This report was commissioned by: Ministry of Economic Affairs, Netherlands
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of abbreviations</td>
<td>5</td>
</tr>
<tr>
<td>Summary</td>
<td>7</td>
</tr>
<tr>
<td><strong>1 Introduction</strong></td>
<td>9</td>
</tr>
<tr>
<td>1.1 Background on St Eustatius</td>
<td>10</td>
</tr>
<tr>
<td>1.2 Economy and demography</td>
<td>10</td>
</tr>
<tr>
<td>1.3 Natural environment and ecosystems</td>
<td>11</td>
</tr>
<tr>
<td>1.4 Threats and impacts</td>
<td>11</td>
</tr>
<tr>
<td>1.5 Objective of the study</td>
<td>12</td>
</tr>
<tr>
<td>1.6 Structure of the report</td>
<td>12</td>
</tr>
<tr>
<td><strong>2 The Model</strong></td>
<td>13</td>
</tr>
<tr>
<td>2.1 Limitations</td>
<td>13</td>
</tr>
<tr>
<td>2.2 The Marine Environment</td>
<td>13</td>
</tr>
<tr>
<td>2.3 The terrestrial environment</td>
<td>19</td>
</tr>
<tr>
<td>2.4 The value of ecosystem services and goods</td>
<td>21</td>
</tr>
<tr>
<td><strong>3 Scenarios</strong></td>
<td>30</td>
</tr>
<tr>
<td>3.1 Baseline scenario St. Eustatius</td>
<td>30</td>
</tr>
<tr>
<td>3.2 Scenario tourism expansion St Eustatius</td>
<td>30</td>
</tr>
<tr>
<td>3.3 Scenario agriculture and managing free roaming livestock</td>
<td>31</td>
</tr>
<tr>
<td>3.4 Oil spill</td>
<td>33</td>
</tr>
<tr>
<td><strong>4 Results</strong></td>
<td>36</td>
</tr>
<tr>
<td>4.1 The environmental outcome</td>
<td>36</td>
</tr>
<tr>
<td>4.2 The economic value</td>
<td>41</td>
</tr>
<tr>
<td><strong>5 Conclusions and recommendations</strong></td>
<td>49</td>
</tr>
<tr>
<td>5.1 The validity of a model</td>
<td>49</td>
</tr>
<tr>
<td>5.2 Model and scenario analysis</td>
<td>49</td>
</tr>
<tr>
<td>5.3 Resilience</td>
<td>50</td>
</tr>
<tr>
<td>5.4 Recommendations</td>
<td>51</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>52</td>
</tr>
<tr>
<td>References</td>
<td>53</td>
</tr>
<tr>
<td><strong>Annex A</strong></td>
<td>59</td>
</tr>
<tr>
<td>Conceptual framework of simulation model</td>
<td></td>
</tr>
<tr>
<td><strong>Annex B</strong></td>
<td>61</td>
</tr>
<tr>
<td>Marine module of simulation model</td>
<td></td>
</tr>
<tr>
<td><strong>Annex C</strong></td>
<td>63</td>
</tr>
<tr>
<td>Terrestrial module of simulation model</td>
<td></td>
</tr>
</tbody>
</table>
List of abbreviations

CPV       Coastal Protection Value
CT        Cruise Tourists
FPA       Fisheries Protected Areas
GDP       Gross Domestic Product
NPV       Net Present Value
SOR       State of the Reef
SOT       Stay-over Tourists
TEV       Total Economic Value
WTP       Willingness to Pay
Summary

This study is part of the research project “What is St Eustatius Nature Worth?”, a project that is part of The Economics of Ecosystems and Biodiversity (TEEB) Caribbean Netherlands. Healthy ecosystems such as the coral reef patches and the forests on the hillsides of Boven and the Quill are critical to the society of St Eustatius. The St Eustatius Strategic Development Plan (SDP) acknowledges the importance of the natural environment as an important attraction and asset for the development of the tourism sector. In the last decades, various local and global developments have turned into serious threats to these fragile ecosystems, thereby jeopardizing the foundations of the island’s economy. It is crucial to understand how nature contributes to the economy and wellbeing to make well-founded decisions that affect the natural environment on this special tropical island.

This research aims to determine the economic value of the main ecosystem services that are provided by the natural resources of St Eustatius and their overall importance to society. The challenge of this project is to deliver insight that supports decision-makers in the long-term management of the island’s economy and natural environment. From the onset of the study, stakeholders participated by facilitating data and simultaneously giving support to the concept of valuing ecosystem services. They address the most relevant ecosystems and ecosystem services for St Eustatius. The study applies a range of economic valuation and evaluation tools. By surveying over a 1,000 people including tourists, local residents, and citizens of the mainland of the Netherlands, this study estimated the willingness of individuals to pay for the protection of nature on St Eustatius.

In total, 8 different ecosystem services have been valued in monetary terms. The total economic value (TEV) is the sum of these ecosystem services provided by the marine and terrestrial ecosystems of St Eustatius. It is calculated to be 25.2 million USD per year. This TEV and its underlying components can be used to build a strategy for effective conservation measures and sustainable development on St Eustatius.

Key findings for St Eustatius

- The current total economic value (TEV) of the natural environment on St Eustatius is 25.2 million USD annually and consists of the following 8 values: non-use, tourism, fisheries, research, carbon sequestration, medicinal plants, local value, and agriculture and livestock.
- The aggregated annual amount for the value for conserving the natural environment by residents of the Netherlands mainland is estimated at 17 million Euros (22 million USD).
- Expansion of the tourism sector to up to 40,000 tourists a year will increase the tourism value up to 6 million USD in the short run, but will lower the TEV from 25.2 million to 17.8 million USD per year. The tourists will impact the natural environment rather severely. Local residents will be left with the degraded nature, while tourists will spend their holiday somewhere else. Slowly expanding the tourism sector is suggested, while tracking the impacts on the environment by monitoring closely.
- With the current pressure on ecosystem services of St Eustatius and without any additional management, the TEV of the natural environment will decrease from 25.2 million USD today to around 20.2 million USD annually within 30 years.
Summary

• Roaming animals are seen as a nuisance, but not every Statian knows that they also have a negative impact on the terrestrial and marine environments. Management of these animals will improve the natural environment of St Eustatius in a cost efficient way and opens up the possibility to agricultural practices.

• When managing free roaming animals is combined with moderate expansion of tourism, nature will be more resilient and can withstand more tourists without degradation of the natural environment.

• With a well-considered growth of the tourism industry and the development of agriculture, the SDP can be realized. Statians will enjoy a higher level of prosperity by maximizing the benefits from ecosystem services while they experience a livable, natural environment.
1 Introduction

Although human wellbeing does not solely depend on economic growth, economic indicators like Gross Domestic Product (GDP) are commonly used as an indicator for the prosperity of a country. The focus on economic benefits disregards social and environmental benefits and costs. To optimize human wellbeing and to assess trade-offs the social and environmental benefits or costs should be included in decision making (Groot et al. 2010).

The Millennium Ecosystem Assessment of 2005 defines ecosystem services as ‘the benefits humans derive from nature’ (MA, 2005a) and, thereby, linking environmental benefits to wellbeing. Daily et al. (2009) propose a framework to valuate these ecosystem services so that these values can be included in policy making (figure 1A). This way policymakers get insight into the effect of their policies on the environment and thereby on their economy. With this insight they are better able to decide between trade-offs. Figure 1B illustrates the trade-off in more detail. There are several ecosystem services, which are beneficial for society and to maximize these benefits the ecosystem should be used sustainable. The optimal amount of use differs between ecosystem services. The sum of ecosystem service value is derived by adding up all economic optimal levels of sustainable use of ecosystem services. Every society makes different use of ecosystem services and will need a different combination of services to optimize their benefits (Braat and Brink 2010).

A. The Daily loop: a simplified framework to integrate ecosystem services and their valuation into decision making (Daily et al. 2009)

B. This graph demonstrates the relation between use and the value of ecosystem services (Braat and Brink 2010)

Figure 1 Ecosystems services, trade-offs and decision making

The economy is strongly linked with the natural environment. This is especially the case for small tropical islands. These islands possess a unique nature with a high number of endemic species and limited resources, and undergo high environmental pressures due to human activity and natural hazards (Van Beukering et al., 2007). The islands of the Caribbean Netherlands share these similarities.

In order to assess threats to ecosystem services of these islands and their effect on the island’s economy a dynamic model is created simulating the relationship between economy and ecological processes. In this chapter we, first, provide background information on the economy and ecology of St Eustatius.
1.1 Background on St Eustatius

Since 10 October 2010 Bonaire, Saba and St Eustatius became a special municipality of the Netherlands. The government of the Netherlands has an obligation to develop a framework for a nature policy plan for the Caribbean Netherlands. The socio-economic valuation of ecosystem services and goods research by Wolfs Company and VU University delivers input for the nature policy of the Caribbean Netherlands. Moreover, the study is part of the Dutch research project, which is called The Economics of Ecosystems and Biodiversity Netherlands (TEEB NL). The research “What is St Eustatius’ Nature Worth?” is part of the TEEB NL research project called TEEB Caribbean Netherlands. Four reports have been produced for “What is St Eustatius’ Nature Worth?” of which this report is about the total economic value of the ecosystem services and goods of St Eustatius (Heide and Ruijs 2010; TEEB 2010).

(A) St Eustatius is situated in the northeastern of the Caribbean. (B)(C) There are two natural areas: the dormant volcano the Quill and the area Boven in the northern part of the island. In between is the Cultuurvlakte situated with the one and only town Oranjestad. Figures are retrieved from Google maps.

1.2 Economy and demography

St Eustatius, usually shortened to Statia, is a small island in the Caribbean. There is one village Oranjestad offering residency to the 4,000 local people in 2009 (Plan n.d.).

In the 17th and 18th century St Eustatius was known as the Golden Rock. It was a densely populated island and functioned as the center of trade in the Caribbean. St Eustatius had several plantations. In the early 19th century most of the available land was used for agricultural practices with 40 plantations. The history of the island is still present in the historical buildings, which is an attractive feature for tourists. Agricultural practices were abandoned in the 20th century. From 1965 onward infrastructural improvements were made, like the establishment of the airport (1971), hotel expansion and the construction of hiking trails. This resulted in the development of a small tourism industry. A major economic change occurred in 1982 when the oil
transshipment company Statia Terminals N.V. was established on St Eustatius. Together with the tourism sector these are currently the most important economic sectors (Ecorys 2013) (Freitas, Rojer, & Debrot, 2012; Rojer, 1997).

The government of St Eustatius wants to develop and diversify the economy of the island. The vision of the government of St Eustatius is stated in their strategic development plan (SDP) ‘In the future, the population of St. Eustatius will enjoy a higher level of prosperity in a livable environment.’ (Velde et al. 2010 p7). According to this strategy economic development is needed. Unfortunately, a lot of information is lacking to monitor such progress, for example, the latest GDP figure of 55 million USD was established in 2004.

1.3 Natural environment and ecosystems

St Eustatius is an island of 21 km², the northwest and southwestern part of the island are hilly and in between, the “Cultuurvlakte”, it is rather flat. The Quill is a dormant Strato Volcano with a top at 600 meters. The average air temperature on St Eustatius is 26.9°C, with an annual average rainfall of 986 mm. St Eustatius lies in the hurricane belt and experiences at least one tropical cyclone within 100 miles once a year and it undergoes hurricane storms every 4 to 5 years (MSNA&A 2010).

St Eustatius flora consists of around 505 species. A few are rather rare and should be protected (Freitas et al. 2012). Recently, a new endemic plant species is discovered, the Gonolobus aloiensis, together with the Morning Glory, St Eustatius is now the proud owner of two endemic species (Krings and Axelrod 2013). Unfortunately, the invasive Mexican Creeper (Corallita) covers 20% of the island and occurs especially in disturbed areas in the Cultuurvlakte (Ernst and Ketner 2007). The fauna of this special island consists of 54 birds, 5 mammals, 13 amphibians and reptiles and 81 invertebrates.

St Eustatius is surrounded by the National Marine Park, which is established in 1996 and covers an area of 27.5 km². The park has only two marine reserves, containing no-take areas where anchoring and fishing are not permitted. The northern reserve (1.61km²) encloses Jenkins Bay up to the northern most point of the island (White, Esteban, and Polino 2006). The southern reserve (3.29km²) runs from Gallows Bay until White Wall. Furthermore, the park consists of a general use zone (22.61km²). The park functions as a permanent habitat, migratory stopover and/or breeding site for 14 IUCN Red List species, 10 CITES Appendix I species and 98 Appendix II species (White and Esteban 2007). Moreover, the St Eustatius Marine Park consists of a variety of habitats, including 18th century and modern shipwrecks, various types of coral reefs like drop off walls, volcanic ‘fingers’ and ‘bombs’(Bervoets 2010).

The management of the Marine Park and the National Terrestrial Parks is in the hands of St Eustatius National Parks Foundation (STENAPA) (Bervoets 2010).

1.4 Threats and impacts

The terrestrial ecosystems of St Eustatius undergo several threats, among which, industrial development, grazing by free roaming animals, invasive plant species and hurricanes (Freitas et al. 2012). Bervoets (2010) depicts the following threats for the marine environment, namely coastal development, anchoring by tankers, oil spills and tourism expansion.

During a workshop with stakeholders and interviews with experts and local residents their view on threats to the natural environment of St Eustatius has been determined.
These were invasive plants, sand mining, storms and hurricanes, littering, overfishing, invasive species, construction and oil spills. The survey among 400 local residents resulted in a top 5 of threats being oil spills, solid waste, car wrecks, rats and invasive plants (Fenkl et al. 2013).

1.5 Objective of the study

This research gives insight in the interconnectedness of the island economy and its terrestrial and marine ecosystem services and goods. Furthermore, the study researched potential impact of certain policy measurements. Local information was gathered via workshops with stakeholders, expert interviews and surveys. This information is used to construct a dynamic simulation model using STELLA program. More information about the methodology can be found in the Bonaire report (Cado van der Lely et al. 2013). The model is used to determine the effect of stressors on environmental indicators and the impact on related economic sectors. At the end of the report, the analysis is described and final conclusions are made.

The research, desk study and writing of the reports for the islands Saba and St. Eustatius occurred simultaneously. The islands are very similar in many respects. Thus for efficiency reasons and in order to avoid being redundant, some parts of this report can also be found in the report of Saba. Of course, the unique characteristics of St. Eustatius were treated as such, and results, methods and recommendations were tailored to the specific needs of the island.

1.6 Structure of the report

The next chapter describes the dynamic simulation model. The model simulates the state of the marine and terrestrial environment, their underlying relations, the human threats impacting these ecosystems and the impact on and relation with the economy. The chapter thereafter discusses future scenarios such as tourism expansion and the management of free roaming livestock. The results of these scenario simulations and the final conclusions can be found in the last two chapters.
2 The Model

The functioning of ecosystems, its delivery of services and the final contribution to welfare is complex. To effectively evaluate the complex interface between ecological and economic processes, simulation modeling can play a useful role representing the main ecological functions and the interaction with the economic sectors. The aim of the model is to see how these interactions vary under different circumstances i.e. how the system as a whole is influenced by different policy choices.

2.1 Limitations

The structure of the model is based on desk research. However, many relationships and interactions that the model simulates have not been documented in literature studied. To compensate for these hiatuses experts where consulted. The model aims at representing a certain part of reality; however, it is still a model and very much depending on availability of information. Although the model is based on information that is of scientific origin, a large fraction of the relationships in the model are assumptions. Not the relationship itself is an assumption, but the curve or the rate of the relationship. To give an example, the fact that sediment runoff has a detrimental effect on coral survival rates is a scientific fact. However, at what rate does the survival of corals decrease as sedimentation rate increases? Such questions have been tackled using available data and expert opinions. The purpose of the model is to give the best possible overview of how different policies impact socio-economic and ecological processes using existing data and expert opinion. In this chapter the model is made as transparent as possible without being superfluous. This chapter gives insight in the construction of the model and the relations between the different indicators and values. It is divided in 3 subchapters regarding modeling the marine environment, the terrestrial environment and the values that are related to the ecosystem services and goods. For a conceptual overview of the model see Appendix A-C.

2.2 The Marine Environment

Ecosystem services that coral reefs provide are closely tied to the qualitative state of the environment. A coral reef ecosystem that is completely degraded has a hard time attracting tourists. The first step in simulating the close bond between coral ecosystems and their services is to model the state of the ecosystem itself. The module of the marine does just that, giving an output that is a relative value that ranges between 0-1, “0” indicating a completely degraded ecosystem and “1” a pristine ecosystem. The second step is to relate the ecosystem services to the indicator. This relationship demonstrates how certain activities and stressors, such as tourism, sedimentation and invasive species, influence ecosystem services that are contingent to the health of the coral reef system. What follows is how the health of a coral reef system has been calculated and simulated.

Framework

Based on the work of Slijkerman et al. (2011) the following parameters were incorporated in the model: 1) coral cover, 2) fish stock, 3) fish diversity and 4) algae cover. Together, these parameters represent the overall state of the marine environment. Internal processes are simulated, such as coral growth and fish
abundance, but also external processes such as anthropogenic stressor i.e. fishing rate, nutrient loading, sedimentation, invasive species and climate change. All of which have significant negative impact on the health of coral reef systems (Newman et al. 2006; Sandin, Sampayo, and Vermeij 2008; Sandin et al. 2008).

Coral and algae cover

Definition

The total percentage of marine coastal area covered by hard corals is labelled coral cover. The output of this sub-module aims to display the change of the total percent of coral cover in the coastal zone. The expansion rate of corals is influenced by many different factors of both biotic and abiotic nature. Inter or intra-specific competition for space between corals and algae species, ambient nutrient conditions, temperature, sedimentation, are factors that influence the presence of corals and its health.

Algae cover is simulated in very similar terms as coral cover. It is expressed as the total percentage of coastal waters of the marine park that is covered either by turf-algae and/or macro-algae. These two types of algae are of most importance when it comes to competition for space with reef building corals. Also, an algae dominated coral reef system is a good indicator of nutrient rich system, i.e. eutrophied. Coral reefs systems are known for very ambient nutrient conditions (Koop et al. 2001; Rasher et al. 2012). One of the requirements for algae to prevail in coral systems is a superfluous amount of nutrients entering coastal waters. A second requirement is a lack of consumers, such as herbivorous fish or turtles. If both these requirements are met, algae will start to dominate the coral system, and slowly but surely take over.

Model: coral expansion

Coral expansion is modelled as a logistical growth equation. Using data from McClellan et al. (2009), Osborne et al. (2011), Wilkinson (2008) and Forester (unpublished data) the intrinsic growth rate (r) and the carrying capacity (k) is calculated. The logistical growth equation is used to model the expansion of coral over time (Figure 2):

\[
\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)
\]

The function (2-1) expresses the change of total percent of coral cover throughout the Marine Parks of Saba. The term K is the carrying capacity of the system. The max intrinsic growth (r) used in the model is: 0.28. In a meta-analysis using data from the aforementioned authors the intrinsic growth rate was calculated.

In coastal ecosystems where sand prevails, finding hard and suitable substrate is a limiting factor in the survival and growth of corals and many other different organisms. There is direct competition for space between macro-algae and reef constructing coral species. Mumby and Harborne (2010) described that coral growth increases in the absence of algae. Thus, in the model the intrinsic growth rate of coral depends on the amount of algae cover. A linear relationship is presumed between the intrinsic growth rate of coral and the amount of algae cover, linear relationship being the least complicated. In the absence of macro-algae, coral growth (r) reaches a maximum of 0.28 and decreases linearly to 0 as macro-algae cover increases.
Another factor negatively influencing corals is the physical destruction caused by tourists. Diving and snorkelling hot spots are usually situated where corals are predominant. In such areas the underwater aesthetics are at its best, as fish and turtle species congregate where reef-building corals are plentiful. Whether it be knowingly or not, tourists physically destroy the coral reef structure (Esteban, MacRae, and Blok 2009; Hawkins et al. 1999, 2005). On an annual basis 2.8% of coral cover is damaged due to physical destruction caused by 12,500 visitors (de Meyer 1998). This rate is assumed to increase linearly as the amount of tourists increase.

The sedimentation rate is used to determine the maximum amount of coral cover that can prevail in coastal waters. In other words, sedimentation rate influences the carrying capacity of coral cover. Sediment entering coastal waters as a result of terrestrial runoff negatively impacts coral survival rates (Fabricius 2005; Rogers 1990). The two main reasons that causing survival rates to diminish is 1) a decrease in the success rate of coral larvae settling on hard substrate, and 2) an increase in coral stress as they have to expel more slime in order to clean sediment grains. In the model the carrying capacity K decreases as the sedimentation rate increase (Begin, 2012). A linear relationship is presumed between the sedimentation rate and carrying capacity. The maximum K is 80.1% (Osborne et al. 2011) at the lowest sedimentation rate and decreases to a minimum value of 10% at the highest sedimentation rate.

**Model: algae cover**

Algae cover is simulated as a logistical growth equation. The growth rate r increases as the amount of nutrients, i.e. nitrates and phosphates increases in the water (McClanahan, Cokos, and Sala 2002; Slijkerman et al. 2011). The model uses a linear relationship between the amount of nutrients and r with a maximum r of 0.5. Ambient nutrient conditions are controlled by the amount of tourists that visit the island; see ‘nutrient’ sub chapter for further information.

Algae do not have the possibility to grow if there are sufficient herbivore fish species present. It is the combination of eutrophied waters and overfishing of herbivorous fish that create excellent conditions for algae. In the model the carrying capacity of algae is related to the number of herbivorous fish in the water column. This relationship is linear (Mumby, Dahlgren, and Harborne 2006) and it is site specific, i.e. the number of fish and algae present is relative to the surface area. A larger coral reef system would need a larger number of fish (e.g. in terms of tons) to sustain the same percentage of algae cover (e.g. 30%) as a system that has a smaller surface area.
The Model

Coral cover can be expressed as a logistic growth function (2-1). This is a simple way of showing a density depended growth that reaches a maximum at $K$. However, defining the intrinsic growth rate ($r$) is an arduous task. Each species of coral has an unique growth rate that varies under a wide range of abiotic and biotic conditions. The model assumes the same growth rate for all coral species.

Nutrients

**Definition**

In the model, nutrients are defined as phosphates (PO$_4^{3-}$) and nitrates (NO$_3^-$). These nutrients are one of the limiting factors for primary production of algae. In a pristine coral reef ecosystem, ambient nutrients conditions are almost undetectable. This is because of high nutrient turnover rates i.e. the system is extremely efficient in recycling of any liberated nutrients. However, often coral ecosystems are located in urbanized coastal areas. Many of such coastal areas have undeveloped sewage treatment facilities and therefore are unable to prevent nutrients from entering coastal waters. Thus as nutrient concentrations increase, algae will be more likely to outcompete corals for space.

**Model**

In the model the total amount of nutrients entering coastal waters is directly related to the number of tourists visiting the island. A linear relationship is presumed. Ambient nutrient conditions and total annual tourist visitors were noted and presumed to be correlated. Nutrient concentrations are derived from the works of Van Beek (2013), McClanahan *et al.* (2002) and Meesters, Slijkerman, and Graaf (2010). At an annual tourist count of 10,000 a PO$_4^{3-}$ concentration of 0.05 µM and a NO$_3^-$ concentration of 0.2 µM was used. As tourists would increases in numbers, so would the amount of nutrients. For every 10,000 tourists, PO$_4^{3-}$ concentration would increase by 0.05 µM and a NO$_3^-$ concentration by 0.2 µM.

Physical destruction

**Definition**

Tourists have a destructive impact on the natural environment. Even the most environmentally aware individuals will in one way or another cause changes to a natural habitat. If tourist numbers are low, such impacts can easily be mitigated and solved. However, as annual numbers start to increase drastically, the cumulative effect of tourists on the marine and terrestrial environment start to tack its toll.

**Model**

The relationship between the number of divers and how much damage they cause is fairly straight forward. Esteban, et. al (2005) and de Meyer (1998) conducted studies on the damage tourists caused to corals while diving. Based on these reports, the annual rate at which coral would decrease in surface area is calculated.

In the model the total number of tourists visiting the island are presumed to have a negative impact on coral cover. For every 13,000 tourists that visit the island, a destruction rate of 0.028 is presumed (de Meyer 1998). That means that on an annual basis the total coral cover decreases by a percentage of 2.8.
Fish stock and fish diversity

Definition

Fish abundance and the amount of fish species present are a good measure to determine the state of a coral reef ecosystem (Slijkerman et al. 2011). Coral reef systems are very diverse and have plenty of other fauna present, but no other type of fauna has such an extensive database. An incredible amount of studies have been conducted on fish abundance and species richness in coral reef systems. It is for this reason that fish were chosen as an indicator species for the coral system. Fish abundance is defined as the amount of tons of fish present in the water column. Fish diversity is defined as the number of fish species in the water column that are associated with coral reefs.

Model

The change of fish abundance is modeled as a density-dependent function. Fish abundance increases quickly at low densities. At higher densities the growth rate decreases as it reaches an asymptote. The asymptote is defined as the carrying capacity (K), i.e. how many fish (in terms of kg) the coral reef system can sustain. For the coast of St Eustatius K was calculated at a maximum of 5,000 tons. This number was calculated using data from Klomp and Kooistra (2003), White (2006) and McClellan et al. (2009). Based on the data in these reports a trend was extrapolated and a maximum K of 5,000 tons was deemed appropriate.

For the coast Saba K was calculated at a maximum of 600 tons. This number was based on data found in Klomp and Kooistra (2003) and Noble et al. (2013). The trend found was extrapolated and a maximum K was defined. For the Saba Bank a larger K was calculated. Based on data found for St Eustatius and Saba, and taking into account the size of the marine park where there is suitable habitat for coral reefs to grow (respectively: 27km2, 13km2 and 44km2 for the Saba Bank) a K of 8,000 tons was calculated.

In the model K is not a static parameter. It is linearly related to the amount of the coral cover. This relationship is based on the works of Roberts and Ormond (1987) and Vincent and Hincksman (2011). At maximum coral cover, the maximum K is used. K decreases linearly as coral cover decreases. Using data from the aforementioned authors a maximum an intrinsic growth rate (r) of 0.325 is calculated and used in the model.

Fishing rate

Definition

The fishing industry consists of lobster fisheries, pelagic fisheries and reef fish. Although lucrative, it is an industry that exerts a large amount of stress and pressure on a marine ecosystem. Fish and invertebrates are a finite resource and as their numbers are artificially lowered, the effects will be felt and seen throughout the system. Annual landings consist of different type of fish species. In this module, the total amount of tons of reef associated fish that are landed annually, represents the fishing rate. The module influences the total amount of fishing stock and fish diversity. In terms of percentage of revenue, lobsters contribute the most to the fishing industry. However, there is a big hiatus concerning population dynamics of lobster species on the island. Therefore, they were not included in the model.
**Model**

Numbers on annual landings are few and hard to define. In addition estimates on current standing stock are inconsistent in measuring techniques (Klomp and Kooistra 2003; Mcclellan et al. 2009; Toller et al. 2010; White et al. 2006; Boonstra 2013; Poiesz 2013; Reg 2013). Therefore, determining a concise rate of decrease based on annual landings was not possible. Annual landings were found at values such as 34 tons of red fish and 8 tons of mixed reef fish for Saba. Annual landings were found at values such as 283 Lbs. of red fish and 5493 Lbs. of mixed reef fish for St Eustatius. These values represent the baseline of fishing pressure: it is presumed that there will be a slight decrease of fish stock. If landings are to increase fishing rate increases.

A simple yet insightful scenario analyses is conducted to analyze the relation between the fishing industry, its impact on the natural environment and its economical values of the marine ecosystem services and goods for St Eustatius, being non-use value, local value, and tourism value. The aim being to give insight in how an increase or decrease of annual landings would not only effect the fishing industry itself, but also other industries and values that are closely tied to ecosystem services that depend on a healthy ecosystem.

**Marine indicator**

**Definition**

The different environmental parameters collectively influence the marine indicator, which has a relative value ranging between 0-1. A value of 0 represents a completely degraded system. In terms of coral reef ecosystems this is a system where most corals are bleached or dead, most of the surface area is covered by macro and/or turf algae and fauna diversity is very low. A value of 1 represents a pristine ecosystem. Pristine is a problematic term, as defining the baseline for a pristine habitat is complex and fragile. Nonetheless, a pristine coral habitat is one where there is an abundance of coral cover and species, low nutrient concentrations, apex predators present (e.g. sharks), and a high number of flora and fauna species.

**Model**

The marine indicator is calculated using the parameters coral cover, algae cover, fish abundance and fish biodiversity. All these values are transformed into relative terms, i.e. the ratio between currently levels and what the maximum possible value can be:

\[ V_n = \frac{V_p}{V_{max}} \]

Using equation 2-2 a normative value is calculated for each parameter. This value is than related to a factor, each parameter having its own. The factor represents the weight that is given to the parameter in determining the marine indicator. Coral cover has the highest score for the multiplier of 0.4. Fish biodiversity and abundance have respective multipliers of 0.3 and 0.2. Finally the algae have a negative influence on the marine indicator with a multiplier of 0.3. The weights for each parameter were chosen based on their relative importance as an indicator for a healthy ecosystem. Since coral cover forms the very fundament of this system, it has the highest score. A healthy coral system is, furthermore, defined by how much fish there are. However, if they are all of the same species the coral system is not in a healthy state. Biodiversity is of great importance in coral systems, and for this reason it is that fish diversity is weighed heavier than fish abundance. Algae are a serious threat for corals, and have thus been weighed appropriately.
2.3 The terrestrial environment

The terrestrial environment is an integral part of the experience of a small tropical island. Not just aesthetically are these ecosystems of importance but also functionally, in terms of water retention or habitat connectivity, which is important for the proliferation of certain species. A lot of what takes place on land influences the marine environment. Terrestrial ecosystem services on small tropical islands should not be underestimated. Attracting tourists to a completely barren island would prove to be an arduous task. The health of the terrestrial environment is expressed in the terrestrial indicator. It sums up the qualitative state of the environment, it is determined by the parameters: mature habitat, degraded habitat area and flora richness. These parameters were chosen because they are able to give an indication of the health of the environment and because information was readily available.

Mature & degraded forests

Definition

A fraction of the island of St Eustatius is urbanized. The remainder consists of small areas for agriculture and habitat that has degraded or areas with healthy and mature vegetation. Habitat that is degraded is defined as landscape that has lost its capacity to retain water. The main reason is free roaming livestock such as goats, sheep or cows. Each livestock species expresses a certain amount of pressure on the land, termed tropical livestock unit (TLU). For example one TLU represents: 1.5 cattle, 10 sheep, 10 goat, 2 donkeys or 1 horse. At the onset of the simulation there is a total of 1,370 TLU and results in 7.13% of land pressure. This means that on a yearly basis 7.13% of the total amount of healthy land is converted to degraded habitat. Because livestock consume vegetation, especially young vegetation, plants are unable to enter more mature stages of their life cycle. The older plant species become, the more able they are at preventing erosion. However, time is needed in order to mature. Once an area of vegetation is without external pressure it will be able to flourish, both in terms of biomass and diversity. It is this cycle of recovery and degradation that is modeled in this module.

Model

Degraded and healthy habitat is modeled as two pools; one pool for healthy land and another for degraded land, in terms of hectares. Since the model is not spatial, the rate at which the landscape recovers is the rate at which the degraded pool enters into the healthy pool. The sum of these two pools is the total hectare of land that can become forest. Meaning that areas that are urbanized or that are used for agriculture are not taken into account in this pool. Every 10 years 10% of the degraded land reverts back to healthy land.

Healthy land becomes degraded at a rate that is directly related to the amount of free roaming livestock on the island. The biggest threats are the free roaming goats. Their numbers increase gradually during the simulation and so does then the total TLU. At the onset of the simulation there are 400 TLU. They result in a total land pressure of 7.13%. It is at this rate that healthy land becomes degraded.
Plant richness

**Definition**

On the island, 480-560 plant species have been identified thus far (Royer 1997a, 1997b and Freitas, Royer, and Debrot 2012). It is well documented that species richness can be expressed as a function of the total amount of suitable habitat (Gleason 1922; Plotkin et al. 2000). The species-area function states that as the surface area increase of a biotope the total number of species present also increases.

**Model**

In the model the total number of species was calculated according to a species-area function (Figure 3). In Figure 3 a relative value is given. The island will never exceed its current surface. However for values of surface area between 0-50km² the function in figure 4 still holds, and is thus applicable. At a surface area of 21km² the highest relative number of species was calculated. This was then set as a maximum value and corresponded to a maximum of 600 plant species.

![Relationship between surface area of a biotope and the relative amount of species. Data based on Croezen et al. (2011)](image)

Terrestrial indicator

**Definition**

The different environmental parameters collectively influence the terrestrial indicator, a relative value that ranges between 0-1. A value of 0 represents a completely degraded system. In terms of a forest on a small tropical island, a value of 0 means that all land is degraded thereby losing its capacity of water retention, while plant and animal biodiversity is very low. A value of 1 would mean that in non-urbanized areas all is green and a high percentage of the flora is at a mature stage, and thus the sedimentation rates are low, with high amount of flora and fauna species.

**Model**

The terrestrial indicator is calculated using the parameters healthy land, degraded land and total species abundance. All these values are transformed into relative terms, i.e. the ratio between how much is currently present and what the maximum possible value can be. Using equation (2-2) a normative value is calculated for each parameter. These values are than summed up and the average is calculated.
2.4 The value of ecosystem services and goods

The main ecosystem services and goods provided by the marine and terrestrial environment of St Eustatius can be translated into values. The values chosen for St Eustatius are carbon sequestration, medicinal plants, agriculture and livestock, fisheries, research, tourism, local and the non-use value. These values and their valuation are discussed in the following section. Some of the values initial economic values in the model are different from the values calculated in other reports of “What is St Eustatius Nature Worth?” This is caused by the fact that the initial values in the model are assumed to be below their full potential and will reach higher values if environmental indicators change positively as well.

Carbon sequestration

Carbon sequestration is a regulating service provided by the local ecosystem which is beneficial to the society locally and worldwide according to the Millennium Ecosystem Assessment (2005) (Groot et al. 2010). This means that it should be taken into account in calculating the total economic value of nature on St Eustatius. First, it is explained in general how the value can be determined. This information will be applied specific to the island by defining the main ecosystems on St Eustatius including their ability to attribute to carbon sequestration. At the end, the valuation of carbon sequestration on St Eustatius is determined.

Determining the value of carbon sequestration

The value of carbon sequestration is determined by the total amount of healthy forest and coral cover in terms of hectares. Each hectare of healthy forest is able to sequester between 8-21 tons of carbon per year and a hectare of reef building corals is able to sequester between 0.04-1.06 tons of carbon per year. The value of carbon sequestration is than calculated by summing the total amount of carbon that is sequestered annually by these two ecosystems and then multiplying it by the market price for one ton of carbon:

\[
\text{Total Value (\$)} = \sum (A_C + A_F) \times P
\]

\[
A_C = \text{Area Coral} \times 1.06
\]

\[
A_F = \text{Area Forest} \times 21
\]

where \(A_C\) and \(A_F\) are the respective total amount of sequestered carbon for coral and forest ecosystems and \(P\) is the market price in USD for carbon. The price of $7 is used in the model. It is not easy to determine local carbon fixation as rates fluctuate and are highly dependent on local circumstances. This means that this value gives an indication of the impact of carbon sequestration and local measurements might provide more certainty. Though it is even possible that an area turns from a carbon sink into a carbon source (Van Beukering and Wolfs 2012; Montagnini and Nair 2012; Saleska et al. 2003).

The current carbon market is not in place as it was envisioned. When carbon prices will resemble the true value of carbon it will make management possibilities like reforestation even more economically attractive (Van Beukering and Wolfs 2012; Montagnini and Nair 2012; Nelson et al. 2009). To calculate the value of carbon sequestration first the ecosystem involved need to be determined. For St Eustatius these are the dry forests and coral reefs. The area of these ecosystems are multiplied with the average carbon price used in the world market for carbon trading (Climate Group, 2013).
The capacity of each type of ecosystem to sequester carbon.  

<table>
<thead>
<tr>
<th>Ecosystem</th>
<th>Carbon (t/ha/yr) sequestration</th>
<th>Value Used in Model (t/ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>8 - 21</td>
<td>21</td>
</tr>
<tr>
<td>Coral reef</td>
<td>-0.04 - 1.06</td>
<td>1.06</td>
</tr>
</tbody>
</table>

**Medicinal plants**

The natural environment may provide medicinal plants used by local residents, which are beneficial for their health (de Groot, Wilson, and Boumans 2002). First, it is explained in general how this value is determined. Interviews have been held to examine the local attitude towards medicinal plants use on St Eustatius (Fenkl et al. 2013). This information is used to determine the local value of medicinal plants.

To determine the value the replacement method is used as explained by Van Beukering and Wolfs (2012). On St Eustatius there is no local medicinal market, so a market based approach is not suitable. Instead the avoided costs of not visiting a doctor have been proposed by Brown (1994) and the same can be said for avoided medicine costs (Van Beukering and Wolfs 2012; Brown 1994). In the study of the value of nature on Bonaire this opportunity cost approach was used. The chance on finding medicinal plants is correlated to the size of the natural vegetation area. The current terrestrial indicator is set on 0.6 and is related to the current number of users. The relation is defined as an S-curve. If there is less natural vegetation, the terrestrial indicator will be lower and less people will be using medicinal plants or it will take more time to gather them.

Fenkl et al. (2013) showed that 77% of the population of St Eustatius (2009: 3,500) uses medicinal plants at certain times. In order to estimate the money saved on modern medicine the average money spend on medicine, adjusted for income, (USD/med) is multiplied with the number of users and the assumed reduction of modern medicine spending. So the value of avoided medicine costs is \( Y = \text{USD/med} \times \text{users (\#)} \times \text{reduction} \). For the reduction we assumed the same percentage as was used on Bonaire, which is 25% (Van Beukering and Wolfs 2012). As there is no information present about doctors’ visits this was excluded from the calculation. The expenditures on medicine are estimated to be 163 USD per capita per year. This number is based on the calculation presented in Table 2.

The estimated value of medicinal plants is an underestimation as avoided costs for doctors’ visits are not accounted for. Though the method of Brown (1994) did not take into account the time spent to collect the plants and preparing them for medicinal use. The plants are also often used to add flavor to food instead of only using them for a medicinal reason. The expected medicine reduction is an assumption as well, as the principle of direct substitutability, which might not correspond to reality. However, 77% of the local residents use plants at times and this means that this ecosystem service provides benefits to a majority of the population of St Eustatius. It is important to take this value into account.
Table 2. An educated guess on medicine expenditures is made via comparing it to the Dutch situation corrected for the GDP per capita on St Eustatius

<table>
<thead>
<tr>
<th>Indicator</th>
<th>The Netherlands</th>
<th>St Eustatius</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP per capita (USD)</td>
<td>40,000</td>
<td>15,714</td>
</tr>
<tr>
<td>GDP factor (compared to NL)</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Medicine expenditure (USD)</td>
<td>414</td>
<td>163</td>
</tr>
<tr>
<td>Users of medicinal plants (%)</td>
<td>N/A</td>
<td>77</td>
</tr>
</tbody>
</table>

Non-use Value

The non-use value of coral reefs is determined by the WTP of people for goods and services they do not use in a direct way, hereby taking into account the WTP of Dutch mainland households to preserve the state of the reef. Lacle et al. (2012) determined that the WTP of Dutch mainland citizens depends on the quality of the reef. A survey done presented that the WTP of locals to improve the state of the reef from poor to high is 3.1 USD per month. This value was determined to vary according to the state of the reef.

Methods used to determine the WTP were the contingent valuation and a choice experiment. See the report on the WTP by van Beukering et al (2012) for a complete explanation of these methods. Furthermore, all calculations used in the model, are derived from the van Beukering et al (2012) report.

Livestock and agriculture

Livestock and agriculture are schoolbook examples of provisioning services by terrestrial ecosystems. At the moment these are not fully developed on St Eustatius and this offers an opportunity to benefit from what nature has to offer. We will demonstrate the potential value for St Eustatius when these sectors will be developed.

This value demonstrates the potential benefits St Eustatius could obtain from livestock and agriculture. It all comes down to which agricultural practices will be used. Agriculture can provide services like regulation of soil and water quality and carbon sequestration, especially if you compare it to the current degraded land. Agriculture can also provide disservices; this includes loss of habitat, nutrient leakage, erosion and pollution of pesticides. It is possible to create a win-win situation under appropriate agricultural management (Power 2010). We assume this will be taken into account, therefore, we focus on the economic benefits and costs.

The Strategic Development Plan (SDP) of the Statian government includes managing free roaming livestock and proposes a fenced area for (commercial) husbandry. Furthermore, areas for (commercial) agriculture or horticulture are also suggested in the new development plan (Hoogenboezem et al. 2010).

Livestock

Currently, it is estimated that almost 6,500 animals roam freely on St Eustatius. Roberto Hensen, department of agriculture, livestock farming and fisheries (LVV), has shared their vision how to manage these free roaming animals (pers. comm. Roberto Hensen – LVV). The number of animals will be reduced as presented in Table 3 and some of the animals will be fenced as described in the SDP. The idea is to set up a meat market providing surrounding tourist islands with high-end biological meat. In our calculation of the value of livestock we estimated and included the costs for this
new situation. These costs include catching and removing free roaming animals, setting up and maintaining fences, furthermore, costs of slaughter and storage equipment, staff to maintain the fenced animals are included as well. In 2004 a goat eradication plan was carried out on Saba and these costs were extrapolated in order to give an estimation of the costs for free roaming animal eradication on St Eustatius. The animals will be grazing on pastureland and they will be extra fed with grass harvested from the area near the airport. This should result in better quality meat, which can then be sold for a higher price. Moreover, managing free roaming animals removes grazing pressure on large parts of the island, thereby reducing erosion. Natural vegetation has a chance to regrow and water and soil will be retained. Profit related to milk, cheese and manure production were not taken into account.

As mentioned in the previous paragraph not all aspects are taken into account due to a lack of information and restriction in time. However, the data processed give an indication of the potential value of livestock. This model does not contain spatial aspects, though it is important to consider the location of the fenced area. For example, a steep pasture will have a higher erosion rate. If it lies directly near a coral reef it will have a great impact on it due to sedimentation and nutrient leakage. If we would model this, it would result in a lower marine indicator decreasing the tourism value.

Erosion or run off can be addressed by the use of retention ponds, which also provides fresh water for the animals. For more information about this topic we refer to the watershed master plan report (Sangster & Brans, 2012). Nutrient leakage could be limited by collecting manure. This manure could then be used for local agriculture or sold to other islands. In general it brings potential to diversify the economy of the island.

**Table 3.** The number of free roaming animals on St Eustatius in 2010 and in the new situation proposed by the department of agriculture, livestock and fisheries (pers. comm. Roberto Hensen – LVV).

<table>
<thead>
<tr>
<th>Livestock</th>
<th>2010</th>
<th>New Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td># Goats</td>
<td>4,000</td>
<td>1,700</td>
</tr>
<tr>
<td># Sheep</td>
<td>1,000</td>
<td>300</td>
</tr>
<tr>
<td># Cows</td>
<td>1,100</td>
<td>350</td>
</tr>
<tr>
<td># Pigs</td>
<td>200</td>
<td>0</td>
</tr>
<tr>
<td># Donkeys</td>
<td>120</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>6,420</td>
<td>2,350</td>
</tr>
</tbody>
</table>

**Agriculture**

As St Eustatius has limited capacity for agriculture they want to focus on high end agricultural products. Roberto Hensen of LVV mentions products such as mini cucumbers and specific medicinal plants. For the calculation of the value of agriculture data from the agricultural sector of neighboring islands St. Kitts and Nevis has been used. The islands are comparable to each other regarding climate and soil type (pers. comm. Roberto Hensen). The agricultural sector of these islands consists of 6,000 hectares and accounts for 1.9 % of the total GDP (CIA, 2014). In this way a value of 2,672 USD per hectare per year has been determined. As GDP is the added value of goods and services within a year, it already takes into account the costs of agriculture, including wages. Following the SDP (2010) a desired agricultural area of 280 hectare has been determined.
This is probably an underestimation, as the focus of St Eustatius lies on high end products, therefore, it is very possible that the investment costs will also be higher. This report did not depict specific types of agricultural practices. Neither were nutrient leakage, pesticides and the effect on biodiversity taken into account. Currently, there are options to reduce these potential impacts.

Another aspect to keep in mind is that agriculture might also play a role in carbon sequestration. Montagnini & Nair (2012) already point out the potential of agroforestry systems where carbon payments are present. Agroforestry might not be the most interesting type of agriculture for St Eustatius, but there are other forms which can contribute to reduce atmospheric CO2. Lal (2004) demonstrates several examples of soil carbon sequestration to battle climate change, while it also improves and sustains agronomic productivity (Lal 2004).

Local recreational and cultural value

Local residents, especially on small islands, have often a close relationship with their natural environment. This environment is an essential source of non-material well-being and is central for a sustainable society (de Groot et al. 2002). First, it will be explained in general how this value can be determined followed by the approach taken on St Eustatius. This information will be used to determine the local value.

In addition to provisioning, regulating and supporting services, social and cultural services play an important role in determining the importance of ecosystems to human society. They provide functions like recreation, spirituality, aesthetics and feelings of pride. These are non-consumptive uses that do not impact the natural environment directly, but still involves the direct presence of the people appreciating it (Beukering et al. 2007; de Groot et al. 2002). This indirect use value is not easy to determine as there are no market prices available. Valuation techniques like contingent valuation and choice modeling are stated preference methods that can be used to estimate the economic value of cultural services. With contingent valuation a survey is conducted and people are asked directly what they are willing to pay for a specific ecosystem service. Choice modeling is a hypothetical method where people are asked to choose between different sets of scenarios. These sets consist of attributes in various conditions, e.g. the state of the marine environment can be moderate, good or excellent. A money indicator is included to determine the willingness to pay for certain sets of attributes (Beukering et al. 2007).

The importance of the natural environment to the residents of St Eustatius has been assessed through a public survey. A total of 400 households on St Eustatius participated in this household survey, addressing a wide range of issues such as ecosystem threats, benefits, and preferred environmental management options. This survey contained contingent valuation and choice modeling to determine the willingness to pay from the local residents.

The choice modeling contained the following attributes: the state of the coastal waters, the natural landscape and the archaeological heritage and management of the free roaming goats including a contribution per year as payment vehicle. The detailed set up and results can be found in the study of Fenkl et al. (2013). This value will show the trade-offs people have made and will provide input for policy decisions. Choice modeling is a technique to value non-market benefits from ecosystem services. It is often opposed that it only entails a hypothetical value which does not correspond to the real value. However, this can be overcome by a smart design and a good preparation of the interview team. It is an intuitive technique to reveal a non-market value and trade-offs of the individuals can be further assessed.
Research value

The natural environment of St Eustatius provides important services for research and education. The marine and terrestrial environments of the island are of interest to academics conducting and publishing research based on the unique and easily accessible ecosystems. Without the presence of healthy ecosystems, St Eustatius would not attract the same number of researchers. The importance for academic research is highlighted by the current development of the Caribbean Netherlands Science Institute (CNSI). The CNSI is a collaborative project by local parties and various Dutch research institutes \(^1\). The institute officially opens its doors in April 2014.

The research value is estimated in a straightforward manner. Research expenses that were assigned to study on the natural environment of St Eustatius are taken into account. It has to be noted that these research expenses are not necessarily made on the island itself: the allocated budgets finance wages and research costs made on St Eustatius and elsewhere.

In addition, the funds of the CNSI for the next 5 years have been included. The development of the CNSI is likely to have a relatively large impact on the local economy.

The research institutes related to the Wageningen University are the only organizations that structurally conducts research of significant extent on the natural environment of the island. With financial information from the university an average of the research budgets of the last 4 years and coming 2 years is calculated. In 2013 Wolfs Company and VU University Amsterdam conducted research of which budgets are available as well. The rest of the research on St Eustatius is mostly conducted on project basis by individual researchers. In 2013, 7 additional researchers visited St Eustatius for scientific research; their budgets are unknown. The results of the budget inquiries are presented in table 4, which indicate an estimate of the number of visiting researchers; and table 5, which demonstrate that an annual total of around 370,000 USD is spent on nature related research.

The CNSI has a budget of 2.5 million dollars for the coming 5 years. The money will be spent on the development of the station, research facilities, research, education and outreach. An annual value of 325,000 USD is calculated to be attributable to nature on St Eustatius. Of this amount, roughly 60% is spent directly on the island itself.

Furthermore, the Netherlands Organisation for Scientific Research (NWO) has reserved 10 million euros for scientific research in the Caribbean for the coming 5 years. Around 70% of the proposals indicate that research will be conducted from the CNSI. A rough estimate indicates that this will increase the annual research value of ecosystems on St Eustatius with almost 1.5 million USD over the coming 5 years (300,000 USD per year).

Because of the low predictability of the allocation of the NWO budgets, only the current research budgets and the budget for the CNSI are taken into account for the calculation of the total research value. This results in a total annual research value of 695,000 USD that is estimated to be attributable to the natural environment on St Eustatius.

\(^1\) For more information on the CNSI partners visit: http://www.cnsi.nl/partners
Table 4. Overview of parties (2013).

<table>
<thead>
<tr>
<th>Organization</th>
<th>Average number of researchers per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wageningen UR</td>
<td>13+ researchers</td>
</tr>
<tr>
<td></td>
<td>6 interns</td>
</tr>
<tr>
<td>Wolfs Company/VU</td>
<td>3 researchers</td>
</tr>
<tr>
<td></td>
<td>2 interns</td>
</tr>
<tr>
<td>Other researchers</td>
<td>7 researchers</td>
</tr>
</tbody>
</table>

Table 5. Total annual research value.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Annual budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current research</td>
<td>370,000 USD</td>
</tr>
<tr>
<td>CNSI budget (attributable to nature related research)</td>
<td>325,000 USD</td>
</tr>
<tr>
<td>Total research value</td>
<td>695,000 USD</td>
</tr>
</tbody>
</table>

Fisheries value

Fisheries are a minor contributor to the economy of St Eustatius. According to a report by ECORYS (2010) 15 people are currently employed in the fishing sector, although interviews with local experts and fishermen indicate that this is probably an overestimate. Not much information is available on the state of the fisheries in terms of size and sustainability. Funded by the Dutch Ministry of Economic Affairs, IMARES recently started an extensive monitoring program to keep track of fish stocks and the landings on St Eustatius and Saba, but it would be premature to draw any conclusions about whether stocks and landings are constant.

The Caribbean spiny lobster and a mix of reef fish species are the main target for the fishermen on St Eustatius, who fish with pots for most of their trips. A minor share of pelagic fish and red fish are also caught. Especially, the share of pelagic fish is likely to increase, due to efforts of the Department of Agriculture & Fisheries (LVV) to install a Fish Attracting Device of the coast of St Eustatius. For the valuation of the local ecosystems of St Eustatius, only the value of reef related fisheries is included. The total value of fisheries is estimated by aggregating the various categories of reef fish and lobster. Information about the costs involved with fishing is not available. Neither are the intentions of fishermen to go fishing. Considering the scale of the fisheries, it is likely that fishermen fish for a combination of commercial, recreational and subsistence purposes.

Eric Boman, who works with both LVV and STENAPA and manages the fish-monitoring program on St Eustatius, shared his monitoring data based on research done in 2012 and 2013. Based on the information provided by Boman, mixed reef fish account for the largest catch category by local fishermen (Table 6). Lobster fisheries are of similar importance. Conch and Red fish fisheries are very limited in size.

---

2 Information based on interview with Eric Boman, LVV and STENAPA.
3 It has to be noted that although the health of the lobster population is dependent on the health of the local ecosystems, there is no scientific consensus as to how important other areas in the Caribbean are for the recruitment of lobster on the reefs of St Eustatius.
The total meat value of the fisheries on St Eustatius is calculated by aggregating the values of four different categories of reef species. The total value of the 252 fishing trips that have been logged in the monitoring program amount up to a total of almost 100,000 USD. According to Boman, however, this is not a representative value because some of the fishing trips have not been logged. He estimates a total of 500 annual fishing trips resulting in an annual value of 190,000 USD for reef related fisheries of St Eustatius.

Table 6. Valuation of fisheries on St Eustatius.

<table>
<thead>
<tr>
<th></th>
<th>Lbs</th>
<th>Price per Lbs</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Fish</td>
<td>283</td>
<td>$ 8.00</td>
<td>$ 2,264</td>
</tr>
<tr>
<td>Mixed Reef Fish</td>
<td>5493</td>
<td>$ 6.00</td>
<td>$ 32,958</td>
</tr>
<tr>
<td>Lobster</td>
<td>3,790</td>
<td>$ 8.00</td>
<td>$ 30,324</td>
</tr>
<tr>
<td>Conch</td>
<td>5,000</td>
<td>$ 6.00</td>
<td>$ 30,000</td>
</tr>
<tr>
<td><strong>Total logged catch (252 logged trips)</strong></td>
<td></td>
<td></td>
<td><strong>$ 95,546</strong></td>
</tr>
<tr>
<td><strong>Total catch (500 estimated trips)</strong></td>
<td></td>
<td></td>
<td><strong>$ 189,575</strong></td>
</tr>
</tbody>
</table>

Tourism value

Tourism is a major contributor to the total value of coral reefs and terrestrial ecosystems on St Eustatius. Although, tourism is not the most important sector for the island, the tourism industry provides almost as many jobs as the oil terminal NuStar (Ecorys, 2010). The island receives 10,250 visitors on an annual basis. These visitors have been divided into three groups: tourists that visit exclusively for leisure, people that visit family and friends during their vacation and business travelers that combine work and leisure. All groups contribute to the tourism value of coral reefs and terrestrial ecosystems on St Eustatius.

Tourists generate revenues that can be directly related to the natural environment on the island, for example a fee payment for recreational activities such as diving and snorkeling. Revenues that are indirectly related to the natural environment are expenditures for accommodation and restaurants. Because the natural environment is such an important attraction for tourists on St Eustatius, the indirect expenditure still dependent on a healthy environment. Moreover, research demonstrates that tourists have a positive willingness to pay (WTP) for additional nature conservation on the island, this information is also included in the tourism value.

Van de Kerkhof et al. (2014) investigate the expenditures and WTP of tourists for nature management to value the ecosystem services that are related to tourism on St Eustatius. A total annual value of approximately 3 million USD is calculated for the marine and terrestrial ecosystems. Of the estimated added value that is created in the tourism industry, around 2.2 million USD is attributable to nature. The study estimates that visitors are willing to contribute 750,000 USD to maintain the natural beauty of St Eustatius. This supports the hypothesis that nature is a crucial factor for the islands tourism.

According to many stakeholders, the tourism industry is a great potential to develop the island economy. However, tourism does not only have a positive impact. Development of the tourism industry requires investments for proper infrastructure and sufficient facilities for visitors. Developing these facilities are likely to increase pressure on the very same ecosystems that attract these visitors.
Research by Van de Kerkhof et al. (2014) demonstrates that over 60% of the visitors plan to return to St Eustatius (see figure 5). This willingness to return significantly decreases to approximately 40% when the marine environment degrades.

**Figure 5.** Return rate of tourists on St Eustatius based on changes in island characteristics.
3 Scenarios

This chapter describes the structure and content of future scenarios, which have been developed based on discussions with stakeholders on St Eustatius. The scenarios consist of a baseline scenario, which is the current situation and two scenarios being the expansion of the tourism industry and the development of agriculture including managing free roaming animals. The scenarios are analyzed within a timeframe of 30 years. The analyses of the baseline scenario in comparison with two development options give insight in the impact of these developments on the natural environment and, thereby, on the values provided by the ecosystem resulting in an economic impact. This model includes local human stressors and not global stressors such as climate change.

Local human stressors refer to the threats described in the first chapter of this report. Due to a lack of information the analysis of the impact by an oil spill could not be addressed, which is further explained in this chapter. Local information is retrieved from articles, reports and interviews with local and international experts. When local information was not available, information from literature has been translated to the specific situation on St Eustatius. In this chapter first the baseline scenario is explained, thereafter, the two scenarios.

3.1 Baseline scenario St. Eustatius

The baseline scenario extrapolates the current conditions into the future assuming no changes in the current development are taking place, no alternative management options or development strategies are realized. The current situation demonstrates that the number of last year’s visiting tourists is slightly declining with 5%, this trend is extrapolated into the future. The population growth is constructed according to the sustainable scenario of 5,500 residents in 2030 according to the SDP. Furthermore, the free roaming goats remain without management interventions; resulting in continuation of grazing efforts. This will result in a degradation of land and a higher rate of run-off and erosion. The fisheries sector is assumed to remain constant. The government of St Eustatius aims for a higher level of prosperity in a livable environment for their residents. This scenario analyzes the consequences if no specific development strategies are implemented. Table 7 presents the values provided by the services of the marine and terrestrial ecosystem of St Eustatius. It describes the expected impact on these values if there is no management intervention implemented from a specific development strategy.

3.2 Scenario tourism expansion St Eustatius

The second scenario, next to the baseline scenario, demonstrates the effect of implementing the development strategy of expanding the tourism industry on St Eustatius. Currently more than 10,000 tourists visit St Eustatius per year. Most tourists stay over on an average of 13 nights (van der Kerkhof et al. 2013). The SDP envisions an expansion of the number of hotel rooms from 75 to 300 rooms. The model entails day and stay-over tourists and assumes that the ratio between them will remain the same during the expansion of the industry. This holds as well for the percentage of divers and snorkelers.
To facilitate these increasing numbers of tourists, investment in infrastructure is needed. This contains expansion of hotels, restaurants, other facilities and maintenance of the historical sites and the conservation of the natural environment. This expansion result in less available natural vegetation, as a consequence of less vegetation, less water will be retained and erosion shall increase. Run off with sediment particles and nutrients will enter the surrounding water and this has a negative impact on the marine environment. Coral recruitment gets hampered and algae growth is stimulated. Moreover, divers and snorkelers physically destruct parts of the coral reef. Rapid and extensive tourism development is associated with deforestation, pollution and loss of species (Fabricius 2005; McElroy and de Albuquerque 1998; Velde et al. 2010). St Eustatius benefits from the generation of income, jobs, tax revenues, and maintenance of the natural surroundings. This scenario gives insight in impacts of a quadruple tourism expansion.

Table 7. The expected impact on the values derived from ecosystem services if nothing changes (baseline scenario) or if the tourism sector will expand. The new scenarios are compared to the baseline scenario.

<table>
<thead>
<tr>
<th>Values</th>
<th>Baseline scenario</th>
<th>Tourism expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expected change</td>
<td>Explanation</td>
</tr>
<tr>
<td>Tourism</td>
<td>v</td>
<td>Slight decline in tourist numbers</td>
</tr>
<tr>
<td>Local: cultural and recreational</td>
<td>v</td>
<td>Decline in natural environment (terrestrial and marine) due to grazing and sedimentation</td>
</tr>
<tr>
<td>Non-use</td>
<td>v</td>
<td>Decline in natural environment (terrestrial and marine) due to grazing and sedimentation</td>
</tr>
<tr>
<td>Fisheries</td>
<td>v</td>
<td>Coral cover will decrease</td>
</tr>
<tr>
<td>Carbon sequestration</td>
<td>v</td>
<td>Decline in natural environment (terrestrial and marine) due to grazing and sedimentation</td>
</tr>
<tr>
<td>Medicinal plants</td>
<td>v</td>
<td>Decline in natural environment (terrestrial and marine) due to grazing and sedimentation</td>
</tr>
<tr>
<td>Research, Education</td>
<td>=</td>
<td>Remains constant</td>
</tr>
<tr>
<td>Agriculture and livestock</td>
<td>=</td>
<td>Remains constant</td>
</tr>
</tbody>
</table>

3.3 Scenario agriculture and managing free roaming livestock

St Eustatius is faced with similar threats and economic problems as small island development states (SIDS) in the Caribbean. One of their threats is their dependence on import of food products and agriculture can be an important economic sector on these islands to secure food supply and provide affordable fruit, vegetables and meat. Furthermore, agriculture can provide job opportunities and income (Rawlins et al. 1998). An aspect of the development of the agricultural sector on St Eustatius is the management of free roaming animals. The free roaming animals will eat and, thereby, destroy the crop.
Livestock

Not managing the unbridled grazing by free roaming livestock on the island has disastrous consequences for the natural environment. The cows, goats, sheep, donkeys and pigs roam freely around the island minimizing the natural vegetation. This results in run off and erosion entering the surrounding marine environment. Sedimentation impacts coral reefs by suffocating live coral and as a consequence decrease coral cover. According to Roberto Hensen (LVV) the island has reached its carrying capacity alleviating the population growth of the free roaming animals. The conclusion by Mr Hensen is that the current number of animals will remain stable without interference.

Livestock is not fed by fodder and only utilizes the natural vegetation of the island. This means that the inception of nutrients by the soil is not taking place; runoff takes the nutrients along and there are fewer nutrients left for an increase in biomass of the vegetation. Moreover, the grazing prevents the growth of different vegetation types. Currently, more than 6,400 animals roam freely on St Eustatius and this number is in the agricultural scenario diminished to a maximum of 2,350 fenced animals. Assuming 30% of the animals will be slaughtered every year, while these animals will be healthy, fed and gain weight and therefore contain a higher meat value. The goats caught during the eradication program of 2004 on Saba weighted around 11 kg, whereas the FAO estimates the weight of a fenced goat at 23 kg (FAO 1991). The quality of the meat is improved so the price rises with 2 dollars/kg.

Agriculture

Agriculture is an example of a provisioning service depending on supporting services delivered by nature (MEA, 2005; Swinton, Lupi, Robertson, & Hamilton, 2007). To develop agriculture, clearance of natural vegetation is needed. This clearance is one of the biggest negative impacts on agriculture. Land clearance results in a higher rate of erosion. This is transferred to a negative impact on the natural environment in the model. Currently, agriculture is not an important economic sector on St Eustatius. Factors limiting agricultural practices are the hurricane season and droughts in summer. A strong storm is able to ruin the turnover of an entire year. This insecurity affects the interest of local residents to participate in this sector. Furthermore, the perception is that manual labor not the type of work is local residents are interested in, especially the youth (Volkerink and Meindert 2011).

The SDP of St Eustatius sees a strategic opportunity in increasing the agricultural sector. The plan allocates 15 hectares (0.15 km2) to agricultural purposes. We model what the potential might be if this is tenfold. The soil on St Eustatius is comparable to neighboring islands St Kitts and Nevis (Veerenbos, 1955; pers. comm. Roberto Hensen-LVV). Between the natural parks Boven and the Quill the soil is sandy loam and not too steep (<7%) making it appropriate for agricultural practices (Velde et al. 2010).

While the SDP, published in 2010, mainly aims for subsistence crops, both Darlene Berkel (Development & Investment officer) and Roberto Hensen (LVV) see an important market for high-tech agriculture and high-end products for the surrounding touristic islands. As land is scarce, they aim for the highest revenue per area. Presumably, jobs related to high technology will be more interesting for residents compared to traditional agriculture.
Table 8. The expected impact on the values derived from ecosystem services if the free roaming animals are managed compared to the baseline scenario. Agriculture is only possible when there are no free roaming animals. The impact of agriculture is compared to the scenario of managing free roaming animals.

<table>
<thead>
<tr>
<th>Values</th>
<th>Manage free roaming animals</th>
<th>Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expected change</td>
<td>Explanation</td>
</tr>
<tr>
<td>Tourism</td>
<td>🡩</td>
<td>More natural vegetation, higher WTP</td>
</tr>
<tr>
<td>Local: cultural and recreational</td>
<td>🡩</td>
<td>No nuisance anymore, more natural vegetation</td>
</tr>
<tr>
<td>Non-use</td>
<td>🡩</td>
<td>Increase in natural environment (terrestrial and marine)</td>
</tr>
<tr>
<td>Fisheries</td>
<td>🡩</td>
<td>Coral cover increases</td>
</tr>
<tr>
<td>Carbon sequestration</td>
<td>🡩</td>
<td>More natural vegetation, more carbon sequestration</td>
</tr>
<tr>
<td>Medicinal plants</td>
<td>🡩</td>
<td>More natural vegetation</td>
</tr>
<tr>
<td>Research, Education</td>
<td>🡨</td>
<td>Remains constant</td>
</tr>
<tr>
<td>Agriculture and livestock</td>
<td>🡩</td>
<td>Revenue from meat market</td>
</tr>
</tbody>
</table>

3.4 Oil spill

One of the major threats for St Eustatius is the occurrence of an oil spill. In the process of data collection it became apparent that suitable data is lacking to actual realize a scenario to model the chance on an oil spill. There are too many uncertainties to estimate the potential impact of an expansion on nature and economy. This paragraph provides background information about oil spills and an overview of which data is present or missing.

Background

Local residents see the occurrence of an oil spill as one of the main threats for Saba, St Eustatius and the Saba Bank (Dekker 2013; Fenkl 2013). Oil disasters like the Exxon Valdez in 1989 and the Deepwater Horizon spill in 2010 ended up being catastrophic events for the environment. During those oil spills it was not just the environment that was damaged but also coastal economies; the Deepwater Horizon spill cost the USA 22.7 billion USD over a period of three years (Oxford Economics 2010).

Direct contact with oil is often lethal for both animals as plants. However, the type and magnitude of the effects differ and are depend on geographical location, habitat and taxa (Jackson et al. 1989). It can be lethal to coral reefs as well, either via a short exposure with high concentrations or a long exposure with low concentrations. During reproduction and the early life stages the effects of oil spill on coral survival and longevity are the most severe (Yender and Michel 2010). Not just Coral species but the
entire system is directly affected, or indirectly because of cascading effects (Peterson et al. 2003). However, environmental recovery can be relatively quick, with a time frame of 2–10 years the system can be back to its original state prior to the disaster (Kingston 2002).

NuStar Energy L.P. is active on the northern part of the island and is the largest private employer, facilitating 131 jobs on St Eustatius (Ecorys 2013). They would like to further expand their business, which would include an increased capacity to store oil, i.e. their tank farm, further expand their current infrastructure and build a jetty (Klok, Debrot, and Stapel 2011; Royal haskoning 2011). However, at the moment this expansion is on hold. NuStar expects to grow in the future as the oil production in the USA will probably increase dramatically (pers. comm. Terrence Keogh - NuStar). This expansion would increase economic activity on St Eustatius. In 2010, it was estimated that NuStar contributed 38% to the GDP of St Eustatius. This includes direct and indirect expenses (AIB Economic and Financial Services, 2011). The expansion would also lead to the destruction of several historical sites, impact the island scenic views and, therefore, have the potential to hamper the tourism industry. Furthermore, the expansion increases risks of accidents that could damage the islands unique ecosystem and destroy reefs in the St Eustatius Natural Marine Reserve.

Potential impact

Preferably an oil spill would be modelled stochastically to demonstrate what the effect could be in combination with other stressor. Multiple runs on a stochastic simulation model would be insightful and provide information on the resilience of the marine and coastal environment. Simply put the chances of an oil spill and its impact on the environment can be expressed as:

$$\text{Spill risk} = \text{probability of spill} \times \text{impacts of spill}$$ (French-McCay et al. 2009)

The probability of the spill depends on transport data, collision and grounding risk. Wind and current direction, fuel type, depth, sediments and habitats are other factors which are important in defining the spill risk (French-McCay et al. 2009). Annually, NuStar receives 98 chemical tankers and 198 oil tankers which dock to load or discharge their cargo. Around 573 tankers visit to bunker. From all the vessels it is unknown if they are loaded and with what. Furthermore, over 1,250 ships pass the waters around St Eustatius, Saba and the Saba Bank. As these routes are closer to the Saba Bank this area is most at risk. A nautical risk assessment considers ship grounding at St Eustatius unlikely as the prevailing wind direction is east (Folbert and Kodenhof 2012.). This does not mean it won’t occur. On February 26th 2002 the tanker Paulina moored at the St Eustatius Oil Terminal and accidently pumped out ballast water mixed with oil (Klok et al. 2011).

To determine the probability of the spill is difficult as precise data is lacking, though qualitative estimations have been made (Folbert and Kodenhof 2012). Moreover, the impact of the spill is even more difficult to predict. This depends on the resilience of an ecosystem, seasonal changes and spatial allocation and this would preferably been translated in risk maps. Jackson et al. (1989) described a coral cover reduction of 45% at 12 meters depth. The tourism sector of Saba and St. Eustatius will be very vulnerable as both are known for their diving opportunities. After an oil spill it can take 12-28 months before the tourist spending returns to the baseline (figure 6)(Oxford Economics 2010).
Missing data

One report that has some information is a qualitative nautical risk assessment study done by Folbert and Kodenhof (2012). The study provides mainly qualitative data. All the traffic streams, ship type and cargo of ships in the EEZ are unknown. This includes vessels that dock in Saba and St Eustatius and other cargo and cruiseships that are just passing by (Folbert and Kodenhof 2012). NuStar is obliged to report any accident related to their activities and this information should be provided by Rijkswaterstaat or NuStar itself. This could help to establish events that occurred in the past (Klok et al. 2011).

Figure 6. This graph displays the average range of months before the tourist spending returns to normal after an oil spill (Oxford Economics 2010).
This chapter presents the results of the analysis of the different scenarios, being the baseline scenario, the scenario with tourism expansion, and the scenario with the expansion of agriculture and the management of livestock. The tourism and agriculture scenarios are compared to the baseline scenario. All scenarios analyze the impact of these different policy actions on the natural environment and the economy over a period of 30 years. Summarized, this chapter aims at giving insight in the economic benefits and costs of each of these scenarios.

4.1 The environmental outcome

Figure 7 presents the results of the coral and algae cover for the different scenarios. The baseline scenario demonstrates a slight increase in coral cover after which it drops down again to a value of 17%. An initial increase is seen caused by a decrease in visiting tourists annually. Coral cover eventually decreases because algae are able to outcompete the coral for space. Algae cover displays a steady incline over the next 30 years, reaching a value of 65%.

The other two scenarios manifest a visible distinction regarding their environmental impact. During the simulation of the expansion of the tourism industry, the increase has detrimental effects on the health of the environment. Coral cover declines steadily, reaching a minimum at 10%. No less harmful, is the increase in algae cover, reaching a maximum of 69% (Figure 7). The negative impact on the environment is explained by first, the direct impacts tourists have on corals. Around 40% of the tourists that visit St Eustatius go diving and snorkeling (Van der Kerkhof et al. 2013). These activities make the Caribbean such a great vacation spot; sadly though these activities also impact the corals. Such a vast and uncontrolled increase in yearly visiting tourists causes the corals to decrease in absolute cover (Figure 7). Second, the total amount of nutrients (i.e. nitrates and phosphates) produced by the visitors enter the coastal waters; this creates conditions more favorable for algae. St Eustatius lacks a complete sewage treatment system. Thus as the number of tourists increases, so will the amount of nutrients entering the waters.

The agricultural scenario results in favorable conditions for the marine environment. The biggest contributor is the fencing of the free roaming animals. Through a series of links between the terrestrial environment and the marine environment, the model indicates that fencing all free roaming animals causes coral cover to increase and algae cover to increase less. The reason why algae cover increases in all scenarios is because there is insufficient herbivorous fish to keep the algae population in check. And insufficient herbivorous fish are a result of annual fishing pressure, which does not allow fish populations to recover.
Fencing free roaming animals also allow the terrestrial environment to flourish more rapidly. As vegetation enters older stages of its lifecycle, it decreases the amount of sediment runoff. It is this concept that the model simulates and causes coral cover to peak at almost 30% in the scenario where the goats are fenced. Algae cover still predominates, but it has decreased to a value of 65%. The remaining percentage is presumed to be sand and rubble.

The three different scenarios display a clear distinction regarding their environmental impact. The baseline indicates a slight decrease, while an impulse in the tourism industry indicates a negative impact on the environment, and finally, the removal of free roaming animals displays an environmental system with signs of recovery. This trend carries on for the parameters fish abundance and fish diversity (Figure 8). In the baseline scenario there is a slight increase in the fish abundance, whereas fish diversity slightly decreases. Fish abundance reaches a value of 2,034 tons, and 106 fish species being present after 30 years. The tourism expansion results in a decline in fish abundance, dropping down to 1,805 tons. The total fish species also declines, reaching a minimum at 67 species. The scenario in which animals are fenced results in a recovery of both the fish stock and the fish diversity. A maximum value of 2,357 tons is reached with a total of 146 fish species. Both these parameters increase in value as a direct result of the increase in coral cover.

**Figure 7.** Percentage of Coral and Algae Cover in the coastal system of the island. Each line in the graph represents a different scenarios. The Graph depicts how the percentage cover the next thirty years.
In accordance with all the above-mentioned parameters, the marine indicator, the overall state of the marine environment, demonstrates a similar trend (Figure 9). Any value below 0.2 should be interpreted as a degraded ecosystem, degraded to such a state that restoration is only possible through active human intervention. A value between 0.2-0.4 indicates a system that is damaged but is able to restore itself, if not threatened any longer. Of all the scenarios only the fencing of the animals results in a rise of the quality of the environment. All scenarios display an initial decline. This decline is caused by the increase in the algae cover, as it negatively influences the indicator. Another contribution to the decline is the decrease in fish species. For the baseline scenario, this decline levels out and reaches a final value of 0.18. The expansion of tourism reaches a very low value of 0.06. What figure 8 indicates are the consequences if no measures are taken to preserve nature. This result in a coast dominated by algae, barely any coral reef and a more homogenous group of fish species. The management of goats presents how a system can react to measures that are taken on land. It emphasizes the close relationship between land and sea. In this scenario, the marine indicator reaches a final value of 0.31. This is just a bit higher than the initial value of 0.24. Taking a timeframe of 30 years into account, such a minor increase is realistic.
Figure 9. The graph indicates how the marine indicator varies over time. The y-axis represents a relative value that varies between 0-1. A pristine ecosystem at a value of 1, and a completely degraded ecosystem at a value of 0

The effects of the different scenarios on the marine environment have been outlined. Now follows the description of how the scenarios impact the terrestrial environment. The interest lies on how the terrestrial environment reacts to the fencing of free roaming livestock. Especially, in the case of enclosed ecosystems such as small tropical islands, invasive species can have far reaching consequences. As in the case of the marine environment, the fencing of the livestock proves to be a betterment of the terrestrial ecosystem. The two scenarios that display no improvement are the baseline and the tourist expansion (figure 10). They follow the same trend, showing a slight increase in degraded habitat and a decrease in healthy habitat. The reason why they are similar is because tourism is not modeled to have an impact on the restoration or destruction rate of land. The baseline scenario has a total of 726 hectare of healthy land and 933 hectare of degraded land at the end of the simulation. The expansion of tourists indicates an identical trend. The removal of livestock demonstrates the exact opposite since foraging of goats is the main reason for degraded landscape. In this scenario healthy landscape reaches a maximum at 1,635 hectare. Degraded areas on the island are barely visible, only 22 hectares are left.

Tourists, in relation to the terrestrial environment, are modeled as having an impact on the relative number of plant species. The value of the species abundance indicator is partly influenced by the number of tourists that visit the island. The lowest value for this parameter is reached in the tourism expansion scenario (figure 11). It reaches a minimum of 223 species within 20 years after which it increases again to 310 species, just below its initial value. The reason why the value drops at first is because annual number of tourists increases, and each tourist does some damage to the environment. However, because both the marine and terrestrial environment have degraded so much, the island becomes a less attractive tourist destination. Thus, as the number of tourists decreases, they cause less harm to the environment. This allows the environment to recover and eventually species richness increases to its original value.
Results

Figure 10. Graphs present the variation of healthy and degraded land over time for the three scenarios. Both graphs depict the variation in terms of total hectare on the island.

Figure 11. Mean species abundance is presented as it varies over the next 30 years. The graph represents the total number of vascular plant species on the island.

Based on the species abundance indicator and the total surface of healthy land, the terrestrial indicator is calculated. As with the marine indicator, this is a relative value that gives an indication of the state of the ecosystem. Any value below 0.2 should be interpreted as a degraded ecosystem, degraded to such a state that restoration is only possible through active human intervention. A value between 0.2-0.4 indicates a system that is damaged but is able to restore itself if not threatened any longer. A value higher than 0.4 but lower than 0.8 is in good condition but still suffers from anthropogenic influences; there is still sufficient exogenous stress causing detrimental effects. A value of 0.8 or higher can be seen as a pristine ecosystem. Of all the
scenarios only the fencing of the animals results in a rise of the quality of the environment. The terrestrial indicator (figure 12) displays a similar trend as the terrestrial species richness in figure 11, the three scenarios demonstrate distinctions from the onset of the simulation. The baseline scenario indicates the least spread, ranging between 0.45-0.60. An increase in yearly tourist population causes the indicator to decrease even further, reaching a minimum value of 0.37. After 30 years it increases to just below the baseline scenario with a value of 0.43. The removal of the free grazing animals causes the terrestrial ecosystem to slowly recover. At a value of 0.79 this scenario proves to be the most promising in terms of ecosystem restoration.

![Terrestrial Indicator](image)

**Figure 12.** Terrestrial Indicator over time. The y-axis represents a relative value that varies between 0-1. A pristine ecosystem at a value of 1, and a completely degraded ecosystem at a value of 0

### 4.2 The economic value

How the scenarios influenced the environment has been described in the previous chapter. The discourse below aims to depict how the different scenarios influence the economic value generated by the ecosystem goods and services of St Eustatius. It boils down to how the environment influences the value i.e., how ecosystem service provisioning changes as the qualitative state of the environment changes.

The results of the simulation indicate that the tourism industry is one of the largest contributors to the total economic value (TEV). It is in the tourism expansion scenario that the tourism value reaches the highest value. Again a clear distinction is seen between scenarios. Together with the baseline scenario, the managing of free roaming animals results in a similar downward trend in annual tourists. At the end of the 30-year simulation the baseline and fencing goat scenarios reach respective values of 1.27 million and 1.80 million USD (Figure 13). However, these values are far less compared to the tourism expansion scenario. At its peak the tourist industry has a value of 7.93 million USD. This value, however, does not persist. It is still higher compared to the other two scenarios, but it drops down to final value of 2.52 million USD. In this scenario the growth rate of tourism is artificially enlarged, but despite this, the tourist population decreases because the environment is in such a degraded state. These two factors result in the parabola seen in figure 13. A steep increase is caused by an artificial increase in growth, but finally such high numbers of tourists cause its own demise, as the natural environment starts to deteriorate.
Another industry on the island is fisheries. This industry accounts for a large fraction of the TEV, having an annual value of 190,000 USD per year. For the three different scenarios it is the managing of free roaming animals that results in the highest value. The fencing of the goats causes an increase in coral cover as sedimentation rates decrease, thus allowing the carrying capacity of the system to increase. In figure 14 the management of free roaming goats ends with a fishery value of over 400,000 USD. The baseline is just below that with a value of 335,000 USD and the tourism expansion scenario having the lowest value of 290,000 USD.

Locals also account to the TEV with sum of almost 90,000 USD per year. This value accounts for the direct, indirect expenses related to nature and the WTP of the locals in order to preserve nature. All the scenarios indicate an increase in local value, which is a direct result of a steady increase in the total amount of inhabitants of the island. However, there is more than a 150,000 USD difference between the scenarios in which the goats are fenced and the tourism expansion scenario. The divergence is caused by
the difference in the qualitative state of the environment. The value of the WTP per household is directly related to the state of nature, as nature deteriorates the willingness of individuals to contribute to preserve it decreases. This is exactly what is seen in figure 15. In the scenario of managing free roaming animals by fencing the goats, there is an initial rapid rise value. The initial rise is a result that locals are willing to pay more to increase the environment from a bad state to a moderate state than they are willing to pay to improve the environment from a good state to an excellent state. The slope in the graph decreases because the state of the environment has become good, and to further improve it to an excellent state the WTP decreases.

![Local Value Graph](image)

**Figure 15.** The economic value of the local inhabitants. Direct, indirect and WTP values are incorporated in the graph.

Unlike in many western countries, where most people live in heavily urbanized cities, the use of medicinal plants on the island is still common practice. Since islands such as St Eustatius have such high percentage of flora, it is possible to use medicinal plants instead of medicine bought at a drug store that would fulfill a similar purpose. A healthy ecosystem provides more species present and thus increasing the chances of finding the necessary plant. What is seen in figure 16 is the result of this relationship. The baseline scenario depicts a steady incline in value over the next 30 years; the main reason being that the terrestrial indicator stays constant and the annual visiting number of tourist decreases. The expansion of tourism causes the value to drop drastically because of the increased pressures that the tourism industry entails. However as tourist numbers decrease, the value of medicinal plants rises. After 30 years the respective values are a bit over 109,000 USD and 90,000 USD for baseline and tourist expansion scenarios. Fencing the goats, results in the highest value. Free roaming livestock are a major source of pressure on the terrestrial ecosystem. Removing them allows for a recovery and increases the value of the medicinal plants. The annual value is 130,000 USD at the end of the simulation.
**Results**

Figure 16. The value of medicinal plants. This value is the result of local inhabitants using medicinal plants to cure minor illnesses instead of pharmaceuticals, which can be bought.

It is the management of the agricultural industry that influences ecosystem services and is therefore of interest. There are a lot of possibilities to minimize these effects and it depends on the practices being used. The value presents a static depiction of how the agriculture and livestock differs for each scenario. The tourism expansion and the baseline scenario end up with exactly the same value. Fencing livestock, producing meat and allocating some land to high end products, agriculture results in a higher value; in a timeframe of 10 years it increases to just over 427,710 USD. The other two scenarios have an annual value of 12,500 USD (Figure 17).

Figure 17. The value of agriculture and livestock. The sum of these two industries is presented in the graph for the different scenarios.
Carbon sequestration is another value that very much depends on the qualitative state of the environment. The capacity of an ecosystem to store CO2 is directly related to how much hectares of healthy vegetation or corals there are. Thus as the area of these ecosystems increases, so will the value. Only in the case of the scenario where the animals are fenced does this value increase. The percentage of coral cover and amount of healthy land increases in this scenario. This results in a maximum carbon sequestration value of 171,000 USD. The other two scenarios decrease to a value less than 78,000 USD.

**Figure 18.** The value of carbon sequestration for the different scenarios. Baseline scenario and tourism expansion are roughly the same. The value in the graph is the sum the marine and terrestrial system to store CO2.

Figure 19 presents the non-use value for the three different scenarios. In all cases the health of the environment is equal. As the differences in policies of each scenario takes effect on the environment, the non-use values start to diverge. After 30 years the baseline scenario is slightly lower than where it started, having a final value of 15.7 million USD. The value in the expansion of tourism scenario decreases substantially. The WTP of Dutch mainland households decreases as the state of the natural environment does. Their willingness to financially contribute to the preservation of a degraded ecosystem decreases. Managing free roaming animals does result in a higher non-use value. It reaches a maximum at 26.7 million USD and is likely to increase as the environment continues to improve.

In terms of both natural and social science, there is still quite a bit to discover in the Caribbean archipelago. Since Saba, St Eustatius and Bonaire have become part of the Netherlands, a series of studies have been initiated and will continue to do so in the immediate future. Be it studies such as this one or studies conducted by the WUR or IMARES, on an annual basis the amount of money invested in research has been almost 695,000 USD. This value is likely to vary over the next years, but is not expected to alter much.
All the individually described values are summed up and give an overall indication of what the Total Economic Value (TEV) of the natural environment is. The tourism expansion has the lowest TEV reaching a minimum of 17.8 million USD. It is the management of free roaming animals that results in the highest TEV, reaching a final value of 32.5 million USD. However, when the non-use value is excluded from the TEV, the graph looks different. In this case the TEV of the tourism expansion has the highest value, peaking at 11.0 million USD. In the scenario, where all the livestock has been fenced, the value levels out a bit below 6 million USD. The baseline has the lowest value at 4.4 million USD. Here, the environment continues to degrade, causing a further decrease in annual visiting tourists.

The simulation gives predictions on values over the next thirty years. It is therefore necessary to include a discount percentage and determine how these values will vary based on different discount rates. In figure 21 the NPV for the different scenarios are presented. Depending on which discount rate is expected (0-15%) the NPV will vary accordingly. There is a large range between the different discount rates. At a discount rate of 0%, the highest value is 821 million USD for the scenario in which the goats are fenced. A discount rate of 0% is very unlikely however; to calculate a NPV a discount rate of 4% is assumed. At this rate, the NPV is 480 million USD for the goat fencing scenario. Although a substantial decrease, it is a more realistic outlook.
Figure 20 The Total Economic Value for the different scenarios. The top graph includes the non-use value of Dutch mainland households. In the bottom graph this value is not included.

A cost benefit ratio is shown in figure 21 for one of the scenarios. It was only possible to provide such a graph for the fencing-goats-scenario, because information on the costs of such an investment was ample. Benefits are expressed as the net difference between the TEV of the baseline scenario and the scenario in which the goats are fenced. The graph demonstrates that irrespective of the discount rate, the ratio is always positive, indicating the investment pays off.

Figure 21. The Net Present Value (NPV) is presented in the top graph. Different discount rates ranging between 0-15% result in different NPVs. The values represent the sum of the TEV over a time frame of 30 years discounted at a specific rate.
Synergy

It is possible to combine the agricultural and tourism scenarios, this will slow down the degradation, but it won’t stop it. In this scenario aspects of both tourism and goat fencing scenario are combined. The negative impacts of tourist might partly be counteracted if the free roaming animals are managed. This will result in a synergy where the TEV won’t collapse, so tourism can grow supported by additional measures to fence the livestock. There are also other options to maintain a healthy environment. Exclude, for example, tourists that visit specific natural areas in certain periods of the year, e.g. breeding season, or limit the number of tourists per day. Furthermore, tourists love to eat locally produced food. This might have a positive effect on the fisheries and the agricultural sector, but also a negative impact on the fish stock. Overfishing is one of the mayor threats to the marine environment. On the other hand, an increase in the tourism and agricultural sector will further diversify the economy of St Eustatius, though the export of agricultural produces is also targeted for the tourism sector on surrounding islands.
5 Conclusions and recommendations

'In the future, the population of St Eustatius will enjoy a higher level of prosperity in a livable environment.' (SDP, 2010). This is the future envisioned for St Eustatius. It already displays the intention of the government of St Eustatius to take the environment into account. This report demonstrates that the economy of St Eustatius is tightly linked to the environment and economic development also has social and environmental implications. This study gives insight in the tradeoffs and reveals the benefits of maintaining and even improving the natural environment while maximizing the socio-economic benefits derived from ecosystem services.

5.1 The validity of a model

This study made use of a dynamic model to recreate the current situation on the island and to give insight in possible future scenarios based on policy options. Every model is a simplified version of reality and does not contain all elements that are present. It helps to model complex and interconnected relations and to emphasize interdependencies between different fields, which are not clearly visible on first sight. A model is created to answer a specific question and cannot be used for other purposes. It is important to keep the limitations of the model in mind. A model cannot provide definitive answers! However, this does not mean it is not useful. It is a tool to indicate the state of a given system, the (possible) impacts on this system and how this state might change over time (Christensen and Walters 2004). This research used the indicators as suggested by Becking and Slijkerman (2012) to monitor the state of nature. Not all indicators could be incorporated due to a lack of information. The importance of monitoring is clear as management actions can be made upon changes. At the moment limited monitoring takes place and we recommend that this should be further expanded on. Investments are needed and at the same time it should be kept in mind that it is much more difficult to restore a degraded ecosystem instead of maintaining a healthy one (Hughes et al. 2005).

5.2 Model and scenario analysis

The results of this TEEB Caribbean Netherlands study show that the citizens of the Netherlands mainland really value nature on St Eustatius, though they might never visit. This high non-use annual value of 22 million dollars indicates that Dutch mainland citizens would like to see the natural environment of St Eustatius is taken care of. This is an important message to the Dutch government. If the natural environment of St Eustatius degrades, i.e. as demonstrated in the tourism scenario, the Dutch are less willing to pay. It is important to be aware that this non-use value might even drop with 30%.

The natural environment of St Eustatius will further degrade if no measurements are taken, thereby causing it to become less economically valuable. The marine environment will encounter an increase in macro algae and this has a negative effect on the coral reefs. Fewer tourists will visit St Eustatius if the environment further degrades. To stop this degradation, one of the policy options is to fence the free roaming animals. This results in a restoration of natural vegetation, causing less erosion and opens up the possibility to start with agricultural practices. Especially, the Cultuurvlakte is very suitable for agriculture. This generates a potential ecosystem
service where the people of St Eustatius can benefit from. Furthermore, it will provide the local residents with fresh vegetables and fruit every day and that will make the community less dependent on the import of goods via St Maarten.

Another possibility is to expand the tourism sector. On the short term this results in an annual increase in revenue up to over 10.6 million USD. The suggested tourism growth will however, have a negative impact on the natural environment in the long run. The increased pressure by the larger amount of tourists leads to a degradation of the marine and terrestrial environments. Tourists will look for islands with more natural resources and will not come to visit St Eustatius anymore. After 20 years the number of tourists will decrease as well, leading to a decrease of its value. To be clear, the maximum number of tourists used in this simulation is 40,000 per year. This corresponds to the vision demonstrated in the SDP where it is suggested to quadruple the number of hotel rooms from 75 to 300. This simulation makes it visible that this might be too much. The coral cover starts to decrease if more than 30,000 visit St Eustatius yearly. Perhaps this is the maximum number of tourists, which can visit St Eustatius without severely impacting the marine environment. If there are more tourists visiting, the local residents will pay the price and are left with a degraded environment. An alternative is to expand the tourism industry in a moderate pace and to monitor the impact and take appropriate action where needed. With additional investments in nature conservation such as the management of roaming livestock, the carrying capacity to host a maximum number of tourist can increase. The outcome indicates that there is still quite some potential revenue to benefit from what ecosystem services have to offer.

5.3 Resilience

This study focused on local stressors and did not take into account the influence of climate change. Debrot and Bugter (2010) already assessed the possible consequences for the biodiversity of St Eustatius (Debrot and Bugter n.d.). This will definitely have a negative impact on the natural environment of St Eustatius and thus will affect the economy as well. Flooding, droughts and higher frequency of hurricanes will impact the growth of agricultural crops. Increased erosion, coral bleaching, diseases and fish mortality will affect the marine environment and, as demonstrated, will impact the tourism sector. Climate change is something local policy makers cannot influence. However, as Carilli et al. (2009) describes minimizing local stressors like sedimentation, nutrient input and fishing pressure attribute to the resilience of the system towards climate change (Carilli et al. 2009). This is where local policy makers can make the difference. For example, managing the free roaming animals will contribute to coral resilience as natural vegetation is restored and sedimentation is decreased. Otherwise, there is the possibility of a regime shift into a marco-algae dominated environment (Hughes et al. 2005; Mumby, Hastings, and Edwards 2007). Mumby et al (2007) tried to model this shift and suggest certain targets for coral cover and herbivore grazing of algae to prevent this shift. This stresses the importance of monitoring functional groups. Furthermore, seasonal changes and spatial differences should be taken into account. Mapping values and local threats will show the threatened areas and will help to make trade-offs and prioritize (Tieskens et al. 2014).

The challenge is to manage the trade-offs between immediate economic development and maintaining the capacity to provide goods and services in the long term. An ecosystem based approach as this study gives insight in these trade-offs and will help to benefit from the services that nature has to offer in a sustainable manner.
5.4 Recommendations

Without additional management the natural environment of St Eustatius will slowly deteriorate, even without considering the effect of climate change. The option to manage the free roaming animals will definitely improve the state of the natural environment. The investment might be high, but the benefits from a healthy environment, livestock and agriculture are significant for the long term and can be sustainable. However, the negative impacts of agriculture should be taken into account and appropriate measurements should be taken. It can be recommended combining this with a moderate tourism expansion to optimally benefit from what nature has to offer. In general, we would like to stress the importance of monitoring in order for appropriate action to be taken when needed. In the end, it will be more costly to restore an ecosystem than to maintain a healthy one. This will result in a higher level of prosperity for all Statians in a livable environment!
Acknowledgements

This study would not have been possible without the support of numerous people and organizations on St Eustatius. It was great to start our visit with a discussion with the Executive Council, government officials of the St Eustatius government and employees of STENAPA. We would like to express our gratitude to commissioner Tearr and the Executive Council for their hospitality and the time mister Tearr took to share his vision.

Moreover, we like to thank all the people who attended the workshop on valuing the natural environment of St Eustatius and others who gave us valuable information on St Eustatius; especially Roberto Hensen (LVV), Jessica Berkel, Claire Blair, Hannah Madden and Steve Piontek from STENAPA, Maldwyn Timber and Siem Dijkshoorn from Planning & Project Bureau of St Eustatius, investment officer Darlene Berkel, Erik Boman (LVV, STENAPA), Terrence Keogh (NuStar) Johan Stapel (CNSI) Charles Lindo, Maya Leon-Pandt from the the St Eustatius Tourism Development Foundation and many others, we thank you for your expert opinion and the data you provided. Your contribution was crucial for the success of this study.

Furthermore, we have had the privilege to work with a great interview team, consisting of Heleen Visser, Cherida Creebsburg, Fraukje Vonk, Brenda Nous, Perla Duinkerk, Rafaela Busby, Maruska Simmons, Solandy Sanchez Bianca Schmidt, Felicia Schmidt and Mariana Schmidt.

IMARES was of great assistance and provided us with local data and model suggestions to further improve this research. Thank you Bert Brinkman, Martin de Graaf and Erik Meesters for your expertise and discussions.

We would also like to express our gratitude towards Ruth Rivers Woodley from the Rijksdienst Caribisch Nederland (RCN). Thank you Ruth, for your warm welcome and the facilitating services. The Lions Club for providing their facilities for the workshop. We would like to thank Gay Soetekouw, Ruud Stelten and the other people from S.E.C.A.R. for their accommodating services and their knowledge of the historical heritage of St Eustatius.
References

Debrot, Adolphe O., and Rob Bugter. n.d. “Climate Change Effects on the Biodiversity of the BES Islands.”


Van der Kerkhof, Sophie. 2013. The Tourism Value of Nature on Saba and Statia.


Van Kuijk, Tiedo. 2013. The Effect of Marine Reserve Protection and Habitat Type on the Structure of Tropical Reef Fish Assemblages around St. Eustatius.


Plan, Strategic Development. n.d. “Sint Eustatius Strategic Development Plan.”


Rojer, Anna. 1997a. *BIOLOGICAL INVENTORY OF SABA BIOLOGICAL INVENTORY.*


TEEB, ROF. 2010. “MAINSTREAMING THE ECONOMICS OF NATURE.”


White, Joanna, Nicole Esteban, and Michele Polino. 2006. *Fisheries Baseline Assessment of St Eustatius, Netherlands Antilles.*


Annex A  Conceptual framework of simulation model

Figure 4  A conceptual representation of the model. The red boxes represent the threats and exogenous factors influencing the environment. All are anthropogenic of origin. The green boxes represent nature and the associated ecosystem services. Below, in blue, are the different values, that all contribute to the Total Economic Value.
Annex B  Marine module of simulation model

Figure 5  A conceptual representation of the model. The red boxes represent the threats and exogenous factors influencing the environment. All are anthropogenic of origin. Red arrows represent negative impacts and the green arrows a positive influence. The blue boxes are the ecological parameters that contribute to the overall marine indicator.
Annex C  Terrestrial module of simulation model

Figure 6 A conceptual representation of the model. The red boxes represent the threats and exogenous factors influencing the environment. All are anthropogenic of origin. Red arrows represent a negative impact and green arrows a positive influence. The dark green boxes are the ecological parameters that contribute to the overall terrestrial indicator.