240,000	240,000	173,913	173,913	173,913	
Chicken farm	Chicken sales		1 farm, 80 m2	201,600	226,800	239,400	146,087	164,348	173,478	
Investment	Construction	6	Pond 400 m2	48,000	-	-	34,783	-	-	
		2	Pond 660 m2	24,000	-	-	17,391	-	-	
	Aquaculture kits	1		10,568	1,057	1,057	7,658	766	766	
	Waterpump	1		40,000	-	-	28,986	-	-	
	Construction chicken farm			100,000	-	-	72,464	-	-	
Input										
Aquaculture	Fingerlings			422,720	422,720	422,720	306,319	306,319	306,319	
	Fishfeed			2,967,494	2,967,494	2,967,494	2,150,358	2,150,358	2,150,358	
	Fishfeed from maize			24,416	24,416	24,416	17,693	17,693	17,693	
	Fishfeed from chicken byproducts			18,473	18,473	18,473	13,386	13,386	13,386	
	Fertilizer			84,544	84,544	84,544	61,264	61,264	61,264	
	Domestic fertilizer			40,581	40,581	40,581	29,407	29,407	29,407	
Agriculture	Cabbage seed			985	985	985	714	714	714	
	Maize seed			1,110	1,110	1,110	804	804	804	
	Potato			14,029	14,029	14,029	10,166	10,166	10,166	
	Fertilizer			2,351	2,351	2,351	1,704	1,704	1,704	
	Pesticides			2,165	2,165	2,165	1,569	1,569	1,569	
	Manure + domestic fertilizer			-	-	-	-	-	-	
Chicken farm	Day old chicks			16,000	16,000	16,000	11,594	11,594	11,594	
	Feed			26,589	26,589	26,589	19,267	19,267	19,267	
	Vaccines, antibiotics			858	858	858	622	622	622	
	Equipment/farm tools			1,141	1,141	1,141	827	827	827	
Labour										
Family labour	Aquaculture			48,000	48,000	48,000	34,783	34,783	34,783	
	Agriculture			11,777	11,777	11,777	8,534	8,534	8,534	
	Chicken farm			14,000	14,000	14,000	10,145	10,145	10,145	
Hired labour	Aquaculture		Pond labour	160,000	160,000	160,000	115,942	115,942	115,942	
	Agriculture			4,473	4,473	4,473	3,241	3,241	3,241	
	Chicken farm			-	-	-	-	-	-	
	Security			8,000	8,000	8,000	5,797	5,797	5,797	
Others	Transport to market			17,543	17,543	17,543	12,712	12,712	12,712	
	Bags (50kg)			46,499	46,499	46,499	33,695	33,695	33,695	
	Water tank (rainwater for chicken)			20,000	-	-	14,493	-	-	
	Total costs			**4,176,317**	**3,934,806**	**3,934,806**	**3,026,317**	**2,851,309**	**2,851,309**	
	Total revenue			**4,545,681**	**5,016,690**	**5,475,099**	**3,293,972**	**3,635,282**	**3,967,463**	
	Net revenue			**369,363**	**1,081,884**	**1,540,293**	**267,655**	**783,974**	**1,116,154**	

Step 3 & 4: Net Present Value and Benefit-Cost Ratio

Net Present Value and Benefit-Cost Ratio for Policy 1

14 out of 286 respondents (4.9%) to the baseline survey stated they logged mangroves for charcoal (N=9), or to sell wood (N=5). Looking at the total number of households Icidua (N_{tot}=1860), this would be approximately 90 people. One person cutting mangroves on average sells 5 bags of charcoal/fuelwood/construction material per month, earning 350 MZN per bag (one bag being equal to one adult mangrove). Table 10 shows the result of the SCBA for the BaU alternative per ha at a discount rate of 10%. The scenario accounts for a complete loss of mangroves in the area after 10 years due to deforestation, based on the current mangrove cover of 371 trees per ha and 90 people cutting 5 trees per month (APPENDIX I). The average total costs are 9,000 MZN, and the average total benefit is 6,000 MZN per ha per year, averaged over 20 years. Results show a net negative economic impact of 992 MZN, and a BCR of 0.99.

Table 10, Social Cost-Benefit Analysis of the Business as Usual policy alternative (1 ha) at a discount rate of 10%. Costs and benefits are listed in MZN.

Year	Total cost (ha)	Total benefit (ha)	Discount rate (10%)	Present value of benefit	Present value of cost	NPV
2022	7,055	12,194	0.9091	11085	6414	4671
2023	5,569	12,194	0.8264	10077	4602	5475
2024	9,749	12,194	0.7513	9161	7325	1836
2025	9,749	12,194	0.6830	8328	6659	1670
2026	9,749	12,194	0.6209	7571	6053	1518
2027	9,749	12,194	0.5645	6883	5503	1380
2028	9,749	12,194	0.5132	6257	5003	1254
2029	9,749	12,194	0.4665	5688	4548	1140
2030	9,749	12,194	0.4241	5171	4135	1037
2031	9,749	12,194	0.3855	4701	3759	942
2032	9,232	-	0.3505	0	3236	-3236
2033	9,232	-	0.3186	0	2942	-2942
2034	9,232	-	0.2897	0	2674	-2674
2035	9,232	-	0.2634	0	2432	-2432
2036	9,232	-	0.2389	0	2205	-2205
2037	9,232	-	0.2229	0	2058	-2058
2038	9,232	-	0.1978	0	1827	-1827
2039	9,232	-	0.1799	0	1661	-1661
2040	9,232	-	0.1635	0	1510	-1510
2041	9,232	-	0.1486	0	1372	-1372
			Total	74924	75916	-992
					NPV	-992
					BCR	0.99

Net Present Value and Benefit-Cost Ratio for Policy 2

The SCBA of the second policy alternative is provided in Table 11. This data is based on a total area of 1.38 ha and was converted to 1 ha to calculate the SCBA for the years 2022 until 2041 over a 10% discount rate (Table 9). The average cost of 1 ha development of a combination of aquaculture, agriculture and chicken farming is about 2,900,000 MZN per year. The annual costs and benefits are allocated to several households who run the ponds and farms. The average annual benefits generated from 1 ha are about 3,900,000 MZN per year. The NPV accounts for about 8,500,000 MZN and the BCR is approximately 1.35 (10% discount rate).

Table 11, Social Cost-Benefit Analysis of the Alternative Livelihood Development Policy (1 ha) at a discount rate of 10%. Costs and benefits are listed in MZN.

Year	Total cost (ha)	Total benefit (ha)	Discount rate (10%)	Present value of benefit	Present value of cost	NPV
2022	3,026,317	3,293,972	0.9091	2,994,520	2,751,197	243,322
2023	2,851,309	3,635,282	0.8264	3,004,366	2,356,454	647,912
2024	2,851,309	3,967,463	0.7513	2,980,814	2,142,230	838,583
2025	2,851,309	3,967,463	0.6830	2,709,830	1,947,482	762,348
2026	2,851,309	3,967,463	0.6209	2,463,482	1,770,438	693,044
2027	2,851,309	3,967,463	0.5645	2,239,529	1,609,489	630,040
2028	2,851,309	3,967,463	0.5132	2,035,936	1,463,172	572,764
2029	2,851,309	3,967,463	0.4665	1,850,851	1,330,157	520,694
2030	2,851,309	3,967,463	0.4241	1,682,592	1,209,233	473,358
2031	2,851,309	3,967,463	0.3855	1,529,629	1,099,303	430,326
2032	2,851,309	3,967,463	0.3505	1,390,571	999,366	391,205
2033	2,851,309	3,967,463	0.3186	1,264,158	908,516	355,642
2034	2,851,309	3,967,463	0.2897	1,149,212	825,908	323,304
2035	2,851,309	3,967,463	0.2634	1,044,967	750,989	293,977
2036	2,851,309	3,967,463	0.2389	947,682	681,074	266,609
2037	2,851,309	3,967,463	0.2229	884,403	635,597	248,806
2038	2,851,309	3,967,463	0.1978	784,941	564,116	220,825
2039	2,851,309	3,967,463	0.1799	713,583	512,833	200,750
2040	2,851,309	3,967,463	0.1635	648,712	466,212	182,500
2041	2,851,309	3,967,463	0.1486	589,738	423,829	165,909
			Total	32,909,515	24,447,596	8,461,919
					NPV [MZN]	8,461,919
					BCR	1.35

Step 5: Sensitivity Analyses

A sensitivity analysis was carried out based on the SCBAs of the two policy options for discount rates 5%, 10% and 15%, of which the results are shown in Table 12. The sensitivity analysis shows that the BaU alternative will lead to economic loss for a discount rate of 5% (18533 MZN) and 10% (992 MZN). For a discount rate of 15%, the BaU alternative will lead to a net positive economic impact of 6318 MZN. In contrast, ALD generates a net positive economic impact for all discount rates, with the highest benefit of about 12,800,000 MZN at a discount rate of 5%. The BCR for ALD is relatively stable, varying between 1.33 and 1.36 for discounts rates of 15% and 5%, respectively. The BaU alternative shows a negative BCR for discount rates of 5% and 10%.

Table 12, Sensitivity analysis of the two policy alternatives for discount rates of 5%, 10%, and 15%.

Sensitivity analysis				
	Policy 1		Policy 2	
Discount rate	NPV [MZN]	BCR	NPV [MZN]	BCR
5%	-18,533	0.84	12,800,355	1.36
10%	-992	0.99	8,461,919	1.35
15%	6,318	1.12	5,997,377	1.33

Sensitivity Analysis for Policy 1

In addition, a sensitivity analysis was executed on the input values for both policy alternatives, of which the results are listed in Table 13. For the BaU alternative, the mangrove cover was both doubled and halved, of which the former leads to presence of adult mangroves until 21 years in the area. The latter leads to a fully deforested area after 6 years. Furthermore, the total revenue, and damage to houses caused by floods and erosion were increased and decreased by 50%. Table 13 shows that both

the extent of mangrove cover and amount of revenue from sales have a large impact to determine the net positive or negative outcome of the scenario.

Table 13, Sensitivity analysis of policy option 1: Business as Usual, performed by decreasing and increasing the mangrove cover density, damage, and revenue by 50%.

Sensitivity analysis for Policy option 1: Business as Usual												
	0 revenue at t=6y		0 revenue at t=21y		50% less damage		50% more damage		50% less revenue		50% more revenue	
Discount rate	NPV [MZN]	BCR	NPV [MZN]	BCR	NPV [MZN]	BCR	NPV [MZN]	BCR	NPV [MZN]	BCR	NPV [MZN]	BCR
5%	-58,143	0.48	36,820	1.32	-13,106	0.88	-29,387	0.762	-65,611	0.42	75,622	1.67
10%	-28,476	0.62	26,726	1.35	2,718	1.04	-8,411	0.899	-38,454	0.49	73,932	1.97
15%	-13,142	0.76	20,804	1.37	9,044	1.17	867	1.014	-24,280	0.56	67,515	2.23

Sensitivity Analysis for Policy 2

Results of the sensitivity analysis of ALD are presented in Table 14. The sensitivity analysis was executed by increasing and decreasing the revenue obtained from potatoes, maize, cabbage, aquaculture, and chicken farming by 50%. 50% less aquaculture revenue would lead to net negative economic benefits at all discount rates. The decrease in revenue of the other input variables would still generate a net positive economic benefit. The sensitivity analysis shows that a change in aquaculture input has the largest effect of the economic outcome of the alternative.

Table 14, Sensitivity analysis of policy option 2: Alternative Livelihood Development, performed by increasing and decreasing the revenue of potato, maize, cabbage, aquaculture, and chicken farming by 50%.

Sensitivity analysis for Policy option 2: Alternative Livelihood Development										
50% less revenue										
	Potato		Maize		Cabbage		Aquaculture		Chicken farming	
Discount rate	NPV [MZN]	BCR	NPV [MZN]	BCR	NPV [MZN]	BCR	NPV [MZN]	BCR	NPV [MZN]	BCR
5%	11,716,684	1.33	12,404,774	1.35	10,768,473	1.30	-6,875,055	0.807	11,736,578	1.33
10%	7,721,191	1.32	8,191,526	1.34	7,073,055	1.29	-4,870,201	0.801	7,739,267	1.32
15%	5,453,087	1.30	5,798,690	1.35	4,976,833	1.28	-3,709,959	0.794	5,469,809	1.30
50% more revenue										
	Potato		Maize		Cabbage		Aquaculture		Chicken farming	
Discount rate	NPV [MZN]	BCR	NPV [MZN]	BCR	NPV [MZN]	BCR	NPV [MZN]	BCR	NPV [MZN]	BCR
5%	14,967,696	1.42	13,591,515	1.38	16,864,119	1.47	52,151,173	2.461	14,927,909	1.42
10%	9,943,374	1.41	8,191,526	1.37	11,239,648	1.46	35,126,158	2.437	9,907,224	1.41
15%	7,085,956	1.39	6,394,749	1.36	8,038,463	1.45	25,412,047	2.412	7,052,512	1.39

5. Discussion

Each subsequent question was informed by the former, creating a stronger architecture of inquiry. With the foundation of one question leading to another, this bolsters the structural integrity of the project. When follow up questions are informed by previous findings, this allows methodological, pertinent, and informed research.

The research objective was to identify the most beneficial livelihood-related policy alternative for the Icidua community. Research Question 1 set the basis of this study by creating an overview of the state-of-the-science of mangrove restoration projects implemented with the provision of alternative livelihoods. Research Question 2 analysed these livelihoods based on applicability to Icidua together with local knowledge from meetings with the community and other stakeholders. This resulted in the top three alternative livelihoods selected by the community and stakeholders. These livelihoods were used to design two policies of which the costs and benefits were analysed to find out which scenario would be more beneficial; the current ongoing mangrove logging business, or the implementation of alternative livelihoods. The coming sections reflect on each of the research questions and the impact the methodology may have had on the outcome.

5.1 Systematic Literature Review

The SLR showed the variety of ecosystem services and livelihoods created with mangrove restoration projects in the past. The SLR's goal was to identify potential livelihoods to be implemented in Icidua as an alternative to logging mangroves. Out of the 452 research articles related to mangrove restoration and livelihoods, a mere 29 papers described alternative livelihoods which were provided to local communities. This is abysmal considering community engagement is key to successful mangrove restoration (Rönnbäck et al., 2007; Stone et al., 2008).

Areas in which restoration projects with alternative livelihoods have been reported were divided over Latin America, Africa, West Asia, and Southeast Asia. As can be seen in Figure 15, most of the mangrove restoration projects related to alternative livelihoods have been implemented in Southeast Asia. Eco-tourism is the only livelihood which has been implemented in all four areas. Due to the low number of projects implemented in Latin America and Africa compared to Asia, it was not possible to detect clear spatial patterns.

The low number of research articles appearing in this study does not necessarily mean that fewer mangrove restoration projects have been implemented in the tropics other than Southeast Asia. However, it may be that mangrove restoration projects in Latin America and in Africa have not involved the local communities by looking into alternative livelihoods. This indicates room for progress in future mangrove restoration projects on these continents which consider the importance of local community support to generate long term sustainable restoration outcomes (Saunders et al., 2020). That the SLR showed no clear spatial patterns meant there were no clear directions for the implementation of alternative livelihoods to be derived from projects in areas with similar socio-economic and climatic circumstances to Mozambique (i.e. neither from East Africa, nor from Africa as a whole). Therefore, the global result was used as input for Research Question 2. To compensate, selection criteria were designed to select livelihoods suitable to Icidua, and the opinions of the local community and stakeholders were valued highly.

Applicability to Icidua

It was assumed that livelihoods which are developed frequently after mangrove restoration would have a higher chance of success of implementation in Icidua, due to the available documentation and key lessons which are depicted in previous research studies. However, not all were

suitable to Icidua. Fishing, the livelihood scoring the highest in the SLR, was excluded after consulting the community leaders and local government. Mr. Manuel Bronge, Icidua community leader, stated that overfishing is an issue, due to fishermen using mosquito nets to catch fish. As a result, fish get caught at premature stages, a serious problem to the fish population. Thus, fishing was excluded from the policy design.

Another livelihood which scored high in Research Question 1 but was excluded from the policy design is eco-tourism. Eco-tourism may provide monetary benefits from non-consumptive uses and economic alternatives to forest resources (i.e., mangrove wood), leading to socio-economic development resulting in local community support for mangrove restoration (Roy, 2016). The poorest often benefit most from timber forest products (Kumar, 2002), as was also the case in Icidua. Whereas forest products are a continuous source of income, tourism is often highly seasonal. Eco-tourism may therefore not guarantee community members to stop logging the mangroves (Delang, 2006). Furthermore, introducing eco-tourism to an area which is not touristic yet demands for a project with a larger scope than mangrove restoration and community engagement activities. Considering the current state of development and lack of tourism in Icidua, eco-tourism was excluded from the policy design.

Likewise, fuelwood scored in the top five of the SLR but was not recommended for Van Oord's mangrove restoration project. The reason for this is that currently the main problem of the decrease in mangrove cover in Icidua is logging for charcoal and fuelwood, as was established by the baseline survey. These livelihoods would therefore not provide alternatives.

Even though the SLR sketched an overview of what has been done in terms of mangrove restoration and livelihoods, it was important to analyse site-specific preferences of livelihood alternatives. A thorough understanding of local stakeholders' preferences for mangrove ecosystem services strengthens the connection between the local community and conservation actors for sustainable mangrove management (Nyangoko et al., 2020). Thus, a meeting with the community leaders and the local government was held, and the community consultations were organized. From the community consultations and from the meeting with Jan de Moor (a Dutch irrigation expert who has been working in Quelimane for over 30 years), it became clear that community members in Icidua experienced problems with agriculture practices due to salinization of their farmlands. Farmers who used to cultivate rice in Icidua, now have to walk 10 to 15 km to their rice fields on less saline soils. Therefore, agriculture was included as a livelihood. More specifically, salt resistant crops, as has been investigated by SaltFarm Texel (de Vos et al., 2016). Based on community consultations, potato, cabbage, and maize have been selected to include in the SCBA. Potato and cabbage are crops which can grow in saline soils (de Vos et al., 2016). Maize is generally moderately sensitive to salt stress (Farooq et al., 2015), yet salt-resistant maize hybrids have been developed (Schubert et al., 2009). Cultivating maize would be of value for Icidua, as maize flour is used as fish feed for the aquaculture tanks of AJCD.

Aquaculture has been reported as alternative livelihood following mangrove restoration (e.g., Christian et al., 2021; Wilms et al., 2017 & Malik et al., 2017). However, aquaculture is also frequently reported as the cause of mangrove destruction (e.g., Debrot et al., 2022; Schmitt et al., 2013 & Garcia et al., 2019). The possibilities of implementing aquaculture in the area have been discussed with IDH (The Sustainable Trade Initiative) and IFAD, which support sustainable aquaculture in Mozambique with the goal of maximizing financial, social, and environmental benefits for local communities. Icidua so far contained one example of aquaculture. At the time of the field visit, community aquaculture association AJCD was constructing aquaculture ponds by employing men who used to log mangroves (Figure 24). In addition, the community leaders stated that chicken farming would be a good

alternative livelihood to discuss during community consultations. Chicken farming is currently not done on a large scale in Icidua; however, some people breed their own chickens. Byproducts of chicken can also be used as fish feed for the aquaculture ponds (IFAD, 2019).

Figure 24, Digging of an aquaculture pond by AJCD, the community aquaculture association of Icidua.

Monitoring

Van Oord's project strived to identify sustainable livelihoods which could be carried out in harmony with a healthy mangrove forest. The mangrove restoration projects in the SLR were often written shortly after the start of restoration. The projects mostly lacked documentation of several years of monitoring, and therefore it is currently unknown whether the implementation of a certain livelihood was successful and led to a sustainable outcome of a project.

5.2 Community and Stakeholder Consultations

After gathering an overview of alternative livelihoods through the SLR, the community and stakeholder consultations were held to select the top three livelihoods to be included in the policy design. The community engagement programme of the field trip consisted of a baseline survey and community consultations. This section assesses the validity and reliability of the community engagement activities.

Validity

The baseline survey was used to obtain an overview of the current livelihoods in Icidua. There were no official demographic statistics of the population of Icidua available, and therefore it could not be stated with certainty that the sample was representative of the entire population. However, it was

strived to obtain a representative sample based on national statistics: In 2020, the total Mozambican population consisted of 51.4% women (The World Bank Group, 2022b), so the baseline respondents consisting of 52.8% women seemed representative.

Reliability

It was deliberately chosen not to join the 10 UEM students whilst they were conducting the baseline household surveys. This was to ensure that community members felt anonymous, and could speak openly to the students because mangrove logging is prohibited in Mozambique. All surveys were conducted orally and filled out by the students using pen and paper. Later, the surveys were processed online by our team members. Thus, per question there were 2 moments in which the processing of the answer could have been done incorrectly. This could have been avoided by providing the students with iPads, however this would risk robbery or running out of battery. As for the community consultations, we received feedback from the community members that they tend not to speak up easily with presidents of associations present, reducing the reliability of the results.

5.3 Social Cost-Benefit Analysis

For the first 20 years after the start of the project (2022 to 2041), the BaU scenario showed a net negative economic outcome at a discount rate of 10% (BCR<1) (Table 12). Based on estimations there would be no adult mangroves left in Icidua after 10 years of the current logging practices. The BaU alternative is therefore not sustainable. The BaU policy also leads to a negative economic outcome for a discount rate of 5%, with a BCR of 0.84. A discount rate of 15% would result in a BCR of 1.12. The ALD policy, on the contrary, leads to net positive economic outcomes for all discount rates, showing more stable BCRs varying from 1.33 (15% discount rate) to 1.36 (5% discount rate). For this scenario, the benefits thus exceed the costs at all discount rates. From the main policy outcomes it can be concluded that the ALD policy would be more beneficial to the local community, providing a stable income during the first 20 years after the start of the project. The next section discusses the influence of a change in input value for both alternatives.

Sensitivity Analysis

The values of the input variables for the SCBA were not fully reliable; community members often experienced trouble with providing monetary values to mangrove ecosystem services and the perceived damage. Some of the findings should therefore be interpreted with caution, which is why a sensitivity analysis was conducted, as is discussed below.

Business as Usual

For the BaU policy, the sensitivity analysis has shown to be critical for outcome of the project. Table 13 showed that in case the mangrove density is double from what was estimated, adult mangroves would disappear after 21 years, and results for all discount rates increase to a net positive economic outcome. In case the mangrove cover is half of what is estimated, mangroves would disappear after 6 years, resulting in a net negative economic outcome for all discount rates. However, the estimate used in this study of 371 trees per ha, which was based on the field measurements along the transects, corresponds to previous research; another study conducting a CBA of mangrove restoration in Quelimane assumed 364 trees per ha (Narayan et al., 2017). It is therefore not expected that the mangrove cover would deviate by 50% from the input of 371 trees per ha. However, what may deviate is the amount of ha containing adult mangroves. It was assumed that 155 ha of adult mangroves were available, based on an estimation of the current situation. This estimation was made based on Google Earth satellite imagery and on information from the transects. The estimation is not highly accurate as the transects did not cover the entire area; other vegetation types on satellite imagery may have been interpreted as mangrove cover.

Similar to the effect of mangrove density input on the outcome, the impact of the amount of revenue from charcoal sales was high; in case the revenue was doubled, the BCR would be larger than the ALD policy for all discount rates. Nonetheless, it is unlikely that revenue from mangrove sales is double from what was estimated during the community consultations, as community members were asked to give a minimum and maximum value of their earnings per bag of charcoal, which ranged from 300 to 400 MZN. The input benefit from charcoal sales of 350 MZN per bag thus seems representative. In addition, the perceived damage from floods was also based on information from the community consultations. The perceived damage was of significant less influence on the total NPV, than that of mangrove cover or revenue (Table 13). Yet, this damage from floods is of large impact to community members, and mangrove restoration could potentially lead to visible positive impacts for many. As the sensitivity analysis has shown that a change in input value is of high impact on the outcome of the BaU scenario, it would be recommended for Van Oord to collect more data to improve the reliability of the estimates.

Alternative Livelihood Development

For the ALD policy, the sensitivity analysis has shown that, except for when reducing aquaculture revenue by 50%, the policy outcomes would lead to a net positive economic impact (Table 14). The revenue generated from aquaculture was based on costs provided by the community aquaculture association (AJCD), and estimated benefits based on an aquaculture design report for Mozambique (IFAD, 2019). AJCD could not provide data on the benefits as their ponds were not productive yet. Revenue provided by aquaculture is of relatively large impact on the outcome of this study; if the revenue is 50% of what is estimated, the BCR reduces to about 0.8. On the other hand, if the revenue is double of what is estimated, the BCR increases to about 2.4. According to AJCD, the productivity of their ponds strongly depends on the type of fish feed and on their demand for a water pump, as they stated during our site visit. It is aimed to support AJCD to increase their productivity rates through connecting them to UEM and its expertise on aquaculture.

As for agriculture, input values were derived through the Market Based Valuation Method (for cabbage), and through the Benefit Transfer Method (used to estimate average yield per ha of maize and potato) based on information from other areas in Mozambique (Amaral et al., 2020; FAOSTAT, 2022); the latter method is potentially susceptible to errors resulting from a lack of correspondence between locations (Plummer, 2009). This is especially true considering the saline soils of Icidua. Yet, the revenue of the agricultural products in the policy showed to be stable from the sensitivity analysis, with BCRs varying between 1.28 and 1.47 for all discount rates. The overall ALD policy outcome is therefore not much affected by the uncertainty of agriculture revenues.

Lastly, calculations regarding chicken farming were made based on the Market Based Valuation Method and the Benefit Transfer Method. Revenues from chicken farming largely depend on the size of the farm and survival of the chickens. Village or backyard poultry production is an important aspect of rural development in Mozambique, where families generally keep between 6-15 chickens (FAO, 2013). However, mortality rates of chicken in Mozambique are reported to be high during dry season due to disease and lack of feed (FAO, 2013). To account for this, this study considered investments in vaccines and antibiotics to reduce chicken mortality. These investments, as well as mortality rates applied in the SCBA, were derived from the aquaculture design report in which aquaculture was combined with chicken farming (IFAD, 2019). The sensitivity analysis has shown that a 50% decrease or increase in revenue would both result in a net positive economic outcome ranging from 1.30 to 1.42. The outcome of the SCBA is thus not highly effected by chicken farm revenues.

Overall, the small impact caused by a change in agriculture or chicken farming on the SCBA result can be explained by the relatively large importance of aquaculture in the policy design. The revenue

of aquaculture is of much larger impact on the SCBA than that of agriculture or chicken farming, due to the size of AJCDs aquaculture ponds and due to the price of fish compared to that of crops (potato, maize and cabbage). As AJCD was already constructing the ponds at the time of this study, it was chosen to use the sizes of their aquaculture ponds as input for this study. Changing the area of the agriculture ponds, or increasing the agriculture fields or the size of the chicken farm would lead to a different outcome. This is something that Van Oord should take into account when designing their project plan. Further estimations need to be made to estimate the size of agricultural lands, aquaculture ponds, and chicken farms needed to sustain 90 households whilst saving enough space for mangrove restoration. Yet, the alternative livelihoods would provide a wide variety of job opportunities; other than digging ponds, constructing a chicken farm, or working on the land, among others, transporters and market vendors should be employed which could provide a great stimulation to the local economy.

5.4 Limitations and Future Research

This research contains several shortcomings. The first is related to agriculture as alternative livelihood. As stated before, cabbage and potato have shown to be salt resistant in previous research (de Vos et al., 2016). As for maize, which is usually not tolerant to salt, some salt resistant hybrids exist (Schubert et al., 2009). Yet it cannot be assured that these crops will grow and produce the desired yields in Icidua. Soil samples were taken along the transects, but these had not been analyzed by the laboratory in Maputo at the time of thesis writing. Further research is needed to determine whether these crops will be able to grow in Icidua based on soil salinity levels.

The second limitation is related to the BaU policy. Needs vary across sub-groups; communities are heterogeneous, and outsiders likely also use the mangrove forest (Le, 2008; Stone et al., 2008), as is also the case in Icidua and surroundings. An important aspect to consider is the amount of people who come from outside areas to log mangroves in Icidua. Based on the baseline survey results, the amount of community members from Icidua logging mangroves was roughly estimated to lie around 90. However, some may not openly speak about cutting mangroves, as it is prohibited. Thus, the actual number of people in Icidua logging mangroves may be higher than estimated, which would further reduce the economic outcome of the BaU policy.

Another BaU policy limitation is related to the re-growth of mangrove forests. The scenario does not consider the growth rate of Avicennia Marina (i.e. the most common species in Icidua). Little documentation exists on growth rates of Avicennia Marina in Mozambique, however on an island nearby Icidua our team found trees exceeding 15 m in height. Thus, with an average height of 2.26m, trees in Icidua are often cut at a premature stage. In addition, no data was available on seedlings survival. Van Oord intends to conduct a pilot study in Icidua to monitor seedlings survival. This data could be used to improve the calculations of the effect of logging intensity on mangrove cover in the area.

Furthermore, the SCBA does not consider risks related to climate change. Mozambique is prone to tropical storms, such as storm Idai which occurred in 2019. If a tropical cyclone would cross Icidua, aquaculture ponds and farmlands may be destroyed. This is something to consider when designing the project. Finally, the SCBA is designed without consideration of potential funds which Van Oord is applying for. External funds would decrease the investment costs of alternative livelihoods.

5.5 Recommendations for Community Engagement Plan

The research goal was to provide recommendations for the community engagement plan of Van Oord's mangrove restoration project. As has been stated in literature, community empowerment is key to success in mangrove restoration (Rönnbäck et al., 2007; Stone et al., 2008), and sustainable

outcomes will not be generated if there is a lack of long-term support from local communities (Saunders et al., 2020). Communication and cooperation with the local community is essential to ensure community empowerment and to create a sense of local project ownership (Mangora, 2011). To achieve community empowerment, the local community should be represented in sustainable management policies. This would give them a sense of ownership and legal empowerment to achieve full community support for the sustainable mangrove resource utilization and management (Mangora, 2011; Roy, 2016). To create ownership of the project by the local community, it is recommended to initiate a Mangrove Management Committee which should be a representative group of the community. This has been done in several previous projects and helps to gain trust of the local community, who are the long-term managers of the mangrove forest (Aheto et al., 2016; Damastuti & de Groot, 2017; Das & Mandal, 2016; Le, 2008; Lin, 2005; Mangora, 2011; Roy, 2016; Stone et al., 2008).

The most important recommendation for Van Oord's community engagement plan is to aid the local community in the development of alternative livelihoods. This research has shown it is economically beneficial to implement aquaculture, salt resistant agriculture, and chicken farming as alternative livelihoods, which is also in line with the community's needs. Introducing new livelihood activities to Icidua will require input to train the local communities and to provide them with the necessary equipment. Previous examples come from Demak, where Aquaculture Field Schools were initiated to teach smallholder aquaculture farmers how to conduct environmentally friendly aquaculture. The farmers were shown how to use less chemicals whilst increasing their milkfish or shrimp yield (Yuniati et al., 2021). Likewise, IDH has set up the Chicoa Fish Farms to teach smallholder farmers how to efficiently conduct cage aquaculture in Mozambique. IDH supports smallholder farmers with funds for their equipment and trainings with the goal to contribute to a sustainable tilapia industry in Mozambique (IDH, 2020). In Icidua, it is recommended to arrange technical support to the aquaculture association through UEM, the local university in Quelimane with a master on aquaculture.

Additionally, it is recommended to investigate alternative cooking methods to reduce the demand of mangrove wood. This was raised as an alternative livelihood possibility by the community during the community consultations. Possibilities to do so have been explored in a meeting with AVSI, a sustainable cooking stove foundation. It is recommended to further explore possibilities for cooperation to set up a business of sustainable stoves in the area with the goal to generate livelihoods. This would mean that the stoves are e.g., manufactured, sold, and repaired in Icidua. Besides, there are two possibilities to reduce the demand for mangrove wood in Icidua. First, the community members opted the use of brick making machines to reduce the demand for mangrove wood as construction materials. Second, there could be possibilities to plant fast growing trees to provide alternative fuelwood. Lastly, bicycles and bicycle taxis are a common mean of transport in Icidua. Bike repair workshops could therefore also be an opportunity.

Finally, an issue outside the scope of this thesis but still significant, is related to people building houses inside mangrove areas. From the community consultations it appeared this is due to a lack of space. This should be taken into account when designing the mangrove restoration project plan.

6. Conclusion

This study was conducted with the goal to find the most beneficial policy plan to the local community of Icidua in Mozambique. This chapter provides answers to the research questions in a structured manner.

1) *Which cases of mangrove restorations worldwide have been implemented with explicit considerations of identifying alternative livelihoods for affected communities?*

A systematic literature review showed that out of 35 cases of mangrove restoration projects related to alternative livelihoods, the livelihoods of fishing, eco-tourism, food production from mangroves, aquaculture, and mangrove management and nurseries were implemented most frequently in previous mangrove restoration projects. These mangrove restoration projects were mostly concentrated in Asia, although some were located in Latin America and Africa.

2) *Which of the identified livelihoods from literature would be relevant to the Icidua community and which alternative has the best potential according to them?*

From the baseline survey, it was established that mangroves in Icidua are mostly logged for production of charcoal, firewood and construction materials, which is the main reason for their disappearance. Other common livelihoods in Icidua are fishing, agriculture, and small businesses such as street vendors or bicycle taxis. Out of the most common livelihoods from literature, only aquaculture would be relevant to adopt in Icidua. In correspondence with the community leaders and the local government, it was decided to also include beekeeping, crab catching, livestock (goats and chicken), and agriculture in the community consultations and stakeholder meetings. Together with the community members and relevant stakeholders, a top three consisting of aquaculture, salt resistant agriculture, and chicken farming was determined as good potential as alternative to mangrove logging.

3) *Which policy alternative would be most beneficial to the Icidua community following a Social Cost-Benefit Analysis?*

Two policy plans were designed based on the previous research questions: 1) Business as Usual, and 2) Alternative Livelihood Development. The NPV of the BaU policy was about -1,000 MZN. The NPV related to ALD was approximately 8,500,000 MZN, both at a discount rate of 10%. A sensitivity analysis of the two policies showed that ALD would generate the most favourable BCR for all discount rates (5%, 10%, and 15%). Based on the SCBA, it was recommended to Van Oord to include the alternative livelihoods in the community engagement plan for their mangrove restoration project in Icidua.

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APPENDIX A - Informed Consent Form

Utrecht University

INFORMED CONSENT FORM for participation in:

Social Cost-Benefit Analysis for mangrove rehabilitation in Mozambique

To be completed by the participant:

I confirm that:

- I am satisfied with the received information about the research;
- I have been given opportunity to ask questions about the research and that any questions that have been risen have been answered satisfactorily;
- I had the opportunity to think carefully about participating in the study;
- I will give an honest answer to the questions asked.

I agree that:

- the data to be collected will be obtained and stored for scientific purposes;
- the collected, completely anonymous, research data can be shared and re-used by scientists to answer other research questions;
- video and/or audio recordings may also be used for scientific purposes.

I understand that:

- I have the right to withdraw my consent to use the data;
- I have the right to see the research report afterwards.

Name of participant: _____

Signature: _____ Date, place: ___ / ___ / ____, _____

To be completed by the investigator:

I declare that I have explained the above-mentioned participant what participation means and the reasons for data collection. I guarantee the privacy of the data.

Name: _____

Signature : _____ Date : _____ / _____ / _____ (dd/mm/yyyy)

APPENDIX B – Baseline Survey

A. Introduction

READ: Hello! My name is …….. and I conduct this survey for the INOM mangrove restoration program. INOM is the Mozambican Oceanographic Institute. INOM has partnerships with different organizations who partner in the mangrove restoration program to help mangroves return along the entire Mozambican coast.

This survey is conducted for a project with the goal to restore mangroves, reduce carbon emissions and to build climate resilience and create sustainable livelihoods. The outcome of this survey will help to design the project in Icidua. One of the INOM partners in this project is Van Oord, a Dutch family company with over 150 years of experience as an international maritime contractor. Because community engagement is very important for the restoration of mangroves, Van Oord set up this survey and the project will be conducted together with communities.

Your cooperation with this survey will help to develop the project based on community needs and interests.

This survey is completely anonymous. Please answer the questions based on what you *really* think or do. There is no right or wrong answer!

Are you ready to start? It will take approximately 15 minutes.
Thank you for your time and help!

	Question	Answers	Instructions
	Are you 15 years or older and do you agree to participate in this survey?	(a) Yes (b) No	Please tick one. If answer (b) 'No', thank the person and look for another person. Keep count of the amount of people who refuse to participate!

B. Demographic information

READ: "Let us start this survey with some general questions"

	Question	Answers	Instructions
1	Sex	☐ Female ☐ Male	Read the options and please tick one
2	Age	☐ 15-25 ☐ 26-35 ☐ 36-45 ☐ 46 and above	Pease tick one.
3	Name of neighbourhood		Please write the answer
4a	Occupation	☐ Student ☐ Employed (Public servant/Private or non-profit Sector Employee) ☐ Smallholder farmer ☐ Fisher ☐ Charcoal producer ☐ Wood seller ☐ Security Services (Police, Military) ☐ Employed for mangrove restoration, management, protection, or monitoring ☐ Unemployed ☐ Other, namely: _____	Multiple answers possible. Please tick one or more

4b	What is your average household income?	☐ Per day: _____ MZN ☐ Per week: _____MZN ☐ Per month: _____MZN ☐ Per year: _____MZN	
5	Educational Level (highest degree received)	☐ Technical/Vocational Training ☐ Secondary School ☐ Primary School ☐ None ☐ Other, namely: _____	Please tick one

C. Community awareness and support

6	What are the benefits of mangroves according to you?	☐ Increased amount of fish catches ☐ to reduce soil erosion ☐ wood resources ☐ other, namely: _____ _____ _____ ☐ no benefits	Multiple answers possible. Please tick one or more
7	Bringing back (restoring) the mangroves of Icidua is a good idea: And why?	☐ completely agree ☐ agree ☐ neutral ☐ disagree ☐ completely disagree Because: _____ _____ _____	Please tick one and write down their explanation
8	With the general status of mangroves in Icidua (size, health, and quality), I am ...	☐ satisfied ☐ no opinion ☐ unsatisfied	Please tick one
9	With the current amount of mangroves in Icidua, I am … And why?	☐ satisfied ☐ no opinion ☐ unsatisfied Because: _____ _____ _____	Please tick one and write down their explanation
10	Should mangroves be protected from cutting?	☐ Yes ☐ Maybe ☐ No	Please tick one
11	Do you experience damage from floods?	☐ Yes, a lot ☐ Yes, a bit ☐ No	Please tick one

12	Which type of damage from floods have you experienced?	☐ loss of human life ☐ loss of livestock ☐ damage to house property ☐ loss of house property ☐ damage to land property ☐ loss of land property ☐ damage to infrastructure ☐ damage to public areas ☐ other, namely: _____ ☐ no damage	Multiple answers possible. Please tick one or more
13	Do you experience damage from erosion?	☐ Yes, a lot ☐ Yes, a bit ☐ No	Please tick one
14	Which type of damage from erosion have you experienced?	☐ damage to house property ☐ loss of house property ☐ damage to land property ☐ loss of land property ☐ damage to infrastructure ☐ damage to public areas ☐ other, namely: _____ ☐ no damage	Multiple answers possible. Please tick one or more
15	Are you involved in a community mangrove restoration program? And why?	☐ yes, because: _____ _____ _____ ☐ no, because: _____ _____ _____	Please tick one and write down their explanation
16	Would you like to be involved in community mangrove restoration? And why?	☐ yes, because: _____ _____ _____ ☐ no, because: _____ _____ _____	Please tick one and write down their explanation
17	In which way would you like to be involved?	☐ restoration support (technical works) ☐ protection ☐ monitoring ☐ management ☐ maintenance ☐ other, namely: _____ _____ ☐ I do not wish to be involved	Multiple answers possible. Please tick one or more
18	Would you expect any type of compensation for taking part in	☐ No ☐ Yes, namely: _____	Please tick one. If (yes), write down their answer

	community mangrove restoration? If yes, what type of compensation?	_____ _____	
19	Are you involved in any other type of community program or council? If yes, what are you involved in?	☐ No ☐ Yes, namely: _____ _____ _____	Please tick one. If (yes), write down their answer

D. Livelihoods and energy

20	Do the mangroves contribute to the community livelihoods?	☐ Yes, entirely ☐ Yes, a big part ☐ Yes, a small part ☐ No	Please tick one.
21	The community uses the mangroves for the following:	☐ community employment for mangrove restoration, protection, management, and monitoring ☐ charcoal production ☐ firewood collection ☐ medicines ☐ housing material ☐ other construction material, namely: _____ ☐ beekeeping ☐ other, namely: _____ ☐ the community does not use the mangroves	Multiple answers possible. Please tick one or more.
22	Which of the mangrove uses is the most common?	☐ community employment for mangrove restoration, protection, management, and monitoring ☐ charcoal production ☐ firewood collection ☐ medicines ☐ housing material ☐ other construction material, namely: _____ ☐ beekeeping ☐ other, namely: _____ ☐ the community does not use the mangroves	Multiple answers possible. Please tick one or more.
23	Does the community of Icidua use the mangroves as a latrine?	☐ yes, many people ☐ yes, some people ☐ no	Please tick one.
24	Are there currently other livelihood	☐ fishing ☐ crab/shellfish/clam collection ☐ agriculture	Multiple answers possible. Please tick one or more.

	activities present that make the community less dependent on mangroves?	☐ aquaculture ☐ saltpans ☐ livestock ☐ other, namely: _____ ☐ no	In case of (no), skip to question 26.
25	Which of the following alternative livelihoods is the most common to make the community less dependent on mangroves?	☐ fishing ☐ crab/shellfish/clam collection ☐ agriculture ☐ aquaculture ☐ saltpans ☐ livestock ☐ other, namely: _____	Please tick one.
26	Are communities building houses inside mangrove areas?	☐ yes ☐ no Because: _____ _____ _____	Please tick one and write down their explanation
27	Have you heard about community funds through the increase of carbon storage from mangrove forest restoration?	☐ No ☐ Yes, but the community doesn't receive funds. ☐ Yes, and the community receives funds.	Please tick one.
28	Are there currently other energy sources or stoves that make you less dependent on wood from mangroves?	☐ sustainable charcoal ☐ solar energy ☐ sustainable cooking stoves ☐ bio ethanol ☐ biogas ☐ bio-digestive latrines ☐ other, namely: _____ ☐ no	Multiple answers possible. Please tick one or more.
29	Were there any matters not addressed in the survey that you would like to mention?	☐ no ☐ yes, namely: _____ _____ _____	Please tick one. If (yes), write down their answer
30	Do you want to be informed on or be engaged in the mangrove restoration project?	☐ no ☐ yes, my name is: _____ and my phone number is: _____ The name of my community representative focal point is: _____	Please tick one. If (yes), write down their contact details (name + telephone number+ community focal point)

E. Other

20	Were there any matters not addressed in the survey that you would like to mention?	(a) no (b) yes, namely:	Please tick one. If (b), write down their answer.
21	Do you want to be informed on or be engaged in the mangrove restoration project?	(a) no (b) yes, my name is _____ and my phone number is _____ Or my e-mail address is _____	Please tick one. If (b), write down their contact details (name + telephone number)

Thank you **-** Your input will be used to design the project in Icidua.

APPENDIX C – Students Instruction Baseline Survey

Instruction for students

1. Look for a respondent who is 15 years or older. If not sure about the age, please ask first: "Are you 15 years or older". If the respondent is 15 years or older, please continue as follows:
2. Say that you are from the university and ask if he or she is interested in answering some questions about mangroves for a mangrove restoration program.
3. If the respondent does not agree, keep track of the amount of people who don't wish to participate in the survey. Do this tracking on a separate piece of paper, as follows: 
4. If the respondent agrees, ask if he/she prefers to talk in Portuguese or Chuabo and then give the brief introduction about the survey and the mangrove restoration project as follows:

<u>READ</u>: Hello! My name is ……………………. and I conduct this survey for the INOM mangrove restoration program. INOM is the Oceanographic Institute of Mozambique, part of the Ministry of Sea, Inland Waters and Fisheries. INOM has partnerships with different organizations who partner in the mangrove restoration program to help mangroves return along the entire Mozambican coast.
This survey is conducted for a project with the goal to restore mangroves, reduce carbon emissions and to build climate resilience and create sustainable livelihoods. The outcome of this survey will help to design the project in Icidua. One of the INOM partners in this project is Van Oord, a Dutch family company with over 150 years of experience as an international maritime contractor. Because community engagement is very important for the restoration of mangroves, Van Oord set up this survey and the project will be conducted together with communities.
Your cooperation with this survey will help to develop the project based on community needs and interests.
This survey is <u>completely anonymous</u>. Please answer the questions based on what you *really* think or do. <u>There is no right or wrong answer!</u>
Are you ready to start? The survey will take approximately <u>15 minutes.</u>

5. Aim to include men and women in balance
6. Read the question and the answers to the survey respondent. Mark their answer as follows: 

   In case the respondents want to <u>change</u> their answer, do the following: 

Instruction of the Eduardo Mondlane University students who were to conduct the baseline survey amongst the community of Icidua.

APPENDIX D – Livelihood Posters

Pesca (caranguejo)

Van Oord
Marine ingenuity

Gado

Van Oord
Marine ingenuity

Apicultura

Van Oord
Marine ingenuity

Agricultura

Van Oord
Marine ingenuity

Culturas resistentes a salinidade: Cenoras, batatas, repolho e beterraba

Aquicultura

Van Oord
Marine ingenuity



APPENDIX E – Community Consultations

Questions for discussion table Community Awareness & Support

1. What are the cultural values and perceptions of the local community in Icidua?
2. What are the main challenges for inhabitants of Icidua?
3. Who are the key stakeholders to involve in the mangrove restoration project, including religious leaders if any, stakeholders from surrounding areas? If yes which areas?
4. Are there according to the communities and other relevant stakeholders any risks and opportunities we should consider for a mangrove project in Icidua?
5. Are there any land conflicts between the communities, and could we potentially cause land conflicts?
6. How is land tenure arranged in Icidua?
7. Are there any social-cultural heritage locations in the area, or ritual sites that should be considered? If yes, where?

Mangrove protection & restoration, management & monitoring

8. What kind of help does the community want with mangrove restoration?
9. In which way could the communities participate in mangrove restoration and protection? (e.g., which solutions and strategies would work in the communities and what would be preferred?)
10. Are there entities that have permits to cut mangroves? If yes, which entities?
11. Which existing community programmes for mangrove restoration and other community programmes are there? And what are the activities of these community programmes? What are the success factors or challenges of these community programmes?
12. Are the community associations that conduct mangrove restoration programmes legal entities?
13. What is the size of the mangrove area which has already been restored by the community through a nursery programme?
14. In which way could the communities participate in mangrove maintenance and monitoring? (e.g., which solutions and strategies would work in the communities and what would be preferred?) (Could mangrove management be a livelihood for some community members?)
15. Are trainings for mangrove restoration techniques, mangrove management and monitoring needed? If yes, define which ones.

Education and awareness

16. What level of community commitment and support can we expect, and what is needed to obtain their support?
17. What is the urgency for communities to restore mangroves?
18. What are according to the community the benefits of mangrove restoration?
19. What are the preferred community channels and methods (e.g., which schools/community/youth places, educational curricula, what kind of communication materials e.g., flyers/radio/via community leaders, which languages?)?
20. Does the community think that the mangroves should be protected from cutting?

Closing questions:

21. Were there any matters not addressed that you would like to mention?
22. Do you want to be informed on or be engaged in the mangrove restoration project? If yes, please highlight your name with a marker on the participant list before you leave home.

Questions for discussion table Livelihoods and Energy

1. What are the different types of mangrove related livelihoods in Icidua?
2. Which non-mangrove related livelihoods exist in Icidua? (e.g., land and sea/river related livelihoods) and what are the most common livelihoods?
3. Do communities use the mangroves as latrine? And why? What would be a solution to this issue?

Alternative livelihoods

4. To which extent do the mangroves contribute to the community livelihoods?
5. Which livelihoods do the mangroves provide to the community? (Charcoal, firewood, construction materials, medicines, community mangrove management, other?)
6. How much income can be generated from these practices? (How much does it cost to produce and for how much is mangrove wood being sold?)
7. What is the most common livelihood from mangroves?
8. Are there significant differences within the community on mangrove dependence?
9. Which other livelihoods are there that make the community less dependent on mangroves? And which of these is the most common?
10. What is needed according to the communities to stop the cutting of mangroves and what is needed in return for their support? (Is that e.g., support in building alternative livelihoods? Salary for mangrove management?)
11. Which alternative livelihoods would be favourable for the local community, according to themselves, but also according to us and Local authorities (e.g., Municipality)? --> show the posters with visualisations
12. Are there livelihoods other than the ones on the posters which could be valuable for Icidua?
13. Would community members be open to receive trainings for mangrove alternative livelihoods, e.g., as the Coastal Field Schools as in Indonesia?
14. Fish catches: What type of fish species do they catch? And by whom are fish catches conducted? What type of fish species do they eat? Do they also eat crabs and shrimps? Would they like to eat Tilapia?
15. Aquaculture: would mangrove-based aquaculture be sustainable and profitable? Are small holder farmers interested in improving/performing aquaculture? Is there a market nearby where the fish can be sold?
16. What are the opportunities for alternative energy sources?
17. Are the local communities willing to adopt alternative energy sources/sustainable cooking methods? E.g., solar energy, sustainable stoves, bioethanol, bio-digestive latrines, etc.

Closing questions:

18. Were there any matters not addressed that you would like to mention?
19. Do you want to be informed on or be engaged in the mangrove restoration project? If yes, please highlight your name with a marker on the participant list before you leave home.

Questions for discussion table Environmental

Prior to asking the questions try to identify where the community member lives or where he/she owns land property. Realise that the community member may not be able to read a map. Points of orientation could be:

- The venue of the community consultation: Venue Casa do Bairro
- North Icidua- Sangariveira Market
- West Icidua- Thorrone Market
- Hospital of Icidua
- Police station of Icidua

Water Infrastructure:

8. Where do you get your drinking water from?
9. Where do you get your shower/bathing water from?
10. Where did your (grand) parents get their water from?
11. Which are the fresh water sources?
12. Are there any rivers that go through the city?
13. Are the rivers man made or natural?
14. Up to which part of the river have you observed daily changes in water level (from the tide)? How far inland does the river come during high tide?
15. Are the rivers man made or natural?
16. Does the river in the city ever run dry? If yes, how often?
17. Did it run dry in 10 years ago? Did it run dry with your (grand)parents?
18. Do you know why the river dries up?
19. Did you notice any changes in the river south of the Sangariveira Market? If yes: what do you think has changed?
20. Have you seen erosion of the riverbanks? If yes, where have you seen this?
21. Have you experienced damage to your property from erosion or do you know people who have?

House construction

22. Do you build houses in wet/muddy areas?
23. Did the community build houses in wet areas 10 years ago?
24. Have your (grand) parents build houses in wet/muddy areas?
25. When did the community start building houses in wet areas? And why?
26. Do you expect more people building houses and settling in what is currently mangrove area?
27. Does your house ever get wet? If so, does it get wet all year? Does it get wet in the rainy season? Does it get wet in the dry season?

Rainfall

28. When is the rainy season?
29. When is the dry season?

Cyclones

30. Are there ever any big storms (cyclones) in this area?
31. How often does that happen per year?
32. During a big storm, do you know if there are specific areas in the city where there is a lot of water?
33. Does water from the street enter your house during a big storm?
34. Do you know people, friends/family, where water enters their house during a big storm?

35. When there is a big storm, does your house or your property get damaged? Do you have to buy new things? Do you have to repair things in your house? Do you have to throw away things?

Floods

36. In which neighbourhoods/location did people experience damage from floods?
37. How high does the water get? To your ankles? To your hips? To your shoulders?
38. Which areas have the highest water?
39. Do you or others in the community experience damage to your house or land caused by floods? If yes, can you explain what type of damage is encountered? Do you have to buy new things? Do you have to repair things in your house? Do you have to throw away things?
40. Have you or other community members been forced to move houses or leave land/property due to damage caused by floods?

Mangrove species

41. How do you call these plants? (Show pictures of the different species of the mangroves)
42. Which of these plants are present near the sea and river?
43. Have these plants always been here? Could you show on the map where they are? What do you use these plants for?
44. Would you build houses near these plants?
45. Do these plants have any special value to you or your culture?
46. Do you use these plants for anything?
47. Are the areas with the mangroves part of your lives? Do you value them positive or negative?

Closing questions:

Were there any matters not addressed that you would like to mention?

Do you want to be informed on or be engaged in the mangrove restoration project? If yes, please highlight your name with a marker on the participant list before you leave home.

APPENDIX F – Livelihood Questionnaire Local Community

A1	**General information**				
A1.1	Number:		**A1.6**	Major occupation:	
A1.2	Date [dd/mm/yyyy]:	/ /	**A1.7**	Age:	
A1.3	Village/community:		**A1.8**	Gender:	☐ Female ☐ Male
A1.4	Location:		**A1.9**	Name of interviewer:	
A1.5	Name interviewee/title: (optional)		**A1.10**	Name of note taker: (optional)	

A2	**Livelihood**	**Potential**		**Comment**
A2.1	Fishing (including shellfish)	□Yes	□No	
A2.2	Aquaculture	□Yes	□No	
A2.3	Agriculture	□Yes	□No	
A2.4	Food production (fruits, herbs, sugar, or honey)	□Yes	□No	
A2.5	Income from carbon credits	□Yes	□No	
A2.6	Other ideas?			

APPENDIX G – Livelihood Questionnaire Stakeholders

B1	**General information**				
B1.1	Number:		**B1.6**	Organization:	
B1.2	Date [dd/mm/yyyy]:	/ /	**B1.7**	Gender:	☐ Female ☐ Male
B1.3	Stakeholder type*:		**B1.8**	Name of interviewer:	
B1.4	Location:		**B1.9**	Start time:	
B1.5	Name interviewee/title: (optional)		**B1.10**	Name of note taker: (optional)	

***e.g., local, or regional government, religious authorities, local councils*

B2	**Livelihood**	**Potential**		**Comment**
B2.1	Fishing (including shellfish)	□Yes	□No	
B2.2	Aquaculture	□Yes	□No	
B2.3	Agriculture	□Yes	□No	
B2.4	Food production (fruits, herbs, sugar, or honey)	□Yes	□No	
B2.5	Income from carbon credits	□Yes	□No	
B2.6	Other ideas?			

APPENDIX H – Sources Included in the Systematic Literature Review

	Author	Publication	Title	Country
1	Christian et al.	2021	Supporting community-based mangrove forest management as Essential Ecosystem Area in Sungai Pakning, Riau	Indonesia
2	Massiseng et al.	2020	A dynamic simulation of mangrove ecotourism management at the Lantebung of Makassar City	Indonesia
3	Teka et al.	2019	Mangroves in Benin, West Africa: threats, uses and conservation opportunities	Benin (3 locations)
4	Sánchez et al.	2018	Mangrove restoration an economical alternative for generating incomes	Mexico
5	Wilms et al.	2017	Building with nature-an integrated approach for coastal zone solutions using natural, socio economic and institutional processes	Indonesia
6	Iftekhar & Islam	2004	Managing mangroves in Bangladesh: A strategy analysis	Bangladesh
7	Rennaud et al.	2012	Challenges of Community-Forestry Based Carbon Projects: Process, Participation, Performance	India
8	Barua et al.	2019	Sustainable Livelihood of Vulnerable Communities in Southern Coast of Bangladesh through the Utilization of Mangroves	Bangladesh
9	Damastuti & de Groot	2017	Effectiveness of community-based mangrove management for sustainable resource use and livelihood support: A case study of four villages in Central Java, Indonesia	Indonesia
10	Malik et al.	2017	Mangrove forest decline: consequences for livelihoods and environment in South Sulawesi	Indonesia
11	Debrot et al.	2022	Early increases in artisanal shore-based fisheries in a nature-based solutions mangrove rehabilitation project on the north coast of Java	Indonesia
12	Tri et al.	1998	Natural resource management in mitigating climate impacts: the example of mangrove restoration in Vietnam	Vietnam
13	Lestari & Noor'an	2019	Population Density and Habitat Characteristics of Nipa Fruticans in Degraded Mangrove Ecosystem (Case Study in Mahakam Delta, East Kalimantan)	Kalimantan
14	Schmitt et al.	2013	Site-specific and integrated adaptation to climate change in the coastal mangrove zone of Soc Trang Province, Viet Nam	Vietnam
15	Yamindago	2014	Restoring coastal ecosystems - a case study Malang and Gresik regency, Indonesia	Indonesia
16	Das	2017	Ecological Restoration and Livelihood: Contribution of Planted Mangroves as Nursery and Habitat for Artisanal and Commercial Fishery	India
17	Islam et al.	2018	Sundarbans mangrove forest of Bangladesh: causes of degradation and sustainable management options	Bangladesh
18	Biswas et al.	2009	A unified framework for the restoration of Southeast Asian mangroves—bridging ecology, society, and economics	Bangladesh
19	Thompson & Friess	2019	Stakeholder preferences for payments for ecosystem services (PES) versus other environmental management approaches for mangrove forests.	Thailand (2 locations)
20	Darkwa & Smardon	2010	Ecosystem Restoration: Evaluating Local Knowledge and Management Systems of Fishermen in Fosu Lagoon, Ghana	Ghana
21	Dey & Kar	2013	Scaling of mangrove afforestation with carbon finance to create significant impact on the biodiversity - a new paradigm in biodiversity conservation models	Bangladesh
22	Rakotomahazo et al.	2019	Participatory planning of a community-based payments for ecosystem services initiative in Madagascar's mangroves	Madagascar
23	Wickramasinghe	2017	Chapter 10 Regreening the Coast: Community-Based Mangrove Conservation and Restoration in Sri Lanka (in book: Participatory mangrove management in a changing climate: perspectives from the Asia-Pacific)	Sri Lanka
24	Walton et al.	2006	Are mangroves worth replanting? The direct economic benefits of a community-based reforestation project	Philippines

25	Kamali et al.	2010	Mangrove restoration without planting	Malaysia
26	Rodríguez	2018	Mangrove Concessions: An Innovative Strategy for Community Mangrove Conservation in Ecuador	Ecuador
27	Haroun et al.	2018	Mangrove Habitats in São Tomé and Príncipe (Gulf of Guinea, Africa): Conservation and Management Status	São Tomé
28	Fernandes et al.	2018	Mangroves on the Brazilian Amazon Coast: Uses and Rehabilitation	Brazil
29	Garcia et al.	2019	Sustainable Mangrove Rehabilitation for Global and Local Benefits	Philippines & Myanmar

APPENDIX I – Cost and Benefit Estimations

Policy 1: Business as Usual

From the community consultations, it was learned that about 350 MZN can be earned with one bag of charcoal or a single adult mangrove worth of fuelwood or construction material. Community members stated that one adult mangrove with a circumference of 5 m is sufficient to produce two bags of charcoal. However, trees of such a size hardly exist in Icidua. Therefore, it was estimated that the average mangrove tree in Icidua is sufficient to produce only one bag of charcoal.

The field measurements showed that one hectare in Icidua contains on average 371 adult mangroves with an average height of 2.26 m. With 90 people cutting 5 adult mangroves per month, 5400 mangroves are cut per year. With a total of 57505 mangroves in the area, all the mangroves will disappear within about 10.6 years. Each bag of charcoal produced from one mangrove is worth 350 MZN, so 1,890,000 MZN can be earned per year by these 90 people for 11 years. Input variables to produce charcoal are matches, a metal drum, shovel, bags, saw, and a rope; costs of these were obtained from market prices in Quelimane.

River erosion at the main river is 6.5 m per year. The bridge east of Icidua has already collapsed and based on input from Amrit Cado van der Lelij (consultant nature-based solutions for marine environments at Deltares), it was assumed that the bridge west of Icidua will also collapse within the coming years with the current rates of erosion. A one-way trip to cross the river by boat costs 10 MZN, which is accounted for in the SCBA. According to the baseline survey, 50% (N=143) of the households have experienced damage from floods to their house property. In the SCBA it was therefore assumed that 45 out of 90 people experience damage from floods. Furthermore, it was assumed that the costs of replacing the wooden structure of the house due to floods lies at about 3000 MZN per year (i.e., the cost of one canoe full of mangrove wood).

Policy 2: Alternative Livelihood Development

The average price of 1 cabbage is 30 MZN in Quelimane. The optimum to plant cabbage is at 30,000 plants per ha (Ayres, 2019). The average price of 1kg of maize is 350 MZN. The average maize yield in Zambezia from 2002 to 2015 was 1001.25 kg per ha per year (Amaral et al., 2020). The average price of 1 kg of potato is 60 MZN. In Mozambique, potatoes are grown with average yields of about 16,000 kg per ha per year (FAOSTAT, 2022). To calculate the SCBA, Cabbage, maize and potato were calculated for areas of 0.5 ha, 0.25 ha and 0.25 ha, respectively. This ratio was chosen considering cabbage is currently not produced in Icidua or Quelimane, but it is imported from surrounding areas. Maize and potato are currently being cultivated in Quelimane. During the field trip it became clear that the mangroves are often used as latrines. Human faeces could also be used as fertilizer to the agricultural lands.

Input data for aquaculture development was derived from the community aquaculture association AJCD. At the time of the field visit, AJCD was constructing 8 aquaculture ponds: 6 ponds of 400 m^2 and 2 ponds of 660 m^2. According to AJCD, constructing the ponds costs 8,000 MZN and 12,000 MZN, respectively. AJCD makes use of maize flour as fish feed. During our field visit the ponds were not productive yet, so no information could be derived on revenues. Data gaps were filled with information provided by the International Fund for Agricultural Development (IFAD), and their detailed project design report on a Small-scale Aquaculture Promotion Project in Mozambique (IFAD, 2019). The report was written for a 500 m^2 aquaculture pond. Input variables derived from the report were converted to ratio of the 400 m^2 and 660 m^2 ponds. The aquaculture design report was written in 2019, so the input values were compensated for an inflation rate of 5.68% from 2019 to 2022

(Statista, 2022). In addition to maize flour, chicken by-products were also used as fish feed. Revenue from chicken sales was derived from market prices in Quelimane. A chicken (frango) can be sold for 350 MZN. Chicken can be farmed at 4 birds per square meter (FAO, 2004), and on average, chicken can be harvested 3 times per year (Harun & Massango, 2001). No data was available on prices to construct a chicken farm in Icidua; costs were estimated to lie at 100,000 MZN.