SCBA Framework for Boskalis Blue Carbon and Building with Nature projects.

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1 Abstract

Blue Carbon is part of Boskalis strategy to become net zero in 2050. It offsets their remaining carbon emissions that cannot be reduced in other ways. When implementing such a project, a social cost benefits analysis can be a tool to quantify the benefits that a local community of an appointed area could receive. Currently, there is no specific framework present at Boskalis, on how to perform a social cost benefits analysis. Therefore, this study aims to develop a social cost benefits analysis framework for Blue Carbon projects for Boskalis based on a literature study and find out if it is possible to execute that framework as a desktop study. In this social cost benefits analysis, the environmental and social aspects are quantified to give a more real value of the costs and benefits. The natural or total ecosystem value is measured by the ecosystem services that are provided. The ecosystem service use is converted through a specific valuation method. The methods to quantify the ecosystem services depend on the amount of data that is available. If a desk study is performed, it is more likely that benefit transfer method is needed to value the ecosystem. However, when it is close to the implementation phase, more data can be collected so the outcomes can be made more precise. Other benefits can be measured by looking at their local welfare. The welfare of the population can be determined by various techniques, the most commonly used in carbon projects is the 'attacking poverty framework'. The costs that local communities suffer are defined as negative impacts (or negative benefits). The socioeconomic impact that is caused by the project is also dependent on agreements between the contractor and local communities (i.e., job opportunities that are created for locals). Concluding, if the social cost benefits analysis is done on in the site selection phase, desktop implementation can be sufficient to approximate social and environmental effects on the local communities.

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3 Management summary

Building with Nature is a design strategy from Ecoshape, a consortium that Boskalis is part of. The design strategy entails that nature is included in the project design. Next to Building with Nature projects, Boskalis also want to be active in Blue Carbon. Blue Carbon stands for the carbon or CO_2 that is sequestered by marine ecosystems, such as mangroves. This carbon is stored by the plants in biomass, and therefore can be estimated. The carbon that is sequestered by the ecosystem can be converted to carbon credits and sold on the voluntary carbon market. These credits can also be used to offset company emissions, making it possible for the company to become net zero.

When implementing a Building with Nature or Blue Carbon project, a social cost benefits analysis can be a tool to understand if the local community in a potential area will benefit when hosting such a project. Both projects have in common that nature is enhanced is the project area. However, local community often underestimate the value that ecosystems offer them, and instead want to use the area for other purposes. Yet, the cooperation of the local community is a vital aspect in the successfulness of a Blue Carbon or Building with Nature project. For that reason, the local community needs to be educated about the benefits such project would offer them. Hence, I researched if a social cost benefits analysis framework for Building with Nature and Blue Carbon projects can be made for Boskalis based on a literature study, if it can be executed from behind the desktop.

There are already various social cost benefits analysis frameworks already in existence, for example from the CPB and PBL, but they are commonly used for checking government policies. Therefore, I combined the relevant components with new elements to develop a new social cost benefits analysis framework, which fits Boskalis Blue Carbon and Building with Nature strategy (Figure 1).

In this social cost benefits analysis, the environmental and social aspects are quantified to give a truer value of the costs and benefits received. The environment or ecosystem value is measured by the ecosystem services that are provided. The use of the specific ecosystem service determines which valuation method gives the most genuine value. The different valuation methods that can be used to monetize the ecosystem services are market pricing & production approach, contingent valuation method, travel costing, replacement costing, avoided costing and hedonic pricing.

Other benefits can be measured by looking at the welfare of local communities. The welfare of the local population can be measured via different techniques. The most commonly used in carbon projects is the ‘attacking poverty framework’. Other frameworks that are used are ‘The sustainable livelihood framework’ and ‘the nested speres of poverty framework’. The costs are defined as negative socio-economic and environmental impacts for the community. For example, if the ecosystem decreases, the service it provides is less effective and accordingly provides less benefits.

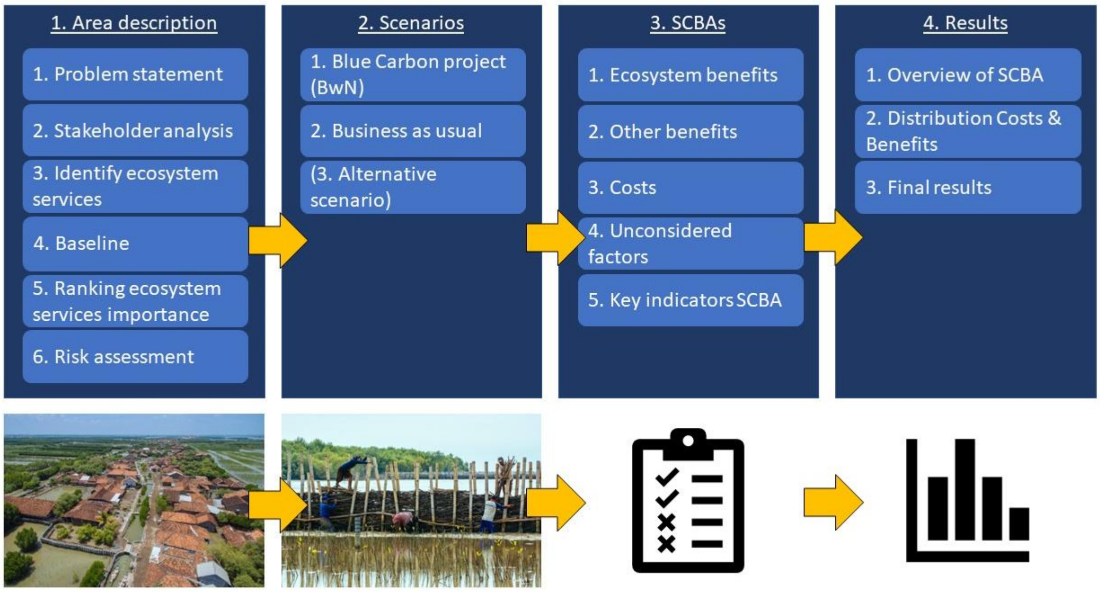


Figure 1. The proposed social cost benefits framework.

The framework I propose consist of four major categories, which are divided further (Figure 1). The first category is the area description. There, the first step is to discuss the reason a project should happen there in the problem statement. The second step is to identify all relevant stakeholders and their needs during the stakeholder analysis. In the third step, the ecosystem and its services are identified as well. This information is used in the fourth step, where a baseline for the area is formed, so the effects of the different scenarios can be compared later on. In the fifth step, the ecosystem services are ranked on their relevance for the area. Last, a risk assessment is done to understand the potential risk of having a project in that area.

Then, the second category arises, where the different scenarios are worked out. These include the Building with Nature or Blue Carbon scenario, the business-as-usual scenario and possibly also other alternative scenarios that were planned to be implemented in the project area.

Next the costs and benefits are calculated for the different scenarios, these include the ecosystem benefits, other benefits, and costs. When these are all calculated, they must be used to calculate the key indicators for the social cost benefits analysis, such as the benefit costs ratio (BCR), net present value (NPV) and internal rate of return (IRR). These parameters can be used to compare the different scenarios, and discern which scenario is most beneficial for the area. Other factors that play a significant role in the scenario, but cannot be quantified, should still be noted. So, these factors must be written in the unconsidered factors section of the social cost benefits analysis. They are still relevant to consider when discussing the scenarios.

If all the costs and benefits are identified, the last category will focus on the results. First, an overview of the social cost benefits analysis scenarios should be made to be able to better compare the scenarios. Then, the benefits should be used to compensate local stakeholders that are expected to only have negative effects. This way, the project would not harm these stakeholders' welfare. Afterwards, the final results and conclusions of the SCBA should be stated.

To validate the effectiveness of the SCBA framework, it is evaluated by performing a case study of a building with nature project in Demak. From the case study it could be concluded that the framework works. However, the ability to quantify the ecosystem services with these methods depend on the amount of data that is available. If a desk study is performed, it is more likely that benefit transfer method is needed to value the ecosystem. When the project is in the implementation phase, being on location will enable opportunities to collect data, so a more realistic image can be made. The social impact that is caused by the project is also very dependent on agreements between the contractor and local communities (i.e., job opportunities that are created for locals). Therefore, they can also be more accurate when the local communities engage in the design plan. Concludingly, if the social cost benefits analysis is done on in the site selection phase, desktop implementation can be sufficient to approximate social and environmental effects on the local communities. To obtain the most precise values, field studies must be performed.

4 Introduction

Building with Nature (BwN) is a design philosophy that helps decision makers understand how they can improve their water-related infrastructure designs with natural solutions, so it will benefit the environment, economy, and society. The concept is developed by Ecoshape, a consortium between multiple Dutch companies and knowledge institutes (Ecoshape. 2021a). Other such nature inclusive design frameworks exist, for instance also the World Bank and IUCN have a framework that aims to include more nature in infrastructure projects.

Boskalis, an international maritime contracting company and member of the Ecoshape consortium, aims to expand nature inclusive design through promoting the BwN framework. Besides this, Boskalis is evaluating 'Blue Carbon' as a potential financing source for BwN projects. Blue Carbon stands for all carbon that is captured and stored by marine and coastal ecosystems. The sequestered and stored carbon is translated to carbon credits (CC), which can be sold on the voluntary carbon market (VCM), that so companies and individuals can use the credits to voluntarily offset their emissions.

Boskalis also wants to explore to what extent a Blue Carbon scope could be integrated in a credible way in their mitigation strategy to become carbon neutral in 2050. As part of their decarbonization efforts, companies are increasingly compensating their residual emissions with carbon credits, originating from example from 'Nature Based Solutions' (NBS): actions that aim at addressing significant societal challenges by sustainably managing, restoring, or protecting nature, while benefiting both human wellbeing and biodiversity. The estimated mitigation potential of land based NBS, by avoiding and reducing CO_2 emissions and enhancing carbon sinks, amounts to around 10 Gt CO_2e per year, or 27% of global annual CO_2 emissions.

To master the process of Blue Carbon project implementation and execution, Boskalis is working together in a consortium with Wetlands International and Permian Global. Wetlands International is an NGO that aims to restore and conserve wetlands globally (Wetlands International, 2023). Permian Global is a project developer that is working in different carbon projects and mostly focuses on tropical forest restoration and conservation (Permian Global, 2023). More information about Boskalis is stated in textbox 1. Together, the consortium wants to initiate a Blue Carbon project pilot as learning exercise and guideline for future, large scale, Blue Carbon projects. In these Blue Carbon projects, Boskalis wants to build upon its BwN capabilities. One key aspect that determines the success of BwN projects is engagement of local communities (Ecoshape, 2021c).

Textbox 1. Royal Boskalis NV company profile

Boskalis was founded in 1910 in Sliedrecht as dredging company (Royal Boskalis N.V., n.d.-a). They expanded fast and were famous due to its efforts in for example the delta works. Nowadays, with a fleet of 600 vessels and floating equipment they operate worldwide (over 90 countries) and on many different types of projects, such as salvage, land reclamation, the construction of offshore windfarms and all other water related infrastructure projects (Royal Boskalis N.V., n.d.-b). Together, all these projects generate a revenue of 2,957 million euros, a net profit of 151 million euros and a CO_2 emission scope of over 1 million tons (Figure 1; Royal Boskalis N.V., 2021-a*). Boskalis is recently acquired by HAL for €33.- per share, who now own 98.9% of the shares. HAL is also major shareholder in for example FD mediagroep and Van Wijnen but has also shares in Coolblue and others (HAL Investments, n.d.). Boskalis is divided in multiple divisions, which are further divided in subdivisions (*Figure 2*; Royal Boskalis N.V., n.d.-c).*

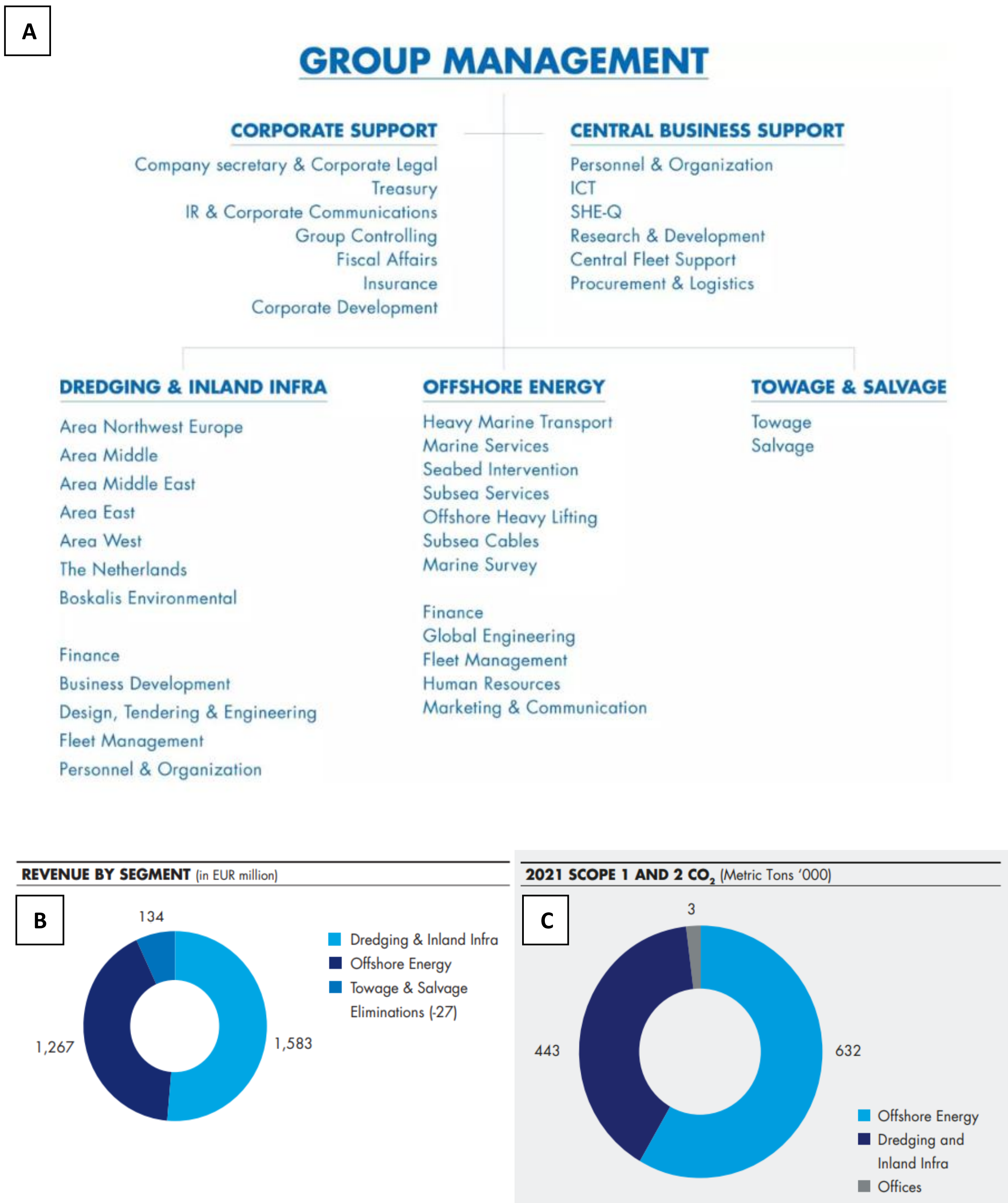


Figure 2. Boskalis corporate structure (a), Revenue (b) and CO2 emission scope (b) by segment for 2021. Adapted from Royal Boskalis NV. (n.d.-c) and Royal Boskalis N.V. (2021-a)

There are several types of projects that Boskalis works on, projects they won by tendering and projects they developed themselves. A client, for example by a regional government / harbor, will examine the tenders offered by different contractors and picks the one that fits their needs best. In the tendering phase, Boskalis often must compete with other major dredging companies such as Van Oord, Deme, and Jan De Nul Group, and for smaller projects also with smaller (local) dredging firms. One criterion that becomes increasingly important, is the social and environmental impact that a project will have on the local community and environment. Especially since the EU and the Dutch government are proposing new laws to make companies more liable for their social and environmental impacts

(European Parliament, 2022; Ministerie van Algemene Zaken, 2022). Although Boskalis criticized the Dutch government on their proposed law, and even threatened to relocate their headquarters to another country, they want to adhere to OESO standards and proclaim the need for corporate social and environmental responsibility.

Boskalis business mission is as follows:" We strive to be the leading dredging and marine contracting experts, creating new horizons for all our stakeholders. "(Royal Boskalis N.V., 2021-a). The sustainability mission is to be net zero in 2050. Boskalis developed a strategy on sustainability, explaining how they aim to reach that goal. Next to identifying all carbon emissions and reducing as many as possible by switching to more sustainable work methods and hardware, there might still be some emissions left for which they need to compensate. Boskalis aims to offset their residual emissions by establishing Blue Carbon projects. In these projects, an insured amount of carbon is stored by a marine ecosystem and can be used to subtract from the residual emissions to become net zero (Royal Boskalis N.V., 2021-b). Unfortunately, there are still many things unknown for developing a Blue Carbon project. Therefore, Boskalis aims to learn how it can reduce their negative impact and increase the benefits they provide for the local community. A tool that can be used to understand such project impacts is a Social Cost Benefit Analysis.

Since local communities are vital stakeholders for the success of BwN projects, they need to take part in the project. A way to convince the local community of the importance of such a project is via a social cost benefit analysis (SCBA). The tool can be used during the site selection phase, to roughly estimate if a local community would potentially be interested in a BwN project, compared to other potential locations. In that situation, less extensive research needs to be done. The SCBA tool can also be used to help include the local stakeholders needs into the design when the project is already near implementation phase. In that case, the SCBA should be continuously updated when newer information is available. This way, the SCBA can be more accurate when going more in depth in a project. A Social Cost Benefit Analysis is a tool that offers a broad impact analysis of a project on a local community. It aids decision making by monetizing all relevant benefits and costs that a local community will experience during and after a project (Eijgenraam et al., 2000). This includes costs and benefits that do not have a clear market price, such as ecosystem services (Romijn & Renes, 2013). Ecosystem services are products, regulated processes and cultural services (and ecosystem supporting services) provided by an ecosystem. Ecosystem Services can for example be fruit production, carbon sequestration or flood protection. An increase or decrease of these services can be translated into costs and benefits for a SCBA. When the ecosystem enhances the local economy or welfare, it is beneficial to the local community and should be improved. A decreasing ecosystem, and thus the decline of the valuable ecosystem services, might be interpreted as a loss to the local welfare and hence should be labeled as cost in a SCBA. Depending on the value added by that ecosystem service compared to the alternative use and value of that area.

The question rises what the important steps in a BwN SCBA are. In addition, can they be fit in a framework that can be used by Boskalis as desk study to understand if a BwN project would be appealing to local communities in specified locations. The benefits of a BwN project are the ecosystem services that the project provides, plus other extra socio-economic activities that occur due to the BwN project. The costs of a BwN project would be the loss of certain socio-economic activity compared to the baseline.

The problem definition

When Boskalis wants to implement a Blue Carbon project, that fits in their BwN philosophy, they must convince the local communities about the importance of such projects to make the project successful.

A tool that is often used to help the local communities see the added value of such a project, is a SCBA. However, such a SCBA framework for BwN projects, which includes Blue Carbon, does not yet exist at Boskalis.

4.1 The research questions.

1. Can we create a BwN SCBA framework based on a literature study?
2. Can we apply the BwN SCBA framework to a Blue Carbon Project?
3. Can we perform a BwN SCBA based on desktop study?

4.2 List of definitions

4.2.1 Blue Carbon

When CO_2 is taken up out of the air by an ecosystem during photosynthesis, and fixed into structural component of the organisms, such as wood and leaves in plants and the soil below, it is called carbon sequestration. The amount of carbon that ecosystems sequester can be translated into carbon credits. These credits can be sold on the carbon market. Companies that emit GHG can offset their CO_2 emissions by buying these carbon credits, and in this way become net-zero emitting companies. Blue Carbon is carbon sequestration by marine and coastal ecosystems. Mangrove forests are among the most efficient marine ecosystems when it comes to carbon sequestration (Duarte & Cebrián, 1996). Consequently, mangrove forest restoration and conservation might be a promising opportunity for Blue Carbon projects.

The amount of carbon that is taken up by the ecosystem can be translated to carbon credits. The amount of credits that can be claimed depend on the type of credit that is issued. For example, depending on if the mangrove area is restored or in conservation, different credit types apply. Moreover, how the carbon storage is distributed by the plant (i.e., in the soil or in above ground biomass) is also a relevant attribute to consider when calculating the amount of carbon credits that can be claimed. All relevant criteria are set by VERRA, the institution that sanctions the carbon credits. The claimed amount of carbon credits must also be audited for these specific criteria by an auditing firm.

To be able to yield the maximum number of credits possible in a Blue Carbon project, it is important for companies to preserve the specified ecosystem area. The best way to protect these ecosystems is via active and dynamic management (Ecoshape, 2021d). This type of management requires local hands on the ground. Therefore, the role of local communities is important as they can offer local labor in the form of rangers, firefighters and more.

4.2.2 Building with Nature (BwN)

Building with nature (BwN) is a design approach that aims to use nature in their design solution. This approach is especially applied for water related infrastructure. A BwN project must go through two phases, the design phase, and the implementation phase. The design phase of BwN projects consists of a five steps approach (Figure 3; Ecoshape, 2020). The first step is to understand the system, so all the distinct aspects of the system, in which the project is going to take place, are studied. This includes an analysis of the physical, socio-economic, and governmental components of the system. The second step focusses on identifying realistic nature inclusive design solutions. In the third step, these different solutions (also conventional solutions) are evaluated, and one solution is selected. This solution is refined in step 4 and prepared for implementation in step 5.

BwN is often overlooked as a design strategy, as it can be difficult to quantify the natural parameters to make a nature inclusive design (Ecoshape. 2021a). Therefore, natural processes, also known as ecosystem services, are often ignored, and disregarded instead of adopted. Ecosystem services are the processes in an ecosystem that contribute to needs and welfare of people (Fisher et al., 2009), see paragraph X (include reference). BwN helps to understand on how different ecosystem services can be used beneficially, so nature is included in the solution. BwN pilot projects are done to decrease this knowledge gap, so BwN alternatives can be a realistic competitor for current “grey” infrastructure designs.

One of the current gaps in knowledge is how ecosystem services can be quantified realistically to give a clear indication of its value for stakeholders involved in the project. Ecosystem service valuation could help engage stakeholders to participate and apply more BwN solutions. Local communities play a crucial role in implementing and regulating a BwN area (Ecoshape, 2021b).

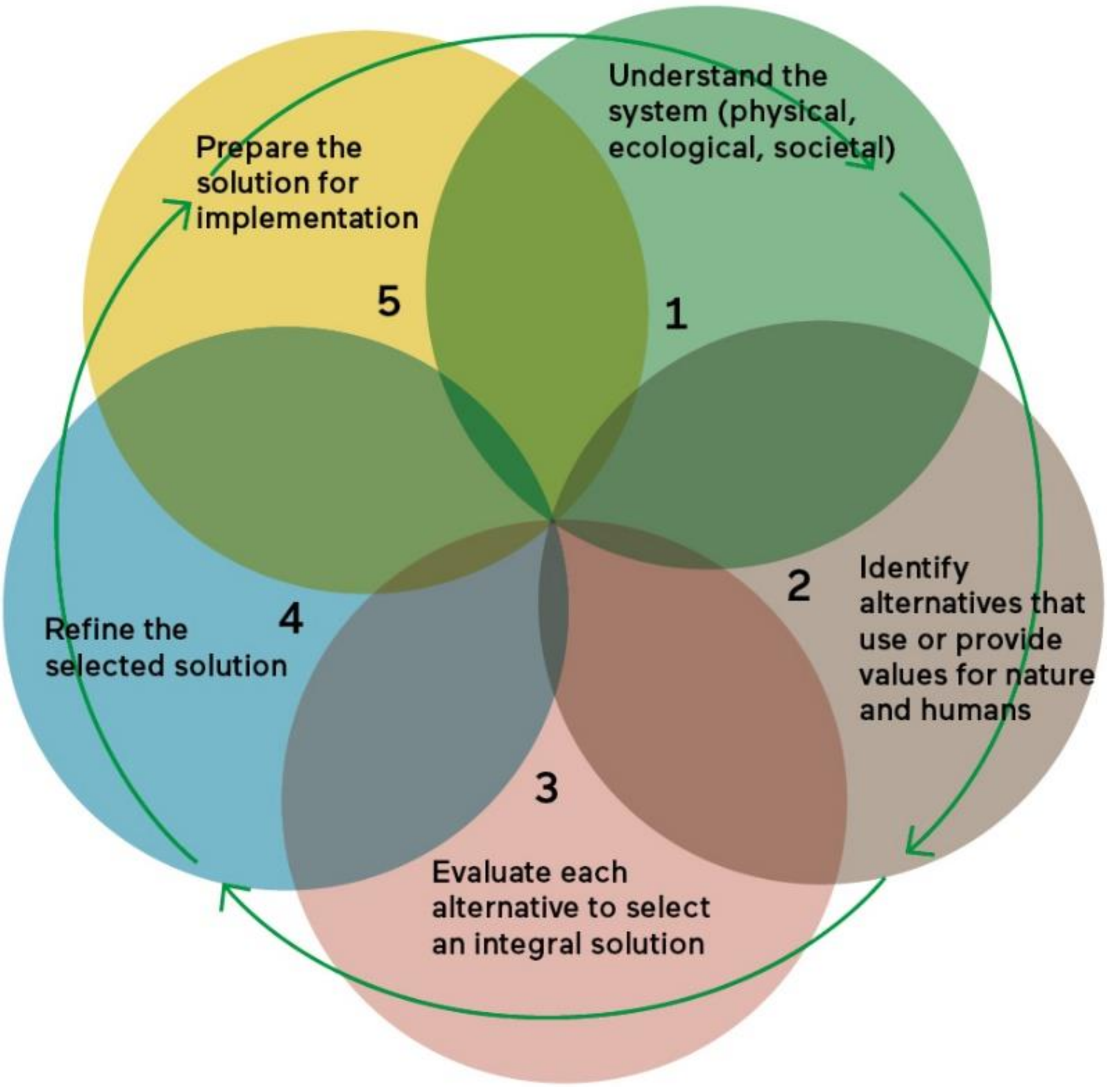


Figure 3. The five steps in the design phase (Ecoshape, 2020)

4.2.3 Ecosystem Services

Ecosystems services are all benefits that an ecosystem provides for humans (Figure 4). The services differ per ecosystem and culture. There are multiple ways to classify ecosystem services, three common classifications used are by MA, TEEB and CICES. MA, Millennium Ecosystem Assessment in full, was an UN established project to produce an ecosystem categorization framework (MA, 2005).

TEEB is based on MA, but more focused on analyzing the economic value of biodiversity. CICES is based on both MA and TEEB, and is more focused on ecosystem accounting (CICES, 2022; European Commission, 2014). These frameworks sort the ecosystem services in four distinct categories, depending on how the service functions. These categories are production services, regulation services, cultural services and supporting services (Fisher et al., 2009). Production services can be directly taken from the ecosystem, such as fruits and firewood in a forest ecosystem. Regulating services provide their services indirect, by regulating other processes, similar to how mangroves provide coastal protection attenuating storm surges with their structure. Cultural services are dependent on how communities perceive an ecosystem. For example, the aesthetics of an ecosystem are considered to be very pleasant by people, hence it is a popular recreation site and offers multiple opportunities for recreational purposes. All the ecosystem services mentioned before are usable now or provide an option to be used later when needed. Supporting ecosystem aid the functioning of other ecosystem services, such as the production of biomass. Because ecosystem supporting services do not give value themselves, bet help give other ecosystem services value, they are often left out when identifying ecosystem services.

Figure 4. Examples of ecosystem services from a mangrove forest. Retrieved from Boskalis internal documents.

4.2.4 SCBA

A SCBA is a tool that creates more insight for a decision-making process. In comparison to a SROI (Social Return Of Investment), a SCBA assesses all the costs and the benefits of the whole local community instead of just an individual stakeholder during a SROI (Krlev et al., 2013). Because the assessment is specifically focused on local communities, it does not take the costs for the project development and management into account. It focusses solely on the impact that a project will have on the local community in comparison to a baseline scenario. The baseline scenario is determined by examining historic data and using that to predict future trends in the area. In a SCBA, costs and benefits do not necessarily have to be monetary, however, it is easier to evaluate the costs and benefits if the individual components are monetized. Therefore, ecosystem services can be expressed for the respective monetary value they offer. These values can also be offered various manners. Hence it differs from ecosystem accounting. As ecosystem accounting is a measurement where all ecosystem services that directly add value are included. The SCBA will also focus on ecosystem services that indirectly (and culturally) add value.

4.3 Approach

To answer what the important building blocks of BwN SCBA are, first there must be examined how SCBA analyses are currently performed. This will be done by conducting a literature study on current SCBA frameworks, especially focused on frameworks that include natural and socio-economic processes (5.2 SCBA (MKBA)). In Addition, I will also study the natural processes that are prominent in a BwN and Blue Carbon project (5.2.2 Ecosystem Services), and how they relate to a SCBA (5.3 Ecosystem service valuation methods). After the different SCBA approaches are analyzed, I will construct a SCBA framework specified for BwN (6 Methodology). This framework will be tested on a BwN case study (7 Analysis of data) and improved where necessary (8 Discussion). In the end, a conclusion will be drawn about the effectiveness of the new SCBA BwN framework (8 Discussion, Conclusion & Recommendation, Conclusion & Recommendation).

5 Theoretical section

5.1 Abstract theoretical section

To identify what building blocks are important for a BwN SCBA framework in Blue Carbon projects, we must break down the components of BwN/Blue Carbon SCBA. Currently, multiple frameworks exist that explain how ecosystem services can be valued (Eijgenraam et al.,2000; Romijn & Renes, 2013). The scientific consensus is that ecological structures and processes produce ecosystem services that offer value. These services can be categorized on how they give value, i.e., direct, or indirect. Those ecosystem services can be monetized via assorted pricing methods. Therefor e, first all mangrove ecosystem services are identified and sorted depending on how they provide value. Further, these ecosystems need to be ranked on which ecosystem services are more important for the local population, so economic and spatial tradeoff ambiguities can be resolved. Then, after it is studied what the total ecosystem value is for the local community, key indicators, such as the BCR, NPV and IRR, can be formulated to find out if a BwN Blue Carbon project would benefit the local communities.

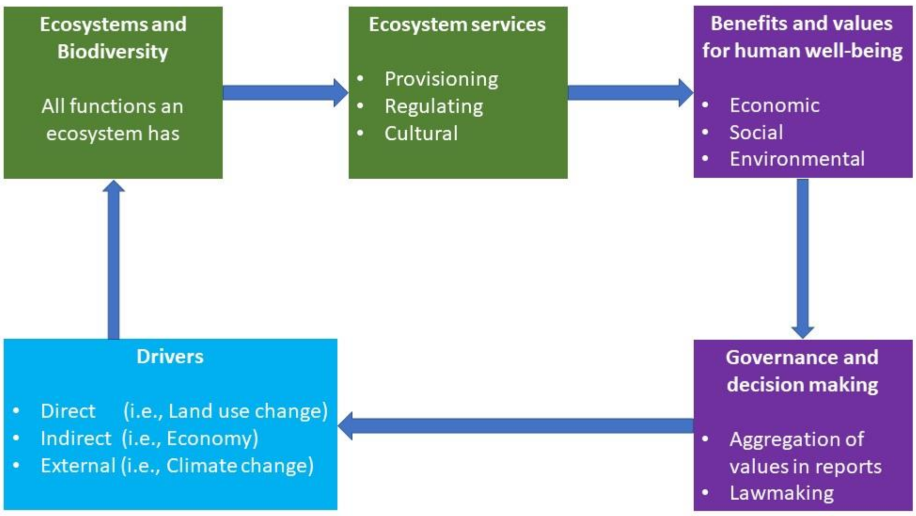


Figure 5. Framework on how ecosystems can offer and economic, societal, and ecological benefits; and how that can improve more sustainable decision-making processes. Retrieved from TEEB (2010).

5.2 SCBA (MKBA)

As stated in the introduction, Social Cost Benefit Analysis (SCBA) can be a useful tool for stakeholder engagement. By involving and engaging local stakeholders, they can connect with the project. By allowing them a seat at the table, they are more accepting and supportive of the project as they understand the importance for implementing such a solution in their area (Ecoshape, 2021b). When local communities actively participate in a BwN project, the project has more chance to succeed (Seddon et al., 2021). They can give valuable information about their experiences of the environment, socio-economic drivers, and political climate. Hence, they can contribute clear and extensive knowledge of the project area (Seddon et al., 2021). This local knowledge can be employed in design, implementation, and adaptive management of the system (Seddon et al., 2021). It is important to involve the whole community, as otherwise only the upper class will benefit from the project (Hajjar et al., 2021). If local communities would not be involved, or even ignored, they could potentially even resist the project (Woroniecki et al., 2020).

The application of a (social) cost benefits analysis used to be a widespread practice by the World Bank, however, the implementation is declining and only few CBAs are performed nowadays (Warner, 2010). A lack of data is the main reason the World Bank does not perform that many SCBAs anymore, as the outcomes are more uncertain (Warner, 2010). Bruce (1976) and Ray (1984) offer a standardized methodology on how a (S)CBA should be performed. These methodologies offer a clear framework on how costs and benefits are determined and estimated. Yet, they do not offer the latest consensus on how to include natural values in the SCBA. Hence, more recent frameworks must be studied to find out how all environmental impacts are assessed.

Currently, multiple Dutch organizations and institutes have constructed a SCBA framework (or MKBA in Dutch, which stands for *maatschappelijke kosten-batenanalyse*). The Dutch Ministry of Economic Affairs and Climate Policy and the Ministry of Infrastructure and Water Management has published a report, the *Leidraad OEI*, on how big infrastructure projects should be reviewed by a SCBA in the decision-making process (Eijgenraam et al., 2000). The *Leidraad OEI* describes a SCBA as:

" *Overview of monetary values for al cost and benefits that all parties in the (national) society endure due to the execution of the project, supplemented with (preferably quantitative) information about the effects that cannot be expressed in monetary terms in a responsible manner."* (Eijgenraam et al., 2000*).*

Eijgenraam et al. (2000) states that the Cost Benefits Analysis (CBA) could focus on the local area (partial CBA), or on the whole country (integral CBA), as a project can influence national economics, depending on if the economy is significantly impacted by the project. As all costs and benefits of all stakeholders involved should be assessed, tradeoffs between stakeholders can occur. Part of all the costs and benefits are the environmental effects. Hence, a SCBA should include external environmental effects, which may or may not be easily monetized, even though this is an important aspect of the CBA. In the end, as not all relevant costs and benefits can be monetized, the CBA will not provide a number, but a conclusion of the analysis.

CPB (the Netherlands Bureau for Economic Policy Analysis; CPB, n.d.) and PBL (Netherlands Environmental Assessment Agency; PBL, 2019) are independent research institutes that work on behalf of the Dutch government. They are the main contributors to Dutch policy analysis tools, which expanded the existing OEI SCBA framework (Bos et al., 2022). For example, not monetized values should still be expressed in their volumes and units to still be considered in decision making (Bos et al., 2022). In the end according to Bos et al. (2022), a SCBA must provide a clear overview of at least the following nine aspects:

1. Problem statement
2. The researched policy changes.
3. The value of benefits minus costs
4. The most important contributing factors
5. The sensitivity of the SCBA value
6. Which factors are not considered in the SCBA, and why?
7. Future developments because of changes in policy
8. Insight of the trends (etc.) of the individual factors
9. How the costs and benefits will be distributed amongst all stakeholders

Romijn & Renes (2013) state that according to 'welfare economics', the change in consumer surplus should be used as the basis for a SCBA. So, when demand and supply change for certain goods as an effect of the implementation of a project (i.e., produced by an ecosystem), the social welfare changes thus need to be considered in the SCBA. In this SCBA framework, natural values can be estimated by using different pricing methods that are in agreement with the latest scientific studies, such as hedonic pricing and travel costing (5.3 Ecosystem service valuation methods). Romijn & Renes (2013) express that a SCBA can be made when adhering to the following steps:

1. Problem analysis
2. Define reference alternative
3. Define scenario alternatives
4. Estimate effects and benefits
5. Estimate costs
6. Variance and risk assessment
7. Prepare an overview of all costs and benefits
8. Present results

5.2.1 The difference of the SCBAs

The SCBAs that are discussed earlier (5.2 SCBA (MKBA)) need to be adapted so have a better fit with Boskalis business methods. Therefore, new sections should be added to the proposed SCBA, these include a stakeholder analysis, a separate chapter for identifying ecosystem services, a baseline of the environment, a risk assessment, a chapter dedicated to the Blue Carbon or BwN scenario, separate chapters for ecosystem benefits and other benefits and last, the key indicators. The parts that are left out are about the researched policy changes, future developments as result of changes in policy and insight of the trends (etc.) of the individual factors (Figure 6).

- The stakeholders are analyzed because it is important to find out who is needs the SCBA has to take into account.
- Ecosystem services should be identified so they can be used to find the environmental impact of the project and other scenarios.
- A baseline should be made, as the effects (positive and negative) of the scenarios on the baseline should be quantified in the SCBA.
- Risk assessment is an important but extremely specific part, which identifies the chance that the project will be disturbed by a hazard. These disturbing events can be area or project specific. It costs much time to analyze and is done differently for each area, as it the events that can occur are area specific. However, it can be more easily done for project specific risks.
- Project scenario is not really mentioned in the other SCBA frameworks, but still the proposed design and effects of the project should be identified, to understand how they will impact the local community.
- Ecosystem benefits and Other benefits are split compared to the benefits chapter of the other frameworks. This is done as they will be bigger chapters and, in this way, the environmental part will be highlighted more. Since they are split, there is no need for an extra chapter about the insight of the trends of the individual factors since this will be included in the Ecosystem benefits and Other benefits chapters.
- Key indicators SCBA, such as BCR, NPV and IRR, are also calculated to give make the SCBA scenarios comparable in economic terms. For example, is the project beneficial for the local community and which scenario is more beneficial.
- Researched policy changes are left out since the project implementation will include more than just the effect of policy changes. The changes that the different scenarios have on for example the environment and every policy aspect included are stated in the scenario chapter.
- Future developments as a result of changes in policy are excluded as there is no need, the trends are expected to stay the same for the duration of the project, otherwise the expected carbon credits will be at risk. If there are future trends that need to be accounted for, this

needs to be part of the risk assessment. The insight of the trends (etc.) of the individual factors section are relocated and now part of the benefits and costs chapters.

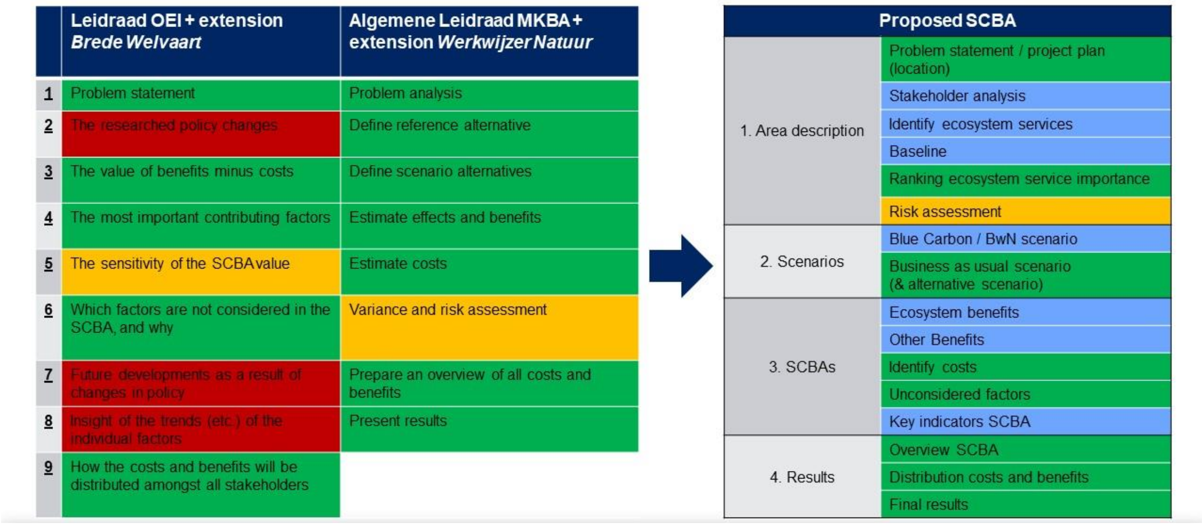


Figure 6. SCBA comparison

Since the aim of the research is to find out if the SCBA can be performed as a desktop study, it should be defined what a desktop study is. For this SCBA, a desktop study means that all information can be sourced by someone at his/her desk. This information must be analyzed from behind the desktop too. Still, calling and emailing local partners to gain more knowledge on the proposed project area still counts as desktop study for this SCBA, as the one performing the SCBA can still do this in a desktop environment. However, traveling to specific sites does not comply with the desktop study criteria.

5.2.2 Ecosystem Services

Bos & Ruijs (2019) argue that ecosystem services and biodiversity are not assessed well enough in most SCBAs currently used. They conclude that assigning points to measure biodiversity on itself are not sufficient. An improvement could be when the biodiversity and ecosystem values are assessed by questioning local communities about their willingness to pay for the maintenance of the ecosystem and ascribe that value to the ecosystem value (Bos & Ruijs, 2019).

Warringa et al. (2018) adds to the concept of Romijn & Renes (2013), by elaborating more in depth on how ecosystem values can be monetized. They assign economical value based on if and how the ecosystem service is used. If the ecosystem service is used, it is described as use-value. If the ecosystem service is not used, it is called a non-use value. The use-values can be divided further in direct-use values, indirect-use values, and option values (Figure 7).

- **A direct use value** is defined as received production services and cultural services that are directly linked to the ecosystem (for instance the production of fruits, or eco-tourism).
- **An indirect use value is** described as regulating services, in other words, an ecosystem service that regulates a process which is beneficial for people (for instance flood protection).
- **An option value** is seen as a use value that can be exploited on a later moment, and therefore can be production, regulation, and cultural services (for instance the option to cut a tree in the future to create fuel wood).

Non-use values can also be divided in three categories, namely existence values, bequest values and altruistic values. Due to their vague nature, their definitions are sometimes overlapping. The intrinsic value of nature is the perceived feeling of nature and influences how you behave around nature, which cannot be monetized properly.

- **Existence values** are based on what people currently perceive, so, how they would value the importance of the current ecosystem, based solely on the notion that it exists.
- **Bequest values** are based on the value that future generations can benefit from the same ecosystem.
- **Altruistic value** is similar to bequest values, except it is just about other people instead for solely future generations.

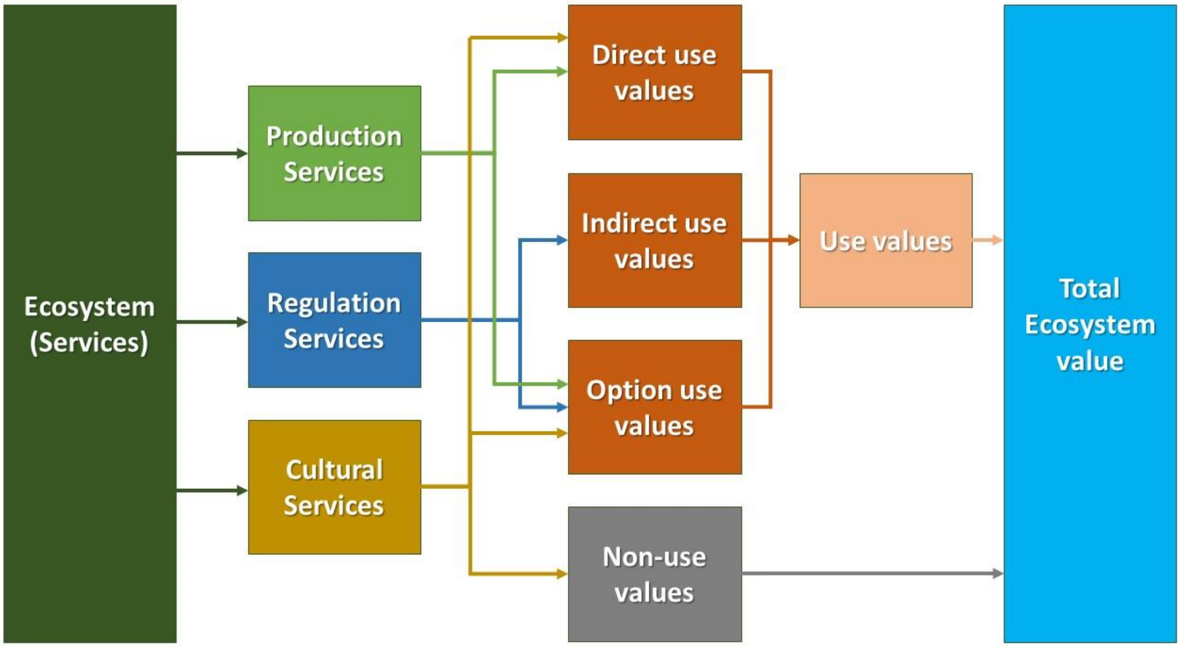


Figure 7. Pathway to categorize ecosystem services to understand their economic values. An Ecosystem can be divided in three types of ecosystem services: Production, Regulation and Cultural. These services can be analyzed by the manner they add value to people: direct, indirect, optional or non-use values. All the values combined show the total ecosystem value. Adapted from Hein et al. (2006), Vo et al. (2012) and Bockarjova & Botzen (2017)

Not only ecosystem services can offer costs and benefits for local communities. Setting up, monitoring, and maintaining a BwN project can offer more opportunities for the communities. Especially when performing a Blue Carbon project, since it needs to meet certain criteria, the monitoring and maintenance are key. This will require local input in the form of job opportunities that boost the local economy. Moreover, the development of the area will benefit the local population too. The BwN solution also needs sustainable management. For example, when implementing a mangrove forest as coastal defense, the local aquaculture farms could benefit from the ecosystem services but benefit extra when adapting to a sustainable aquaculture practice. When farming sustainably, the product value can increase by labeling the product as sustainable. Today, there already are nature restoration projects that are entirely financed by selling local products at a premium due to sustainable certification (Wylie et al., 2016). An example is Markets and Mangroves, where shrimp was farmed in the mangrove forest, and the products got labelled as ecologically friendly. This proved beneficial enough to pay for the whole project (Wylie et al., 2016).

Besides the benefits, also the costs must be determined. The relevant costs are composed of all the costs that the local community would be subjected to, this includes the costs of adapting to a new situation and benefits that would have occurred in the baseline scenario (i.e., opportunity costs, which are the profits that could have been made in alternative cases). Dependent on the level of local community involvement, there could also be cost related to maintaining the BwN site. Opportunity costs can be estimated by formulating a business-as-usual (BAU) scenario. In this scenario, historical data is analyzed and projected into the future to forecast future economic values. In addition, these can be used as baseline to compare with the benefits and investigate if a BwN project would add value to the local community.

After all the data is gathered, the complete SCBA can be performed and the feasibility of the BwN projects can be assessed. Key indicators to determine the successfulness of a project based on SCBA are the Benefits Cost Ratio (BCR), Net Present Value (NPV) and Internal Rate of Return (IRR) (Eijgenraam et al., 2000). These indicators should be estimated for all the different scenarios, including the refence alternative. To estimate the NPV and IRR properly, it is important that a project time and discount rate must be agreed on. A sensitivity analysis that fits the project could help determine the discount rate, by expressing the uncertainty of the projects successfulness in the discount rate. In this project, the different implementation steps should be analyzed based on their effectiveness and the average chance that the project will succeed can be obtained. However, when performing a sensitivity analysis turns out to be too difficult, the Dutch government recommends that the discount rate is set to 3% as a standard, or 2% for ecosystem services that are more uncommon (MKBA, 2009; Ruijs & Renes, 2018). This is done so the sparser ecosystem services will lead to higher NPVs later, making it more valuable to protect them. For Boskalis, also a higher standard can be chosen, because the project long term benefits might be more difficult to predict, and the short-term benefits will then be of a higher importance. For example, the discount rate that is stated in the annual report of the department that will execute the project. The discount rate can also be determined by using the equivalency principle or gamma discounting (Markanday et al., 2019; Weitzman, 2001). The equivalency principle argues that the discount rate can be calculated by comparing the total ecosystem value with the area price of the developed land, depending on the return period (Markanday et al., 2019). If the return period is infinite, then the discount rate can be obtained by dividing the ecosystem benefits by the price per hectare for the developed land, then, adding the appreciation of ecosystem benefits over time (Markanday et al., 2019). The range of discount ranges that were estimated for the different ecosystems that were analyzed is between 1 to 11 percent (Markanday et al., 2019). In gamma discounting, over 2100 experts were questioned about their view on a discount rate for the environment. Based on all the experts' opinions, it was concluded that the discount rate should be shifting from 4 to 0 percent, depending on the return period (Weitzman, 2001). The standard period that is chosen by the Dutch government for green and water-related projects which continue into the future indefinitely is 100 years (MKBA, 2009; Ruijs & Renes, 2018). For this return period, the gamma discounting argues that the first 5 years, the discount rate should be 4, the next 20 years it should be 3, the 50 years after that it should be 2 percent and the remaining time the discount rate should be 1 percent (Weitzman, 2001).

5.3 Ecosystem service valuation methods

To quantify the distinct categories of ecosystem services, and when it is known how they give value, you can now price the service via a pricing method. There are multiple methods available to value an ecosystem service. Using market pricing or production approach as pricing method yields the most forthright price, as it is the most direct way of pricing a product.

- **Market pricing method** is conducted by literally looking up the market price of a product and multiplying it with the amount of product that is in stock (Farber et al., 2006). Production approach method is a bit more complex, as it only examines the extra production that occurs because of the ecosystem service and add that with the market price (Farber et al., 2006).

- **The Contingent valuation method**, also known as willingness-to-pay, is the most applicable way to value an ecosystem service. A contingent valuation is executed by performing a questionnaire or other public poll to ask the target audience how much they are willing to pay for a specific ecosystem service. When compiling all answers, a value can be defined for the ecosystem service. There is some debate on the effectiveness of the contingent valuation method, e.g., some people argue that it is prone to hypothetical bias (when people's views differ from how they would behave in reality; Haab et al., 2013; Hausman, 2012). Though, in current economics, a price is often determined by what costumers are willing to pay for products (Farber et al., 2006) and even though the method might not be perfect yet, it will improve in time (Haab et al., 2013).
- **Travel costs method** are very comparable to contingent valuation, except it assesses how much effort someone is willing to endure, which includes the cost to travel to a certain location, rather than just willing to pay for (Farber et al., 2006).
- **Replacement costing method** is a method which examines what it would cost to replace an ecosystem function. For example, the value of the ecosystem service coastal protection by a mangrove forest would be rated equal to what it would cost to replace the mangrove forest with a dyke that performs the same function (Farber et al., 2006).
- **Avoided costing method** is comparable to replacement costing, despite that it looks at the loss that would occur when a certain ecosystem service is no longer performed. For example, if mangroves would be removed from the coastline, so they cannot perform their coastal protection anymore, how much would the damage to the coastal area cost (Farber et al., 2006).
- **Hedonic pricing method** determines the value of an ecosystem by comparing the price of multiple identical commodities within various distances to a specific ecosystem and attributes the price difference as the (added) value of the ecosystem. For instance, the difference in housing prices of identical houses that are located in regions, specifically where one is close by a nature reserve and the other is far away from that reserve; is based on the proximity to the reserve. It is presumed that the housing price is influenced by the value of the nature reserve (Farber et al., 2006).

Faber et al. (2006) described which pricing methods can be used for each ecosystem service (Table 1). However, for pricing specific ecosystem services, some methods can be more accurate than others. For example, product services are part of direct and option use values and thus more straightforward when assessing their value. Almost all values can be estimated by looking at the products' market price, or, when using the production approach method, the extra profit of the extra production. In other words, when you know how much do the goods cost on the market, and how many products you will obtain more, as result of the ecosystem service benefits, are due to the ecosystem. But for regulation and cultural services, the quantification of those values is more complex, so more valuation methods are possible (Table 1). The most accurate pricing method should be assessed per individual ecosystem service. The mangrove ecosystem services can also be divided in production services (5.3.1 Production services), regulation services (5.3.2 Regulation services) and cultural services (5.3.3 Cultural services) and valued according to the discussed pricing methods.

Table 1. Common economic valuation method, amenability, and transferability for all ecosystem services. Retrieved from Farber et al. (2006)

Ecosystem service	Amenability to economic valuation	Most appropriate method for valuation	Transferability across sites
Gas regulation	Medium	CV, AC, RC	High
Climate regulation	Low	CV	High
Disturbance regulation	High	AC	Medium
Biological regulation	Medium	AC, P	High
Water regulation	High	M, AC, RC, H, P, CV	Medium
Soil retention	Medium	AC, RC, H	Medium
Waste regulation	High	RC, AC, CV	Medium to high
Nutrient regulation	Medium	AC, CV	Medium
Water supply	High	AC, RC, M, TC	Medium
Food	High	M, P	High
Raw materials	High	M, P	High
Genetic resources	Low	M, AC	Low
Medicinal resources	High	AC, RC, P	High
Ornamental resources	High	AC, RC, H	Medium
Recreation	High	TC, CV, ranking	Low
Aesthetics	High	H, CV, TC, ranking	Low
Science and education	Low	Ranking	High
Spiritual and historic	Low	CV, ranking	Low

AC, avoided cost; CV, contingent valuation; H, hedonic pricing; M, market pricing; P, production approach; RC, replacement cost; TC, travel cost.

If these methods cannot be applied, due to for example a lack of data, the benefit transfer method can always be used. The benefit transfer method is easier to apply, but less accurate than the other pricing methods when performed correctly. In the benefit transfer method, other ecosystem valuation studies are used to convert the value of the studied ecosystem to the designated ecosystem, based on their similarity (Plummer, 2009). In other words, the more identical the ecosystems are, the more accurate the value can be transferred between the ecosystems. These studies can for instance be found in the TEEB (2010) database.

5.3.1 Production services

Product services are part of direct and option use values. This means that most values can be estimated by looking at the market price or production approach.

Table 2. An overview of the production services from a mangrove forest, and the pricing method that is most applicable.

Production services		
Food		
	Capturing fish & shellfish	Market pricing
	Aquaculture	Market pricing
	Food (Honey, fruits, nuts etc)	Market pricing
	Fodder	Market pricing
Raw material		
	Wood & Timber	Market pricing
	Pharmaceuticals	Market pricing
	Genetics	Market pricing
	Ornamentals	Market pricing
Water		
	Water purification	Market pricing

5.3.2 Regulation services

Regulation services are part of indirect and option use values. Due to their indirect nature, they are harder to value. The ecosystem services are divided in four categories:

- **Coastal defense**. Mangroves protect the shore by attenuating waves and trapping sediment. Their ability to attenuate waves can be valued in two ways, avoided costs and replacement costs. The first method is by understanding what the value of the land lost and damaged is, which is avoided by having a mangrove forest in place. The second method is by estimating the value of alternative coastal protection methods that are suitable for the area and could be implemented to protect the area instead of the mangrove forest (for example, hard coastal infrastructure such as a dyke). The same two methods go for sediment trapping. One way is to assess the cost and damage of the erosion that takes place in the area. So, how the people and the local GDP are affected. Or, the second option, how much it will cost to retain the current sediment levels, that will otherwise be eroded in a business-as-usual scenario.
- **Chemical characteristics**. Mangroves play a role in nutrient cycling, carbon sequestration and salinization mitigation. Mangroves' ability to pick up and store carbon has been researched extensively and this ability is the basis for the Blue Carbon Voluntary Carbon Market. This market trades in carbon stored in Blue Carbon ecosystems. So, for this characteristic we can use market pricing. The ability of mangroves to accumulate other chemicals, like heavy metals, and make available nutrients, such as nitrogen, phosphorus, and sulfur, does not have such a framework in place (Chiu & Chou, 1991; Qui et al., 2019). To accurately estimate this ability there could be looked at the costs that these nutrients would be artificially added to the system (i.e., fertilizer) when performing agriculture or aquaculture. Moreover, the mangroves can withstand salinization due to their specific roots, this allows them to stand in sea and brackish water (Scholander et al., 1962). Due to the saltwater tolerance and ability to store fresh water, the saltwater is not able to travel deeper

inland and salinize fresh ground water (Shimoda et al., 2009). This enables farmers and communities to obtain freshwater more nearshore. Otherwise, the community would have to make costs to get fresh water in that area, which is why the avoided costs method is important to use for valuating this ecosystem service.

- **Water management**. Mangroves play a key role in managing waterflows, their ability to withstand flooding due to their areal root system can help the area to be used as floodplain and store excess water temporary without the area being damaged. This prevents the watershed from being damaged by floods, this could be flooding caused by high sea or river water levels. Therefore, avoided costs or replacement costs could be used to estimate this value. For avoided costs there could be looked at the damage that could happen when the mangroves are not in place. The replacement costs could be the costs related to taking over this service of floodplain. This can be assessed by looking at risk and exceedance period studies.
- **Pollution abatement**. The mangrove CO2 uptake out of the air and oxygen production when photosynthesizing helps filtering the air. Similarly, the mangroves effectively decrease smog which would otherwise cause many health problems in the local community. So, living near a mangrove forest is healthier than living in a polluted city. This can influence for example housing prices. That is why this ecosystem service could best be valuated using hedonistic pricing. Mangroves also pick up nutrients in the water, thus preventing eutrophication in the area. By having cleaner water, this can be used for other processes. The water should otherwise be cleaned by something else to make it usable. Replacement costing is thus the best way to understand how this ecosystem service should be valued.

Table 3. An overview of the regulation services from a mangrove forest, and the pricing method that is most applicable.

Regulation services		
Coastal defence		
	Wave attenuation	Avoided costs / Replacement costs
	Sediment trapping	Avoided costs / Replacement costs
Chemical characteristics		
	Nutrient cycling	Replacement costs
Production service	Carbon sequestration	Carbon credits model; market price
	Salinization mitigation	Avoided costs
Water management		
	Watershed protection	Avoided costs
Pollution abatement		
	Water bioremediation	Replacement costs
	Air filtration	Hedonistic

5.3.3 Cultural services

Cultural services are part of direct values, option values and non-use values. This means they are more difficult to give a precise value that is true for everyone. This category is broken down into four groups:

- **Recreation.** Recreation can be divided in two categories, eco-tourism, and other activities/services. Eco-tourism economics can be measured by comparing with other already existing eco-tourism locations that have mangroves present & tourist taxation. Otherwise, it can be valued by looking at travel costs, what are people willing to pay to go on an eco-tourist trip. Other activities/services that might be linked to recreation (such as kayaking or hiking) might also already be in place in some comparable sites (value can be dependent on GDP).
- **Education**. By giving seminars or creating courses to help other people understand the value of mangrove forests. Currently there are already projects in place where local communities and perhaps even tourists get training on the important ecosystem services mangroves provide.
- **Aesthetics**. The mangrove forest can be a beautiful place and be very biodiverse. Pricing can be done best by travel costs or contingent valuation via a mix of interviews, questionnaires, and social media analysis. For example, how many activities is measured in a certain area, or how many pictures are made there (how many clicks on a website etc.). With this information, an analysis can be made to understand why certain areas are more beautiful than others, and how to increase the aesthetics in following projects, for instance to increase eco-tourism. Maybe in future more people are interested in traveling to a certain location or spending more money/time there.
- **Miscellaneous**. Other cultural aspects, such as spiritual and historic use can also be valuable for the local communities. This can best be understood by communicating with the local community to understand what is important to them. So, the best way to give value is via contingent valuation by understanding the willingness to pay from the local community. The value might be increased when the local community (communal values) can get a vote in the design of the landscape via participatory mapping.

Table 4. An overview of the cultural services from a mangrove forest, and the pricing method that is most applicable.

Cultural services		
Recreation		
	Eco-tourism	Market pricing (/ Travel costs)
	Activities and services	Market pricing (/ Travel costs)
Education		
	Seminars & courses	Market pricing (/ Contingent valuation)
Aesthetics		
	Biodiversity	Travel costs (/ Contingent valuation)
	Scenery	Travel costs (/ Contingent valuation)
Miscellaneous		
	Spiritual & religious	Contingent valuation
	Historic	Contingent valuation
	Other	Contingent valuation

Table 5. All mangrove ecosystem services categorized with their corresponding pricing method.

Mangrove ecosystem					
Production services		Regulation services		Cultural services	
(sub)Category	Pricing method	(sub)Category	Pricing method	(sub)Category	Pricing method
Food		Coastal defence		Recreation	
Capturing fish & shellfish	Market pricing	Wave attenuation	Avoided costs / Replacement costs	Eco-tourism	Market pricing (/ Travel costs)
Aquaculture	Market pricing	Sediment trapping	Avoided costs / Replacement costs	Activities and service	Market pricing(/ Travel costs)
Other food (Honey, fruits, nuts etc)	Market pricing	Chemical characteristics		Education	
Fodder	Market pricing	Nutrient cycling	Replacement costs	Seminars & courses	Market pricing (/ Contingent valuation)
Raw material		Salinization mitigation	Avoided costs	Aesthetics	
Wood & Timber	Market pricing	Water management		Biodiversity	Travel costs (/ Contingent valuation)
Pharmaceuticals	Market pricing	Watershed protection	Avoided costs / Replacement costs	Scenery	Travel costs (/ Contingent valuation)
Genetics	Market pricing	Pollution abatement		Miscellaneous	
Ornamentals	Market pricing	Water bioremediation	Replacement costs	Spiritual & religious	Contingent valuation
Water		Air filtration	Hedonistic	Historic	Contingent valuation
Water availability	Replacement costs			Other	Contingent valuation
Carbon					
Carbon sequestration	Market pricing				

5.4 Decision-making methods for ranking ecosystem services

After it is reviewed how ecosystem services can be quantified, it is important to find out which ecosystem services are the most important to local communities. Moreover, how will the local community benefit for being involved in a BwN project. Therefore, it is good to know what the local communities perceive as important. For example, a mangrove forest can boost the fish and shellfish population, which positively impacts local fisheries. However, mangroves can also boost aquaculture production and provide timber. This might lead to conflict as all different stakeholders want to secure the most benefits from such a project and would exploit the mangroves differently. So, to discern what would be most valuable to the whole local community, the BwN project has to identify what will be most important and beneficial for the whole community, to focus the BwN design on. Later, the benefits can always be distributed fairly over the different stakeholders.

Currently, information about socio-economic impact and insights about the wants and needs of local communities for Boskalis projects are gathered by external partners. For example, an impact assessment using qualitative questionnaires is performed by the contractor or a consultancy bureau. They often use social economic surveys with key informants to make personas of the different stakeholders in the area. Boskalis only receives the conclusions of the study, which is considered in a project. Other methods for understanding local communities are by connecting with the local communities yourself via qualitative research and/or using quantitative methods such as the Delphi method (DM) or analytical hierarchy process (AHP). For these methods, key informants that have extensive knowledge on the area are chosen. In theory, the contact with these key informants can be done from behind desktop, however, it might be more effective if you would have a face-to-face meeting with these experts. Other decision-making tools that can be considered when DM and AHP are not possible are Brainstorming, Nominal Group Technique and Multi-Voting and.

DM is a helpful tool for ranking the importance of ecosystem services, as it uses questionnaires to gather intelligence of appointed experts about the local communities (Musa et al., 2015; Okoli & Pawlowski, 2004). The first step is to choose between 10 to 18 experts as key informants (Figure 8). Then, let all the experts fill in a prepared questionnaire in which they need to score several factors on a predefined scale (i.e., from one to five). The questionnaires are repeated in multiple rounds until one consensus between the experts is met, so an answer can be given about the factors (Figure 9).

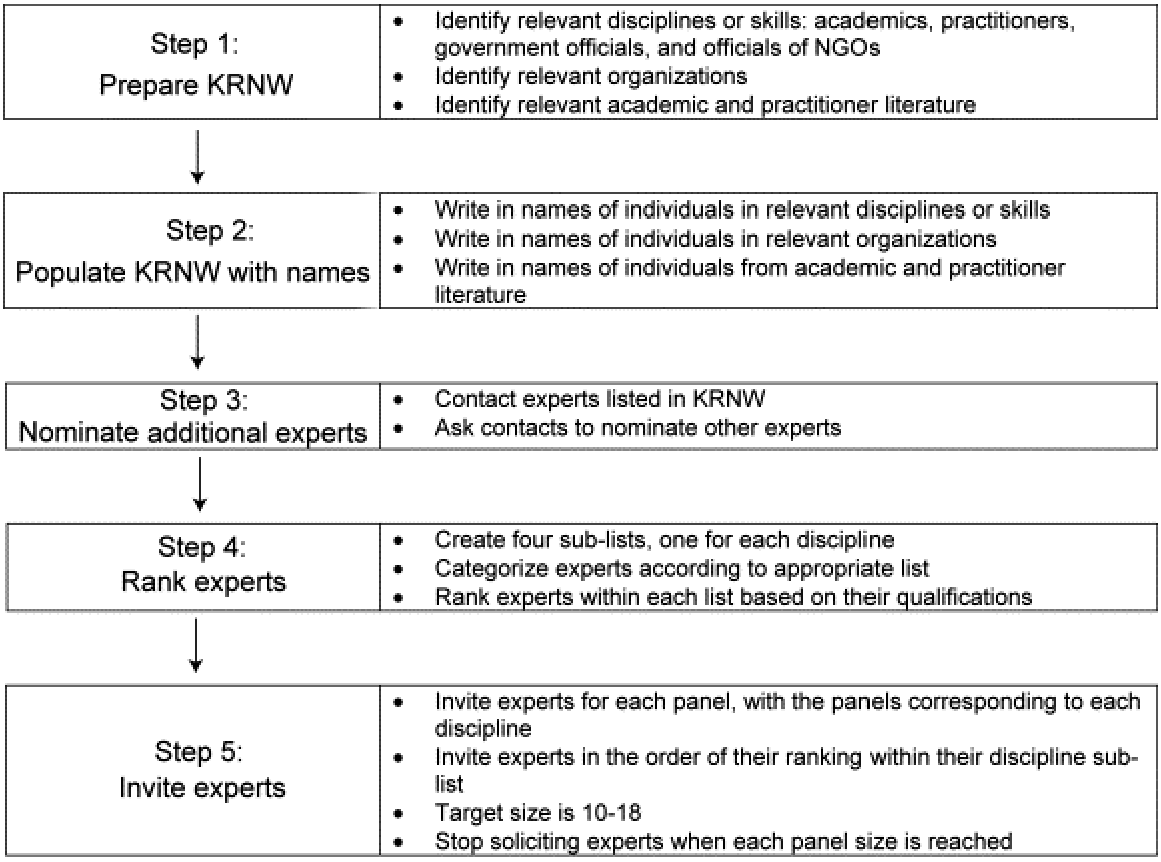


Figure 8. The Delphi method procedure for selecting experts. KRNW is short for knowledge resource nomination worksheet, which is the worksheet where relevant information for expert selection is stored. Retrieved from Okoli & Pawlowski, 2004

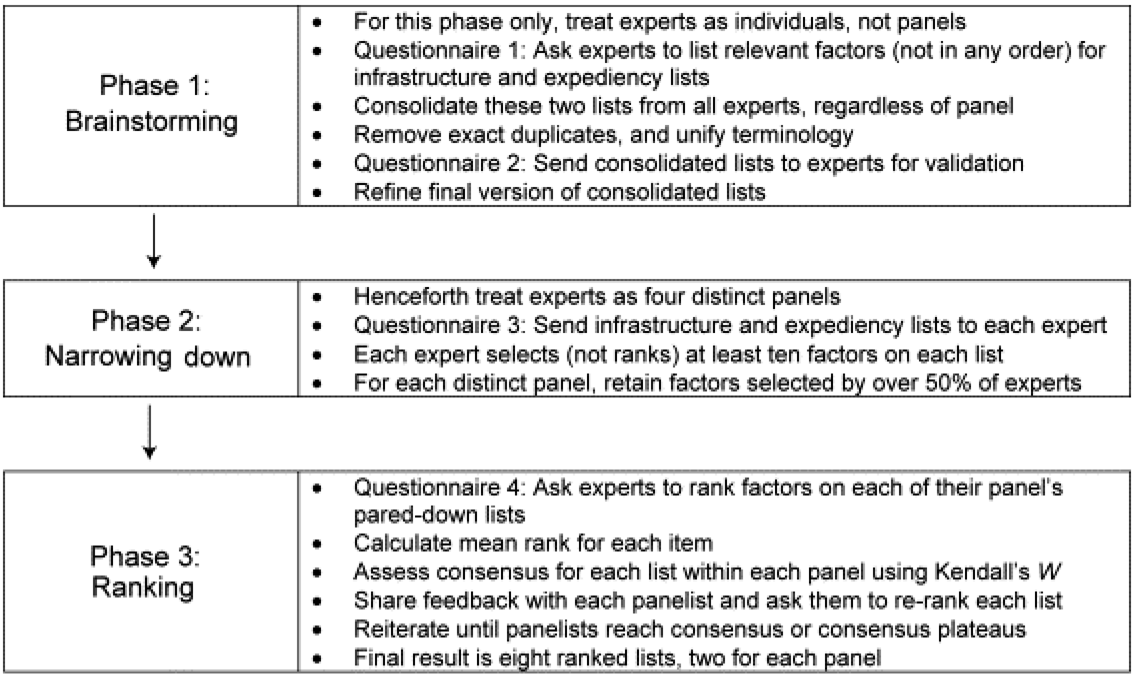


Figure 9. Outline of the ranking process. Retrieved from Okoli & Pawlowski, 2004

AHP is similar to Delphi method, only the type of questions asked are different. First, the experts / key informants are compared with each other based on their decisioning power, for example importance. After that, the experts receive questionnaires that ask for the ratio between all the factors. When the answers are received, they are normalized and weighted based on the decisioning power of the expert. Eventually, the factors can be ranked by their scores.

Combing the Delphi method and AHP with fuzzy statistics will change the input of the answers (Figure 10; Lin & Chuang, 2012; Habibi et al., 2015). For the questions, a certain scale is determined (i.e., from very unimportant to very important). Then the answers are fuzzified, which means that the answers are rewritten in fuzzy numbers. The fuzzy number is not just single one value but is more like a distribution around a specific value with a lower, higher, and mean. The fuzzy numbers are averaged for the different answers there were given, and then defuzzied again, so a certain crisp value will come out per factor. More details and information on how this process works can be found in Appendix A.

In addition, the fuzzy Delphi method (FDM; Ishikawa et al., 1993; Habibi et al., 2015), combined with fuzzy analytical hierarchy process (FAHP; Chang, 1996), can also be applied, as it provides a broader and clearer overview of the sourced data. The FDM and FAHP already analyzes the view of the different experts to a ranking, which can be used to understand the level of importance for the different ecosystem services to the local communities (Rout & George, 2018; Ishikawa et al., 1993). Consequently, as no repetitional rounds of questionnaires are needed, it is less time consuming (Ishikawa et al., 1993). Since surveys need to be distributed locally, it can be tricky to use DM from behind the desktop, so it might be better to use in combination with obtained regional data to give a more complete overview. This regional data should contain local land use, significant local economic drivers and more.

With brainstorming, a group is put together to think about all potential problems and solutions. By conversing, the group builds on each other's knowledge and experience to come to a more elaborate conclusion than an individual would have (McMurray, 1994). However, when performed incorrectly, it is one of the least effective decision-making tools (McMurray, 1994). The nominal group technique is a more structured approach to brainstorming, as the discussion is written and not spoken (McMurray, 1994). Multi-voting is a method where experts will vote on different ideas, so that in the end a conclusion can be drawn about what the most likely answer is. AHP is a method that ranks different alternatives based on multiple criteria. The alternatives are assigned a score and this way, the best alternative can be selected for.

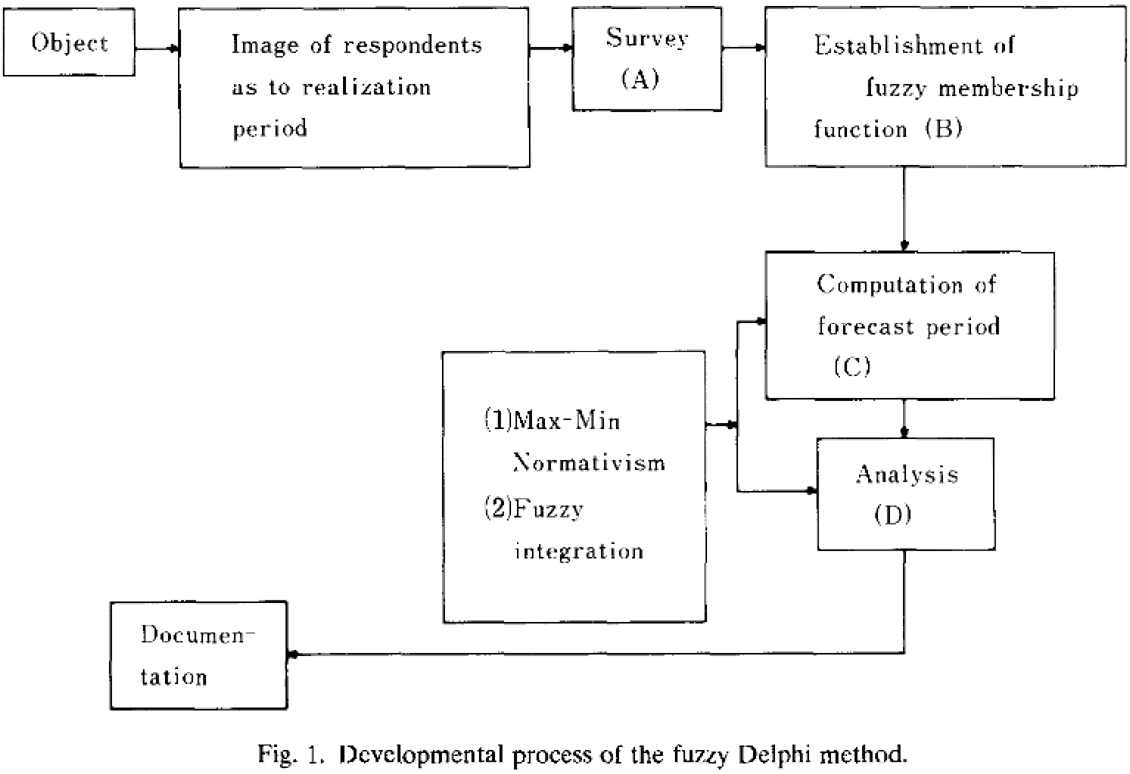


Figure 10. The Fuzzy Delphi method. Retrieved from (Ishikawa et al., 1993)

5.5 Other Benefits and Costs

When defining costs and benefits from a project for a local community, they can be found by looking at all the impact the project will have on the community. First, every individual local stakeholder that is identified must be grouped with other stakeholders that have similar characteristics, so the impact can be assessed per group. Next, it must be agreed on what will contribute to their wellbeing (Narasimhan et al., 2014; Verra, 2017). This can be done by following one of the impact assessment frameworks, such as the 'attacking poverty' framework (Lawlor et al., 2013), 'the sustainable livelihood' framework (Mensah, 2011) or the 'nested spheres of poverty' framework (Gonner et al., 2011). With these frameworks, a baseline of the socioeconomics can be made with which the impacts can be assessed. The impact assessment that is used frequently follows the Social Impact Assessment (SIA) principles, which are developed by the International Association for Impact Assessments (IAIA) (Vanclay, 2003). The do-no-harm principle should be applied in the phase where a scenario is selected for implementation. This principle is explained in various ways, but the definition boils down to selecting for the scenario that has the least negative effects on the local community, also keeping in mind that the business-as-usual scenario can have negative effects on the local community too (Wallace, 2015). If these effects can be quantified, they should be included in the analysis, for example by adding the wages of local laborers. However, if it is not possible to quantify these effects, but are important to consider, they should be included in the unconsidered factors section.

5.5.1 Attacking poverty framework

The attacking poverty framework was developed by the World Bank and is often used in carbon projects, such as REDD+. The framework recognizes opportunities that a local community can expect, improves the communities' security, and aims to empower marginalized groups in a society (Figure 11). These three aspects contribute to the local welfare and wellbeing. The impact that a project can have on these aspects can be benefits if the effect is positive, or costs if the effect is negative (Lawlor et al., 2013).

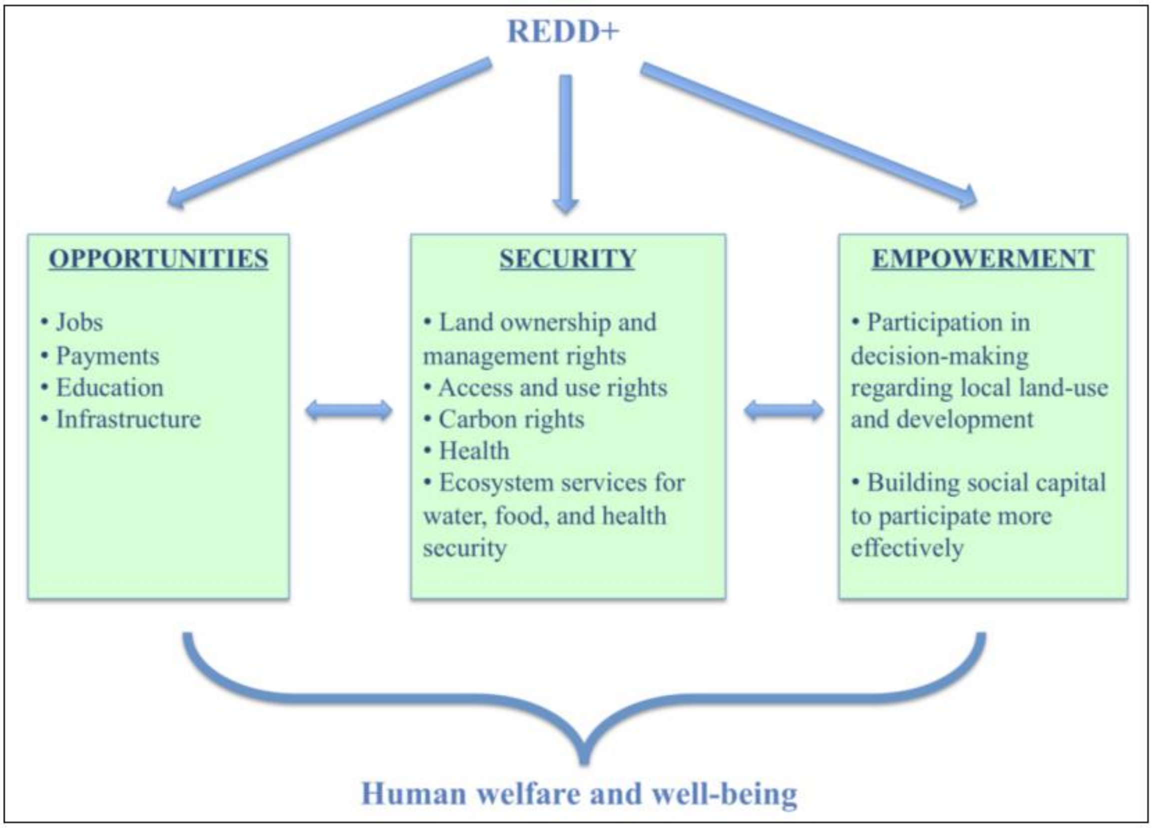


Figure 11. The attacking poverty framework. Retrieved from Lawlor et al. (2013).

5.5.2 The sustainable livelihood framework

According to the sustainable livelihood framework (Figure 12), five assets determine the welfare of people. These are human, natural, financial, social, and physical capital. Human capital is all the knowledge and skills an individual has. Natural capital is measured via their access to natural resources. Financial capital is all the financial capabilities an individual has, including the expected income and so on. Social capital is all groups of people that people have a type of relationship with, so, the extension of their social network. Physical capital are all tangible assets that a person can make use of, such as infrastructure and livestock. The relationship between these assets and the vulnerability should be assessed to understand the livelihood and poverty level (Mensah, 2011).

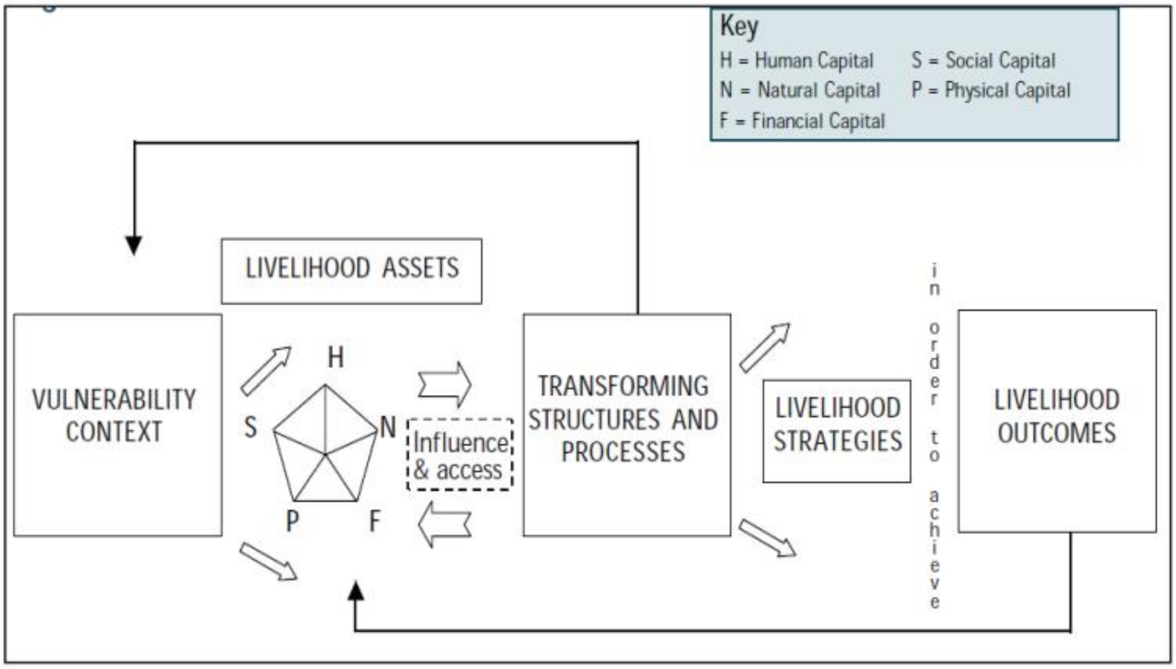


Figure 12. The sustainable livelihood framework. Retrieved from Mensah (2011).

5.5.3 Nested spheres of poverty framework

In the nested spheres of poverty framework (Figure 13), the subjective wellbeing is explained via three major components, which are wealth, health, and knowledge. With these three categories, the level of poverty can be measured by understanding their access to these basic needs. These components can be influenced by the persons natural, economic, social, and political sphere. These spheres and components can be linked to the different explained in the sustainable livelihood framework. Next, the access to infrastructure and government services is also considered in the framework (Gonner et al., 2011).

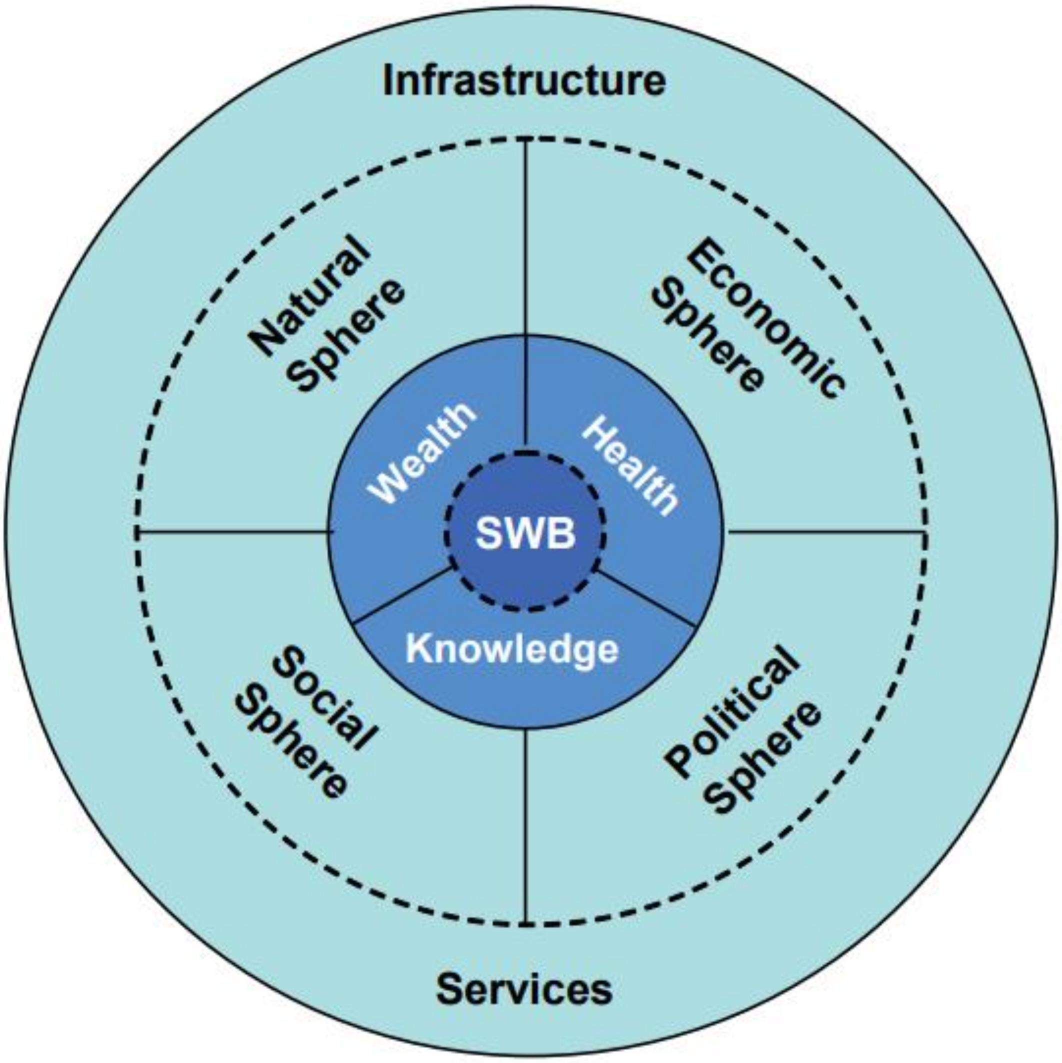


Figure 13. The Nested spheres of poverty framework. In this framework, SWB is subjective wellbeing. Retrieved from Gonner et al. (2011).

6 Methodology

6.1 Abstract

To create the SCBA, I merged some aspects from the other SCBAs in one general framework. Other steps I adapted from the existing, earlier mentioned SCBAs (see 5.2.1 The difference of the SCBAs). The new proposed framework exist of 4 categories: Area description , Scenarios , SCBA and Results (Figure 14).

- For the area description, first the problem must be analyzed, and a plan be made on how the problem is solved. Then, all stakeholders should be identified, and their role should be investigated. Next, the ecosystem services in the area should be identified and a baseline of all characteristics of the area should be made. Afterwards, the ecosystem services should be ranked on their importance for the area and a risk assessment should be made.
- Then, the different scenarios should be designed so they can be compared later. The scenarios include the Blue Carbon/BwN project itself, the business-as-usual scenario and other alternative scenarios that might be developed for the area.
- After the project scenarios are made, the actual costs and benefits (SCBAs) should be estimated for the different scenarios. These include all ecosystem benefits, other benefits, and costs, but also unconsidered factors should be noted as they can play a significant role in decision making. The SCBAs results should be displayed via key indicators, so the scenarios can be compared.
- The results should show an overview of the SCBAs, if some stakeholders will actually decrease in welfare, they should be compensated for their loss, so the expected benefits of the project are distributed fairly, and everyone will be on board. Finally, the end results will give the final overview of the scenarios SCBAs. The effectiveness of this framework will be tested through a case study of a BwN project in Demak, Indonesia (Analysis of data).

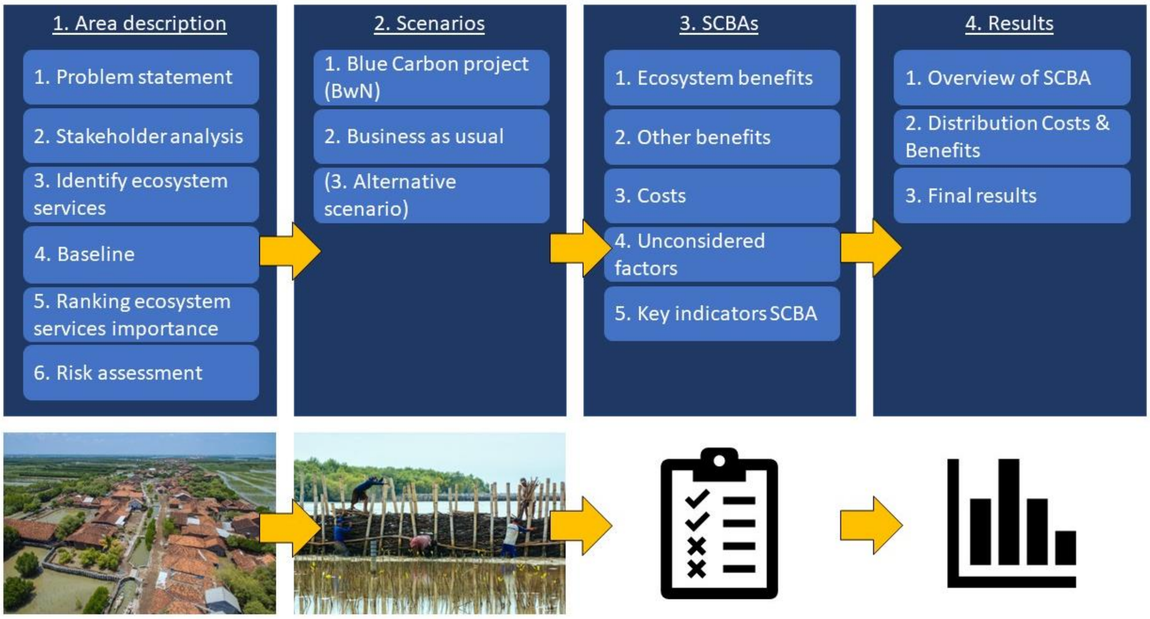


Figure 14. Proposed SCBA framework.

6.2 Area description

6.2.1 Problem statement

In the first step, the main problem of the area must be described. What are the threats of the area that need to be changed? When you want to implement a Blue Carbon project somewhere, there must be a valid reason the selected area is the most suitable for a project. The most important aspect is the expected amounts of CC that can be sold during the project. Boskalis already has made a tool to estimate this. Other aspects are for example that all the legal aspects should be in order, the mangrove restoration plan should be realistic, and so on. If all specified criteria are met, a site can be selected, and a plan can be made on how the mangrove area is restored/ protected. The plan should contain a design, so all the expected project costs can be identified, and a business case can be made. If the plan is feasible to execute by Boskalis, the SCBA should come into play to engage local communities in the project.

The project area selection criteria of a BwN project differs in certain aspects from Blue Carbon project criteria. Whereas Blue Carbon projects aim to be profitable by selling carbon credits, BwN does not use Blue Carbon as main financing method, therefore it is less important. However, a SCBA is still a helpful tool for engaging local stakeholders in the project.

6.2.2 Stakeholder analysis

Next, all the stakeholders that will be involved in the project must be identified. The stakeholders should be categorized and prioritized. This can be done by brainstorming and projecting the stakeholders on the power-interest grid (Figure 15). Now that it is known which stakeholders are the important in the area, their wants and needs can be assessed. Now it is understood which local stakeholders will be included in the SCBA.

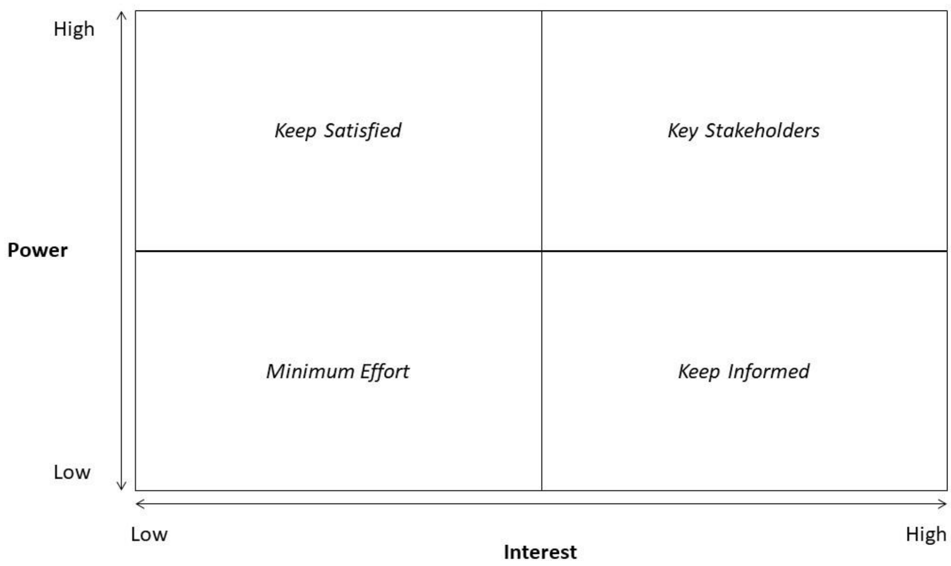


Figure 15. Power-Interest grid that can be used for categorizing and ranking all stakeholders in the project area.

6.2.3 Identification ecosystem services

After the stakeholders are identified, all the ecosystems and their services should be identified in the area. The ecosystem can be identified by remote sensing, searching for available geospatial data, and looking in available literature. Many helpful tools are available, such as Global Forest Watch's land cover data (Global Forest Watch, n.d.). Ecosystem service frameworks such as MA, TEEB and CICES can be used to find the corresponding services for the present ecosystems. The ecosystem services are already classified as production, regulation, and cultural services by the different frameworks.

6.2.4 Baseline

Now that most of the information about the area is found, it can be used, together with historical data to make a baseline of the area. In the baseline, all the relevant trends and characteristics of the area should be identified. The baseline will give important insights in the effects that the different scenarios will have on the area.

6.2.5 Ranking ecosystem services

To understand which ecosystem services are more important in the SCBA, the ecosystem services should be ranked on how they play a role in the daily life of the local community. For Boskalis, information about impact on local stakeholders is usually researched by external consultancy bureaus. They perform qualitative studies to understand the impact on the local communities. However, to be able to quantify the local input as it is needed to determine a ranking of the ecosystem services, a quantitative study can give better insight. To be more effective, this should be performed with pool of 12-18 appointed experts that have extensive knowledge about the environment. The Delphi method and AHP offer two quantitative ways in which the opinions of different experts can be translated into a ranking. By also using fuzzy logic, this process can even be more efficient. Therefore, gathering expert knowledge and using it to form a ranking should be done by using FDM, and if necessary, combining it with FAHP, as FDM is easier to apply.

6.2.6 Risk assessment

The risk assessment will give insight in the feasibility of the project. There might be incidents that will disturb the project. These can be natural or anthropogenic events. All the risks should be analyzed to understand if they are acceptable for the project to continue, based on how Boskalis evaluates the project. In the end, performing a high-risk project can only be profitable when there are also many benefits expected. The risk assessment can be based on the risk that exist in a certain location where you want to implement a Blue Carbon or BwN project, or for the project implementation itself. Since the risk assessment variables for a certain location can differ considerably, the risk assessment in the framework focusses on the risk for implementing the project itself. The expected risk for the projects successfulness should be notable in the discount rate.

6.3 Scenarios

6.3.1 Blue Carbon / BwN project

The design plan of the Blue Carbon / BwN project must be constructed. This project will have certain effects on the current baseline. These effects include impact on the ecosystem services. The marginal change of these services should therefore be assessed. Moreover, other social economic impacts should be predicted to understand the potential costs and benefits of this project.

To find out how the Blue Carbon project will impact the environment, a design plan should be made in which the new environment parameter values are estimated. The design should decrease the problem that is stated in the problem statement, while aiming to benefit local communities too. The design in BwN projects is mostly done via the BwN design strategy.

6.3.2 Business as usual (BAU)

In the business as usual, the environment is also able to change due to current processes. These effects should also be compared with the baseline to find out how business as usual will affect the local community. The business as usual is a continuation of current trends, hence all historic data can be used to make a prediction of the future. The environmental and socio-economic parameter values can thus be estimated. If there is much uncertainty, a best case and worst-case scenario can be made to predict where the actual scenario values will lie between.

6.3.3 Alternative scenario

If there are alternative plans for the area by other parties, their plans with their predicted outcomes need to be assessed to. These alternative plans can potentially be competing with the proposed Blue Carbon / BwN project plan. This scenario should only be assessed if there are already concrete plans in place to implement this.

6.4 SCBA

6.4.1 Ecosystem benefits

All the ranked ecosystem services should be priced for their role in the different scenarios. The benefits are measured by the marginal increase of the ecosystem and their services. These services are monetized using different pricing methods. For a mangrove ecosystem, the different ecosystem services and how they should be valued are stated in Table 5**Error! Reference source not found.**. The specific method on how to quantify these services are found in Appendix B.

6.4.2 Other benefits

Other benefits that can occur by implementing the different scenarios should be identified and assessed. Besides the environmental effect, Blue Carbon or BwN projects also can have a social-economic effects. These benefits can be classed based on one of the proposed impact assessment frameworks. Some of these effects, such as increased job opportunities, could be included in the design phase, and the further specifics can be discussed. What extra social benefits can be offered by the project is dependent on what the local community wants, as long as it is not obstructing the project objective.

6.4.3 Costs

Also, the negative impacts of the suggested scenarios should be identified. The costs for the SCBA should only include relevant costs from all stakeholders. Most costs for Boskalis will depend on the project design, such as investment costs and maintenance costs. However, as the SCBA is focusing on the local community, only the negative social-economic and environmental effects must be included in the costs. These costs can be determined by conducting an impact assessment via interviews, where the cost can be identified by their negative effect on the baseline. There can be uncertainty in defining the amount of costs, to counter this, a best case and worst-case scenario for the costs can be made.

6.4.4 Unconsidered factors

Even though in a SCBA all factors should be monetized, some processes that are important to consider cannot easily be quantified. These processes are for example of cultural or religious nature. However, since they are important to note, they need to be considered still. Therefore, they must be explained and considered when making conclusions about the different scenarios.

6.4.5 Key indicators (after sensitivity analysis)

With the numbers found at the risk assessment, the BCR, NPV and IRR can be calculated. These values give insight in the expected welfare change for the different scenarios. The indicators also allow the SCBA to be compared in a fair manner. BCR is calculated by dividing the benefits by the costs. NPV is calculated as follows, where the initial investment and costs are negative, and the profits are positive:

$$\text{NPV} = \text{initial investment} + \sum_{t=0}^{t} \frac{Cash\ flow}{(1 + discount\ rate)^t}$$

For the NPV, you have to determine the discount rate for the project based on the risk assessment. Otherwise, when no risk assessment about the project can be done, the 2021 pre-tax Boskalis Dredging discount rate stated in the annual report can be used for a project to be conservative, which is 8.4% (Royal Boskalis N.V., 2021-a). The IRR is estimated by assuming NPV is zero, then the discount rate is replaced by IRR.

$$NPV = 0 = initial\ investment + \sum_{t=0}^{t} \frac{Cash\ flow}{(1 + IRR)^t}$$

6.5 Results

6.5.1 Overview of all costs and Benefits

To finalize and summarize all findings, the outcomes of the different SCBAs should be written in a readable overview so the scenario outcomes can be looked up easily for comparison.

6.5.2 Distribution costs and benefits amongst stakeholders

Sometimes, even though the total costs benefits will seem to be beneficial, some stakeholders' welfare will decline. Therefore, it should be reviewed if these stakeholders should be compensated for their loss, for example to keep them on board with the project plan.

6.5.3 Final results

Last, the final results, conclusions and recommendations about the outcomes should be reported. This summarizes all the important subjects that are found and analyzed by the SCBA.

7 Analysis of data

7.1 Area Description of Demak

Figure 16. coastal erosion of the Demak region, Indonesia. Retrieved from Van Eijk (2018)

1. Problem statement

The Demak shoreline regions Sayung, Karangtegah, Bonang and Wedung are under high pressure from the sea. Their muddy shoreline is eroding due to the removal of mangrove forest, to create more space for aquaculture ponds (Figure 16; World Bank, 2018). The elimination of the mangrove ecosystem results in coastal erosion. This is accelerated by the implementation of hard coastal defense structures, which were placed to protect the receding shoreline. The hard infrastructure causes increased erosion in front of the seawall and sinks in the mud due to its weight, rendering it ineffective. Now, the surrounding local villages are flooded due to the rising tides and lack of protection. The flooding damages property and increases saltwater intrusion, which makes groundwater undrinkable and land unusable for agriculture. Since this area houses over one million people, the area should be protected in a secure manner. In addition, the land is also impacted by subsidence. Since all the drinking water for Semarang is pumped up from aquifers, the ground is subsiding due to the depletion of the aquifer. Moreover, this also causes saltwater intrusion in the soil, which can potentially lead to a hyper saline soil. This will be disastrous for the mangrove restoration project. Last, the water is also very polluted by the wastewater discharge coming from Semarang, a major city neighboring the Demak coastline in the south.

2. Stakeholder analysis

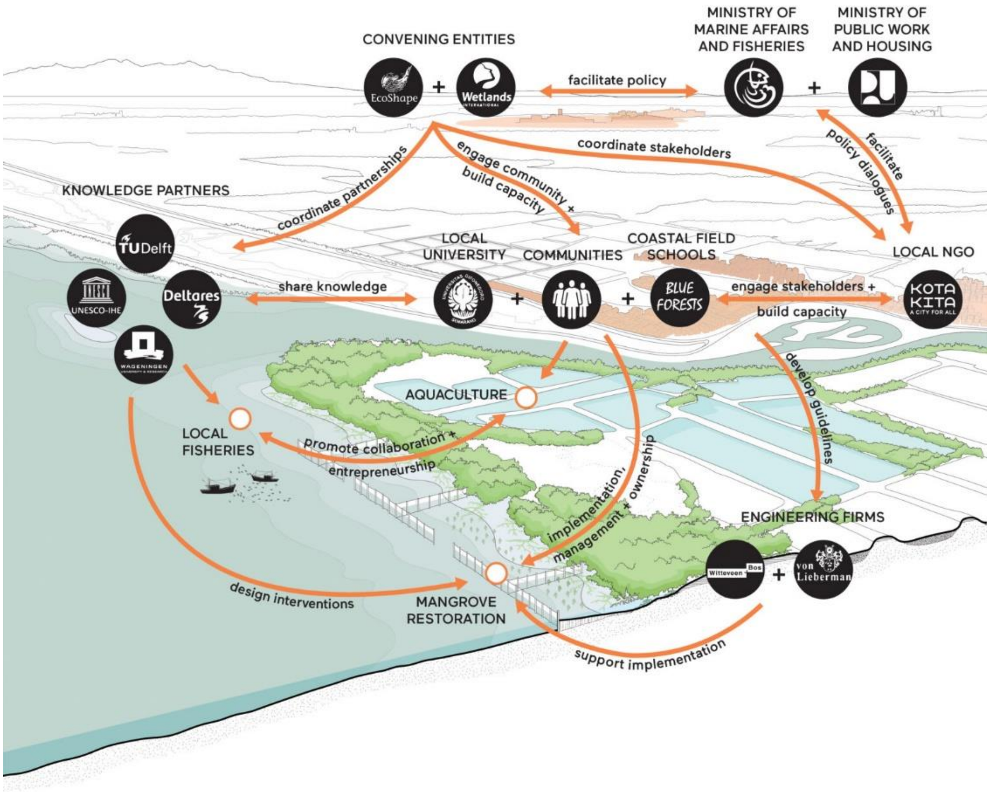


Figure 17. All parties involved in the Demak BwN project and their role. Retrieved from Ecoshape (2021b).

Table 6. All stakeholders that are present in the project area and need to be considered for SCBA. Adapted from Ecoshape (2021b).

Stakeholder	**Objective**
Local society	
Local communities	Be protected, improve welfare & wellbeing
Local aquaculture	Improve aquaculture yields/profits
Local agriculture	Increase agriculture yields/profits
Local fishers	Increase fish catch
(Regional) government	
Ministry of marine affairs and fisheries	Protect fish stock, wellbeing fishers
Ministry of public work and housing	Ensure safety local communities, improve opportunities, securities, and empowerment local population
NGO's	
Kota Kita	Increase human capital local population, increase their wellbeing/welfare

3. ES

The dominant ecosystem is a mangrove forest; therefore, the mangrove ecosystem services will be identified and quantified. Looking in TEEB and CICES databases shows what these ecosystem services are and their classification. All the ecosystem services of mangroves and their respective categories are displayed in Table 5.

4. Baseline

The population is continuously impacted by flooding events when high tide arrives, even damaging local aquaculture. The coast used to be protected by an extensive mangrove belt, but since the aquaculture ponds increased in the area since the nineties, almost no mangroves are left nowadays (Tonneijck et al., 2015). The dominant mangrove species that are left are *Avicennia marina* (also known as the grey/white mangrove) and *Rhizophora mucronata* (also known as the Asiatic/red mangrove), which are pioneer species. Currently, there is some hard infrastructure present to try counter the damage, however, they are ineffective and increase the damage even further. The aquaculture is also influenced by the poor water quality due to Semarang's wastewater influx in the system. Currently, mainly shrimp and milkfish are produced on large scale in the aquaculture ponds left. Around 6000 ha of aquaculture ponds are present in the area but need to be fixed due to flooding damages. The rice production, which used to be a major part in the local economy, has now diminished to around 200 ha for the whole coastal area (Tonneijck et al., 2015).

The local economy is built up out of 70% of the local population is either aquaculture farmer or fisher, 25% is regular farmer, the remaining population are industrial employees, government officials and merchants (Ariyati et al., 2016). The average income of aquaculture is 17.5 million Indonesian rupiah per household per year (1400 USD per year), and fishing income is around (96 USD per year). Closer to Semarang, the area is increasingly inhabited by population industrial workers (Ariyati et al., 2016).

5. Ranking

The ranking of ecosystem services is based on the stakeholder analysis, and future outlook chapter of Witteveen & Bos (2019).

- Food production (mainly aquaculture and fisheries)
- Coastal protection (protection for floodings in high tide)
- Pollution abatement (supporting sustainable aquaculture output)
- Potentially ecotourism and carbon sequestration (not really explored in the project, but tourism is present in Demak)

6. Risk assessment

The risk assessment is performed by Witteveen & Bos, in their SCBA (Witteveen & Bos, 2021). For scoping reasons, it is expected that the risk is identical, and the project will succeed. For this project, RVO (2021) estimated that the discount rate for this Building with Nature project in Indonesia should be set at 7.5 percent.

7.2 Scenarios for Demak

1. BwN scenario

The plan is to build semi-permeable dams to slow down waves, so they release sediments and mud levels are restored. These dams will be placed one hundred meters in front of the shoreline needs to be protected (Winterwerp et al., 2014). In total, in 2015 1.9 km of permeable dams was constructed, but to accelerate sedimentation, an additional 0.8 km is built (World Bank, 2018). When the mud levels have accreted enough for mangroves to recolonize the area, the dams will be placed further seaward so eventually the old shoreline will be restored completely. It is expected that only limited mangrove planting is necessary in the newly stabilized soil, as they will be able to recolonize the new area through nearby mangrove seed dispersion. Moreover, existing aquaculture ponds are dug out, so enough mud is available for mangrove recolonization (van Bijsterveldt et al., 2020). It is estimated that around 55 ha of aquaculture ponds is converted for the mangrove restoration (Lestari, 2021). In the final stage, it is planned to recover around 6000 ha of aquaculture ponds and make them more sustainable (World Bank, 2018). The transition to sustainable aquaculture practices is according to the LEISA methodology (low external inputs in sustainable agriculture; Lestari, 2021). This way, the population is educated on the benefits that mangroves offer to the aquaculture, for example, no antibiotics are needed since the mangroves purify the water. Another socio-economic improvement that is planned, is the construction of a fishery park. Moreover, more benefits can be gained when more focus is put on eco-tourism. An overview of how the area will look like in the future is given in Figure 18 and Figure 19.

Table 7. Predicted area sizes for BwN project. Adapted from Witteveen & Bos *(2021)*

Land use in project area	2015 (Baseline)	2021	2030	2050 - 2100
Mangrove area	310 ha	442 ha	1034 ha	1070 ha
Aquaculture	6000 ha	5639 ha	4802 ha	3227 ha
Inland fisheries	0 ha	238 ha	737 ha	1016 ha (2050) – 1840 ha (2100)

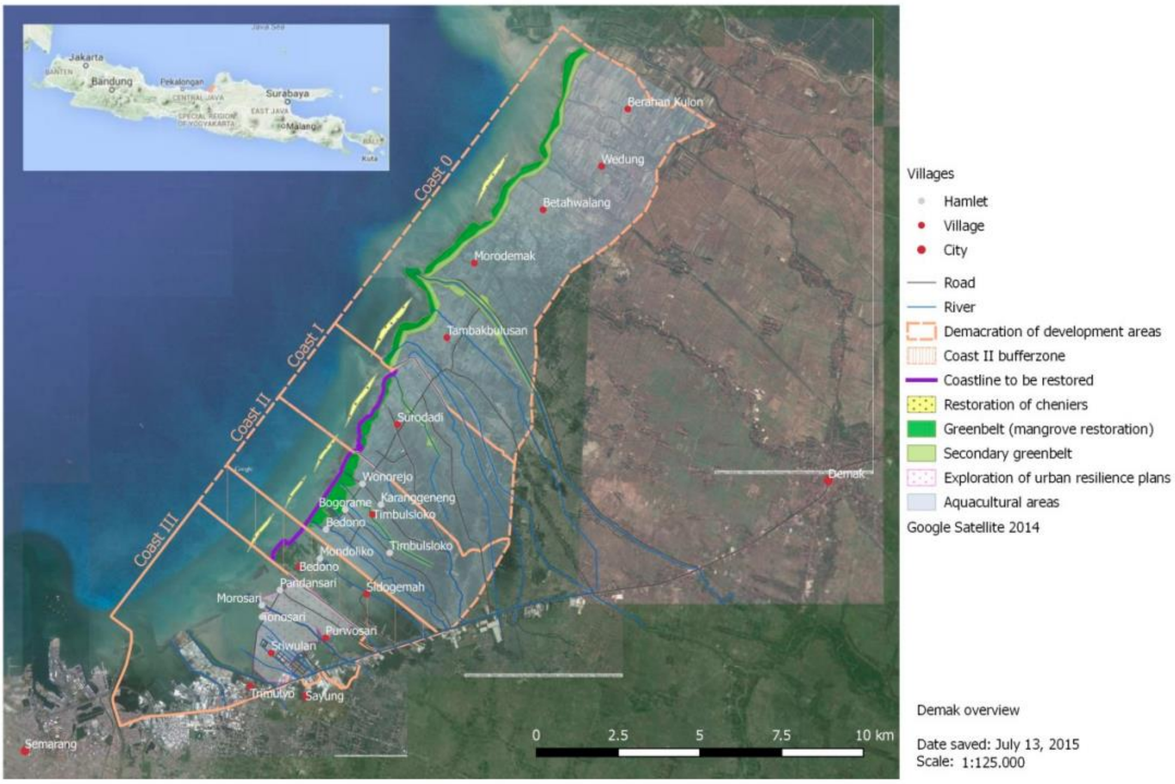
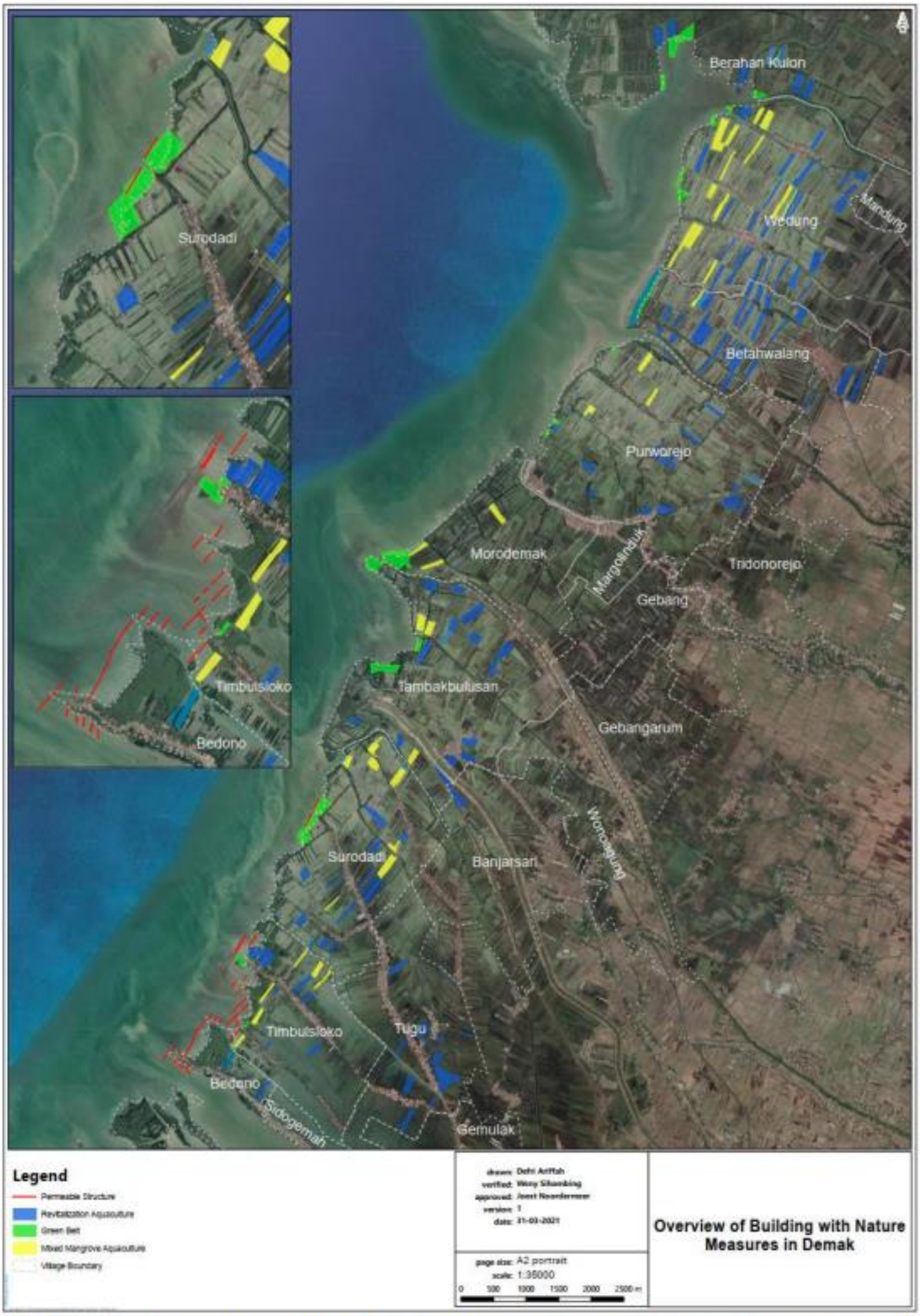


Figure 18. Complete project area design overview. Retrieved from Tonneijck et al. (2015).



Note: Green belt in the legend refers to coastal greenbelt; mixed-mangrove aquaculture refers to riverine greenbelt. These initiatives involved mangrove restoration.

Figure 19. More specific project design overview of a part of the project area. Retrieved from Lestari (2021).

2. Business as usual

In the business-as-usual scenario, it is expected that the erosion will continue to go further inland and will potentially damage the important highway 1, which connects Semarang with Demak. The other grey measures, such as breakwaters and seawalls that are installed, only increased the erosion problem (Tonneijck et al., 2015). Furthermore, the land subsidence will continue as no alternative water source is used, which will cause more severe floodings and eventually the whole area will end up below sea level. Destroying all economic activity in the area, except possibly for limited amount of fishing (Table 8).

Table 8. Predicted area sizes for BAU scenario. Adapted from Witteveen & Bos (2021)

Land use in project area	2015 (Baseline)	2021	2030	2050 - 2100	Source
Mangrove area	310 ha	146 ha	56 ha	0 ha	W&B report
Aquaculture	6000 ha	5879 ha	5422 ha	3920 ha (2050) – 3335 ha (2100)	Barbier (2003)
Inland fisheries	0 ha	0 ha	0 ha	0 ha	Barbier & Strand (1998)

7.3 SCBAs for Demak

1. ES benefits

Following the ranking, the first step to estimate the ecosystem service benefits of the BwN scenario is by investigating the food production services. The food production that has a significant role in the area are fisheries and aquaculture. The value that the extra mangrove forest can offer to the community via fisheries, can be quantified using a regression approach formulated by Barbier & Strand (1998). To estimate the correlation of the variables statistically, data from Demak's regional government is used, the calculations can be found in Appendix C.1. Unfortunately, not all data was easy to find, therefore this equation can be quite challenging to use for other locations. Aquaculture profits can be estimated via the equation of Barbier (2003); however, this requires more data to estimate the statistical parameters. Therefore, the increase of aquaculture production can be more difficult to estimate. Unfortunately, even with all the data collected, not all variables were showing the correlation as explained in Barbier (2003; AppendixAppendix C.3.2). Although it might not be the ideal method to predict the change in aquaculture profitability, the results are still estimated (Table 9). The calculations can be found in Appendix C.

The aquaculture yields can be made more profitable when the pond consists for 30% of mangrove forest (Bosma et al., 2016). The sustainable approach of aquaculture in Demak aims to increase aquaculture profits by 50%, this is mainly due to the improved water purification and nutrient availability that mangroves offer (Tonneijck et al., 2015). So, no additional fertilizer and chemical water cleaners n to be bought, as it is produced by the ecosystem/farmers themselves (i.e., manure and liquid compost; Bosma, 2018). Still, it is assumed that farmers will eventually have higher operational costs, though, the production will increase significantly so eventually it will be more profitable to use LEISA measures (income is expected to increase by 3 to 6 times the current level; Bosma, 2018). However, as a big part of the aquaculture gains is also based on education measures for local farmers, this benefit is described further in the other benefits section.

The coastal protection of the mangroves in Demak can be measured in two ways. One way is to find out what the costs were for the already implemented structural coastal defenses. The other way is to apply the avoided costing method, where the value of the area that will be lost is measured. It can be argued on how this should be valued. A simple method is to estimate the economic activity, or GDP, in the area that is potentially lost, by multiplying the GDP per capita with the number of inhabitants. Other specified methods, which is for example used by Deltares, need more data (Mahya et al., 2021). Tangible asset values of the area itself are calculated, and the expected loss is used to see how much the assets are damaged. Examples of more direct economic damage can be damage to infrastructure and buildings. Examples of indirect damage are increased flood risk and erosion damage of land, which cannot be sold anymore (Mahya et al., 2021). However, these direct and indirect valuation do not assess the impact that a flood has on the local economy, only the assets. The impact on the local economic activity can be estimated by multiplying the GDP per capita with the inhabitants of the area (assuming that GDP and Population do not change over the years compared to the baseline).

Table 9. Overview of all ecosystem benefits that are expected in the BwN scenario.

BwN scenario		2020	2030	2100	Sources
Food production					
	Fisheries	11,416,496 USD	64,174,547 USD	65,731,342 USD	Barbier & Strand (1998)
	Aquaculture	21,277,507 USD	118,752,739 USD	121,629,057 USD	Barbier (2003)
Coastal protection				1,203,576,647 USD	World Bank & census data

For the business-as-usual scenario, it is expected that in 2100, almost all coastal area of Demak regions is lost due to erosion. This means that all economic activity (except perhaps fishing) in the area will be lost. Moreover, since the hard infrastructure that normally protects the shoreline is ineffective, it cannot help the area stop erosion. Therefore, the current mangrove ecosystem will decline further in the future and not supply the area with ecosystem benefits anymore. The losses are described in Table 10, and are calculated the same way as the ecosystem benefits of the BwN scenario.

Table 10. Overview of all ecosystem benefits that are expected in the BAU scenario.

BAU scenario		2020	2030	2100	Sources
Food production					
	Fisheries	3.66 USD	5.67 USD	6.93 USD	Barbier & Strand (1998)
	Aquaculture	-26,021,950 USD	-40,403,541 USD	-49,352,087 USD	Barbier (2003)
Coastal protection				0 USD	World Bank & census data

2. Other Benefits

When considering the attacking poverty framework, we can identify that the BwN project will offer opportunities for the local community to get educated on aquacultural practices. This education enforces the local human capital which increases their wellbeing; therefore, it can be seen as benefit. Education on practicing sustainable aquaculture using LEISA will improve financial profits (Widowati et al., 2021). It is estimated that, although an investment is needed and operation costs are high, the income will at least double if adopted correctly, and become 22 million IDR per hectare per year (Bosma, 2018). If all ponds were to implement this technique, the total income of all the aquaculture farms combined would come down to 9,273,328.45 USD per year. However, the amount of aquaculture area will decrease in the future. In the BwN scenario, the amount of agriculture farms will decline, which has a negative effect on the fish profits. It is expected in the BwN scenario that the aquaculture area will gradually decrease to 3227 ha in 2100, a loss of 2773 ha compared to the baseline. This comes down to a decline of around 4,285,823.30 USD for that year. Therefore, the benefits per year differ based on how many ponds are functioning. Other benefits are extra wages that are paid to implement the project.

3. Costs

The costs that the local inhabitants of Demak will experience can also be described as negative benefits/impacts. So, for the BAU scenario, this includes the negative benefits estimated in the ES benefits part. Furthermore, it also includes all the costs/damages that will occur when the area is eroded away. In the end, if in the BAU scenario all land is eroded away, it will lead to a loss of 1,203,576,647 USD (the current GDP in the area) at minimum. For the BwN scenario, the costs of the implementation of the project are not relevant for the local community. Therefore, they are not included in the costs section. However, in the hypothetical situation where local employees will end up earning less than they would while practicing their conventional labor, the loss of income would be considered a cost.

4. Unconsidered factors

A not considered benefit is the labor costs of locally sourced employees, who are hired to work on the project. They are not considered in this SCBA as I assume that the labor is done voluntarily. Although, the expected labor caused by the dynamic management of the BwN project should be looked further in depth.

5. Key indicators

Now that all the expected costs and benefits are indicated the NPV, and IRR can be calculated. For the NPV, the discount rate should be assessed. For the IRR, the NPV should be set to zero. The BCR of the BwN scenario could not be calculated as the costs were already included in the net profit benefits, and no separate costs could be found. For the BAU scenario, the BCR will become zero as in the end all economic activity is diminished, with high costs as consequence. The NPV is calculated with the 7.5 % discount rate that is assessed by RVO (2021). The NPV for the BwN scenario will be $ 485,547,896.90 and the NPV for the BAU scenario is -$ 2,574,863.98. This number can however change if more specific information about all costs and benefits are available. The IRR could unfortunately not be specified.

7.4 Results of Demak SCBAs

1. Overview all costs and benefits

Table 11. Overview of the SCBA. It uses the estimated ecosystem benefits of the fisheries and coastal protection; however, the predicted LEISA aquaculture income was used instead of the Barbier (2003) equation. For the BAU scenario, I used the local GDP as damage since the local economy would be destroyed by 2100 due to erosion.

BwN scenario	**2020**	**2030**	**2100**	**Sources**
Fisheries	11,416,496 USD	64,174,547 USD	65,731,342 USD	Barbier & Strand (1998)
Leisa aquaculture	9,273,328.25 USD	8,525,202.68 USD	4,285,823.30 USD	(Bosma, 2018)
Coastal protection			1,203,576,647 USD	World Bank & census data
BAU scenario	**2020**	**2030**	**2100**	**Sources**
Erosion			-1,203,576,647 USD	World Bank & census data

In the overview of the SCBA uses the estimated ecosystem benefits of the fisheries and coastal protection, however, I used the predicted LEISA aquaculture income. For the BAU scenario, I used the local GDP as damage since the local economy would be destroyed by 2100 due to erosion.

2. Distribution costs and benefits among stakeholders

For the BAU scenario, the entire population should be relocated to a safe space, this will add to the costs that are already assessed.

In the BwN scenario, all inhabitants benefit from the fact that erosion will be stopped, and they will not lose their home. Moreover, 85% of all inhabitants are aquaculture farmers, it is expected that almost all will benefit the BwN project. However, the aquaculture farmers that are expected to convert their farm to mangrove forest should be compensated. Further, no costs and benefits need to be distributed.

3. Final results

When comparing all the costs and benefits of the BwN scenario and the BAU scenario, the BwN scenario is more beneficial for the local community. The BwN scenario has a positive NPV and the BAU scenario has a negative NPV. Thus, the BwN scenario will add value to the local community while the BAU scenario will negatively impact the economy. This means that the local stakeholders should be educated on the benefits of the BwN project, so they can decide with more confidence to implement the BwN project.

There are some limitations, for example, the data was not really clear for the ecosystem service analysis. Consequently, the regression to estimate aquacultural benefits unreliable. Moreover, not all ecosystem services that were ranked are valued.

8 Discussion, Conclusion & Recommendation

The framework offers a complete and detailed approach on how to perform a SCBA in different projects. The area description was straightforward to perform and did not require too much effort. It provided many insights of the local situation and a clear baseline on which the scenarios can be designed. A big part can be done by performing spatial data analysis to estimate different land uses and combined with literature about the local statistics that is available will give a clear oversight from a desktop perspective. Nevertheless, if there is a possibility to go to the project area to verify the gathered data, the dataset can be updated with more specific local knowledge and increase the accuracy. Hence, this will give a more realistic insight in the data. To predict the future effects that the proposed scenarios, BwN and Business-as-usual, will have on the baseline, the change in variables need to be clearly defined. This requires a clear design plan for the area to be made for the BwN scenario, where all changes in spatial variables are specified. In addition, the information about the historic trends must be used to predict future variable values for the BAU scenario. For the approach to work, much data must be gathered to more accurately predict the real costs and benefits. However, this might be difficult as in many areas data is lacking. Especially in less developed area, the number of reliable studies performed will be low, as they might be very costly and will not benefit the area directly. In such cases, it will not be possible to use the proposed regressions for ecosystem service quantification since they only function when sufficient and accurate data is available. Consequently, alternate approaches like benefit transfer method can be used. The benefit transfer method is easier to apply if a comparable study can be found in a database like TEEB (2010). The tradeoff is that the error of the studied ecosystem service value is also transferred and added with the error on how the value will fit the indicated ecosystem (Plummer, 2009). Therefore, the value will be more like a rough estimate compared to the other valuation methods and should be used only when the other methods fail to function properly. So, depending on which level you perform the SCBA, it can change the accuracy of the ecosystem service valuation methods. If you want to perform a quick scan in the scoping phase or during a feasibility assessment, you can use benefits transfer method to guesstimate the total ecosystem value. However, when you are in the implementation phase, you should research the required parameters to give a more accurate total ecosystem value (Plummer, 2009). Depending on how these parameters are estimated influence the precision of the specific key parameters that can be calculated, and how realistic the comparisons are.

To conclude, I think this framework can be a powerful addition when a Blue Carbon or BwN project will be conducted by Boskalis. It provides a complete overview on what and how a SCBA should be performed, based on scientific literature, in a way that everyone is able to implement it. Depending on the depth of the research, the SCBA requires more data. This will impact the ability to perform the SCBA as a desktop study, however, improve the accuracy of the ecosystem values stated. Hence, I suggest that the scoping level should be considered when interpreting the results of the SCBA, as it will heavily influence the precision of the SCBA outcomes. I expect that the SCBA framework will be most effective when the data is sourced in a field study. There, pricing methods like the contingent valuation method will be easier to execute.

Further additions to this framework can include a more specialized risk assessment methodology and less data intensive but more precise valuation methods for ecosystem services. Moreover, a more explicit strategy on how local stakeholders can benefit from BwN and Blue Carbon projects can be developed and included. Last, more case studies could be performed to test the SCBA frameworks effectiveness, for instance where the framework is used in a field study.

9 Self-reflection

At the start of the internship, I was especially interested in mangroves ecological properties, and how they could be considered more often in coastal developments. I was already familiar with companies that aim to do this. Such as Boskalis, that contributes to consortia such as Ecoshape which focus on using more nature in their coastal designs. Therefore, I saw it as a great opportunity to do my business internship here. At Boskalis I wanted to gain more knowledge about the steps towards application and implementation of building with nature projects, especially related to mangrove forests. As I argued that, for example, the discrepancy between mangrove reforestation for coastal protection, compared to the implementation of gray coastal measures, was mostly caused by the undervaluation of mangrove forest. I wanted to learn if and how the importance of ecosystems can be valued fairer in decision making processes, for example by monetizing the value of a mangrove forest for a community. By doing this, I aimed to find out if building with nature projects can be a competing alternative to gray infrastructure. And especially at Boskalis I wanted to learn how companies are trying to implement BwN and other nature-based solutions in their business strategy. On a more personal level however, I would also like to become more proficient in QGIS and other software programming.

I did not have the knowledge on how a SCBA frameworks typically looked like and what aspects it includes. I was only vaguely familiar with a normal cost benefits analysis (CBA). During this internship, I learned how ecosystem services quantified, so they can be included in a CBA to have a more realistic view of the value of the ecosystem. Moreover, I also became more proficient QGIS as I challenged myself to work more with the program. This ended up being particularly useful for the Blue Carbon project that is currently developed.

During the internship, my biggest challenge was to quantify the value of the mangroves during the case study. Even though relatively much data of the region was available. It still proved difficult to make a reliable regression of the data, where I was confident about its accuracy. Therefore, I eventually concluded that data availability can be a strong limiting factor for the SCBA framework, and that perhaps other methods should be investigated more deeply when you want to perform a desktop study.

I was allowed to join meetings on the implementation of Blue Carbon projects with external partners. From this collaboration I learned a lot about strategy that a company has in project development. For example, there is a Boskalis collaboration with Wetlands International and Permian Global. The consortium wanted to find out if a partnership with another company, would be beneficial in their Blue Carbon strategy. Therefore, they invited other company for an introduction meeting to find out how the companies could add value to each other’s Blue Carbon strategy. There, it was very interesting how the companies aimed to learn from each other without giving away sensitive information about the company’s future plans. As they spoke about how they could hypothetically collaborate and expand the existing project, while keeping in mind that they don’t want to share the profits between too many partners. After the meeting, the meeting was analyzed to try to figure out if and how this collaboration would improve the current Blue Carbon plan when also collaborating with another company. This made me realize how strategically layered such meetings can be, which I think is very interesting. Moreover, during department meetings and when walking around in office, I thought it was very interesting to hear what everyone was doing and how they handled their tasks. The level in which people collaborated and the questions that were asked helped me also to think more thoroughly of the work I was doing myself.

I think what I did well was that I started to draft this report from the start of the internship. By updating the report frequently, I managed to have a complete report without too much deadline stress. Especially since I made a planning which I also updated regularly, to keep an eye on the progress. It helped that I went to office as much as I was able to, as I noticed that it had a positive influence on my efficiency. In addition, by going to office often it really helped me create a bond with coworkers, which helped my personal network expand.

Nevertheless, there are some aspects that can be improved. An example is that sometimes I am too stubborn in trying to solve a problem, while it might be helpful to start doing something else for a little while, so your mind is distracted from that problem. This way, you keep making progress, and as your mind is not continuously focused on the problem, the solution often pops up later by itself. If the solution does not pop up, you can always ask other people how they would approach the problem and learn from their strategy and solution. Further, when listening to other people's feedback, I learned to ask for more follow up questions until it was completely clear for me, even if I thought I understanded the feedback sufficiently, it is always good to verify with additional questions to ensure that you are on the same line.

The internship had many connections with the FBE courses. For example, with the course Strategic Management of Innovation, where the IRR and NPV are used as project selection tools in key innovation strategy areas. These key parameters are also used in the SCBA framework to select for the most beneficial scenario. Another example is the overlap with the course operations management, where linear regressions (a casual forecasting method) is used as forecasting method to predict future values. There is also connection with the internship of the first year. Then, the subject was about the value of mangroves based on their effort to avoid damage during cyclones. So, I tried to find a correlation between their ecosystem service coastal protection and cyclone damage. In this SCBA, I also wanted to quantify ecosystem services by, for example, looking at avoided damage.

I do not think that I would act hugely different in my first job. However, I think my mindset on how I approach new assignments will be more professional. I now want to have a more in-depth approach when I am working on assignments and help other members of the team by trying to ask more in-depth questions. Also, by thinking on how an assignment should add value and fit in the business model (i.e., is it part of the core business) is a particularly important aspect to consider, more than I initially thought. Therefore, I also want to include that too when working on an assignment.

To conclude, I believe I performed well during the internship. I think a was a great fit for the internship based on my previous experience of my research project and the FBE courses. I also learned a lot about the companies practices internally and also how they collaborate with external parties during project development. I learned a lot to have a more professional mindset, that I will definitely take with me in my first job. I think that I reached the goals that I set for myself in the beginning of the internship and therefore conclude that it was a successful internship.

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Appendix

Appendix A Decision making models.

Appendix A.1 Contents

Appendix A.2 Delphi method

In the Delphi method, first between 10 and 18 experts must be assigned by the researcher. The group of experts must have a complete image of all the relevant information of the study area (Okoli & Pawlowski, 2004). Second, brainstorm or ask the experts what factors in the study area should be considered in the questionnaires. After all the questions and experts are decided upon, the scale of the questionnaire answers must be determined to give a generalized score for the different factors, for example 1-5 (very unimportant to very important; Figure 20) or 1-7 (Extremely unimportant to Extremely important; Habibi et al., 2015; Musa et al., 2015). Third, the questionnaires should be distributed to the experts, and the answers should be analyzed to find if there are consensus between the experts about the factors (Musa et al., 2015). If no consensus is found, another round of questionnaires is needed where the answers are revised until a consensus is found (Musa et al., 2015; Okoli & Pawlowski, 2004). There are different methods to understand if there is a consensus between the experts, the main method is Kendall's W (coefficient of concordance; Okoli & Pawlowski, 2004). In this method, 0 is no consensus, 0.7 is a strong agreement (the minimum value for an agreed consensus) and 1 is the max consensus (Okoli & Pawlowski, 2004).

Expert 1	How important is:	Very unimportant	Unimportant	Neutral	Important	Very important
Cat1						
Cat2						
Cat3						
Cat4						

Expert ...	How important is:	Very unimportant	Unimportant	Neutral	Important	Very important
Cat1						
Cat2						
Cat3						
Cat4						

Expert 18	How important is:	Very unimportant	Unimportant	Neutral	Important	Very important
Cat1	Fishing		X			
Cat2	Agriculture				X	
Cat3	Aquaculture					X
Cat4	Forestry			X		

Figure 20. Schematic overview of how Delphi method questionnaire could look like.

Appendix A.3 Fuzzy Delphi

In the fuzzy Delphi method, the questionnaire is the same, however, the way the consensus is found is different (Habibi et al., 2015). The answers are still based on a scale, for example a scale of five (very unimportant to very important). These answers are now fuzzified and become fuzzy numbers. One way to fuzzify the answers is making them triangular fuzzy numbers, where the answer will be rewritten in their minimum (l), mean (m) and maximum (u) value as follows [l; m; u]. For example, neutral will be written as fuzzy number [0.25, 0.5, 0.75] (Figure 21).

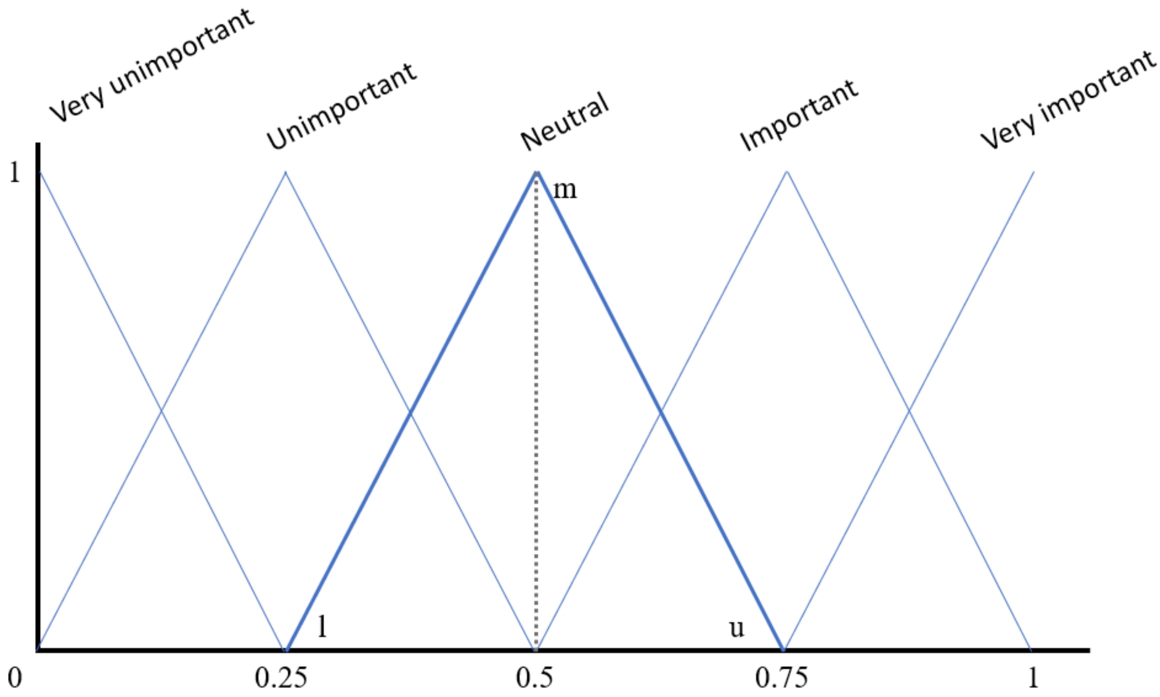

Figure 21. Example of a 5-point scale for triangular fuzzy numbers.

Other distributions (such as a gaussian distribution) can also be used to fuzzify inputs.

After that, the fuzzified numbers are aggregated per category. There are multiple aggregation methods, the simplest is fuzzy average. In fuzzy average, the fuzzy numbers are summed and divided by the number of answers (n) to make a fuzzy average per category (cati).

$$\frac{\sum l_{cati}}{n}, \frac{\sum m_{cati}}{n}, \frac{\sum u_{cati}}{n} = [l_{cati}, m_{cati}, u_{cati}]$$

To give a value to the category, the crisp value of that category is calculated by summing the fuzzy numbers and dividing it by three.

$$\frac{l_{cati} + m_{cati} + u_{cati}}{3} = Z_{cati} = \textit{Crisp value cat i}$$

These crisp values can be compared for the different categories so a ranking can be made.

Appendix A.4 Analytical hierarchy process (AHP)

Analytical hierarchy process (AHP) is a more elaborate process, which involves many different matrices to produce a ranking for the different criteria. A questionnaire is constructed where the relationship about the importance on the decision-making process of one factor is with the other factors is expressed by a ratio. For example, you want to define the ratio between factor X with factor Y. When you estimate that factor X is three times more important in the decision-making process than factor Y, the ratio will be 3. The scale in which AHP inputs are mostly recorded is the Saaty scale (1 for equally important to 9 for extreme importance). The results of the questionnaires are written down in a pairwise comparison matrix (Table 12).

Table 12. An example of a pairwise comparison matrix, which show the ratio of the importance in the decision-making process (weight) between all experts.

Expert ranking	Expert 1	Expert 2	Expert 3	Expert 4
Expert 1	1	3	7	2
Expert 2	1/3	1	5	1/2
Expert 3	1/7	1/5	1	3
Expert 4	1/2	2	1/3	1
SUM	SUM1	SUM2	SUM3	SUM4

After the pairwise comparison matrix is done, the scores should be normalized by dividing them by the column total (SUM1 to SUM4) and rewritten in the normalized pairwise comparison matrix (Table 13). The estimated averages will be used as the weight of each expert's estimation.

When you multiply the input values with their respective criteria weights (CW), and sum these values per row, you get the weighted sum values (WSV) for the different factors. These can be used to check the consistency of the inputs. By dividing the WSV with the corresponding CW you get the principal eigenvalue (λ). When you take the average of all principal eigenvalues you get the λ_{max}. With the λ_{max} you can calculate the consistency index (CI). When you divide the CI with the Random Index (which is a standard index when using the Saaty scale), you get the consistency ratio. When the consistency ratio is lower than 0.10; the AHP inputs are consistent.

$$\frac{WSV_i}{CW_i} = \lambda_i$$

$$\frac{\lambda_{max} - n}{n - 1}) = CI$$

Table 13. Normalized pairwise comparison matrix, where the values of Table 12 are divided by the column total and the rows are averaged. When the table is normalized correctly, the sum of all averages should be 1.

Normalized expert ranking	Expert 1	Expert 2	Expert 3	Expert 4	Average
Expert 1	1 /SUM1	3 /SUM2	7 /SUM3	2 /SUM4	AV1
Expert 2	1/3 /SUM1	1 /SUM2	5 /SUM3	½ /SUM4	AV2
Expert 3	1/7 /SUM1	1/5 /SUM2	1 /SUM3	3 /SUM4	AV3
Expert 4	½ /SUM1	2 /SUM2	1/3 /SUM3	1 /SUM4	AV4
Total					1

When you have multiple experts score the importance of different categories, these values should also be expressed in a pairwise comparison matrix (Table 14). The matrices should be normalized in the same manner as discussed above, and the averages should be calculated too.

Table 14. An example of pairwise comparison matrices for multiple categories scored by multiple experts.

Expert 1	Cat1	Cat2	Cat3	Cat4

Expert …	Cat1	Cat2	Cat3	Cat4

Expert 18	Cat1	Cat2	Cat3	Cat4
Cat1	1	3	7	2
Cat2	1/3	1	5	1/2
Cat3	1/7	1/5	1	3
Cat4	1/2	2	1/3	1

To combine all the inputs, the matrix will use the expert averages (ratio between experts normalized and averaged per row) as weights. Next, the average scores for the categories per expert (i.e. the row of Cat1 averaged → Exp1Av1 and so on) are multiplied with the expert weight (i.e. AV1 and so on) and afterwards summed to determine the final value of the categories (i.e. Score1 etc.; Table 15).

Table 15. A schematic example of the process of AHP, visualized in all the matrices.

Expert ranking	Expert 1	Expert 2	Expert 3	Expert 4
Expert 1	1	3	7	2
Expert 2	1/3	1	5	1/2
Expert 3	1/7	1/5	1	3
Expert 4	1/2	2	1/3	1
SUM	SUM1	SUM2	SUM3	SUM4

Expert 1	Cat1	Cat2	Cat3	Cat4
Cat1				
Cat2				
Cat3				
Cat4				
SUM				

Expert ...	Cat1	Cat2	Cat3	Cat4
Cat1				
Cat2				
Cat3				
Cat4				
SUM				

Expert 18	Cat1	Cat2	Cat3	Cat4
Cat1	1	3	7	2
Cat2	1/3	1	5	½
Cat3	1/7	1/5	1	3
Cat4	1/2	2	1/3	1
SUM	Sum1	Sum2	Sum3	Sum4

1. Divide value of expert ranking (or category) with the sum of the column to normalize the expert value.

Normalized expert ranking	Expert 1	Expert 2	Expert 3	Expert 4	Average
Expert 1	A1	A5	A9	A13	AV1
Expert 2	A2	A6	A10	A14	AV2
Expert 3	A3	A7	A11	A15	AV3
Expert 4	A4	A8	A12	A16	AV4
Total					1

Expert 1	Cat1	Cat2	Cat3	Cat4	Average
Cat1					
Cat2					
Cat3					
Cat4					
Total					

Expert ...	Cat1	Cat2	Cat3	Cat4	Average
Cat1					
Cat2					
Cat3					
Cat4					
Total					

Expert 18	Cat1	Cat2	Cat3	Cat4	Average
Cat1	B1	B5	B9	B13	Exp18Av1
Cat2	B2	B6	B10	B14	Exp18Av2
Cat3	B3	B7	B11	B15	Exp18Av3
Cat4	B4	B8	B12	B16	Exp18Av4
Total					1

2. Take the average of the rows. For the experts, these will be the weights; for the category, these will be the value. The sum of the averages in the matrix must be 1.

Expert scores	Weights	Cat1	Cat2	Cat3	Cat4
Expert1	AV1	Exp1Av1	Exp1Av2	Exp1Av3	Exp1Av4
Expert2	AV2	Exp2Av1	Exp2Av2	Exp2Av3	Exp2Av4
Expert3	AV3	Exp3Av1	Exp3Av2	Exp3Av3	Exp3Av4
Expert4	AV4	Exp4Av1	Exp4Av2	Exp4Av3	Exp4Av4
...	...	...	...	...	...

Ranking	Cat1	Cat2	Cat3	Cat4
Expert1	W1	X1	Y1	Z1
Expert2	W2	X2	Y2	Z2
Expert3	W3	X3	Y3	Z3
Expert4	W4	X4	Y4	Z4
...	...	...	...	...
Total	Score1	Score2	Score3	Score4

3. By multiplying the average of the normalized expert ranking with the average of the values they gave for the distinct categories; their ranking can be visualized. By summing these scores for all the different experts, the final score for each category can be calculated.

Appendix A.5 Fuzzy AHP

With fuzzy AHP, the process is similar to regular AHP, only the numbers are fuzzified again when they are put into the matrices (Figure 22). The scaling of the numbers however is different, for example the Saaty scale that is often used with AHP differs from the scaling that is used with fuzzy Delphi (Figure 23). Moreover, in the fuzzified matrices, it is important to keep the lowest value (l), the mean value (m) and the highest value (u), even after normalization. So, it might be necessary to the order.

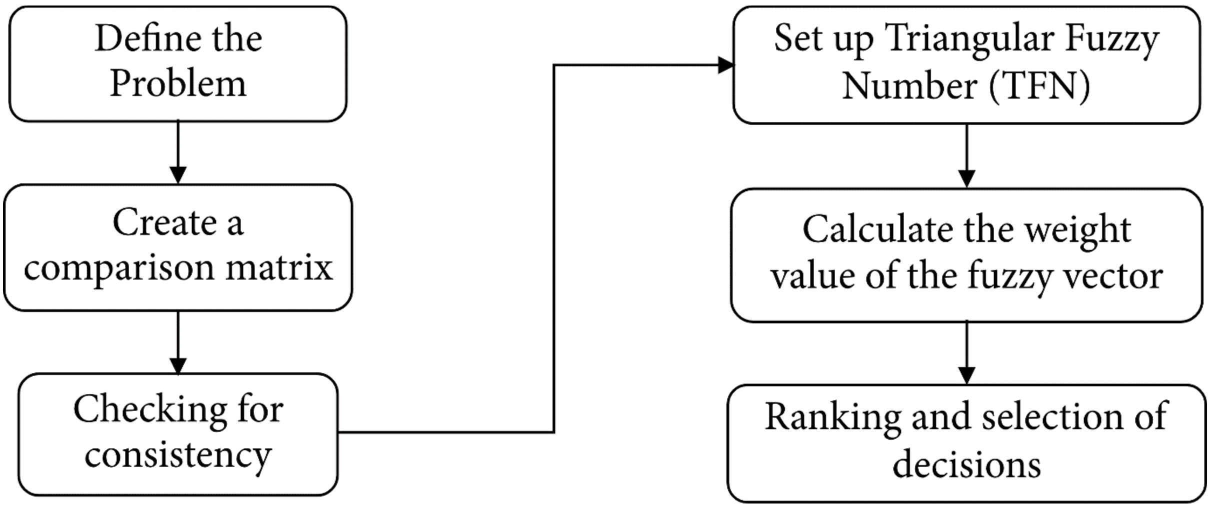

Figure 22. Flowchart of fuzzy AHP process. Retrieved from Putra et al. (2018)

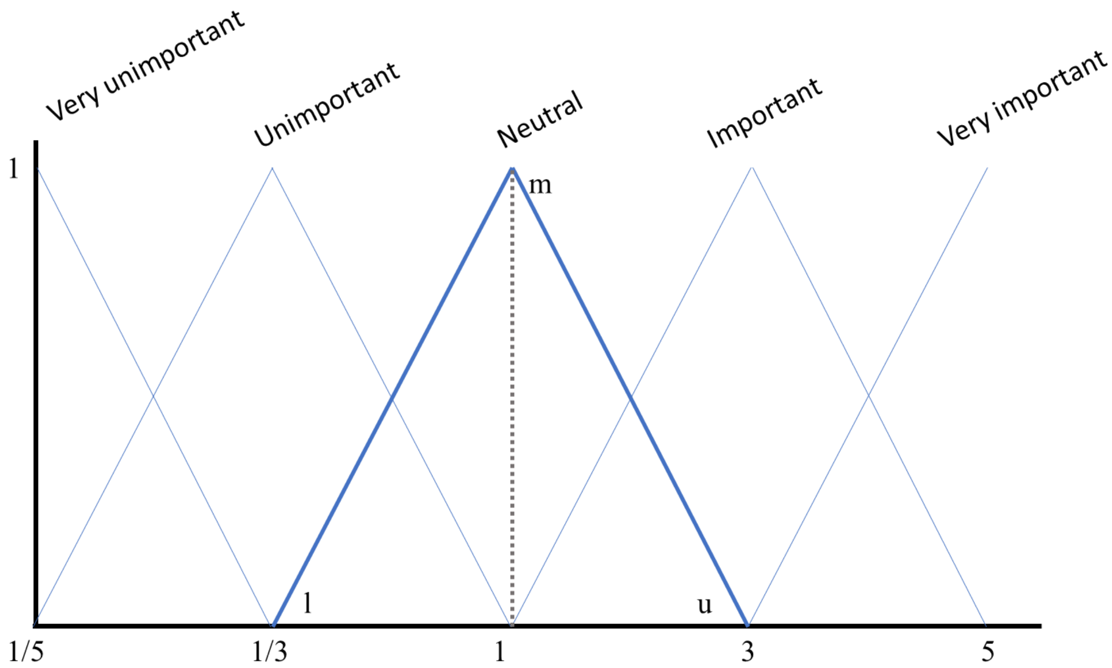

Figure 23. Example of a scale that can be used with fuzzy AHP.

Appendix A.6 References

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Appendix B Equation sheet Bioeconomic Models

Appendix B.1 Contents

Appendix B.2 Mangrove Fishery linkages

There are multiple bioeconomic models that aim to predict the influence of mangrove are on fish stocks and production (Barbier, 2000). Most of them are built on older models, such as the Schaefer-Gordon model (standard bioeconomic model for the fishing industry) or the Cobb–Douglas production function (which describes the production that is dependent on multiple parameters) (Conrad et al., 1984).

Appendix B.2.1 Cobb-Douglas production function (1928)

The equation calculates the harvest (h), that is dependent on the productivity factor (A), effort (E) and wetland area (S) and their output elasticities respectively (a and b).

$$h = AE^{a}S^{b}$$

Appendix B.2.2 Schaefer-Gordon model (1954-1957)

The production function looks similar to the Cobb-Douglas model, as it models the harvest (h) too. However, it is dependent on catchability (q), fish stock (X) and effort (E) at a certain moment in time (t).

$$h_t = qX_tE_t$$

Appendix B.2.3 Barbier & Strand (1998)

This open access fishery model is based on the Schaefer-Gordon model. Its estimates the population change, by subtracting the harvest from the population growth. The fish stock (X), mangrove area (M) and fishing effort or amount of standardized fishing vessels (E) are used to estimate the population growth (F) and harvest (h).

$$X_{t+1} - X_t = F(X_t\,; M_t) - h(X_t\,; E_t);\ for\ \mathrm{F}_X > 0\ \&\ \mathrm{F}_M > 0$$

The equation to estimate the fish stock change or amount of effort (vessels) change is:

$$\mathrm{X}_{t+1} - \mathrm{X}_t\ =\ [\mathrm{r}(\mathrm{K}(\mathrm{M}_t) - \mathrm{X}_t) - \mathrm{qE}_t]\,\mathrm{X}_t$$

$$E_{t+1} - \mathrm{E}_t\ =\ \phi[\mathrm{p}h(\mathrm{X}_t\,;\ \mathrm{E}_t) - \mathrm{cE}_t]$$

where r is the intrinsic growth rate of the fish (species) and K is the carrying capacity of the system, ϕ is the adjustment coefficient, p is the price per unit and c is the cost per unit effort. The mangrove carrying capacity $K_m>0$.

The equation for a **steady state** is when there is no change in effort fish stock or no profit in the long run. (Similar to the Lotka-Volterra predator prey model)

$$X = \frac{c}{pq};\ for\ E_t = E_{t+1}$$

$$\mathrm{E} = \frac{\mathrm{r}(\mathrm{K}(M) - \mathrm{X})}{q};\ for\ X_t = X_{t+1}$$

To show how the system behaves in a steady state, the relations are visualized in a graph.

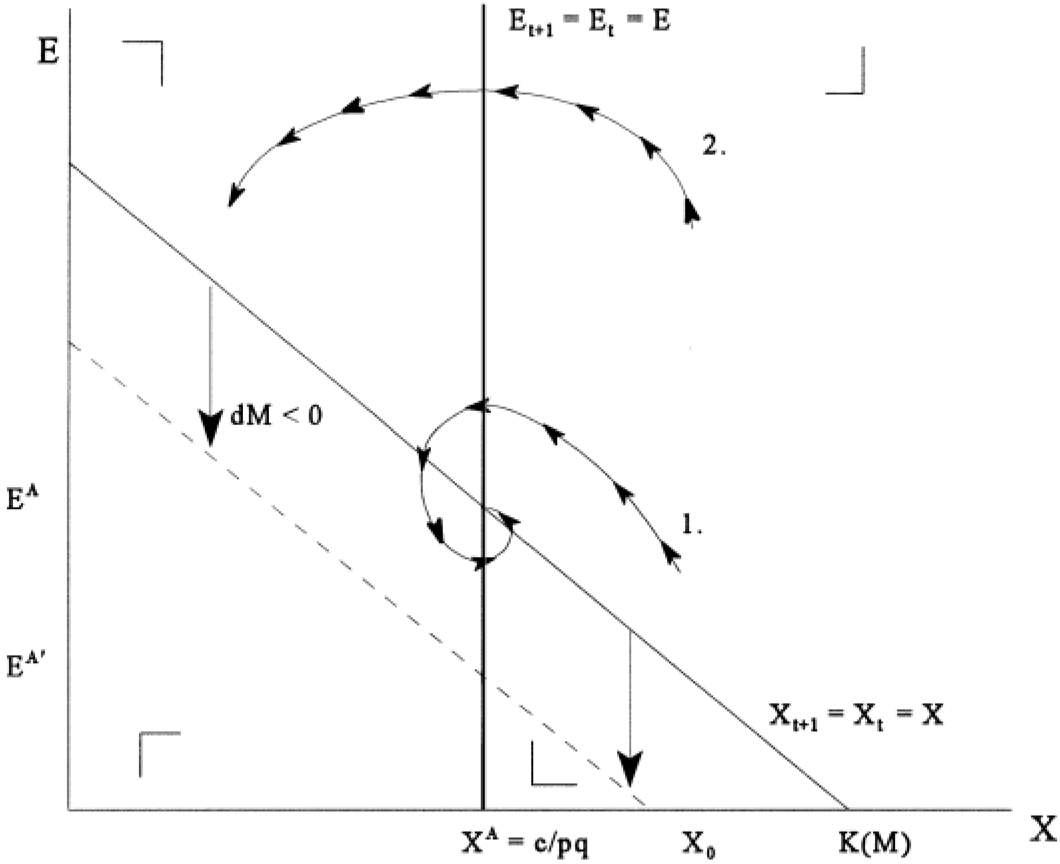

Figure 24. The system will balance itself where the two steady state formulas (isoclines) meet in the graph (stable equilibrium). The carrying capacity is dependent on mangrove area, consequently when mangrove area decreases, the fish stock (and its isocline) will decrease too. Retrieved from Barbier & Strand (1998)

Mangrove area influences the carrying capacity of the area, so when mangrove area changes, the carrying capacity changes too. To understand how much the mangrove area influences the fish stock, the carrying capacity parameter (K(M)) should be substituted by a mangrove area parameter (M). The value for the relationship between mangrove area and carrying capacity is defined as α.

$$K(M) = \alpha M;\ for\ \alpha > 0$$

To be able to model the change in mangrove area the equation above is implemented into the steady state equations. The following equation comes up to predict the equilibrium when the level of fishing effort is still at equilibrium is assumed, where the delta (d) shows that the values can change, and E^A is the equilibrium fishing effort level.

$$0 = [\mathrm{r}(\alpha\mathrm{dM} - \mathrm{dX}) - \mathrm{qd}E^A]\ or \frac{dE^A}{dM} = \frac{\alpha r}{q} > 0$$

To monetize the impact of mangrove area, mangrove area is linked to the harvest at equilibrium level. To find out the revenue, the harvest is also multiplied by the price per unit.

$$dh^A = qX^A dE^A = \alpha r X^A dM = \frac{\alpha rc}{pq} dM > 0$$

$$pdh^A = \frac{\alpha rc}{q} dM > 0$$

Summarizing, the relation of mangrove area and carrying capacity is multiplied with the intrinsic growth rate of the fish and the cost of the vessel per unit. Then, it is divided by the catchability and afterwards multiplied with the change in mangrove area. This will give change in amount of harvest in a steady state equilibrium multiplied by the price per unit, in other words, the revenue.

To simplify the equations, some parameters can be estimated by performing a statistical regression over historic data. The data about fishery can be found in multiple FAO databases. So, the formula must be rearranged into a typical regression equation, so that the parameters can be estimated. The equation of the regression can be expressed by combining multiple equations that are mentioned earlier.

$$h = qEK(M) - \frac{q^2}{r}E^2 = q\alpha ME - \frac{q^2}{r}E^2 \rightarrow h = b_1 ME - b_2 E^2$$

The new estimated parameters b_1 (= qα) and b_2 (= $-\frac{q^2}{r}$) can also help rewrite the change in harvest and revenue as a function of the change in mangrove area.

$$dh^A = \frac{arc}{pq}dM = -\frac{cb_1}{pb_2}dM$$

$$pdh^A = \frac{\alpha rc}{q}dM = -\frac{cb_1}{b_2}dM$$

Concluding, when you know the price per unit of fish (p), cost per fishing vessel effort (c), amount of fishing vessels (E), change in mangrove area (dM) and the total amount of mangroves (M); and when you have estimated b_1 and b_2 via a statistical regression of historic data of the harvest (h); Then you are able to model the additional harvest for extra mangroves and new expected revenue (when the price is not elastic).

Appendix B.2.4 Barbier (2003)

When you want to include the price elasticity, an elasticity parameter (ε) has to be included in the equations. The model of Barbier (2003) does this by using the model of Barbier & Strand (1998) and inserting the elasticity parameter as follows.

$$\varepsilon = \frac{p(h)}{p_h h(X,E)}$$

In this formula, the fish price price per unit (p(h)), and p_h is the value of the relationship between price and harvest.

Then the elasticity is inserted in the steady state equation, so the equation from Barbier & Strand (1998) will be further developed:

$$[\mathrm{r}(\alpha\mathrm{dM} - \mathrm{dX}) - \mathrm{qd}E^A] = 0 \; and \; \frac{dE^A}{dM} = \frac{\alpha r}{q} > 0$$

$$\downarrow$$

$$-\mathrm{rdX} - \mathrm{qdE} + \mathrm{r}K_M\mathrm{dM} = 0 \; and \; \frac{dE}{dX} = -\frac{r}{q} < 0$$

$$\downarrow$$

$$\left((1+\varepsilon)qX - \frac{c\varepsilon}{p(h)}\right)dE + (1+\varepsilon)qEdX = 0 \; and \; \frac{dE}{dX} = -\frac{[(1+\varepsilon)qE]}{\left[\frac{c}{p(h)}\right]} \lesseqgtr 0 \; if \; |\varepsilon| \lesseqgtr 1$$

Where K_M is the value of the relationship between mangrove area and carrying capacity

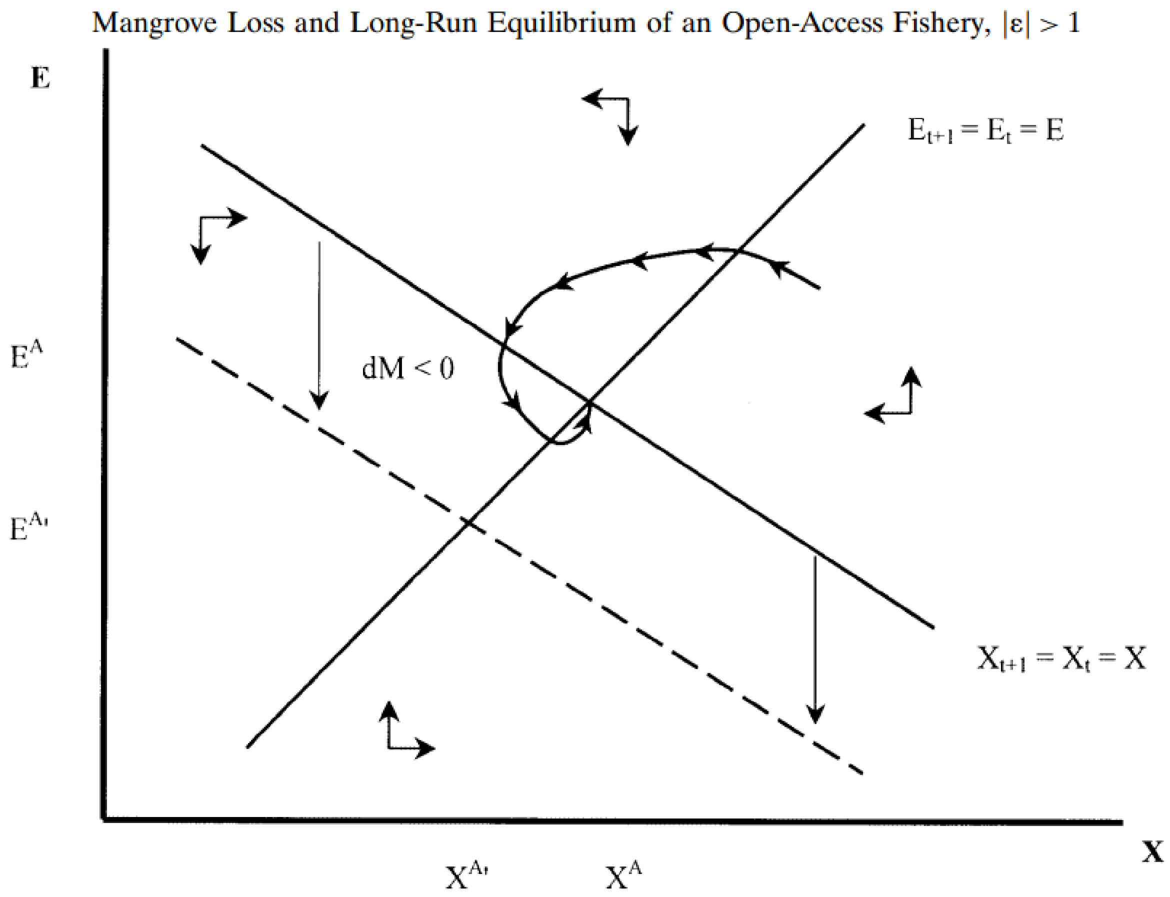

Figure 25 The system will balance itself where the two steady state formulas (isoclines) meet in the graph (stable equilibrium). The carrying capacity is dependent on mangrove area, consequently when mangrove area decreases, the fish stock (and its isocline) will decrease too. Retrieved from Barbier (2003).

The effects that they have are visible in the graph, the isoclines are:

$$\frac{dX^A}{dM} = \frac{rcK_M}{[Dp(h^A)]} = -\frac{rcK_M qX^A}{D} > 0$$

$$\frac{dE^A}{dM} = \frac{[rK_M(1+\varepsilon)qE^A]}{D} \lesseqgtr 0 \; if \; |\varepsilon| \lesseqgtr 1$$

Where D is the discriminant:

$$D = (1+\varepsilon)qE - \frac{cr}{[p(h)]} < 0 \; if \; |\varepsilon| > 1 \; or \; |\varepsilon| < 1 \; and \; \frac{r}{q} > \frac{[(1+\varepsilon)qE]}{cp(h)}$$

Substituting this into the Schaefer-Gordon model will lead to:

$$h^A = qX^AE^A = \frac{rc}{[p(h^A)q]}\left[K(M) - \frac{c}{[p(h^A)q]}\right]$$

The change of mangrove area can be substituted with the carrying capacity when estimating the new harvest equilibrium.

$$\frac{dh^A}{dM} = qX^A\left(\frac{dE^A}{dM}\right) + qE^A\left(\frac{dX^A}{dM}\right) = \frac{\varepsilon h^A rqK_M}{D} = \frac{\varepsilon h^A rq\alpha}{MD}\ if\ D < 0$$

Also, the consumer surplus can now be estimated by an equation.

$$\Delta S = \int_{h^0}^{h^1} p(h)dh - [p^1h^1 - p^0h^0] = \frac{[k\lfloor(h^1)^{\eta+1} - (h^0)^{\eta+1}\rfloor]}{\eta+1} - k[(h^1)^{\eta+1} - (h^0)^{\eta+1}]$$
$$= -\frac{\eta[p^1h^1 - p^0h^0]}{\eta+1}$$

In this equation $p(h) = kh^{\eta},\ \eta = 1/\varepsilon < 0$.

So, the new equation that gives the harvest and is dependent on mangrove area, which can be used in a statistical model is:

$$h = qEK(M) - \frac{q^2}{r}E^2 = q\alpha E\ln(M) - \frac{q^2}{r}E^2 = b_1E\ln(M) + b_2E^2$$

where $b_1 = q\alpha$ and $b_2 = -\frac{q^2}{r}$ in the statistical model. Then the change in harvest equilibrium can be modelled by:

$$dh^A = \left(\frac{\varepsilon h^A b_1}{M\left(-b_2(1+\varepsilon)E^A - \left(\frac{c}{p(h)}\right)\right)}\right)dM$$

Pay attention to what kind of regression you will use to estimate b_1 and b_2, as the effectiveness of the model might differ.

Appendix B.3 Aquaculture

Aquaculture can have benefits from the mangrove forest next to it.

Appendix B.3.1 Barbier (2003)

Barbier (2003) also tried to make a regression model for aquaculture. This model is less complicated than his model for price elastic mangrove fishery linkage but has a lot of parameters that have to be looked up.

$$M_{it} - M_{it+1} = \beta_0 + \beta_1 P_{it} + \beta_2 \omega_{it} + \beta_3 FD_{it} + \beta_4 D_{it} + \beta_5 R_{it} + \beta_6 Y_{it} + \mu_{it}$$

In this regression model M = mangrove area, P = export value ($/Kg), ω = minimal real wage (local currency/h), FD = aquaculture farms in whole area (km^2), D = distance to major city (km), R = interest rate (%) and Y is real per capita gross product (local currency). P can be assessed by multiplying the export value ($/Kg) with the exchange rate (local currency to $).

Appendix B.4 Pharmaceuticals & other uses

Appendix B.4.1 Tri (2002); adapted from Pearce & Puroshothaman

Tri (2002) adapted the equation to calculate the value of the pharmaceutical ecosystem service based on the Pearce & Puroshothaman equation. The species of mangrove that have medicinal use are listed by Bandaranayake (1998).

$$Vp(L) = \frac{NPra\frac{V}{n}}{Hyr^{-1}}$$

The variables in the formulas are:
Vp (L) = The pharmaceutical value of 1 ha of forest (USD ha^{-1})
N = The number of plant species in forests
P = The probability of a "hit"
r = The royalty rate
a = The appropriation rate, or rent capture
V/n = The average value of drugs developed (USD ha^{-1})
H = The area of forest (ha)

Appendix B.4.2 Bandaranayake (1998)

Bandaranayake describes all other non-timber products that can be obtained from a mangrove forest. This includes which food is sourced from mangroves, which mangroves have medicinal uses and other traditional products. The market value of these products can be used to assess the value of these mangrove species.

Appendix B.5 Water availability

Appendix B.5.1 Turpie et al. (1999)

Turpie et al. (1999) suggest that the best method to quantify the water availability is by using the replacement cost method. Then, all the costs of implementing other methods to obtain fresh water, instead using wells that use groundwater. An example of another method to acquire water can be by importing water with trucks. There are some limitations, for example the groundwater level should be balanced and the impact that the mangrove area has on the groundwater level should be assessed. Then, the costs of the current water supply should be compared with the cost of the new water supply. This should be studied by comparing the amount of people that currently rely on groundwater/ the quantity of groundwater that is now used with the costs they can expect when converting to the new water source.

Appendix B.6 Wave attenuation

Appendix B.6.1 Barbier (2007) & Barbier et al. (2008)

Barbier et al. (2008) stated that the marginal protection value of a mangrove forest (MPV in \$/km^2) is linked to the avoided damage in an area, which can be estimated by using the expected damage cost method from Barbier (2007). This method is based on the EM-DAT database model, where al de data is plotted, and a negative binominal model is created. In this model the expected damage (E) is dependent on the economy damaging storm events (Z_{it}), wetland area (S_{it}) and other factors (X_{it}), these variables will give an estimate conditional mean (λ_{it}) with α as parameter for other unobserved effects. When translating the equation to a negative binominal model, the wetland area is substituted by mangrove area (M_{it}) and X_{it} explains for as population density and yearly time trend. To model the parameters values, a statistical regression is performed where the damage (D) is real storm damage data from EM-DAT.

$$E[Z_{it}|S_{it},X_{it}] = \lambda_{it} = e^{\alpha_i+\beta_S S_{it}+\beta' X_{it}} \;, \frac{\partial E[Z_{it}|S_{it},X_{it}]}{\partial S_{it}} = \lambda_{it}\beta_S$$

$$\downarrow$$

$$\ln E[Z_{it}|M_{it},X_{it}] = \ln \lambda_{it} = \alpha_i + \beta_S M_{it} + \beta' X_{it} + \mu_{it}$$

$$\downarrow$$

$$D_{it} = \alpha_i + \beta_S M_{it} + \beta' X_{it} + \mu_{it}$$

Now that we have the MPV, Barbier et al. (2008) made a regression model about the effect of a mangrove forest on wave attenuation. This regression measured the “Proportionate change in wave height at mid-tide as a function of 100 m inshore Kandelia mangrove distance” (Barbier et al., 2008).

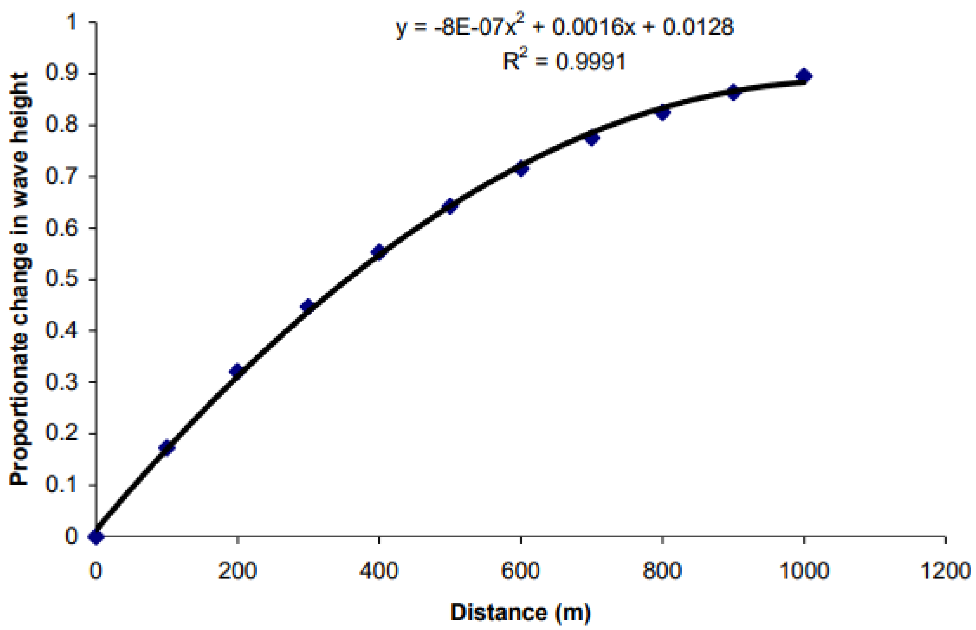

Figure 26. influence of Kandelia mangrove distance on proportionate wave height. Retrieved from Barbier et al. (2008).

The value of coastal protection service of mangroves ($V(M_i)$) is amongst others defined by the proportionate change in wave height ($W(x_i)$).

$$W(x_i) = -8E^{-7}x^2 + 0.0016x + 0.0128$$

$$V(M_i) = V(M_{i-1}) + \left[(MPV) * \left(W(x_i) - W(x_{i-1})\right) * 10\right]$$

Appendix B.7 Sediment trapping

Appendix B.7.1 Ruitenbeek (1994)

The erosion prevention was based on the agriculture production from local farms, which was estimated by conducting a survey. Therefore, when estimating the value of erosion prevention, the local economic output per hectare (or per household) can be multiplied with the erosion rate (and household per ha) to find the value using the avoided cost method. I assume that economic output per hectare will not solely depend on agriculture production, but all the local production in the area (for example including aquaculture etc.).

Appendix B.8 Nutrient Cycling and Salinization mitigation

Salinity occurs when nearby aquifers, where groundwater is stored, is pumped up for anthropogenic use. This water is normally restored by precipitation, however, due to human interference, water is often quickly transported to the sea. Therefore, groundwater is restored by saline seawater, salinizing the fresh groundwater, and causing vegetation to die off. Moreover, with sea level rise, seawater also travels further inland, which also seeps more salt water into fresh groundwater and causing harm to vegetation. The dynamic of saltwater intrusion is described in Holland et al. (2009). Mangroves can often counter this process by increasing groundwater recharge capabilities and speed. However, mangroves also abate in hypersaline conditions.

Appendix B.9 Water bioremediation

Mangroves have a capability absorb to chemicals and certain heavy metals to a certain extend. This way, mangroves can grow normally while these chemicals get filtered out of the system (Chiu & Chou, 1991; Qui et al., 2019).

Appendix B.9.1 Turpie et al. (1999)

Mangroves maximum capacity to take up these chemicals can be used to quantify how much a forest can filter the water. This can be compared with other water filtering processes to find the replacement costs of this ecosystem service. The water needs to be filtered so it is below the maximum contaminant level set by the government, i.e., the US EPA drinking water regulations.

Appendix B.10 Eco tourism

Ecotourism can provide additional income to the local community (Kim et al., 2019). However, it can be difficult to value, as it provides more than just economic value, it offers all sorts of job opportunities too (Stronza, 2007). Therefore, the drivers of the ecosystem value all affect each other in a certain way (Beall et al., 2021). Using statistical analysis, the correlation between all driver for ecotourism can be estimated (Beall et al., 2021). One of the drivers is the natural aesthetics of the ecosystem.

.

Appendix B.11 Databases

Some useful databases and their corresponding hyperlinks.

Topic	Author	Link
Damages	EM-DAT	https://public.emdat.be/
Fish production	FishStatJ	FAO (2022). Fishery and Aquaculture Statistics. Global production by production source 1950-2020 (FishStatJ). In: FAO Fisheries and Aquaculture Division [online]. Rome. Updated 2022. www.fao.org/fishery/statistics/software/fishstatj/en
Ecosystem values	TEEB	TEEB (2010), The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations. Edited by Pushpam Kumar. Earthscan: London and Washington. https://teebweb.org/publications/teeb-for/research-and-academia/
Fish production	WAPI	https://www.fao.org/fishery/en/statistics/software/wapi
Food production	FAOSTAT	https://www.fao.org/faostat/en/#data/FBS
Seafood production	AQUASTAT	https://tableau.apps.fao.org/views/ReviewDashboard-v1/country_dashboard?%3Aembed=y&%3AisGuestRedirectFromVizportal=y
Mangrove based medicine	Bandaranayake (1998)	Bandaranayake, W. M. (1998). Traditional and medicinal uses of mangroves. *Mangroves and salt marshes*, *2*(3), 133-148. https://doi-org.proxy.library.uu.nl/10.1023/A:1009988607044
Global mangrove distribution	Global Mangrove watch	https://data.unep-wcmc.org/datasets/45
Forrest densities	Earth Data	https://daac.ornl.gov/CMS/guides/CMS_Global_Map_Mangrove_Canopy.html
Global maps	Global Resource Watch	https://resourcewatch.org/data/explore
Global forest maps	Global Forest Watch	https://www.globalforestwatch.org/map/

Appendix B.12 Literature

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Ruitenbeek, H. J. (1994). Modelling economy-ecology linkages in mangroves: economic evidence for promoting conservation in Bintuni Bay, Indonesia. *Ecological economics*, *10*(3), 233-247.

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Appendix C Predicted values Demak

Appendix C.1 Fisheries

Variable	***Value***	***Unit***	***Explanation***	***Note***	***Source***
p	$ 1.18	$	Unit price of fish	IDR 32.088.089.000,00	Badan Pusat Statistik. (2016, November 3). https://demakkab.bps.go.id/publication/2016/11/03/fb49a19bc9bd413d6a635e8d/statistik-sosial-kependudukan-kabupaten-demak-2015.html
h		i.e., kg	harvested number of fish	2178688	Badan Pusat Statistik. (2016b, November 3). https://demakkab.bps.go.id/publication/2016/11/03/fb49a19bc9bd413d6a635e8d/statistik-sosial-kependudukan-kabupaten-demak-2015.html
c	5080	$/vessel	Cost per fishing vessel effort (wages and maintenance)	Rp. 635,000,000; around 10% is maintenance costs	Indonetwork. (n.d.). Jual Kapal Ikan Bahan Fiber 5GT Jawa Timur - CV. Maju Bangkit. Retrieved from https://www.indonetwork.co.id/product/kapal-ikan-bahan-fiber-5gt-6458044
E		vessel	Amount of fishing vessels (kapal ikan 5GT)		Demak Regency. (n.d.). Jumlah Perahu/Kapal Penangkapan Ikan Laut di Kabupaten Demak Tahun 2020. http://data.demakkab.go.id/nl/dataset/jumlah-perahu-kapal-penangkapan-ikan-laut-di-kabupaten-demak-tahun-2020/resource/a1ff058b-d0fb-48ec-9a96-62b30ce0cf0c
M	3,1	i.e., km2	Mangrove area		SCBA W&B
dM	6	i.e., km2	Change of mangrove area / mangrove area new		Bunting P., Rosenqvist A., Lucas R., Rebelo L-M., Hilarides L., Thomas N., Hardy A., Itoh T., Shimada M. and Finlayson C.M. (2018). The Global Mangrove Watch – a New 2010 Global Baseline of Mangrove Extent. Remote Sensing 10(10): 1669. doi: 10.3390/rs1010669

Data

Predicted h	Y	E	h	c	M	E^2	ExM	dM
4.575.731,31	2020	4199		5080	3,023169	17631601	12694,29	15,646531
3.613.975,42	2019	4199	3.744.695,00	5080	2,9285618	17631601	12297,03	15,9905568
3.368.391,47	2018	4052		5080	2,8339546	16418704	11483,18	16,3345826
2.440.305,06	2017	4052	1.936.158,00	5080	2,7393474	16418704	11099,84	16,6786084
1.961.587,92	2016	3962	2.420.197,00	5080	2,6447402	15697444	10478,46	17,0226342
2.251.890,84	2015	3709	2.178.688,00	5080	2,550133	13756681	9458,443	17,36666
2.023.409,54	2014	3709	2.006.762,00	5080	2,5246882	13756681	9364,069	17,4294606
1.794.928,24	2013		2.101.035,00	5080	2,4992434	13756681	9269,694	17,4922612
1.566.446,93	2012		1.341.247,00	5080	2,4737986	13756681	9175,319	17,5550618
1.337.965,63	2011		1.306.508,00	5080	2,4483538	13756681	9080,944	17,6178624

Appendix C.2 Aquaculture

Variable	*Value*	*Unit*	*Explanation*	*Note*	*Source*
M	9,1	i.e., km2	Mangrove area	GMW	Bunting, P.; Rosenqvist, A.; Hilarides, L.; Lucas, R.M.; Thomas, T.; Tadono, T.; Worthington, T.A.; Spalding, M.; Murray, N.J.; Rebelo, L-M. Global Mangrove Extent Change 1996 – 2020: Global Mangrove Watch Version 3.0. Remote Sensing. 2022
P	$ 2,18	i.e., $/Kg	Export value	5,7 USD/kg shrimp, 1,6 USD/kg Tilapia and 1 USD/kg Milkfish, ~75% fish, 25% shrimp	Widowati, L. L., Ariyati, R. W., Rejeki, S., & Bosma, R. H. (2021). The impact of aquaculture field school on the shrimp and milkfish yield and income of farmers in Demak, Central Java. *Journal of the World Aquaculture Society*, *52*(2), 362-377.
w	1200000	local currency per hour	Minimal real wage	96 USD/yr.	Ariyati, W., Widowati, L. L., & Bosma, R. H. (2016). Socio-economic and ecological characteristics of aquaculture in villages threatened by the sea in Demark District, North Java.
FD	60	km2	Aquaculture ponds area	85% of area	Tonneijck, F. H., Winterwerp, H., van Weesenbeeck, B., Bosma, R. H., Debrot, A. O., Noor, Y. R., & Wilms, T. (2015). *Building with Nature Indonesia: securing eroding delta coastlines: Design and Engineering Plan*. Ecoshape. https://www.ecoshape.org/app/uploads/sites/2/2017/08/Ecoshape-2015-Result-1-5-Design-Engineering-Plan-v7-0-LAYOUT-Nature-style_2.pdf
D	13,5	km	Distance to major city	On average to Semarang	Google earth
R	8,3%	%	Real Interest Rate		The World Bank, World Development Indicators. (2023). *Real interest rate (%) – Indonesia.* Retrieved from https://data.worldbank.org/indicator/FR.INR.RINR?locations=ID
Y	IDR 41.532.500,00	local currency	Real capita gross product	$ 3.322,60	The World Bank, World Development Indicators. (2023). *GDP per capita (current US$) - Indonesia.* Retrieved from https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=ID
	0,00008	exchange rate	Local currency to USD	World Bank databank GEM	The World Bank, Databank. (2023). *Global Economic Monitor (GEM).* Retrieved from https://databank.worldbank.org/source/global-economic-monitor-(gem)#

data

Year	M	P	w	FD	D	R	Y	Exchange rate IDR/USD
2020	3,023169	IDR 31.705,60	IDR 1.399.419,78	60	13,5	10,00%	IDR 56.768.338,10	14577,2894
2019	2,928562	IDR 30.764,29	IDR 1.357.872,31	60	13,5	8,60%	IDR 58.716.661,92	14144,50326
2018	2,833955	IDR 30.959,76	IDR 1.366.499,64	60	13,5	6,50%	IDR 55.552.480,74	14234,37127
2017	2,739347	IDR 29.102,21	IDR 1.284.511,45	60	13,5	6,50%	IDR 51.377.782,10	13380,32765
2016	2,64474	IDR 28.942,93	IDR 1.277.481,23	60	13,5	9,20%	IDR 47.357.293,88	13307,09618
2015	2,550133	IDR 29.118,96	IDR 1.285.250,68	60	13,5	8,30%	IDR 44.483.061,66	13388,02795
2014	2,524688	IDR 25.808,63	IDR 1.139.139,35	60	13,5	6,80%	IDR 41.253.456,90	11866,03489
2013	2,499243	IDR 22.726,42	IDR 1.003.097,23	60	13,5	6,40%	IDR 37.646.448,18	10448,92952
2012	2,473799	IDR 20.417,56	IDR 901.188,65	60	13,5	7,80%	IDR 34.434.793,96	9387,381811
2011	2,448354	IDR 19.084,31	IDR 842.341,81	60	13,5	4,60%	IDR 31.708.904,65	8774,393892

Appendix C.3 R code

Download needed packages.

```
install.packages("tidyverse")
install.packages("readxl")
library(tidyverse)
library(readxl)
```

Appendix C.3.1 Fisheries

Load dataset into variable

```
Fisheries_demak_dataset <- read_excel("Demak/Fisheries demak dataset.xlsx")
```

Load project parameters in variables for easier use

```
h       <- Fisheries_demak_dataset$h
EII     <- Fisheries_demak_dataset$`E^2`
EM      <- Fisheries_demak_dataset$pEM
EMha    <- Fisheries_demak_dataset$pEMha
E       <- Fisheries_demak_dataset$E
M       <- Fisheries_demak_dataset$pM
Mha     <- Fisheries_demak_dataset$pMha
```

Perform multiple linear regression of project area.

```
y1 <-lm(h ~ EMha + EII , data = Fisheries_demak_dataset)
```

Results of regression

```
summary(y1)
plot(y1)
```

```
Call:
lm(formula = h ~ EM + EII, data = Fisheries_demak_dataset)

Residuals:
      1       2       3       4       5       6       7       8 
 123918 -510400  452669  -78385  -21817  300950 -230345  -36590 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)  
(Intercept) -1.085e+06  1.518e+06  -0.715   0.5066  
EM           2.421e+03  8.371e+02   2.892   0.0341 *
EII         -1.422e+00  6.268e-01  -2.268   0.0726 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 355600 on 5 degrees of freedom
Multiple R-squared:  0.8438,	Adjusted R-squared:  0.7813 
F-statistic:  13.5 on 2 and 5 DF,  p-value: 0.009647
```

<u>Fill in the predicted parameter values, d for whole Demak mangrove area.</u>

```
b0 <- -1.085e+06 #intercept
b1 <- 2.421e+01  #estimate EM
b2 <- -1.422e+00 #estimate EII
z= -(b1/b2)
```

<u>Fill in other parameter values.</u>

```
c        <- 5080          #maintenance per vessel
p        <- 1.18          #price per kg
deltaM   <- -310          #ha
```

<u>Calulate the change in harvest and profit</u>

```
pdh <- z*c*deltaM
dh <- (pdh/p)

view(pdh)
view(dh)
```

Appendix C.3.2 Aquaculture

Load dataset into variable

aquaculture <- read_excel("Demak/aquaculture estimates.xlsx")

Perform regression.

ya <- lm(dM ~ P + w + FD + D + R + Y, data = aquaculture)

Show outcome regression

summary(ya)

```
Call:
lm(formula = dM ~ P + w + FD + D + R + Y, data = aquaculture)

Residuals:
        1         2         3         4         5         6         7 
 0.004693  0.001175 -0.012020 -0.009965 -0.011467  0.033228  0.011906 
        8         9 
-0.001385 -0.016165 

Coefficients: (3 not defined because of singularities)
              Estimate Std. Error t value Pr(>|t|)  
(Intercept)  1.299e-01  4.498e-02   2.887   0.0343 *
P           -6.258e-06  4.920e-06  -1.272   0.2593  
w                   NA         NA      NA       NA  
FD                  NA         NA      NA       NA  
D                   NA         NA      NA       NA  
R           -1.691e-01  5.940e-01  -0.285   0.7873  
Y           -3.763e-10  2.235e-09  -0.168   0.8729  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.01953 on 5 degrees of freedom
Multiple R-squared:  0.8205,	Adjusted R-squared:  0.7128 
F-statistic:  7.62 on 3 and 5 DF,  p-value: 0.02595
```

Fill in estimates in variables to calculate new profits.

```
b0        <- 1.299e-01
b1        <- -6.258e-06
b2        <- -1.691e-01
b3        <- -3.763e-10
R1        <- 7.47
Y1        <-  56768338.10
deltaM2   <- -310
```

Calculate new profit.

dP <- (b0 + b2*R1 + b3*Y1 - deltaM2)/b1

view(dP)

Appendix C.4 Literature

Ariyati, W., Widowati, L. L., & Bosma, R. H. (2016). Socio-economic and ecological characteristics of aquaculture in villages threatened by the sea in Demark District, North Java.

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World Bank, World Development Indicators. (2023). *Real interest rate (%) – Indonesia.* Retrieved from https://data.worldbank.org/indicator/FR.INR.RINR?locations=ID