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The Total Economic Value of Nature on Saba

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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 project “What is Saba’s Nature Worth?” The project is part of the encompassing project The Economics of Ecosystems and Biodiversity Caribbean Netherlands. The key message of TEEB is that the economic value of nature plays an important role in determining the natural capital on the island.

Saban people are proud of their ‘Unspoiled Queen of the Caribbean’ with its lush mountain rainforest and stunning underwater world. This study aims to determine the economic value of the ecosystem services that are provided by the natural resources of Saba and their overall importance to society. It demonstrates how nature contributes to Saba’s economy and wellbeing. This information can be used to make well-founded decisions when managing the economy and nature of this ‘Unspoiled Queen’.

From the onset of the study, stakeholders participated by facilitating data and simultaneously creating support for the concept of valuing ecosystem services on the island. The research addresses the most relevant ecosystems and ecosystem services for Saba and 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 the natural environment of Saba. The data of the economic evaluation and the surveys was used as input for analysis of the different scenarios.

In the scenario analysis 8 different ecosystem services have been valued in monetary terms. The total economic value (TEV) of the ecosystem services provided by the marine and terrestrial ecosystems of Saba is calculated to be 28.4 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 Saba. This study made use of a dynamic model to recreate the current situation on the island and to give insight in possible future scenarios or management options. Three scenarios were developed in close cooperation with local experts and stakeholders: 1) A baseline scenario 2) Management of roaming goats, and 3) Tourism expansion.

If no new management actions are set in motion and the environment is left to fend for itself it will slowly deteriorate. This will result in a decrease of the TEV to a final value of 21.8 million USD. The scenario in which an increase in the number of tourists analyzed, results in a TEV of 23.8 million USD. However such an uncontrolled increase in number of tourist can have deleterious effects on the natural environment of Saba. Tourists visit the island for its tranquility and unspoiled natural landscape and marine environment. Without these assets, Saba will cease to be the attractive destination that it currently is and these tourists will not return to the island. Sustainable development combined with increased investments in natural capital will pay off in the long run. It is stated that it will be more costly to restore an ecosystem than to maintain a healthy one. The scenario in which free roaming goats are controlled, will improve the natural environment and this management option results in a TEV of 29 million USD, moreover, this scenario will keep Saba the ‘Unspoiled Queen’. In combination with a limited growth of the tourism sector Saba can economically benefit from what its nature has to offer.

Key findings Saba

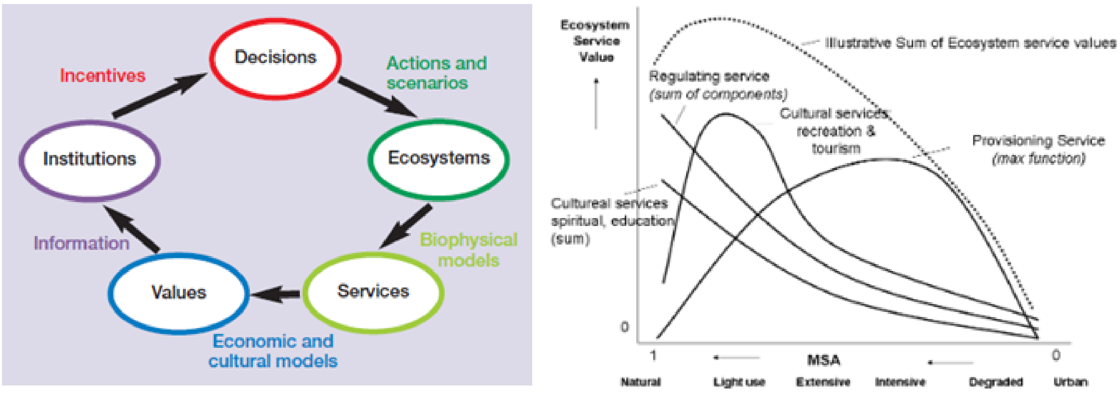
- There are 8 ecosystem service values that contribute to the total economic value of the natural environment on Saba, i.e.: non-use, tourism, fisheries, research, carbon sequestration, medicinal plants, local value and agriculture and livestock.
- The sum of these 8 values, i.e. the total economic value that is attributable to the natural environment on Saba, is 28.4 million USD.
- A total of 7.5 million USD can be directly attributed to the natural environment of Saba and can thus be one on one linked to the economy of the island.
- The tourism sector contributes by far the largest share to the financial value, consisting 65% of the final value.
- For both the marine and terrestrial environment tourists are willing to pay an additional fee in order to improve the quality.
- The aggregated annual amount for the value of nature protection in the Caribbean Netherlands by residents of the Netherlands mainland is estimated at 17 million euro (22 million USD).
- Results of the simulation indicate that over a timeframe of 30 years the annual TEV will drop by 6.6 million USD if nothing is done to preserve the natural environment.
- Expanding annual number of visitors to 50,000 will have short term beneficial effects. The tourism sector will increase in value from 7.5 million USD to 11.7 million USD in 30 years' time. However, results of the simulation indicate that many tourists will have detrimental impact on the natural environment.
- The management of free roaming livestock is beneficial for the environment as for the TEV. Furthermore, the management of livestock will open opportunities for agricultural development.
- When managing free roaming goats is combined with a moderate expansion of the tourism industry, nature will be more resilient and can withstand more tourists without degradation of the natural environment.

These findings support the maximization of the benefits nature has to offer while keeping Saba the 'Unspoiled Queen' that it is.

1 Introduction

Although human wellbeing does not solely dependent 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 natural environment 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 Saba.

1.1 Background information

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 framework for the nature policy plan Caribbean Netherlands. The socio-economic valuation of ecosystem services and goods research by Wolfs Company and VU University delivers input for this nature policy in 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 Saba's Nature Worth?" is part of the part of the TEEB NL research project called TEEB Caribbean Netherlands. Four reports have been produced for "What is Saba's Nature Worth?" of which this report is about the total economic value of the ecosystem services and goods of Saba (Heide and Ruijs 2010; TEEB 2010).

1.2 Economy and demography

Saba is a small volcanic island in the north-eastern Caribbean. There are four villages on the island: The Bottom, St. John's, Windward side and Hell's Gate. These villages are connected with one road which is established in 1958. These residential areas are located in the south-eastern part of the island (Rojer 1997a). The population of Saba on January 1st 2013 consists of 1,991 residents. These residents have different nationalities like Dutch, English, Irish, Scottish and African, representing Saba's history (Dekker 2013; SCF 2005a).

Around 1640, Saba was populated by Dutch and later by English colonists. The island frequently changed hands till Holland took permanent possession of Saba (SCF 2005a). In the 18th century all the available land was cultivated. Large plantations were not present due to the relief of the island. Hurricanes have impacted the agricultural practices on the island. In 1911 up to 2,500 people worked in the agricultural sector. This sector declined in the 20th century when Sabans left the island and abandoned the agricultural plots (Rojer 1997a). Besides the agricultural sector, fisheries were a very important economic sector on Saba (SCF 2005a). Currently, these sectors only contribute 2% to the GDP of Saba (SENSA 2006). Before 1963 the island was very inaccessible until the airport on Saba was constructed and air transport to St. Maarten began. In 1972 the pier in Fort Bay was built, which opened Saba to tourism. Nowadays, tourists come to dive, enjoy the beautiful nature and the friendly atmosphere. The authentic Saban cottages add to the charm of the island. In 1992 the Saban Medical School was opened and became an important economic sector of Saba and provides medical education to over 400 students annually (SCF 2005a; SENSA 2006).

At present, up-to-date information about the economy of Saba is scarce. The latest GDP figures are from 2005, when GDP was around 24 million USD and the most important economic sectors were wholesale and retail trade, the Saban medical school, construction and hotel and catering industry (SENSA 2006).

1.3 Nature and ecosystems

The island of Saba is 13 km2 and consists of the top of a volcano arising from the sea. The top of the island, Mt. Scenery, is the highest point of the Netherlands at 877 meter above sea level. The relief of the island is steep with guts caused by weathering and runoff. There are no permanent sand beaches on Saba, just steep cliffs. A seasonal beach may occur in Well's Bay (Rojer 1997a; SCF 2005b). The climate is tropical with an average temperature of around 25.7°C with an average rainfall of 1101.3 mm per year (1891-1980). Saba lies in the hurricane belt and experiences at least one tropical cyclone within 100 miles once a year and hurricane conditions every 4 to 5 years (MSNA&A 2010).

Temperature, humidity and rainfall vary with altitude. This results in distinctive zones from shrubby vegetation near sea level up to the tropical and rare cloud or elfin forest at the top of the island. Mt. Scenery is almost always covered with clouds (SCF 2005b). It is suggested that this forest attributes to the microclimate of Saba, but the height of the mountain in combination with the evaporation is most likely responsible for the cloud formation (pers. comm. Prof. Dr. L.H. Bruijnzeel, Dr. Ing. M.K. van der Molen). According to de Freitas et al. (2012) the flora of Saba consists of 565 species. From these, six species are only present on a few local islands. For a small island, Saba is rich in flora diversity. The elfin forest is considered very unique. The fauna of Saba consists of 166 species and researchers are still counting (Freitas, Rojer, and Debrot 2012; Rojer 1997a). Saba has the largest number of breeding pairs of the threatened Red-billed Tropicbirds(Lee and Walsh-McGehee 2000). Furthermore, there is an endemic species of lizards, the Anolis Sabanus.

Saba is surrounded by the Saba Marine Park (SMP), which was established in 1987. The aim of the SMP is to allow sustainable use while protecting the marine resources. The SMP covers a total area of 13 km2, with a no-take area of 4.29 km2. The marine environment consists of large volcanic boulders, lava flows and overhangs. Some have become encrusted with corals, sponges and algae. These are so called patch reefs and are different compared to the fringing reefs of Bonaire (Buchan, Framhein, and Fernandes n.d.; Noble et al. 2013).

About 6 km south of Saba lies the largest atoll of the Caribbean, the Saba Bank. It is approximately 40 by 60 km, with an average depth of 25 meters. There is little known about the Saba Bank, but it is an area of great interest for both ecologists and geologists. Many generations of Sabans use the Saba Bank as fishing grounds. A Rapid Assessment Project revealed that the Saba Bank is a regionally unique ecosystem with high biodiversity. It is potentially an important source of fish and invertebrate larvae for the region. It is assigned as marine mammal sanctuary and as a Particularly Sensitive Sea Area (PSSA) (Hoetjes and Carpenter 2010; Meesters et al. 2010; Williams et al. 2010).

The Saba Conservation Foundation (SCF), a non-governmental organization and member of the Dutch Caribbean Nature Alliance (DCNA), is responsible for the management of the Saba National Land Park and the Saba National Marine Park and the hiking trails around the island.

1.4 Threats and impacts

Saba is known as the 'unspoiled Queen'. Nature on Saba is, compared to other islands in the Caribbean, in a relatively good condition. The Sabans are very proud of their beautiful green island. However, to make sure Saba remains unspoiled, the understanding of the impact by human activities on the ecology and thereby the economy is important.

For this research a workshop with stakeholders, including local experts and interviews with local residents have been conducted. During this meeting an overview of current threats to the natural environment on Saba has been developed. The workshop revealed threats such as the grazing by free roaming animals, the increase of invasive plants, animals and fish species, construction activities, waste, illegal fishing, hurricanes, oil spills and anchoring. Local residents were asked about the threats they experience during interviews. The top 5 threats perceived by the community were oil spills, solid waste, erosion and sedimentation, hurricanes and lionfish (Dekker et al. 2014).

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 analyzed potential impact of certain policy measurements. Local information was gathered via the workshop, trough stakeholders and expert interviews, and surveys. The extensive information is used to construct a dynamic simulation model using STELLA program. More information about the methodology can be found in Lely et al. 2012 The model is used to determine the effect of stressors on environmental indicators and the impact on related economic sectors.

1.6 Structure of the report

The following 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 their impact on and relation with the economy. The chapter thereafter discusses future scenarios in which policy inteventions are simulated, being tourism expansion and the management of free roaming livestock. The results of these scenario simulations and its recommendations are described in the final chapters.

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 for St Eustatius. Off course, the unique characteristics of the Saba were treated as such, and results, methods and recommendations are focused on the specific needs of the island.

2 The model

The functioning of ecosystems, their delivery of services and the final contribution to welfare are complex issues. To effectively evaluate the complex interface between ecological and economic processes, simulation modelling 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 aims to simulate have not been documented in literature studied. To compensate for these hiatuses experts where consulted. The model aims at representing a confined part of reality, however, it does depend very much 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 on modeling the marine environment, the terrestrial environment and the socio-economic values that are related to the ecosystem services and goods. For a conceptual overview of the model see the Appendix A-C.

2.2 The marine environment

Ecosystem services that coral reefs provide are closely tied to the qualitative state of the marine 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 marine module does just that, giving an output that is a relative value ranging 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 allows the capacity of coral reefs to provide functional services to vary. 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):

(2-1) $$\frac{dN}{dt}=rN(1-\frac{N}{K})$$

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.

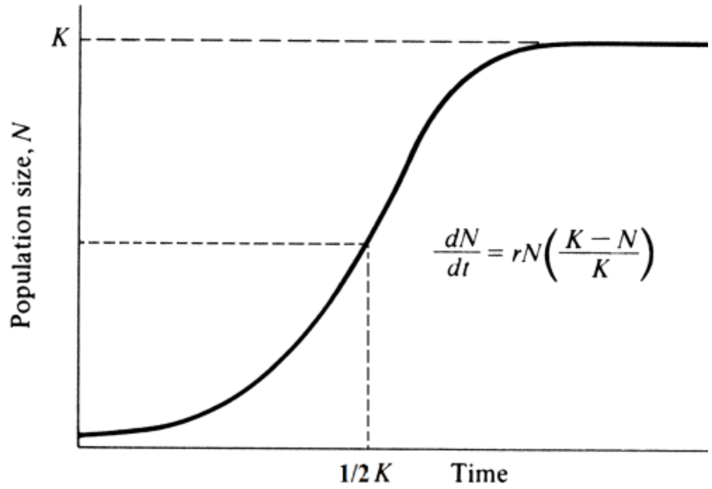


Figure 2 Graph of logistic growth functon, in terms of Percent Coral Cover (N) over time

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 tourist. 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.

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 (PO43-) and nitrates (NO3-). 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 PO43- concentration of 0.05 μM and a NO3- concentration of 0.2 μM was used. As tourists would increases in numbers, so would the amount of nutrients. For every 10,000 tourists, PO43- concentration would increase by 0.05 μM and a NO3- 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 number 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 of 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 total 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 very 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. These values represent the baseline of fishing pressure and it is presumed that there will be a slight decrease of fish stock per year. 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 Saba, 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 affect 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 how much is currently present and what the maximum possible value can be:

(2-2) $$V_n = V_p/V_{max}$$

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 is. 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 habit connectivity, which is important for the proliferation of certain species. A lot of what takes place on land, influences the marine environment. The impact of 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 a terrestrial indicator. It sums up the qualitative state of the terrestrial 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 Saba 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 is capacity to retain water. The main reason for degradation is free roaming livestock such as goats. Livestock species are expressed in the model with a certain amount of pressure on the land, termed Tropical Livestock Unit (TLU). For example one TLU represents: 10 goats. At the onset of the simulation there is a total of 102 TLU and results in 1.8% of land pressure. This means that on a yearly basis 1.8% of the total amount of healthy land is converted to degraded habitat. Because livestock consumes 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 ten 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 1,020 free roaming goats. They result in a total land pressure of 1.8%. 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 (Rojer 1997a, 1997b and Freitas, Rojer, 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 of a biotope increases the total amount of species present also increases.

Model

In the model the total amount of species was calculated according to a species-area function (Figure 3) In 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 3 still holds, and is thus applicable. At a surface area of 13km2 the highest relative amount of species was calculated. This was then set as a maximum value and corresponded to a maximum of plant species.

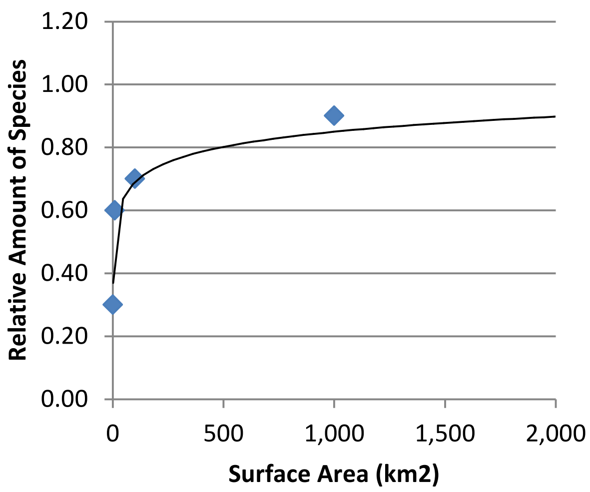


Figure 3 Relationship between surface area of a biotope and the relative amount of species. Data based on Croezen et al. (2011)

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 Saba can be translated into values. The values chosen for Saba 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 Saba’s 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). Climate change can be buffered via the fixation of carbon (de Groot *et al.* 2010). Carbon sequestration plays a role in temperature regulation and precipitation both at the local and global scale (Costanza *et al.* 1997).

Van Beukering and Wolf (2012) determined the ecosystems involved in carbon sequestration on Bonaire. From these ecosystems only coral reefs and dry and tropical forest apply for Saba. In this report we used the same average carbon fixation rate as was used in the Bonaire case. A market-based approach was taken to value carbon sequestration. There are carbon markets in place, but prices vary strongly. A low estimate of 7 USD per ton of carbon is used for calculations in the model.

Table 1 The capacity of each type of ecosystem to sequester carbon.T: Tons, ha:hectare and yr:years.

Ecosystem	Carbon (t/ha/yr) sequestration	Value Used in Model (t/ha/yr)
Dry/Tropical forest	8 - 21	21
Coral reef	-0.04 - 1.06	1.06

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:

$$Total\ Value\ (\$) = \sum (A_C + A_F) \times P$$
$$A_C = Area\ Coral\ \times 1.06$$
$$A_F = Area\ Forest\ \times 21$$

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 (USD) for carbon. 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).

Livestock and agriculture Saba

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

Determining the value of livestock and agriculture

This value shows the potential benefits Saba 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 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.

Model

Currently, it is estimated that over a 1,000 goats roam freely on Saba. We propose the formation of a small meat market to gain revenue from this nuisance. We propose to fence 10% of the goats. To make estimations of the value of livestock in this new situation we included the costs for catching and removing the free roaming goats, to set up and maintain fencing, slaughter and storage equipment and staff to take care of the fenced animals. In 2004 a goat eradication plan was carried out on Saba and these costs were extrapolated to give an idea of the costs for an eradication on Saba. The animals will be grazing on pasture land and they will be fed. This will results in a better quality meat which can be sold for a higher end price. Furthermore, managing the free roaming goats will remove grazing pressure on large parts of the island thereby reducing the erosion rate. Natural vegetation will have the chance to regrow and water and soil will be retained. Profit related to milk, cheese and manure production were not taken into account.

Saba has capacity, though limited, for agricultural practices. In the calculation of the value of agriculture we compared it to the agricultural sector of island St. Kitts and Nevis. The islands are comparable to each other regarding climate and soil type (pers. comm. Tom van 't Hof). 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 US $2672 per hectare per year could be 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. We estimated a desired agricultural area of 65 hectare for Saba based on local expert interviews.

As mentioned in the previous paragraph not all aspects were taken into account due to a lack of local information and time. However, it gives 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 e.g. 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). The manure could be collected, thereby limiting nutrient leakage, and could be used for local agriculture.

This report did not depict specific types of agricultural practices. Nutrient leakage, pesticides and the effect on biodiversity were not 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 points out the potential of agroforestry systems when carbon payments are present. Agroforestry might not be the most interesting type of agriculture for Saba, but there are other forms which can contribute to reduce atmospheric CO_2. Lal (2004) shows several examples of soil carbon sequestration to battle climate change while it also improves and sustains agronomic productivity (Lal 2004).

Research value

The natural environment of Saba 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, Saba would not attract the same number of researchers.

The research value is estimated in a straightforward manner. Research expenses that were assigned to research on the natural environment of Saba 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 Saba and elsewhere.

Determining the value of research

Research institutes connected to the Wageningen University conduct 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 is calculated. The rest of the research on Saba is mostly conducted on project basis by individual researchers. The results of the budget inquiries are presented in Table 2, which indicate an estimate of the amount of visiting researchers. An annual total of around 344,000 USD is spent on nature related research on Saba.

Table 2 Overview of parties (2013)

Organization	Average number of researchers per year
Wageningen UR	13+ researchers 6 interns
Wolfs Company/VU	3 researchers 2 interns

Fisheries value

Fisheries deliver a confined contribution to the economy of Saba (CHL, 2011). There are 9 small fishing vessels with a maximum of 11 meters long. Fishermen fish primarily for commercial purposes on the Saba Bank. The main fishing technique is trap fishing to target lobster and red fish (deep water snapper species); trolling for pelagic species, long line for deep-water snapper and hand lining for mixed reef fish. Most of the red fish and lobster catch is exported for consumption on St Maarten.

For the valuation of the local ecosystems of Saba, the values of reef related fisheries and lobster are included. The total value of fisheries is estimated by aggregating the various categories of reef fish and lobster. The calculated values are merely an indication of the total annual value of the fisheries on Saba. IMARES started active monitoring in 2012, which means that no trends in fish landings can be assessed so far based on this data. Assessment of the Saban fisheries took place in the years 2000, 2007 and 2010.(Boonstra, 2013).

Determining the value of Fisheries

Boonstra (2013) researched the landings of red fish and Van Gerwen (2013) of lobster and mixed reef fish landings. In both studies, port sampling and on-board sampling were conducted. In the process, amongst others species and weight were documented. Their investigation shows that red fish represent the most important species category for the local fisheries (Table 3). Lobster fisheries are considered to be of similar significance and other mixed reef fish are considered to be relatively unimportant to the Saban fishing industry.

The total meat value of the fisheries on Saba is calculated by aggregating the values of four different categories of reef species. This amounts to a value of the Saban fisheries of almost 1.3 million USD per annum. Information about the costs involved with fishing are not available, so the values presented in this paragraph represent gross revenues.

Table 3 Valuation of fisheries on Saba

	Lbs	Price	Value	Source
Red Fish	76300	$7.00	$534,000	(Boonstra, 2013, p. 42)
Mixed Reef Fish	19401	$8.00	$155,000	(Van Gerwen, 2013, p. 40)
Lobster	84556	$7.00	$592,000	(Van Gerwen, 2013, p. 15)
Total value of reef related fisheries			$ 1,381,000	

Local, recreational and cultural value

Local residents, especially on small islands, often have a close relationship with their natural environment. This environment is an essential source of non-material wellbeing 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 Saba. This information will be used to determine the local value.

Determining the local, recreational and cultural 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 method 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 Saba has been assessed through a public survey. A total of 300 households on Saba 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 by the local residents to conserve their natural environment.

The choice modelling contained the following attributes: the state of the coastal waters, the natural landscape, the Saba Bank and the 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 Dekker (2013). This value displays the trade-offs people have made and this result provides relevant input for policy decisions.

Tourism Value

Tourists are a major contributor to the total value of coral reefs and terrestrial ecosystems on Saba. The island receives 22,500 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 travellers that combine work and leisure. All groups contribute to the tourism value of coral reefs and terrestrial ecosystems on Saba.

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 snorkelling. 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 Saba, 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 Saba. A total annual tourism value of 7.5 million USD is calculated for the marine and terrestrial ecosystems. Of the total expenditures by tourists on Saba, being 31.7 million USD per year, around 6 million USD is directly attributable to nature. The study estimates that visitors are willing to contribute another 1.5 million USD to maintain the natural beauty of Saba. This supports the hypothesis that nature is a crucial factor for the islands tourism.

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 the visitors.

Research indicates that over 62% of the visitors plan to return to Saba. This number of returning visitors decreases significantly to approximately 26% return rate when the marine environment is degraded. For more information on the international tourism value of nature on Saba, read Van de Kerkhof *et al.* (2014).

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 households, living on the mainland of the Netherlands, to preserve the state of the reef. Van Beukering et al. (2012) determined that the WTP of Dutch 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.

Medicinal value

The natural environment may also 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 Saba (Dekker, 2014). This information is used to determine the local value of medicinal plants.

Determining the value of medicinal plants

To determine the value the replacement method is used as explained by Van Beukering and Wolfs (2012). On Saba 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 the natural environment of 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.

Dekker et al. (2014) showed that 77% of the population of Saba (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 = USD/med * users (#) * 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.

On a final note, the value for Bioprospecting (pharmaceutical value of biodiversity) by the coral reefs and tropical forest of Saba has turned out to be negligible. Therefore, this ecosystem service has not been described in his Chapter.

3 Scenarios

This chapter describes the structure and content of possible future scenarios. These scenarios are developed based on discussions with stakeholder on Saba. The scenarios consist of a baseline scenario, which is the current situation and two scenarios describing specific developments. The scenarios are analyzed in a time period of 30 years. The analysis 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.

The model, furthermore, includes local human stressors and not on stressors such as climate change. For the scenarios the following local stressors caused by human impact has been taken into account:

- Anchoring, regulation does exist, only enforcement is still an issue that needs to be addressed.
- Damage to coral reefs by marine recreation, such as diving.
- Erosion and related sedimentation and nutrient loading into the marine environment.

Not included are for example the management of waste, as described in a waste plan developed by the Dutch ministry of Infrastructure and Environment. And the influence of coastal developments in the sense of construction activities in relation to the expansion of tourism. Unfortunately, the threat of oil spills has not been addressed in the scenarios, because of lack of solid information.

Three scenarios have been developed: 1) a baseline scenario with a business as usual perspective, 2) an expansion of the tourism industry, and 3) the management of the free roaming goats. Local information is retrieved from articles, reports and interviews with local experts and international experts. When local information was not available, information from literature has been translated to the specific situation to Saba. In this chapter first the baseline scenario is explained, thereafter, the two scenarios. The results are described in chapter 5.

3.1 Baseline scenario

The baseline scenario assumes that the current conditions are extrapolated into the future without any management. The last years the number of tourists is slightly declining with 5% and this trend is extrapolated into the future (Dekker 2013). The population grows is extrapolated from recent years and increases with 1.28% per year. Furthermore, the free roaming goats remain without management and continue grazing. This results in degraded land and a higher run-off and erosion rate. The fisheries sector remain constant. Sabans are very proud on their ‘unspoiled queen’. The island is green on first sight, especially compared to surrounding islands. This scenario will show the consequences if no management actions are taken. Table 4 presents the values, which are derived from services provided by the environment. It demonstrates the expected negative impact on these values if there is no management intervention.

3.2 Scenario tourism expansion

In this scenario only the number of tourists are taken into account. The tourist sector of Saba consists of day tourists, stay-over tourists, cruise tourists and yachties. These different tourists have different impacts on the natural environment of Saba. Currently, there are 12,500 stay-over tourists and 10,000 day tourists. The Tourism Strategic Plan for Saba (2011-2014) entails the vision of doubling the tourist numbers by 2020. This vision was further extrapolated to another doubling of tourist numbers by 2040. The model only takes into account day and stay-over tourists and assumes that the ratio between them will remain the same. This is also the case for the number of divers and snorkelers.

To be able to host these numbers of tourists investment in infrastructure is needed. This entails expansion of hotels, restaurants and other facilities (e.g. expansion of the harbor) and maintenance of the trails to access the natural environment. This will results in less natural vegetation, less water will be retained and erosion will 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. Divers and snorkelers could physically destruct parts of the coral reef. Rapid and extensive tourism development is also associated with deforestation, pollution and loss of species (CHL 2011; Fabricius 2005; McElroy and de Albuquerque 1998). The island of Saba will benefit from tourism as it generates income, job opportunities, tax revenues, and maintenance of the natural surroundings.

This scenario does not make conclusions on the feasibility of this type of tourism expansion. It only displays the possible impact of tourism expansion of this order. Table 5 presents the expected effect on the different values retrieved from nature.

Table 5 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.

	Baseline scenario		Tourism expansion	
Values	**Expected change**	**Explanation**	**Expected change**	**Explanation**
Toursim	v	Slight decline in tourist numbers	^	Increase in tourists results in more revenue
Local: cultural and recreational	v	Decline in natural environment (terrestrial and marine) due to grazing and sedimentation	v v	Tourists impact their surroundings, infrastructure
Non-use	v	Decline in natural environment (terrestrial and marine) due to grazing and sedimentation	v v	Tourists impact their surroundings, infrastructure
Fisheries	v	Coral cover will decrease	v v	Coral cover will decrease
Carbon sequestration	v	Decline in natural environment (terrestrial and marine) due to grazing and sedimentation	v v	More infrastructure, less natural vegetation
Medicinal plants	v	Decline in natural environment (terrestrial and marine) due to grazing and sedimentation	v v	More infrastructure, less natural vegetation
Research, Education	=	Remains constant	=	Remains constant
Agriculture and livestock	=	Remains constant	=	Remains constant

Scenario management of free roaming goats

Romeijn (1987) already mentions the large impact of free roaming goats on the vegetation of Saba. As the free roaming goats do not have any natural enemies they continue grazing and this results in permanent deforestation. Consequences are a change in vegetation type as well as an increase in erosion. Normally, natural vegetation retains water. On degraded areas rain and wind will take away sediments, which will be exported to the surrounding waters. This will have a negative impact on the coral reefs as mentioned before (Rojer 1997a; Romeijn 1987).

On Saba it is tradition to keep goats, but where in the past the goats were kept on a certain area nowadays they roam freely over the entire island. The herds are passed from father to son, but the young people are less interested to take care for these animals and the herds became very big to control. Currently, there are around 20 owners on Saba. Kai Wulf, the park manager of SCF, estimates that even more then 1,020 goats roam freely, namely 4,000 goats. The goats are a nuisance to local residents as they ruin gardens and people have to take measures to keep them out (Dekker 2013).

In 2004, 466 goats were shot and removed from the island, while owners were compensated for their loss. In this scenario we propose to manage the assumed number of 1,020 goats. As a result the degraded, deforested areas have the time to recover to their natural condition.

Table 6 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

	Manage free roaming animals		Agriculture	
Values	**Expected change**	**Explanation**	**Expected change**	**Explanation**
Tourism	^	More natural vegetation, higher WTP	=	Slight decline in tourist numbers
Local: cultural and recreational	^	No nuisance anymore, more natural vegetation	v	Decline in natural vegetation
Non-use	^	Increase in natural environment (terrestrial and marine)	v	Decline in natural vegetation
Fisheries	^	Coral cover increases	v	Coral cover decreases
Carbon sequestration	^	More natural vegetation, more carbon sequestration	v	Decline in natural vegetation
Medicinal plants	^	More natural vegetation	v	Decline in natural vegetation
Research, Education	=	Remains constant	=	Remains constant
Agriculture and livestock	^	Revenue from meat market	^	Revenue from agricultural crops

It is possible to regain revenue from goat management. If for example 10% of the 1,020 goats are fenced and a market is created, both locally as regionally, a new sector could be shaped.). The animals will be healthier, fed and thus gain weight. 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 will be improved so the price can rise with 2 dollars/kg. Every year 30% of these animals could be slaughtered and will result in revenue. This will diversify the economy of Saba and raises the subsistence of the Saban people. Especially, as this opens up the possibility to commercial agriculture or culturing crops in gardens as the goats will no longer roam freely. However, agriculture is labor-intensive on Saba due to the steep slopes. This scenario shows the potential of a meat market and agricultural practices on 65 hectare.

Agriculture is a clear example of a provisioning service which depends on supporting services delivered by nature (MEA, 2005; Swinton, Lupi, Robertson, & Hamilton, 2007). To benefit from agriculture, clearance of natural vegetation is needed. This clearance is one of the most important negative impacts of agriculture. Land clearance results in a higher rate of erosion.

Currently, agriculture is not an important economic sector on Saba. 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, manual labor is not the type of work local residents are interested in, especially the youth (Volkerink and Meindert 2011).

Agriculture was an important economic sector in the past. We propose an expansion of agricultural practices to 65 hectares to demonstrate the potential benefit of this provisioning service.

4 Results

This chapter presents the results of the models for the different scenarios; the baseline scenario, the scenario with the expansion of the tourism sector, and the management of the free roaming goats. The last two scenarios are compared to the baseline scenario, a representation of the status quo that is prolonged. All scenarios display how the environment and the economy respond to the different policy actions over the next 30 years. Thus, this chapter aims at giving insight into what the benefits and costs are for each of the scenarios.

4.1 Impact of scenarios on the environment

Figure 4 presents the results of the different scenarios on coral and algae cover. In the case of the baseline scenario, both the coral and algae cover are fairly stable. Coral cover starts out at 15% and after the simulation, it ends at 21%. The trend of the last decade continues, only showing a slight increase over the next 30 years.

A distinction is visible between the two other scenarios, the expansion in tourism and fencing free roaming goats. During the simulation of the tourism expansion, annual visiting tourists reach a maximum of 49,000 visitors. Compared to the baseline scenario this is a substantial increase. In terms of environmental health, expanding the annual tourist population has detrimental effects. Coral cover declines steadily, reaching a minimum at 9%. An initial increase is seen because annual visiting tourists decrease. Coral cover eventually decreases because algae are able to outcompete the corals for space. Such a drastic increase in algae is also detrimental to the marine environment as it reaches a total of 68% cover of coastal waters.

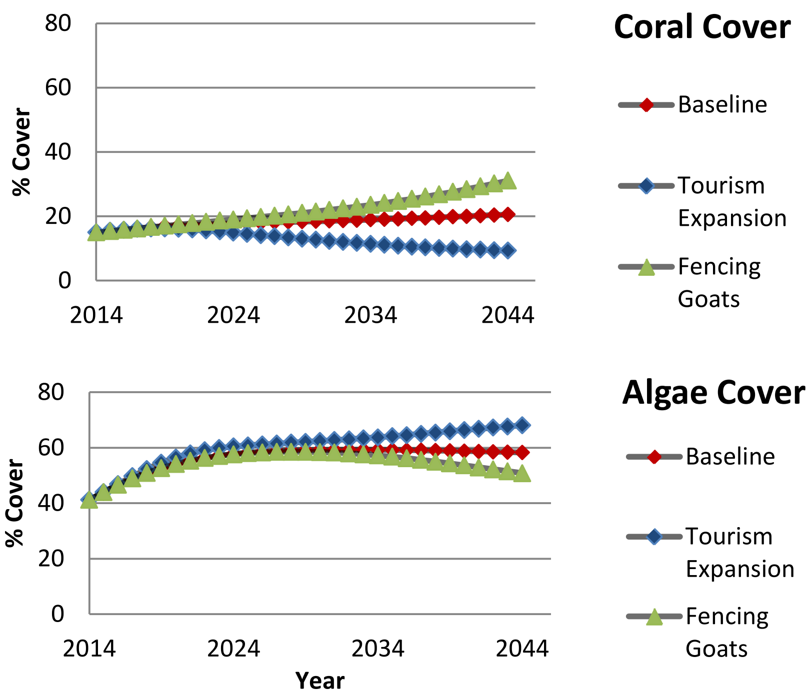


Figure 4 Percentage of Coral and Algae Cover in the coastal system of the island. Each line in the graph represents different scenarios. The Graph depicts how the percentage cover the next thirty years

Figure 4 indicates that the scenario of tourism expansion causes coral cover to decrease and algae cover to increase, the reason for this is twofold. First because of the direct impacts tourists have on corals. A large fraction of tourists that visit the Caribbean Netherlands go diving and snorkeling. These activities are what make the Caribbean such a great vacation spot, sadly though it are these activities that also impact corals. Such a vast and uncontrolled increase in yearly visiting tourists causes the corals to decrease in absolute cover. Second, the total amount of nutrients (i.e. nitrates and phosphates) entering coastal waters will create conditions more favorable for algae. Saba lacks a thorough sewage treatment plant. As the amount of tourist increases, so will the nutrients entering the waters.

It is the fencing of the goats that results in favorable conditions for the marine environment. Through a series of links between the terrestrial environment and the marine environment, the model demonstrates that fencing all free roaming goats causes coral cover to increase and algae cover to decrease. The terrestrial environment is able to flourish more freely and rapidly. As vegetation enters older stages of its lifecycle, the vegetation is able to decrease the amount of sediment runoff. It is this concept that the model simulates. At the end of the simulation coral cover peaks, covering almost 30% of the coastal waters. Algae cover still predominates, but it has decreased to a value of 51%. The remaining percentage is presumed to be sand and/rubble.

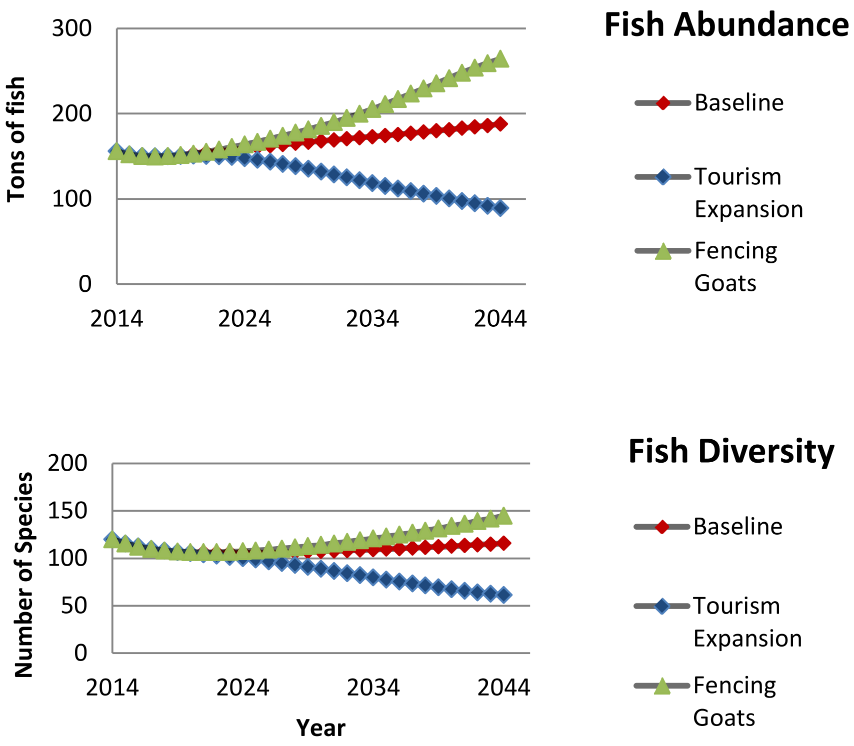


Figure 5 The top graph depicts how the number of fish in coastal waters varies over time. Fish diversity in absolute numbers is shown in the bottom graph.

Already a clear distinction is visible between the three different scenarios. The baseline seems to remain constant, an impulse of tourists displays negative impacts on the environment and finally, the removal of free roaming goats indicates a system with signs of recovery. This trend carries on for the parameters fish abundance and fish diversity (Figure 5). In the baseline scenario there is a slight increase in fish abundance, whereas fish diversity slightly decreases. Fish abundance reaches a value 188 tons, and 116 fish species being present after 30 years. The tourism expansion results in a decline in fish abundance, dropping down to 89 tons. The total fish species also declines, reaching a minimum at 61. The scenario in which goats are fenced results in a recovery of both the fish stock and the diversity. A maximum value of 264 tons is reached with a total of 145 fish species. Both these parameters increase in value as a direct result of the increase in coral cover.

In accordance with all the parameters mentioned above, the marine indicator presents a similar trend (Figure 6). The value of the marine indicator represents the state of the environment. 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 no longer threatened. Of all the scenarios only the fencing of the goats results in a rise of the quality of the environment. All scenarios indicate 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 0.27. Reaching a very low value of 0.12, the expansion of tourism has taken its toll on the marine environment. Figure 6 displays what the consequences could be if no measures are taken in order to preserve nature, i.e. a coast dominated by algae, barely any coral reef and a more homogenous group of fish species. On the other hand, the fencing of goats demonstrates how a system can react to measures that are taken on land. It displays the close relationship between land and sea. In this scenario, the marine indicator reaches a final value of 0.4. This is just slightly higher than the initial value of 0.34. Taking a timeframe of 30 years into account, such a minor increase is realistic.

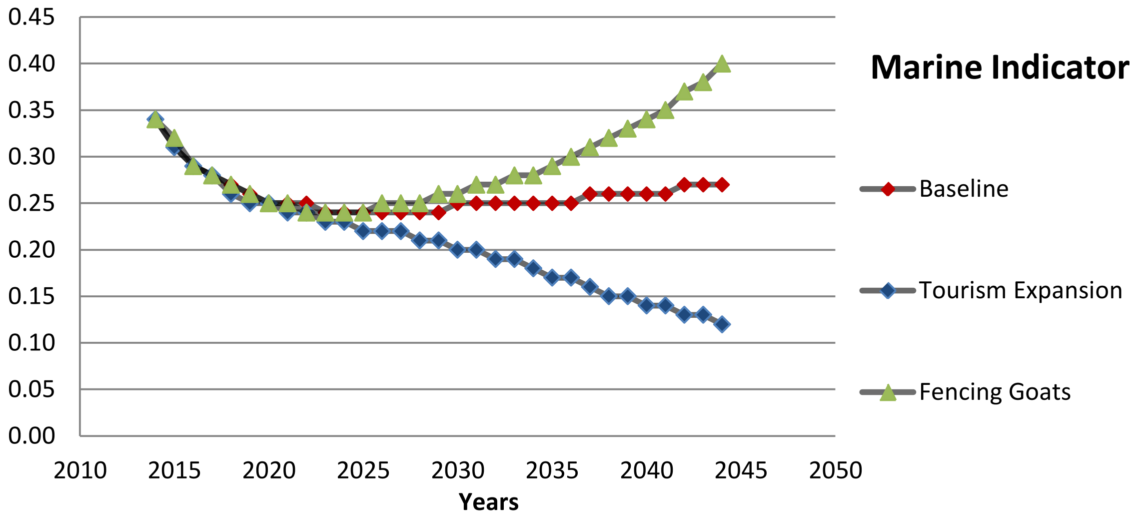


Figure 6 The graph shows how the Marine Indicator varies over time. The y-axis represents a relative value that varies between 0-1. A pristine ecosystem at a value of 1, and a completely degraded ecosystem at a value of 0.

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 in the response of the terrestrial environment to fencing 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 goats proves to be a betterment of the terrestrial ecosystem. The two scenarios that indicate no improvement are the baseline and the expansion of tourism (Figure 7). They present the same trend, demonstrating a slight increase in degraded habitat and a decrease in healthy habitat. One of the main reasons, 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 749 hectare of healthy land and 421 hectare of degraded land at the end of the simulation. The expansion of tourism displays an identical trend. The removal of goats demonstrates the exact opposite. This is not strange, as the foraging of goats is the main reason for degraded landscape. In this scenario healthy landscape reaches a maximum at 1,150 hectare. Degraded areas on the island are barely visible, only 18 hectares are left.

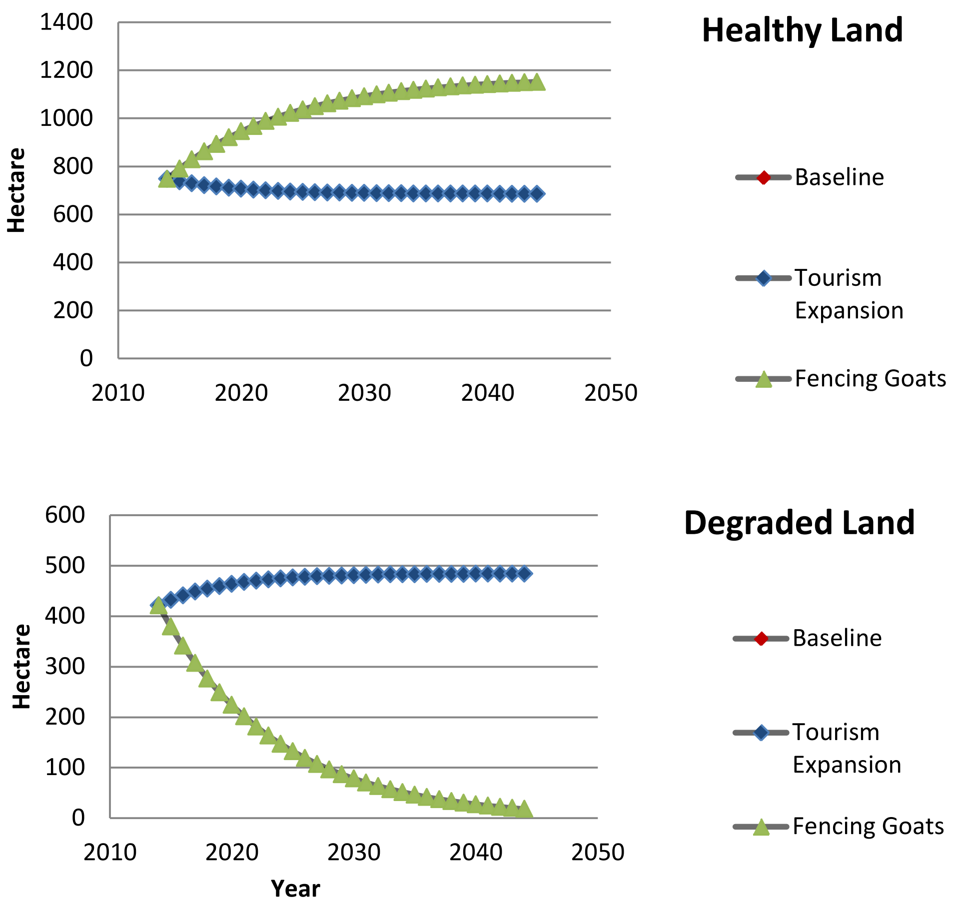


Figure 7 Graphs present the variation of healthy and degraded land over time for the three scenarios. Both graphs depict the variation in terms of total hectare on the island

Tourists are modelled having an impact on the destruction rate of terrestrial habitat, and moreover, influencing the relative amount of plant species. The value of the species abundance indicator is partly influenced by the number of tourists that visit. The lowest value for this parameter is reached in the tourism expansion scenario (Figure 8). It reaches a minimum of 209 species within ten years after which it remains constant. The value remains consistent because in the model it is effected by two things 1) the absolute area of healthy land, and 2) the number of tourists. Thus, the toll the tourists have on species richness causes it to decline rapidly, but it levels out as it can no longer decrease any further, because there is sufficient healthy land to maintain at least some species. However, because both the marine and terrestrial environment has degraded so much, the island becomes a less attractive tourist destination. Causing as the number of tourists to decrease, resulting in less harm to the environment. This allows the environment to recover and eventually species richness to increase to its original value.

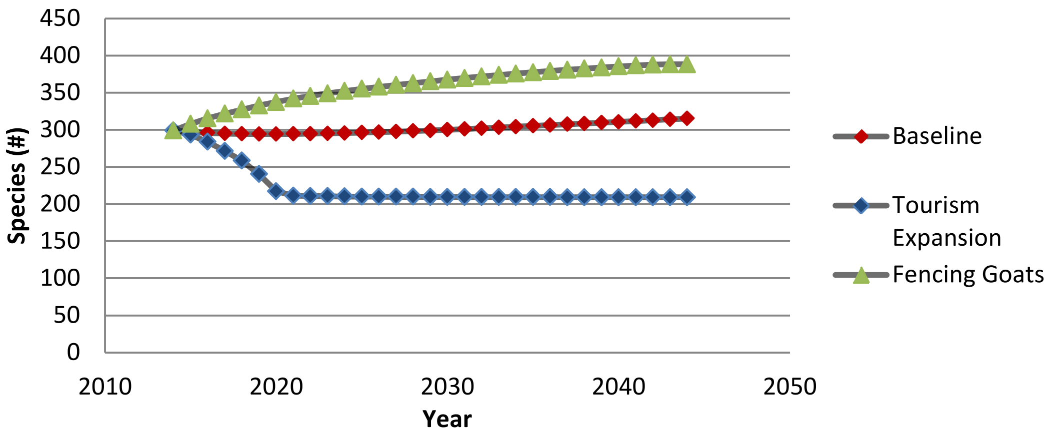


Figure 8 The mean species abundance is presented as it varies of the next 30 years. The graph represents the total amount of vascular plant species on the island.

Based on the species abundance indicator and the total healthy land the terrestrial indicator is calculated. As with the marine indicator, this is a relative value that gives an indication in what state the ecosystem is in. 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 represents ecosystems in good condition, but still suffering from anthropogenic influences, because there is still sufficient exogenous stress causing detrimental effects. A value of can be seen as pristine ecosystem. Of all the scenarios only the fencing of the goats results in a rise of the quality of the environment. The terrestrial indicator (Figure 9) presents a similar trend as the terrestrial species richness in figure 4-5, the three scenarios demonstrate distinctions from the onset of the simulation. The baseline scenario remains fairly constant, ranging between 0.52-0.54. An increase in yearly tourist population causes the indicator to decrease even further. After 30 years it levels out at a value of 0.44. The removal of the goats causes the terrestrial ecosystem to slowly recover. At a value of 0.78, this scenario proves to be the most promising in terms of ecosystem restoration.

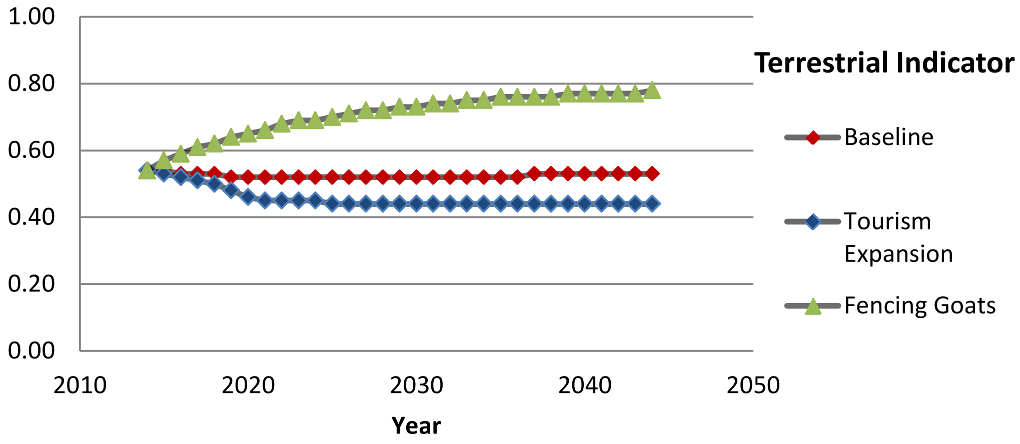


Figure 9 *The graph demonstrates how the Terrestrial Indicator varies over time. The y-axis represents a relative value that varies between 0-1. A pristine ecosystem at a value of 1, and a completely degraded ecosystem at a value of 0.*

4.2 The impact on the economy

How the scenarios influence the environment has been clearly defined. The discourse in this paragraph aims to depict how the different scenarios influence the economic value generated by the natural environment. It is the results of how ecosystem service provisioning changes as the qualitative state of the environment changes.

The results of the simulation demonstrate the tourism industry as being one of the largest contributors to the total economic value (TEV) of the island.

4.2.1 Tourism value

The tourism value accounts for all the direct and indirect expenses of tourists and their willingness to pay to preserve the natural environment. As is to be expected, the tourism expansion scenario results in the highest tourism value. Again a clear distinction is seen between the different scenarios. The scenario where the goats have been fenced there is small increase in the tourism value at the end of the simulation. Although minor, this slight increase is caused by an improved environmental quality attracting more visitors annually. At the end of a 30-year simulation the baseline and fencing goat scenarios reach respective tourism values of 2.95 million USD and 3.33 million USD (Figure 10). However, these values are far less compared to the tourism expansion scenario. At its peak the tourism industry generates a tourism value of 11.7 million USD after 18 years in 2032. This value does not persist, although it remains higher compared to the other two scenarios; it drops down to a final tourism value of 9 million USD. In this scenario finally the tourist population decreases, because the environment is in a degraded state due to the large pressure by the large amount of tourists. These two factors result in the parabola seen in graph of Figure 10. A steep increase caused by the artificial growth that finally leads to the decrease.

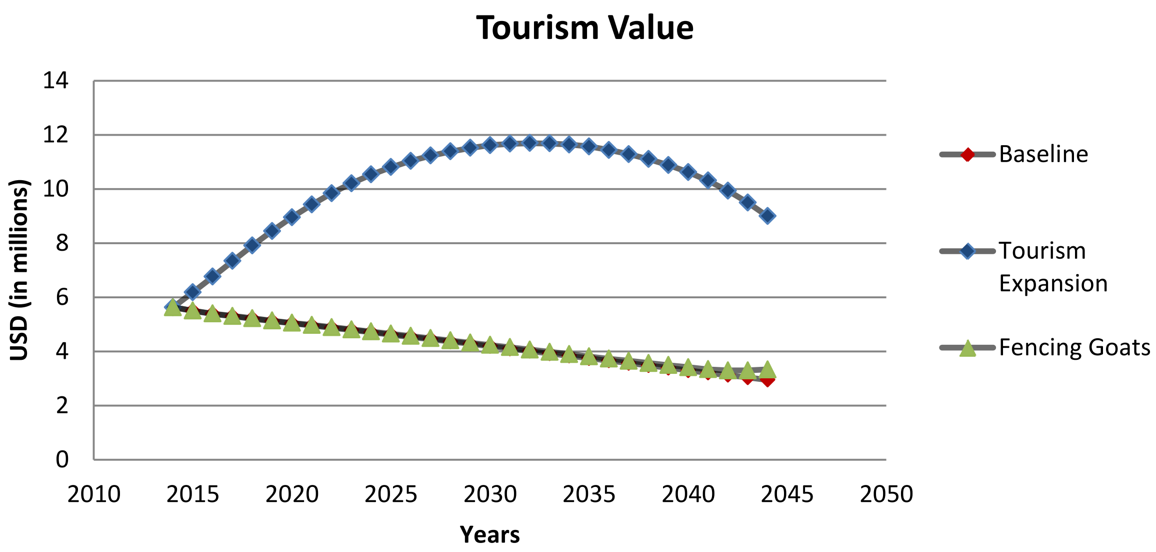
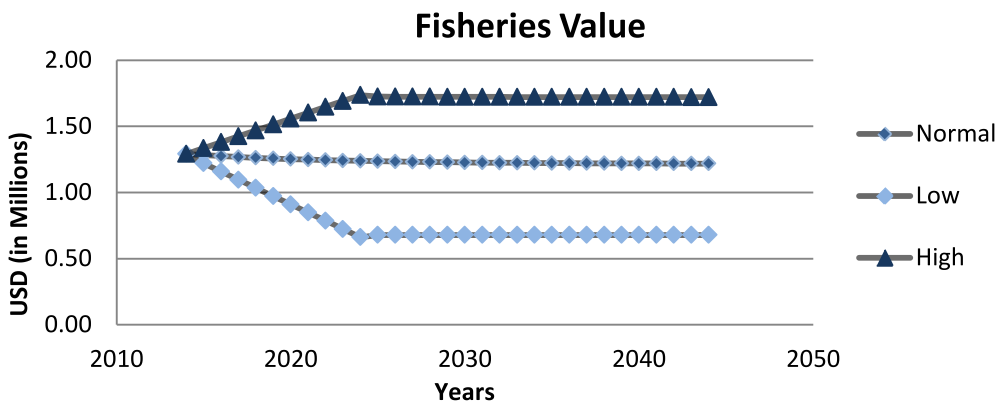


Figure 10 The economic value of the tourism industry on the island. Graph depicts the results for the three different scenarios

4.2.2 Fishery and non-use value

Another industry on the island is fisheries. This industry accounts for a large fraction of the TEV, having an annual value of 1.38 million USD per year. The main reason for this value is the fisheries on the Saba Bank. The value derived from the fisheries on the Saba Bank is not influenced by the different scenarios. The Saba Bank is located far out of the island of Saba, therefore, the activities on the island of Saba do not influence the output of the Saba Bank fisheries. This exact same trends in fisheries value for the different scenarios; i.e. a slight decrease from an annual value of 1.29 to 1.17 million USD. It is important to decide how to continue with fishing, whether or not to increase or decrease annual fishing pressure. No modeling and therefore, no insight has been given into the impact of a change in annual landings in order to maintain sustainable fisheries. There is no sufficient information available to model this.

What can be demonstrated is how the degradation of the marine ecosystem caused by over-fishing, would influence the non-use value. In a comparative analysis of the three different scenarios, the value of fisheries and non-use value differ in relationship with the fishing rate (Figure 11). As the fishing rate increases over the years, the value of the fisheries increases as more fish are caught. However, since a large fraction of fish is removed the marine ecosystem degrades. The theory being that an overfished population will be more homogenous in terms of species richness, algae will dominate and there will be a lack of higher trophic species. The non-use value decreases as a result of a decreased marine environment. In case of a higher fishing rate the non-use value reaches a value as low as 15.9 million USD. This is a substantial decrease, especially compared to the scenario where fishing pressure is halved. In this case, the non-use services reaches a value of 21.3 million USD.



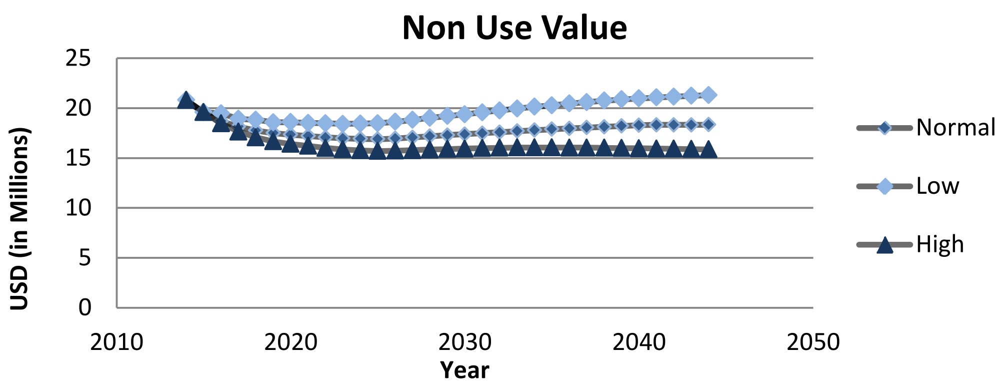


Figure 11 The values of fisheries and non-use with a high, normal and low fishing rate. Compared to the normal scenario, the high and low have a respective fishing rate of 1.5 and 0.5.

4.2.3 Local recreational and cultural value

The value of residents for the natural environment also contributes to the TEV; although it is less than the tourism industry, it is still a substantial sum of 51,000 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 number of inhabitants on the island. However, there is a significant value difference between the scenario in which the goats are fenced and the expansion of tourism scenario (Figure 12), which 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 shown in Figure 12.

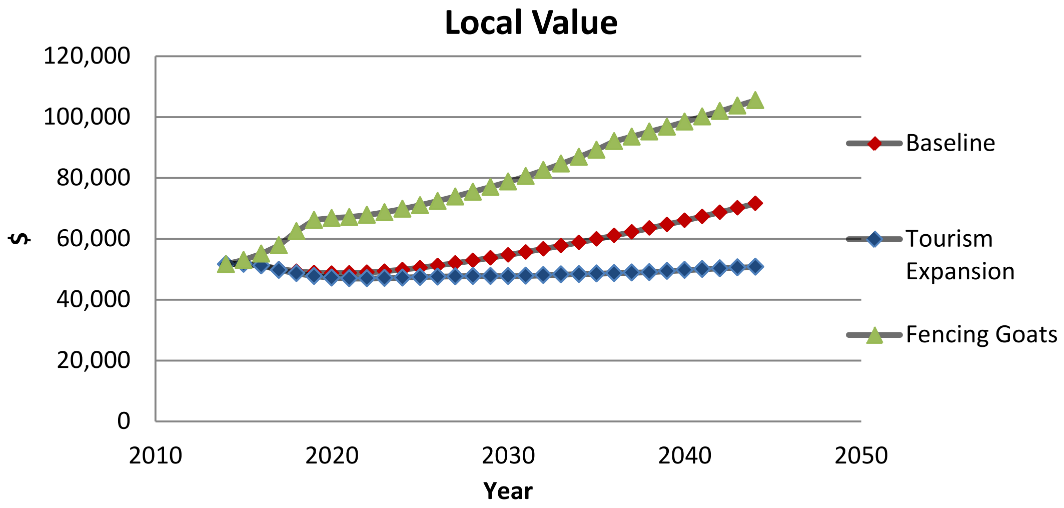


Figure 12 The economic value of the local inhabitants. Direct, indirect and WTP values are incorporated in the graph.

4.2.4 Medicinal plant value

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 Saba have such a 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 and thus increases the chances of finding the necessary plants. What is seen in underneath figure 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. When the number of tourist increases the medicinal plant value drops, as is the case in the scenario of tourism expansion. After 30 years the respective medicinal plant values are a bit over 81,000 USD and 62,000 USD for the baseline and tourism expansion scenarios (Figure 13). 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 110,000 USD at the end of the simulation.

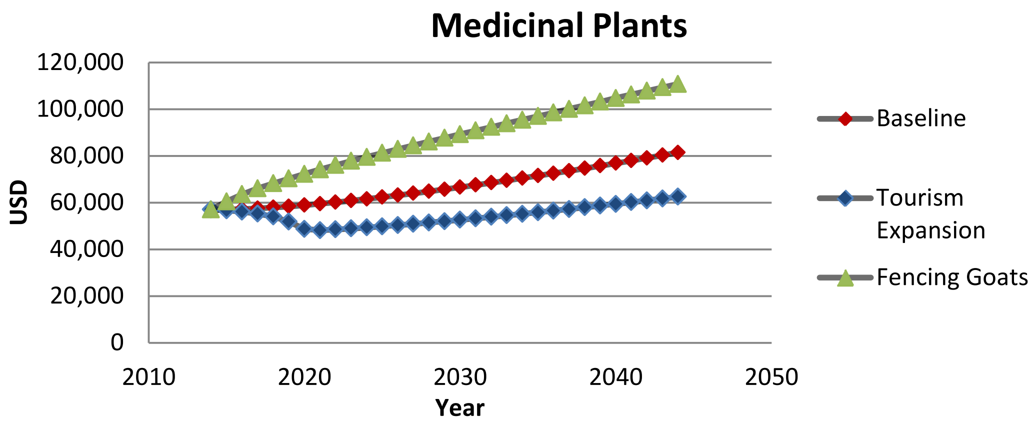


Figure 13 The value of medicinal plants. This value is the result of local inhabitants using medicinal plants ¦to cure minor illnesses instead of pharmaceuticals which can be bought.

4.2.5 Livestock value

It is the management of free roaming goats that influences ecosystem services and it is therefore of interest. There are a lot of possibilities to minimize the effects of livestock and it depends on the practices being used. The value given in Figure 14 presents a static depiction of how livestock differs for each scenario. The tourism expansion and baseline scenario produce exactly the same value. Fencing the goats and allocating some land to high end products, results in a higher value; in a timeframe of 10 years it increases to 180,320 USD. The other two scenarios have an annual value of 11,200 USD per year.

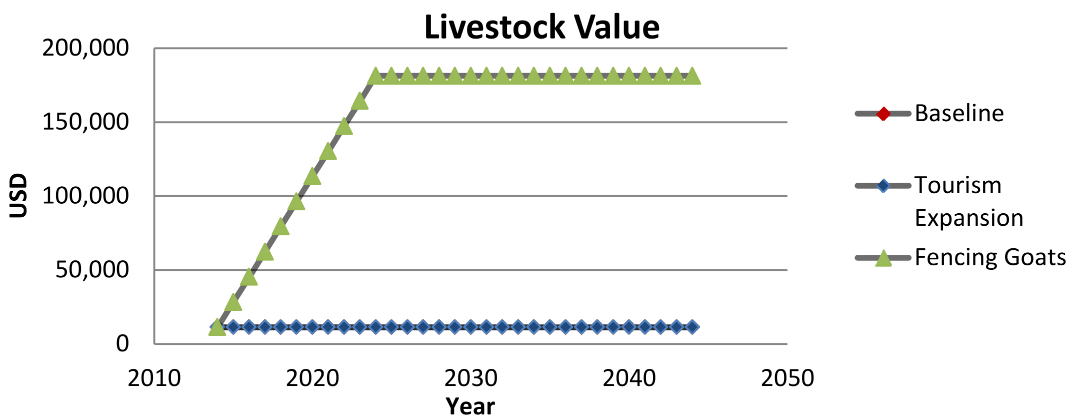


Figure 14 The value of livestock. The sum is presented in the graph for the different scenarios.

4.2.6 Carbon sequestration value

Carbon sequestration is another value that depends on the qualitative state of the environment. The capacity of an ecosystem to store CO_2 is directly related to how much hectare healthy vegetation or corals are available. Thus, as the amount of hectare increases, so will the value. This value only increases in the scenario where the goats are fenced. The percentage of coral cover (Figure 4) and amount of healthy land (Figure 7) increases in this scenario. This results a maximum carbon sequestration value of 178,000 USD (Figure 15). The other two scenarios decrease slightly to a value of 107,000 USD.

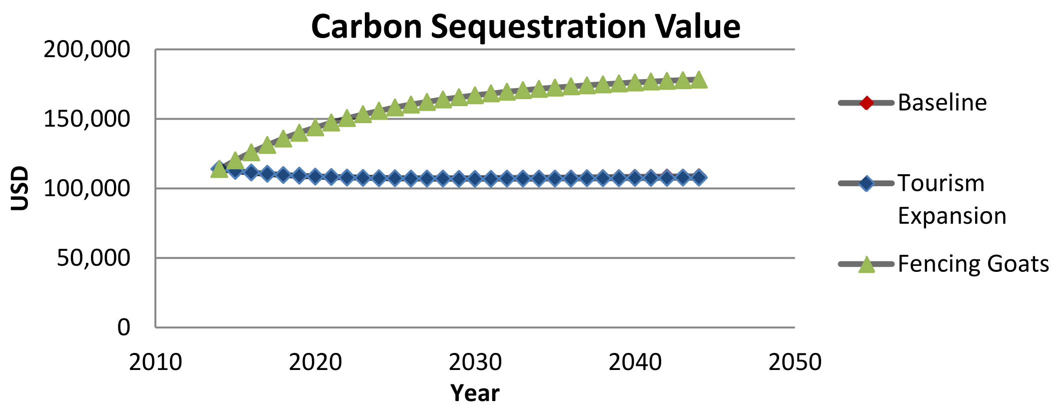


Figure 15 The value of carbon sequestration for the different scenarios. Baseline scenario and tourism expansion are the same. The value in the graph is the sum the marine and terrestrial system to store CO_2.

4.2.7 Non-use value

The variation in the non-use value has been described earlier on. In the image below, the non-use value is presented for the three different scenarios. As the differences in policies of each scenario start to have an effect on the environment, the non-use values start to diverge (Figure 16). After 30 years the baseline scenario is substantially lower resulting in a final value of 16.9 million USD. The non-use value in the scenario of expansion of tourism decreases substantially. The WTP of Dutch mainland households decreases as the state of the environment does, their willingness to financially contribute to the preservation of a degraded ecosystem decreases with a final value of 12.9 million USD. Fencing free roaming goats does result in a higher non-use value. The first 10 years it follows the same trend; however as the fencing of goats start to have a positive impact on the environment, it eventually has the highest value of 23.4 million USD and it is likely to increase as the environment continues to improve.

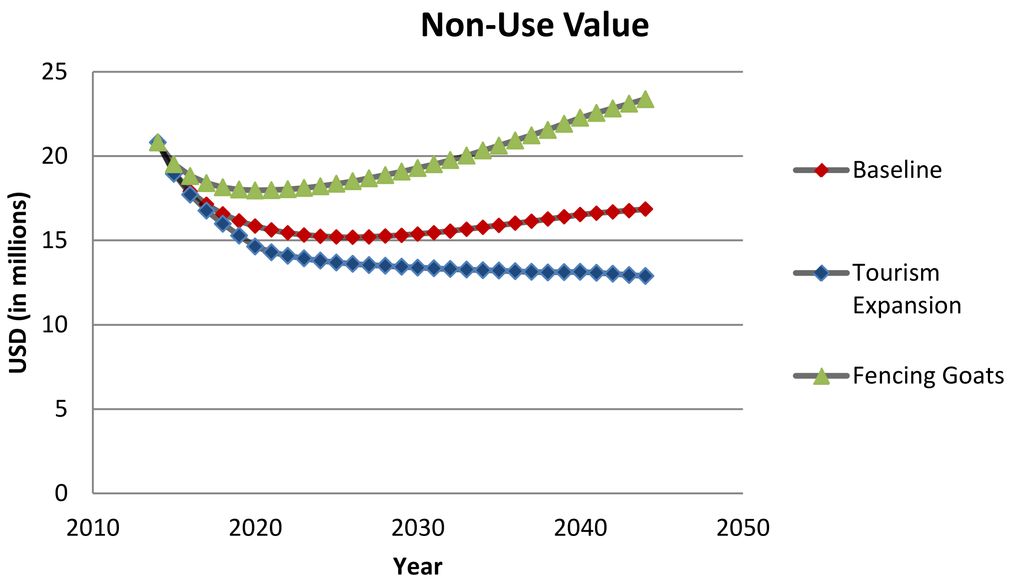


Figure 16 The non-use value for the different scenarios. The non-use value is based on the WTP of households in the Netherlands mainland to preserve nature in the Caribbean Netherlands.

4.2.8 Research value

In terms of both natural and social sciences, 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 it is to be expected that this will continue 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 is almost 344,000 USD. This value is likely to vary over the next years, but is not expected to alter much.

4.2.9 Total economic value

All the above given values are summed up to give an indication of what the total economic value (TEV) of the natural environment on Saba is (Figure 17). The baseline scenario results in a value of 21.8 million USD and the TEV of the tourism expansion scenario results in 23.9 million USD. The scenario of the management of free roaming goats results in a final TEV value of 29 million USD.

As the environment deteriorates in so far that Dutch mainland households are willing to pay less to preserve the natural environment on Saba, which causes the total economic value to decrease. However, when the non-use value is excluded from the TEV, a completely different graph is seen. In the bottom graph of Figure 17 the TEV without the non-use value is presented. In this case, the tourism expansion scenario reaches the highest value at 13.7 million USD. The baseline scenario and fencing the goats decrease both in a similar trend as a result of a decrease in tourism value. There is a slight upward bend at the end of the scenario where the goats are fenced. This is caused by the fact that the environment has improved thus far as to start attracting more tourists.

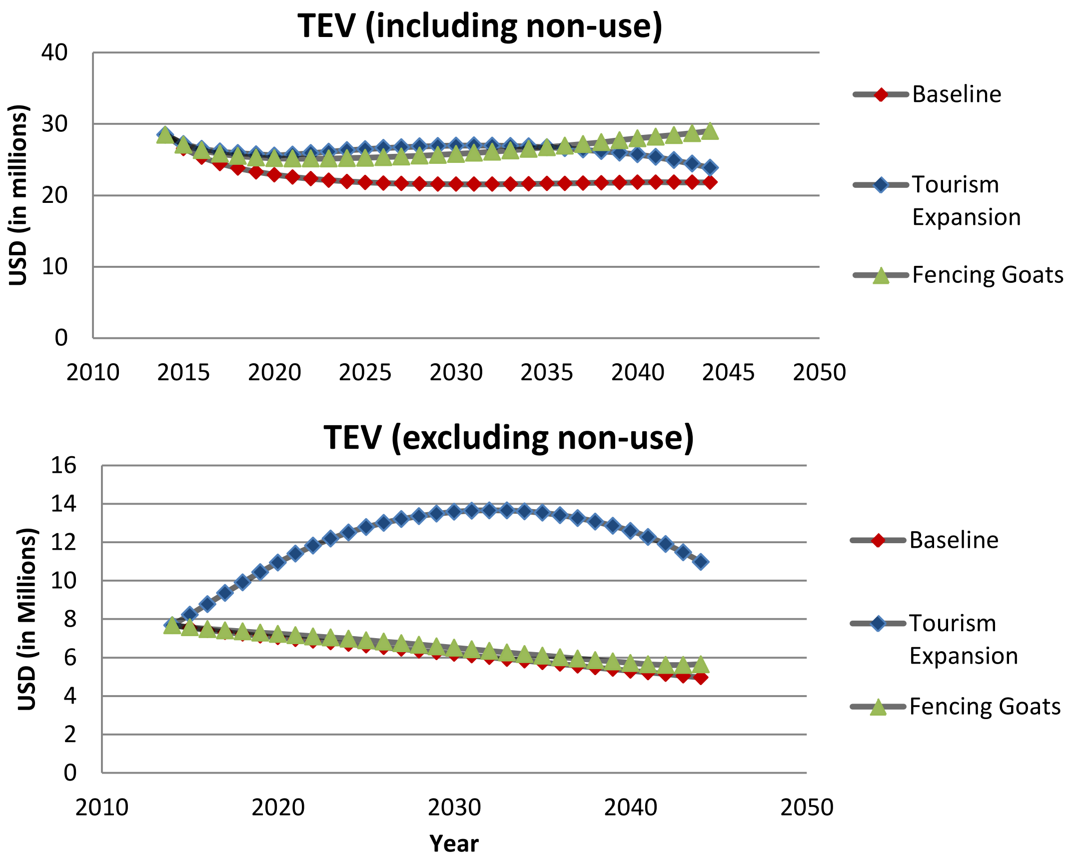
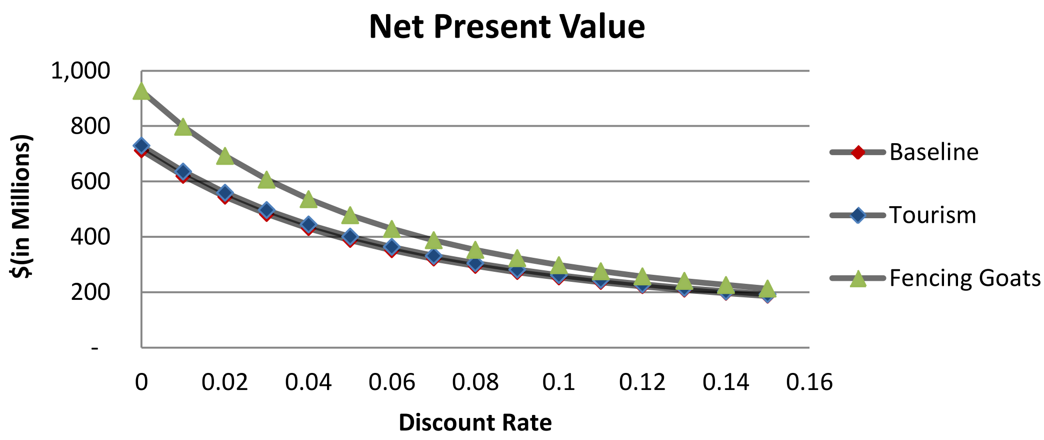


Figure 17 The Total Economic Value for the different scenarios. The top graph includes the non-use value of Dutch mainland Households. In the bottom graph this value is not included.

The simulation entails predictions on values over the next thirty years. It is therefore necessary to discount the values taken into account and display how these values will vary with varying discount rates. In Figure 18 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 927 million USD for the scenario managing the free roaming goats. A discount rate of 0% is very unlikely however; to calculate the NPV a discount rate of 4% is assumed. At this rate, the highest NPV is 536 million USD. Although a substantial lower total economic value, it is a more realistic outlook.

A cost-benefit ratio is presented in Figure 18 for only one of the scenarios. It was only possible to provide such a graph for the scenario in which the free-roaming animals are fences, because information on the costs of such an investment was available. 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 clearly demonstrates that irrespective of which discount rate, the ratio is always positive. Indicating that the investment will pay off.



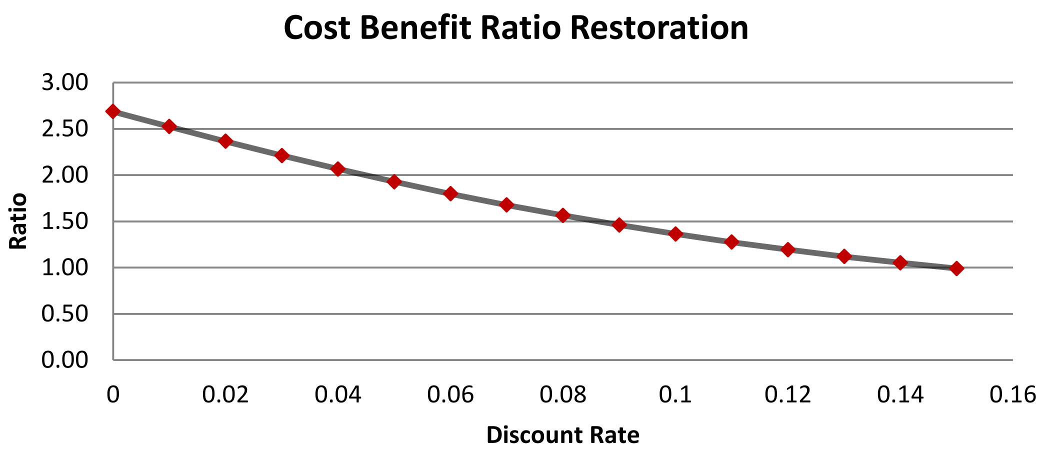


Figure 18 The Net Present Value (NPV) is presented in the top graph. Different discount rates ranging between 0-15% result in different NPVs. The values represent the sum of the TEV over a time frame of 30 years and discounted at the rate shown.
The cost benefit ratio for the scenario in which the free roaming animals are fenced is displayed in the bottom graph.

5 Conclusions and recommendations

Saba is known as the 'Unspoiled Queen', a beautiful name for a unique island. This report describes that in order to keep it unspoiled, certain actions are needed. Valuing the ecosystem services and their threats reveals the strong link between nature and the local economy. This, hopefully, gives policymakers insights to reflect on trade-offs considering not only economic, but also social and environmental aspects.

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 the reality. Modeling complex relations can help to display interdependencies between different sectors, which are not clearly visible at 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 does not provide definitive answers! However, this does not mean it is not useful. It is a tool to analyze a state of a system, the (possible) impacts on this system and how this state might change over time (Christensen and Walters 2004). This research used indicators as suggested by Becking and Slijkerman (2012) to monitor the state of the natural environment. Not all indicators could be incorporated due to a lack of solid information. The importance of monitoring starts to become clear as management actions can be made to change a direction of a specific trend. At the moment limited monitoring takes place and it is our recommendation that it is further expanded. This is especially important, because Saba depends on its natural environment. It should be noted that it is much more difficult to restore an ecosystem instead of maintaining a healthy one (Hughes *et al.* 2005).

Model and scenario analysis

The valuing of the ecosystem goods and services of Saba demonstrates that if Saba does not take any additional measurements, the value of the services provided by their natural environment decreases with 35%, when the non-use value is not taken into account. As the number of tourists decreases the marine indicator will slightly increase after 16 years. The local value increases only due to an increase of residents. This scenario demonstrates that action is needed to keep the environment of Saba in a similar state.

The Dutch mainland citizens really value the natural environment of Saba though they might never visit. This high non-use value of 22 million USD indicates to the Dutch government that Dutch mainland citizens do care and they would like to see that Saba's nature is taken care of. If the natural environment of Saba becomes degraded, i.e. as demonstrated by the tourism scenario, their willingness to pay to conserve the natural environment on Saba decreases.

If we look at the other values there is a high potential for further development of the tourism sector. The growth suggested in the tourism plan is extrapolated and it can be a major economic sector. However, too many tourists will have a negative impact on the natural environment, i.e. decrease in coral cover due to physical disturbance, and this will result in a decrease in tourists numbers. After an increase to 40,000 tourists the coral cover already decreases. Perhaps 40,000 visitors is the maximum number of tourists that can visit Saba, without severely impacting the marine environment, although further research is required to assess the exact impact of a larger amount of visitors on the local ecosystems. If Saba is no longer the Unspoiled Queen, tourists will go to look for other islands to visit. This will impact the local residents in loss of income and jobs and they are left with a degraded environment. The study of Dekker et al. (2014) indicates that 40% of the interviewed residents like to see better management of nature on Saba. Managing the free roaming goats is demonstrated to be a lucrative investment. It will be important to moderately develop the tourism sector and monitor its impacts on the natural capital of Saba.

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 Saba (Debrot and Bugter n.d.). This will definitely have a negative impact on the natural environment of Saba 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 shown, will impact the tourism sector. Climate change cannot be influenced by local policy makers. 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 goats 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.

The challenge is to manage trade-offs between immediate economic development and maintaining the capacity of the ecosystems 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 in order to maintain the status of the ‘Unspoiled Queen’.

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

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Annex A Conceptual framework of simulation model

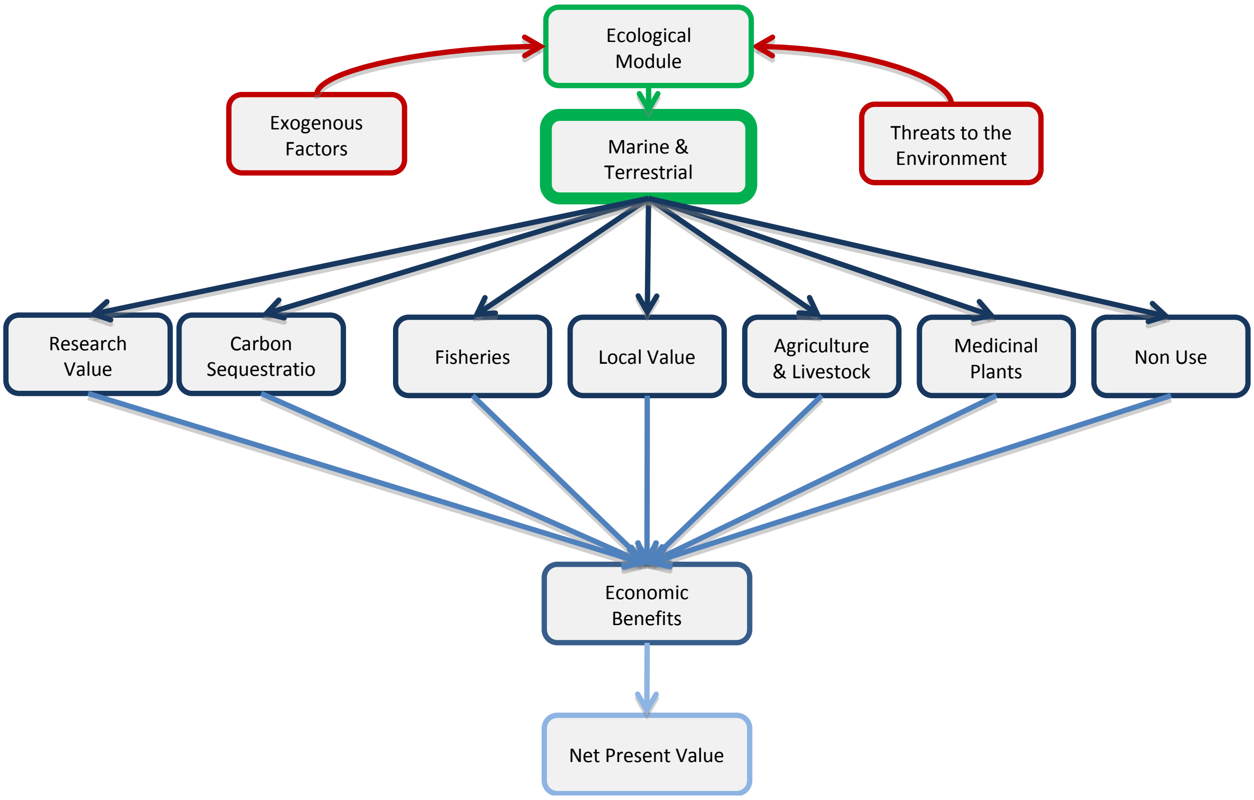

Figure 19 A conceptual representation of the model. The red boxes represent the threats and exogenous factors influencing the environment. All are anthropogenic of origin. The green boxes represent nature and the associated ecosystem services. Below, in blue, are the different values, that all contribute to the Total Economic Value.

Annex B Marine module of simulation model

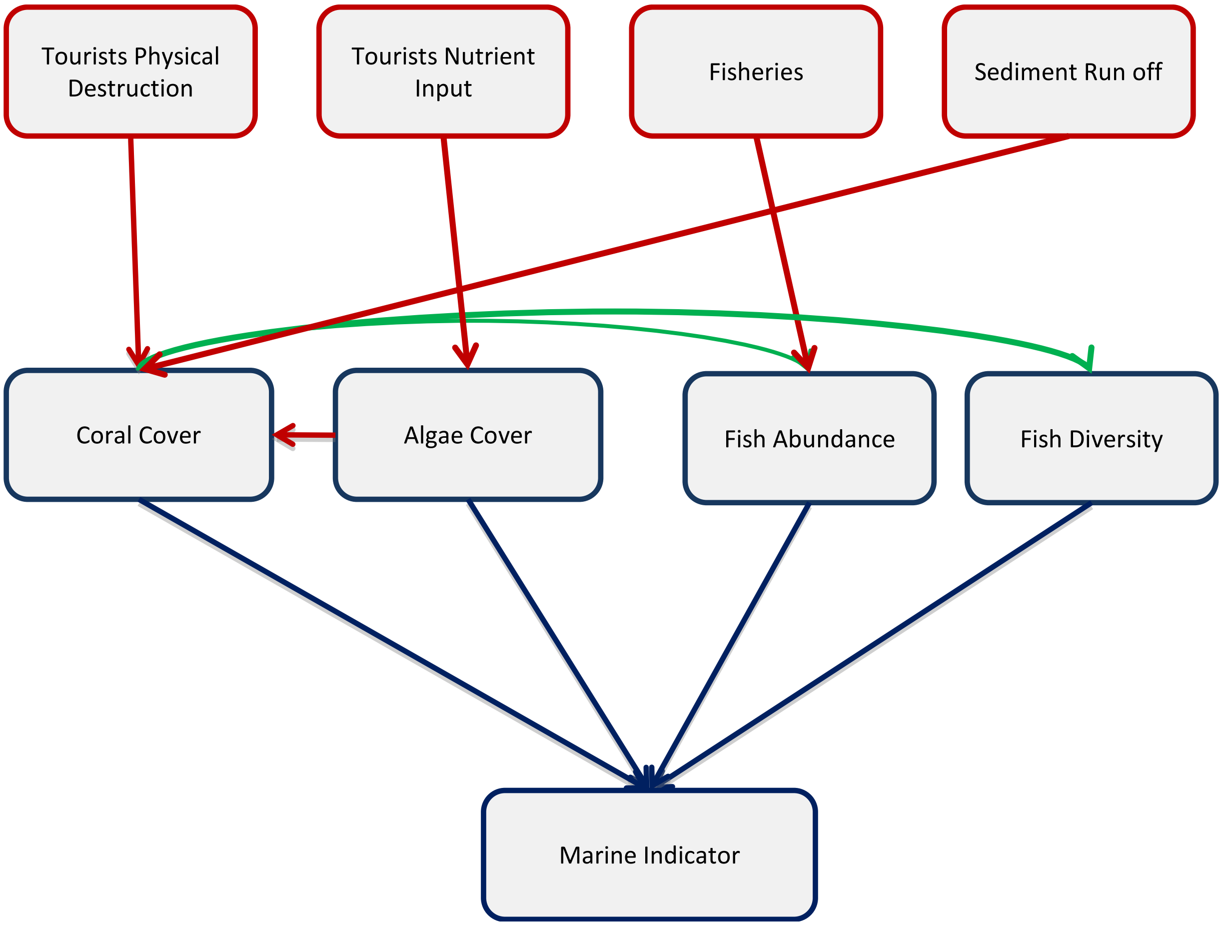

Figure 20 A conceptual representation of the model. The red boxes represent the threats and exogenous factors influencing the environment. All are anthropogenic of origin. Red arrows represent negative impacts and the green arrows a positive influence. The blue boxes are the ecological parameters that contribute to the overall marine indicator.

Annex C Terrestrial module of simulation model

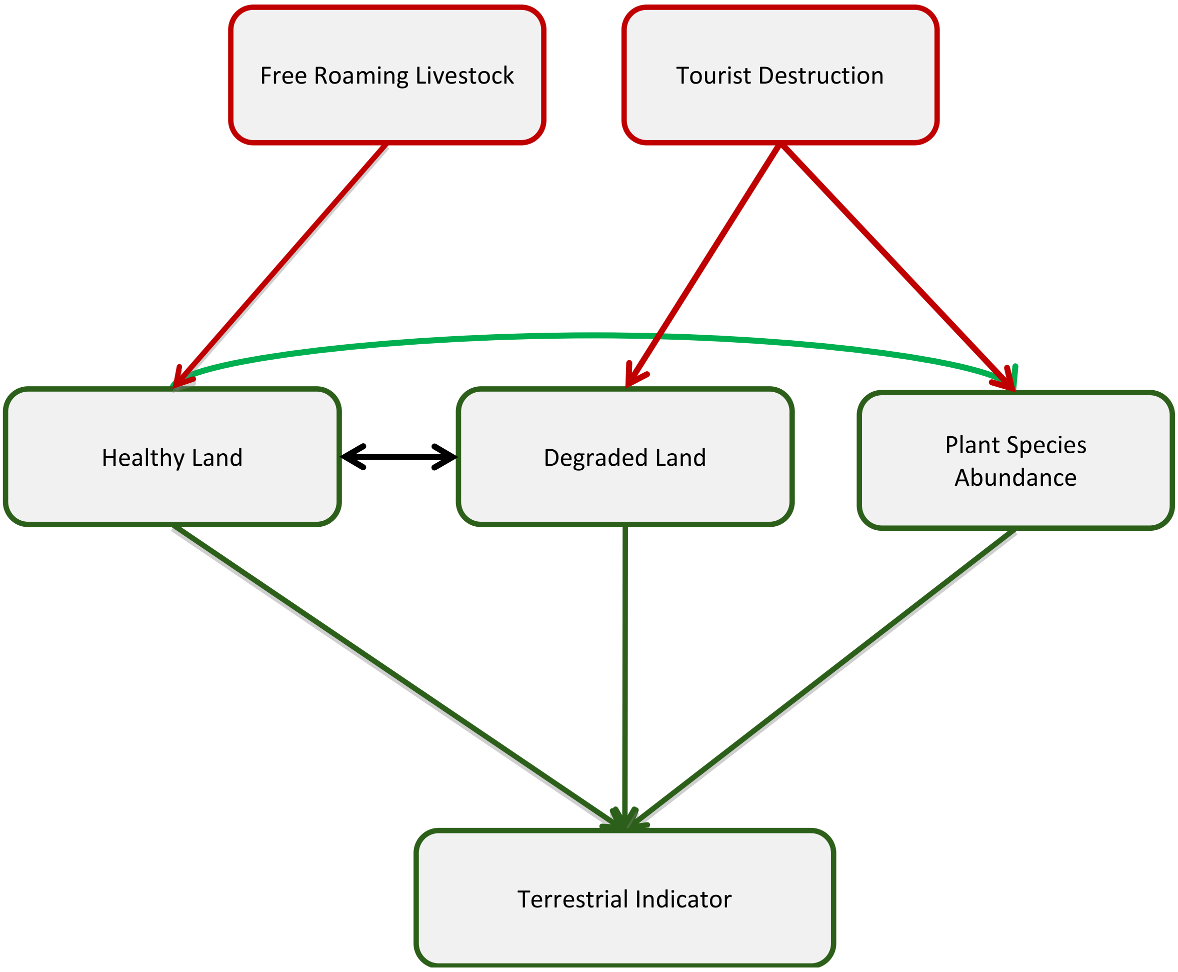

Figure 21 A conceptual representation of the model. The red boxes represent the threats and exogenous factors influencing the environment. All are anthropogenic of origin. Red arrows represent a negative impact and green arrows a positive influence. The dark green boxes are the ecological parameters that contribute to the overall terrestrial indicator.