Bonaire 2050

Putting the vision into numbers

Peter Verweij, Jenny Lazebnik, Michiel van Eupen, Anouk Cormont, Petros Panteleon, Manuel Winograd

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Reviewed by:
René Henkens, Researcher, Wageningen Environmental Research

Approved for publication:
Sander Janssen, teamleader of Earth Informatics

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In collaboration with:
Sherwin Pourier (Bonaire Agri & Aqua Business bv)
Bob Janssen (Bonaire DailyFresh)
Quirijn Coolen (BonBèrdè)
Veroesjka de Windt & Simone Rienks (BONHATA)
Arie Boers (Bon Tera)
Carolyn Caporusso (Clean Coast Bonaire)
Tadzio Bervoets (Dutch Caribbean Nature Alliance)
Maurice Adriaens (LVV)
Danilo Christiaan (Mangazina di Rei)
Ellie Noij-Penning, Frank van Slobbe (Openbaar Lichaam Bonaire)
Yoeri de Vries, Reynolds Oleana (Rijksdienst Caribisch Nederland, resp. LNV and OCW)
Esther Meijer-Sedney, Henk van de Velden (Statistics Netherlands)
Caren Eckrich, Sabine Engel, Jan van der Ploeg, Wijnand de Wolf (STINAPA)
Elsmarie Beukeboom (retired, former director of STINAPA)
Elesiër Angel, Miles Mercera (Tourism Corporation Bonaire)
Hans Staring (WEB)
Jeanne Nel (Wageningen Research)
Bonnie Roefs (Wageningen University student)

Bonaire is facing major challenges including (mass) tourism, population growth, urban expansion, climate change, biodiversity loss and the unilateral dependency on tourism. In thirty years, Bonaire will inevitably look different. Here, two different possible futures are presented, to form a basis for dialogue amongst stakeholders and to stimulate a positive change and sustainability on Bonaire. One of these scenarios follows current trends (business-as-usual), and the other bends those trends into a nature-inclusive future after a vision developed by a trans-disciplinary team of researchers, local experts and stakeholders. For both scenarios drivers and impacts are visualized and documented on climate, tourist numbers, population, infrastructure, resources, land use, erosion and nature.
Visualizing scenarios is one important piece in creating awareness about the future as it allows to shed light of the difficult to grasp long-term effects, and explicitly showcases current trends. It gives opportunities to imagine a future that looks different from the prognosis, and to inspire to work towards a sustainable and desirable future.

Keywords: foresight, indicator, scenario, land, sea, tourism, nature, climate, population

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Approved reviewer who stated the appraisal,

position: researcher biodiversity and policy

name: René Henkens

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Approved team leader responsible for the contents,

name: Sander Janssen

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Preface

Bonaire, one of the Dutch Caribbean islands, is facing major challenges. These include: (mass) tourism, immigration and population growth, urban expansion, high erosion rates, soil depletion, rising costs of energy, drought and other extreme weather events, biodiversity loss and the unilateral dependency on tourism.

In thirty years, Bonaire will inevitably look different. If the current trends continue, it will only increase the gravity of the challenges. A new way of thinking, planning and acting is needed, one that is shaped by the citizens of Bonaire. This plan of action can nurture Bonaire in a way that aligns the citizens' well-being with their cultural heritage, and embraces a flourishing nature: a solid basis for the future.

Prior to the work presented in this report, a vision for Bonaire in 2050 was developed together with local experts (Verweij et al., 2020), in which nature and natural processes play a key role in all development activities – a 'nature inclusive vision'. It outlines a socio-ecological and economic sustainable future, that maintains what is precious, and improves what is impaired or threatened.

This report elaborates on a future following the nature inclusive vision and compares it to a future that follows current trends ('business as usual'). Both futures are laid out in key figures, graphs and maps, based on current, and historical data on Bonaire, as well as fact-based assumptions for the future. The overall objective of this report is to form a basis for dialogue amongst actors, intended to stimulate a positive nature-inclusive change and sustainability on Bonaire.

1 Introduction

1.1 Bonaire: a characterisation

Bonaire is a Small Tropical Island. Small tropical islands are rich in biodiversity and host a wide variety of globally unique natural areas. These areas are a basis for local livelihoods and vital for tourism, which is the major economic pillar for many of these islands. At the same time, there are various pressures that combine to impact both nature and other forms of land- and sea use. This makes the islands susceptible to change and pose a threat to the unique natural features that attract tourism (UNEP, 2014; Wolfs & Schep, 2014; UN, 2015; van der Geest & Slijkerman, 2019; Verweij et al, 2021; Andrade et al., 2021; Peeraer, in prep.).

In recent years an increasing amount of initiatives have supported the view that healthy nature cannot be reached by conservation initiatives alone. Instead, nature must be included in other sectors. In planning, nature should therefore be factored-in up front, rather than compensating for potential detrimental effects afterwards.

Bonaire is a 288 km² volcanic rock that surfaced from the ocean over 60 million years ago, surrounded by calcareous deposits of coral that grew on the volcanic rock. Bonaire experiences high erosion rates (Vergeer, 2017; Debrot et al, 2017). Soil is lost and flushed into the sea, degrading the land and contaminating the reef (van der Geest et al., 2020). The island has a semi-arid climate with an annual precipitation of 463 mm, its dry season is from February till June and its rainy season from September till January. Hurricanes are not common (KNMI, 2017).

Like many other tropical Small Island Development States, Bonaire is facing common challenges exacerbated by climate change (Mori et al., 2014). Its size, combined with increasing numbers of residents and tourists leads to increasing pressures on the local environment and natural landscape. Since the 1960s immigration increased with the emergence of scuba dive tourism, and resulted in a quadrupling of the resident population to over 20.000. Currently, direct tourism expenditure alone accounts for one third of the gross domestic product. On-island food production is not sufficient to support the inhabitants and therefore food imports are essential: 99% of food on the island is imported. Not enough drinking water is available within the natural system and is therefore produced by expensive reverse osmosis technology. For energy, Bonaire heavily depends on imported fossil fuels. Currently 2/3 of the energy supply originates from burning fossil fuels (van der Geest & Teles, 2019; van der Geest & Slijkerman, 2019; Verweij et al., 2020; Oliemans et al., 2019).

External factors can highly affect the local economy. COVID, for example, is estimated to have decreased the Gross Domestic Product for 2020 by 19.3 percent in comparison to 2019. Accommodation, food services and transport activities experienced high impacts (World Bank, 2021). In March 2020 the number of tourists dropped almost to zero. By June 2020, tourism numbers did return to their normal levels (CBS, 2021[a]).

The losses exemplified above are evidence to the fact that the economy and well-being on Bonaire depends on a few critical pillars- which if falter, can have drastic consequences. These pillars include tourism, access to imported food and fuel, and fresh water production. If any of these critically fail or decline- the effect on islanders will be drastic. The corona crisis may have been impossible to predict, but climate change is ongoing, and will have predictable effects. These, and other known effects can for a large part be foreseen at and mitigated for in order to create a resilient landscape and sustainable culture and economy.

1.2 Foresight methodology

A method called 'foresight' is used to enhance spatial planning by developing measures to strengthen nature in all sectors, for the Caribbean island of Bonaire. This method seeks to cope with sustainable development challenges on land and at sea, clean water and sanitation, clean energy, responsible consumption and production, and social well-being. The method uses nature inclusive measures to maintain, restore and enhance the robustness of nature within the society which in turn can boost both productivity and sustainability.

Since the future is uncertain, the exact impact of nature inclusive measures is not definitive. Instead, the 'foresight' approach seeks to improve decision making by exploring uncertain yet possible futures. This way of thinking engages actors and society in exploring how the future might evolve for the interests of different stakeholders. This method helps thinking about alternative pathways that are desirable and possible. Most importantly, it helps to remove the blindfolds caused by moving unconsciously into future situations which can be harmful or undesirable (Vervoort & Gupta, 2018; Foresight4food, 2021). The 'foresight' method is about the facilitation of decision making on the basis of representations of futures that *may* (i.e. possible, probable or plausible), or *should* (i.e. desirable futures) happen (Uruena et al., 2021). Since we know change is inevitable, we use the foresight technique in an attempt to become aware of the potential risks, make projections for the future and steer towards a sustainable future. Although the output of this report is a documentation of scenarios by means of trend projections and envisioning, the main goal is to start a dialogue that engages and provokes local stakeholders and actors.

The following steps were taken in conducting the foresight study on Bonaire (**Figure 1**):

1. *Motivation and purpose* - '**Develop an approach for multi-sectoral nature inclusive planning for Bonaire to enable sustainable development processes**. This objective of the study has been formulated in cooperation with a multidisciplinary team of scientists. The disciplines represented in the research team included: participatory spatial planning, soil science, earth observation, social science, economy, agriculture, tourism and conservation biology. This foresight approach for the island of Bonaire can hopefully be used in the future to help guide sustainable development processes on other small tropical islands
2. *Identify stakeholders* – Stakeholders from a range of sectors have been selected, including: policy, tourism, nature conservation, agriculture, cultural heritage, socio-economics, energy and water.
3. *Understanding the system* – The team members have harmonized their individual perceptions of elements making up the socio-ecological system under study, using the conceptual modelling method from Argent et al. (2016). See Annex 1 for the result.
4. *Drivers, trends and uncertainties* – The knowledge base contains a collection of data on status, historic trends and causalities in the form of maps, graphs, tables and documents. An existing knowledge base (www.dcbd.nl) was used to highlight knowledge gaps. Historical trends and the present situation were analysed for land cover (Mucher and Verweij, 2020), vegetation development (Janssen et al., 2020), impact of terrestrial erosion on coral reefs (van der Geest et al., 2020), tourism distribution (Slijkerman et al., 2019), tourism landscape preferences (Jailani, 2020), distributional equity of tourism expenditure (Soma et al., in prep.), historic trends of population and tourism (Verweij et al., 2020a), and policy development for three decades (Verweij et al., 2020a).
5. *Visions* – Based on the knowledge analysed above a nature inclusive vision to combat the future challenges has been presented. Key challenges were identified as: urban and elite estate expansion; a changing climate; diversifying the economy; managing tourism; recharging freshwater into the soil; using renewable energy; maintaining, enhancing and restoring nature; local produce and healthy diets; and flourishing cultural heritage. Visions were developed for 12 different landscapes. Each vision is based on the history of the landscape and the perceived suitability for specific nature inclusive measures by local stakeholders (Verweij et al., 2020b).
6. *Scenarios* – Possible futures were expressed in numbers. **This report addresses this step** by showing quantifiable trends per indicator, for different scenarios.
7. *Influencing change* – Begins the dialogue to find out what is needed to start the actual implementation of nature inclusive measures. Who will do what, when and where exactly? What needs to be organized by the government, what needs collective effort and what can be done on sectoral or even at individual level? This is the next step after the publication of this report.

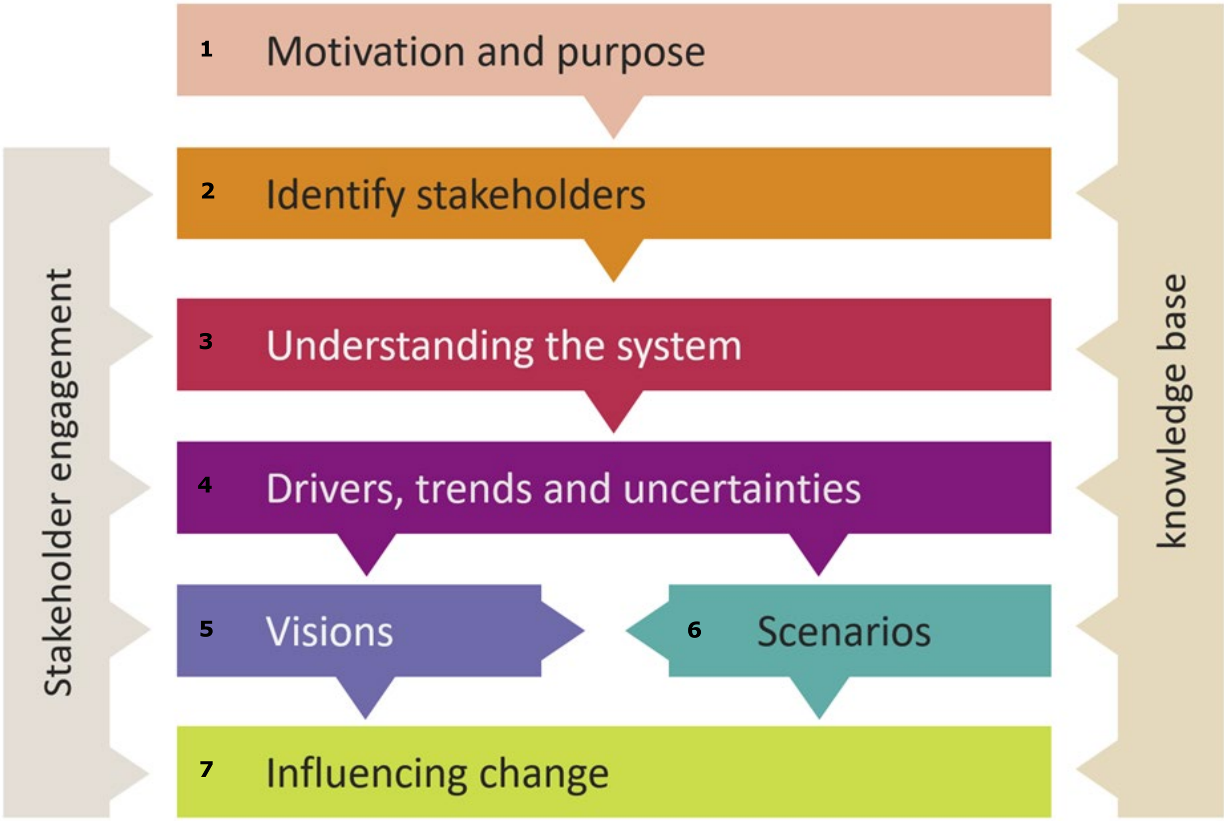

Figure 1 *Steps followed for Bonaire's foresight study, the scenarios step is addressed in this report.*

This remainder of this report describes the foresight step 6: 'scenarios'. In the following chapters, two possible futures for Bonaire are described: Business as Usual (BaU) and Nature Inclusive (NI), comparing the likely effects of these futures on the basis of a set of indicators. Chapter 2 gives a general description of each of these futures, while Chapter 3 details each future by comparing indicators of climate, tourism, population, infrastructure, resources and land use. The report ends with a discussion on the possible implications for different sectors; and a few suggestions (Chapter 4). The discussion is also a platform to start a dialogue to address these findings and its possible consequences for the future of Bonaire.

2 Futures for Bonaire

Since the future is uncertain, we work with different representations of futures (called 'scenarios') which *may* (i.e. possible, probable or plausible), or *should* (i.e. desirable futures) happen. Scenarios are plausible descriptions of futures based on a coherent and internally consistent set of assumptions about key driving forces and their relationships (MA, 2003). Scenarios are associated with alternative pathways from the present towards the image of the future (Raudsepp-Hearne et al., 2019; see Figure 2).

The scientific community uses narratives (Padian, 2018) to describe these pathways using socioeconomic and climatological information (Bishop et al., 2007). Respectively these are called Shared Socioeconomic Pathways (SSP; O'Neill et al., 2017) and Representative Concentration Pathways (RCP; Moss et al., 2010). The pathways used in this study: 'global fossil fuelled development' (coded as 'SSP 5' in O'Neill et al., 2017) and 'global warming due to high emissions' (coded as 'RCP 8.5' in Moss et al., 2010) provided the concrete estimations for sea level rise and precipitation reduction. The implication of these climatic and socioeconomic estimations is further elaborated in the next sections.

Two alternatives for global development are developed as scenarios: 1) Business as Usual and 2) Nature Inclusiveness as means to (partly) counteract the challenges faced on Bonaire (Verweij et al., 2020).

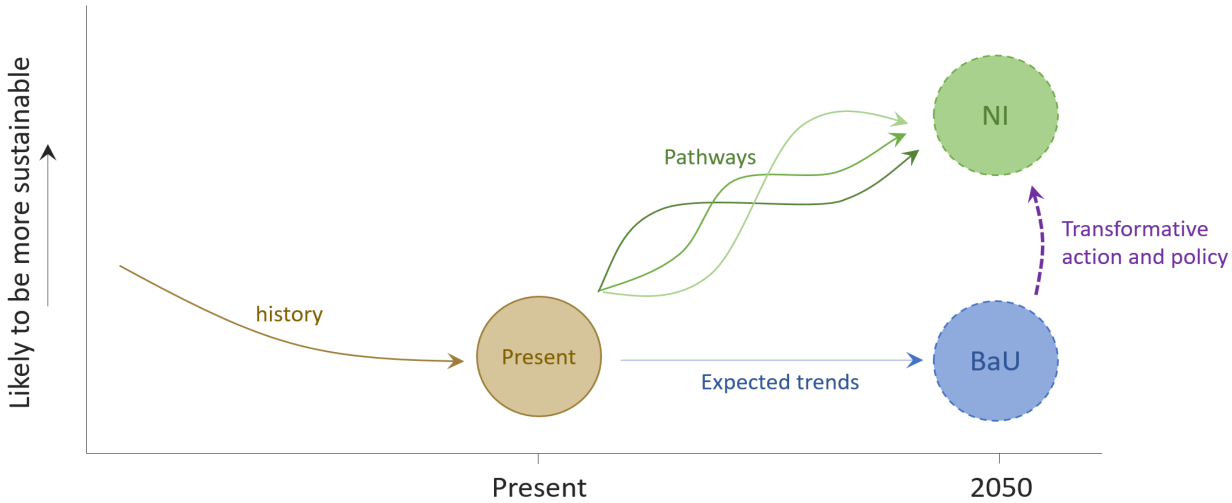

Figure 2 *Futures for Bonaire. The brown circle represents the present situation which can develop into the future in Business as Usual (blue circle) or the Nature Inclusive vision (green circle). Current trends are projected with the 'Business as Usual' future. A likely more sustainable future is expressed in the Nature Inclusive scenario which requires transformative action and policy. Different pathways (influenced by actions and policies) can lead to that Nature Inclusive future (after PBL, 2021).*

2.1 Business as usual

Within the business-as-usual future, economic growth based on tourism guides the future of Bonaire.

Global climate change will continue along current trends. As a small island, Bonaire cannot influence the general climate by itself. Flood and storm damage risk increases especially in the south and along the lower parts of the coast (including Kralendijk and Lac). The mangroves are dying off inland and the natural seaward expansion of the mangrove forest cannot cope with the fast rising sea level which result in a strong reduction of the mangrove extend (STINAPA, 2022). The dykes around the southern flats are raised to protect the flats (including the RAMSAR area Pekelmeer and the salt production industry) from flooding. Flood protection might be compromised by seepages and upwelling in the low lying karst area (Rooth, 1965). Droughts and average temperature increase, lowering the amount of water seeping into the soil causing stress on the natural vegetation and thereby increasing soil erosion and salinization.

Overall for Bonaire, the green cover will decrease due to a reduction in precipitation and high grazing pressure. Free roaming cattle -and thus the grazing pressure- are removed only from the parks which resulting in local vegetation recovery with increased resilience to climate.

A warmer climate boosts energy use for air conditioning and water use to service the population and to water gardens. A few individuals invest in rooftop water harvesting, mainly for watering their own gardens, or growing vegetables on their own private properties. A handful of small-scale entrepreneurs are growing fresh vegetables (like leafy vegetables, long beans, snack cucumber and herbs) that are sold to restaurants, hotels and local supermarkets. These entrepreneurs mostly use grey-water for irrigating their crops.

The main economic driver will remain tourism with an increase in stay-over and cruise ship tourists. The airport capacity will continue to increase catalysing the growth in the number of stay-over tourists. The port will be even further expanded to facilitate flow-of-goods and provide anchoring of cruise ships. Population will continue to grow as it is coupled to (mostly stay-over) tourism growth through an influx of foreign investors (such as hotels, restaurants, related hospitality services, retirees, second home of high-income families and the consequential construction sector). Urban expansion follows population growth with equal distribution in house and lot sizes. Road, energy and water infrastructure is following urban expansion. Technological innovation and private investments increase local energy production from solar and wind coupled with traditional, fossil fuel based, production. Imports (such as food and materials) will increase to stay in line with the growing demand.

In a strip of 200 meters from the sea, a new sewerage system is implemented to protect the environment (mainly the reef) from nutrient influx. Vacuum sewer pipes reduce the amount of water needed to flush toilets (NRC, 2014). Despite these measures, the nutrient load on the natural environment will grow in absolute numbers, as not all buildings are connected to the sewerage system (and erosion rates increase). These unconnected buildings use for example storage tanks, sceptic tanks, or infiltration pits. Water sewerage treatment keeps relative pace with the growing use from population and tourists.

2.2 Nature inclusiveness: measures to combat challenges

Within the Nature Inclusive future, the carrying capacity of the natural system, coupled with economic diversification, guides the future of Bonaire.

Equal to the Business as Usual future: global climate change will continue along current trends. As a small island, Bonaire cannot influence the general climate. Flood and storm damage risk increases especially in the south and along the lower parts of the coast (including Kralendijk and Lac). The mangroves are dying off inland and the natural seaward expansion of the mangrove forest cannot cope with the fast rising sea level which result in a strong reduction of the mangrove extend (STINAPA, 2022). The dykes around the southern flats are raised to protect the flats (including the RAMSAR area Pekelmeer and the salt production industry) from flooding. Flood protection might be compromised by seepages and upwelling in the low lying karst area (Rooth, 1965). Droughts and average temperature increase, lowering the amount of water seeping into the soil causing stress on the natural vegetation.

As a contrast to Business as Usual: with nature inclusive measures, removing the grazing pressure by eradicating all free roaming cattle, not only in the park[1]. Natural vegetation can grow and fully develop, including a well-developed rooting system that holds the soil and leaves less bare soil. Soil fungi are

[1] A very limited amount of free roaming cattle may have a positive effect on nature by dispersing nutrients and seeds (Mangazina di Rei, 2021).

stimulated to provide better nutrient and water retention in the soil, particularly in periods of drought (Coban et al., 2022). A 25-meter conservation buffer in which the natural vegetation can fully develop, is laid around all dry riverbeds ('rooien'). Runoff resulting from rain on infrastructure is halted through e.g. vegetated roadsides and permeable road pavements. Together these reduce the risk of erosion.

A warmer climate also boosts energy use for air conditioning and water use to service the population and to water gardens. Construction of new buildings make optimal use of prevailing wind direction, window blinds and shading by vegetation to create a comfortable indoor climate and limit the need for air-conditioning. For new construction projects the natural vegetation is kept mostly intact; no full allotment clearances take place. Half of the private individuals invest in rooftop water harvesting, mainly for watering their gardens, but also for growing vegetables on their private properties, or in community gardens. Primary and secondary schools actively promote growing your own food to new generations. Dozens of small-scale entrepreneurs form cooperations that are also growing fresh vegetables (like leafy vegetables, long beans, snack cucumber and herbs) that they sell to restaurants, hotels, local supermarkets and to cruise-ships. These entrepreneurs use grey-water for irrigating their crops. Residues are used as fodder for goats that are kept for meat in fenced ranches close to the arable farms. The latter use the goat dung as manure. Both businesses are clustered to enable shared use of infrastructure and facilities. Grey water is being delivered by truck from the water treatment plant, and, if required, by first stage reverse osmosis (WEB, 2021[c]). This circular system increases the self-sufficiency of the island and diversifies the economy. In the valley of Rincon a food forest (syntropic farming) is developed following up on a Brazilian cerrado success (Andrada et al., 2020; Gietzen, 2019). Fish is sustainably caught and only sold for the Bonairean market.

The main economic driver will remain tourism with a gradual stabilization in stay-over and cruise ship tourists. There is a clear shift to high-end (eco)tourism with family inns, boutique hotels and country retreats. The population stabilizes following the trend of tourism stabilization. With the degrowth in tourism, less additional labourers are needed in this sector. Nevertheless skilled immigrants are needed in the healthcare sector to service the aging population (CBS, 2021[b]). Urbanization follows the population trend and is steered towards urban densification with smaller houses, smaller lots and three to a max of four floor condominiums, thereby reducing urban sprawl and prohibiting urban encroachment (e.g. along the coast). Locations for built-up areas are carefully planned and used to strengthen the resilience of the natural environment which is currently degraded. Examples of land-use planning include: all new buildings are constructed at least 200 meter from the projected coastline and at least 1.5 meter above the projected flood line, protection against the sealing of agriculturally viable soils, buffer zone development around streams, gardens with native vegetation for communities to gather and grow their own fruits and vegetables, and drainage and purification of rain and stormwater from roads. Roof tops of most buildings are used for water harvesting and/or solar panels. Capacities of the airport and ports remain at current size and do not expand further.

Wind-energy turbines produce most of the energy. Most households, businesses and governmental buildings are equipped with solar panels that are connected to the grid. Much of the solar energy is stored in household battery systems. Any fluctuations in wind & solar energy availability, are absorbed by using imported fossil fuels. Off-grid users have solar panels with battery systems.

In Kralendijk and Rincon, a new sewerage system is implemented to protect the environment from nutrient influx and to enhance circularity. The vacuum sewer pipes reduce the amount of water needed to flush toilets (NRC, 2014). In the kunuku and other remote areas people live off-grid, and more kunukus are used for plant-based food production. Unconnected off-grid homes use waste storage tanks, sceptic tanks, infiltration pits, or plant-based infiltration systems. Tanks can be regularly transported to the sewerage treatment plant to purify the sludge, i.e. remove medicine and paint residues, to make it reusable as fertilizer for agriculture. Organic waste flows (e.g. food residues and peels) are composted and also used as fertilizer for agriculture and in gardens.

3 Comparing the possible futures

We have chosen several common measurable indicators to compare the described Business as Usual (BaU) and Nature Inclusive (NI) scenarios. The selection of indicators was based on literature study (Czucz et al., 2018; UN, 2013; Ravn Boess et al., 2021), interviews with local stakeholders (Annex 4, 5) and expert consultation (Annex 6). The indicators used were selected for their relevance to the main pillars on which the island prosperity depends with a focus on the spatial dimension (as this study is about spatial planning and land use). The selection of the indicators was influenced by what you can measure, detect or calculate.

The quantified indicators are part of the system described in Figure 3. The system describes drivers (living conditions) such as the natural system (we quantified these using certain climate indicators) and the cultural system (Bonairean socio-economical and policy system). These drivers create a framework under which the actors can live and make decisions about land use. The way the land is used as well as the available technologies in turn dictate the resulting impact indicators. The indicator values are compared as they are presently and two future scenarios proposed for 2050 (Table 1). The indicators are described and their values are discussed in each subsection of Chapter 3.

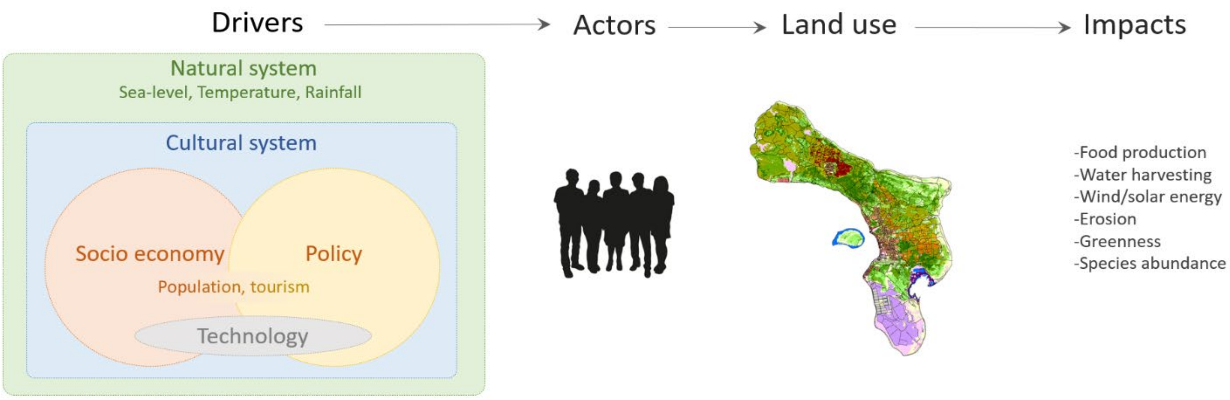

Figure 3 *Indicators used for the causal relationship between drivers of change, actors taking measures that lead to land use change and the impacts of these land use changes (inspired by Hersperger et al., 2018 and van Bets et al., 2017).*

Table 1 *Comparison table of indicator values at their present state, and two projection scenarios: Business as Usual in 2050 (based on extrapolation of historical trends) and Nature inclusive in 2050 (based on historic trends and proposed nature inclusive measures).*

Indicator	Present	2050		Remarks
		Business as Usual	Nature Inclusive	
Climate				
Sea-level rise *[cm]*	0	40	40	RCP 8.5 projects a 40 cm sea-level rise
Temperature *[degrees Celsius]*	29	31.5	31.5	Projected to increase at 0.08 degrees per year; 2.5 degrees Celsius warmer by 2050
Precipitation *[mm/year]*	463	311	311	Projected to decrease by 33%
Tourism				
Stay-over *[tourists /year]*	157.800	270.000	190.000	In BaU the growth trend extrapolation is made possible by expanding the airport capacity. In NI the airport capacity is not expanded limiting the max number of tourists. Also policies limiting the urban expansion are in place.

Indicator	Present	2050		Remarks
		Business as Usual	Nature Inclusive	
Cruise ship *[passengers / year]*	457.700	2.400.000	300.000	In BaU the growth trend extrapolation is made possible by infrastructural expansion and technological innovation in bigger cruise ships. In NI cruise ship numbers are downsized to lower the pressure on infrastructure.
Population				
Inhabitants *[people]*	20.104	35.000	27.000	Population growth is strongly influenced by tourism numbers and is made up of mostly off-island immigrants servicing tourists
Infrastructure				
Hotel capacity *[room count]*	2.280	3.850	2.700	Hotel capacity is assumed to follow airport capacity. In BaU the airport is expanded. In NI no airport expansion
Hotel and resort areal increase *[hectare]*	0	60	20	The areal demand for hotels and resorts follows the increase in number of rooms
Residential areal increase *[hectare]*	0	770	290	The areal demand for residential houses follows the population. In NI houses and plots are smaller, and have more floors
Roof area *[hectare]*	161	493	231	This is under the assumption that 40% of the total parcel area (hotel, resort and residential) will be roof top area in BaU and 20% of the parcel area will be roof top area in NI. In NI houses are smaller, and have more floors.
Resources				
Total water use *[m^3/day]*	4449	7455	4523	Water use follows the population and number of tourists.
Actual roof water capture as percentage of daily need	~0%	~0%	22%	No change in water capture in BaU, whereas 22% of the daily need for fresh water is captured from roofs in NI. Roof water capture installations are assumed to increase in NI, as are water saving installations (e.g. flushing toilets), but less precipitation limits volumes harvested. Moreover, as population increases, less water will become available per person.
Potential roof water capture as percentage of daily need	46%	56%	44%	This is what potentially can be harvested from the roofs, if all roofs would be used to capture rainwater. In BaU, there is more roof area due to urban sprawl, which compensates for the reduction in precipitation (climate change) and the increase in total water use. In NI, the daily water use is lower than in BaU, but the roof area is also smaller, which makes the potential for capture less than under BaU.
Solar and wind energy *[percentage of total]*	33	10 to 15	60 to 70	In BaU a lack of investments in installations (under SSP 5) and growing population lower the fraction. In NI investments are made to enhance alternatives to fossil fuels for a degrown population.
Area for local food production *[hectare]*	1408	1361	1625	Local food production is nearly absent in the present and BaU. In the NI scenario area for local food production increases.
Land use				
Greenness index *[percentage of >80]*	19	15	22	The precipitation deceases in the future, limiting the growth of plants. In NI the removal of the grazing pressure enables plant growth to recover. NI also has far less urban expansion than BaU.
Land based erosion risk *[percentage of high to very high]*	14	14	10	Erosion risk follows the greenness as the roots of healthy plants will keep the soil together
Climate regulation *[percentage of cooler than average]*	53	51	58	Green cover has a cooling effect
Mean species abundance [percentage of moderate to very high]	10	10	18	Healthy vegetation provides a habitat to many species. Many smaller species use the coast and dry river beds as corridors between habitats. In NI the network of corridors are protected against urbanisation.

3.1 Climate

For both 'Business as Usual' (BaU) and 'Nature Inclusive' (NI) scenarios, we assume that global climate trends will continue in both cases. The island of Bonaire is too small to in itself alter the global climate change patterns even if the land use patterns change.

Currently a mean annual temperature is 29 degrees Celcius. By 2050, a mean annual temperature increase of 2.5 degrees Celsius is predicted.

Bonaire has experienced a decreasing trend in annual rainfall (KNMI, 2009). The current rainfall of 463mm per year is predicted to decrease by 152 mm by 2050, a reduction of 33% -around 1% reduction per year of the current rainfall of 463mm per year (Navarro-Racines et al., 2020; Kadaba, 2018)[2] which leads to an annual total precipitation of 463 (KNMI, 2017) – 152 = 311 mm by 2050.

By 2050 the sea level rise of 40 cm by 2050 is expected to flood large parts of the coastal area, especially in the south and Klein Bonaire (RCP 8.5). More frequent and severe storms are also predicted. The map in Figure 3 shows the projected flooded areas in red (climate central, 2021; Kopp et al., 2017). Annex 12 illustrates the modelled coastal exposure to storm waves and surge for 2050.

[2] World Precipitation Change 2050s Scenario: IPCC 5AR CIAT downscaled NCAR CCSM4 model under Scenario 8.5 from CCAFS and partners.

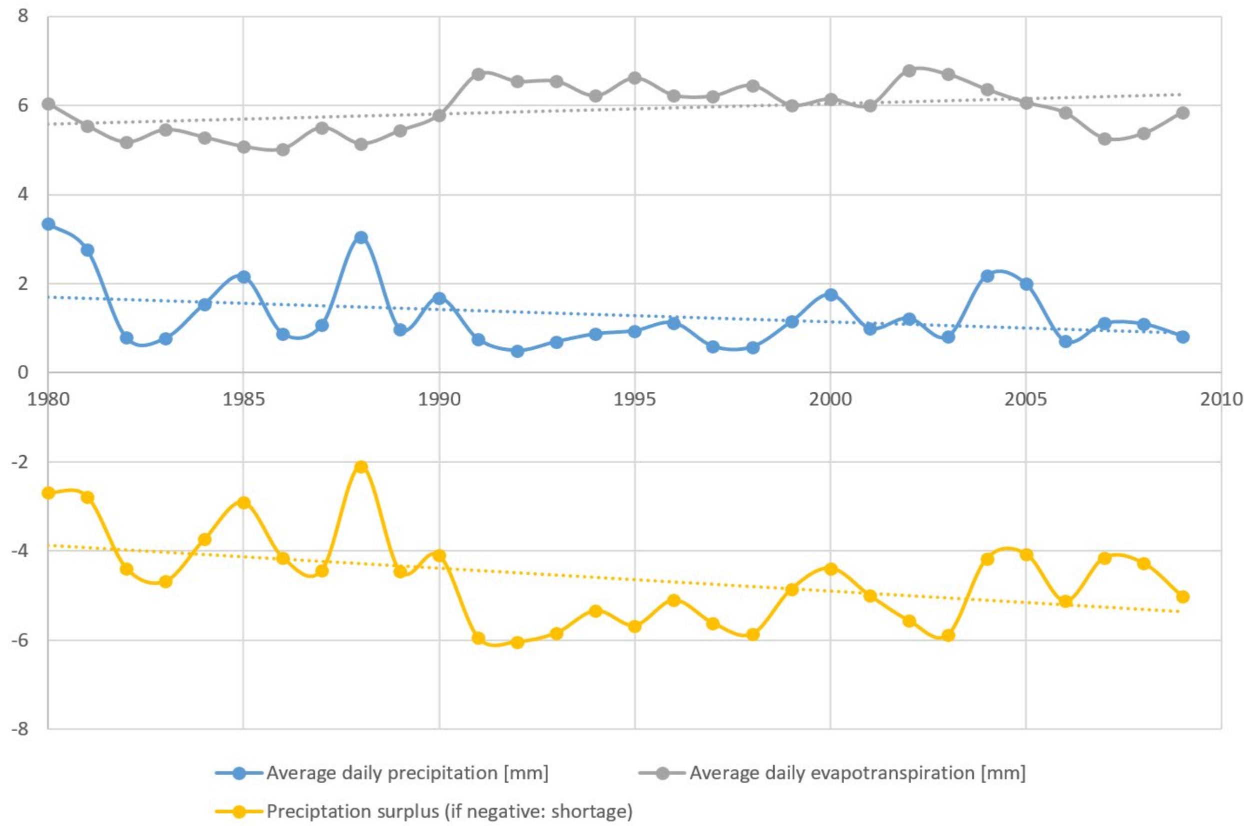

Figure 4 *Climate on Bonaire. The top figure depicts precipitation, evapotranspiration and resulting precipitation deficit on Flamingo airport over a period of 30 years (KNMI, 2009). Deficit has increased over time. Increased sea level rise will lead to flooded land areas on Bonaire's coastlines (bottom left image, in red) which can lead to local flooding disasters (bottom right).*

3.2 Tourists

Stay over tourists
In 2019 there were 157.800 stay-over tourists (Statistics Netherlands, 2020). In the same year throughput of passengers at Flamingo airport was 385.000. Throughput is measured by adding all incoming and all outgoing passengers, i.e. inhabitants, business visits, family visits, tourists, etc. Table 2 shows the ratio between passenger throughput and stay over tourists from 2012-2019. The ratio stays close to 80% throughout the years (see Table 2). This ratio of 80% is used to estimate future capacity needs of the airport.

Table 2 *Number of passenger throughput at Flamingo airport and number of stay-over tourists (Statistics Netherlands, 2022).*

	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Number of passengers throughput at Flamingo airport (P)	328860	332820	325810	342570	341440	323110	359350	385000
Number of stay-over tourists (T)	127600	131000	128900	133400	135800	128500	147800	157800
Ratio T/(P/2)*100%	77	79	79	79	79	79	82	82

Under the Business as Usual scenario, the stay-over tourists trend is extrapolated from 2012 onwards (Figure 5, based on Statistics Netherlands, 2020). By this prediction, Bonaire will host 270.000 stay-over tourists in 2050. This increase in tourists represents 170% of the 2019 numbers. At the end of 2010, Bonaire became a special municipality of the Netherlands, and from 2012 the tourism rates significantly increased (presumably from an increase in Dutch tourists).

If this increase persists in the BaU scenario, there will be 270 000 stay-over tourists by 2050, and therefore 675 000 inbound and outbound airport passengers (given the ratio of 80% calculated in Table 2: 270.000/80%*2). This airport-throughput capacity prediction exceeds the 2006 all-time high for the Flamingo airport of Bonaire at around 575.000 (world airports, 2018). This means the airport would need an expansion to support this growth. TCB (2021) confirms plans to airport expansion to a max of 900.000 inbound and outbound passengers.

In the Nature Inclusive scenario, we continue to assume the number of stay-over tourists will increase, but propose this increase to stay within the limits of current airport throughput capacity. This means the growth rate should slow down by 50% compared to BaU, and will stabilize by 2050 to support the airport limit and also will limit urban expansion of hotels. Consequently the 2050 increase will be limited to 120% (as opposed to 170% in BaU) in comparison to 2019, resulting in 190.000 stay-over tourists by 2050 in the NI scenario. Policies will have to be implemented surrounding the maximum flights, tourists, and hotels in order to change the current trajectory.

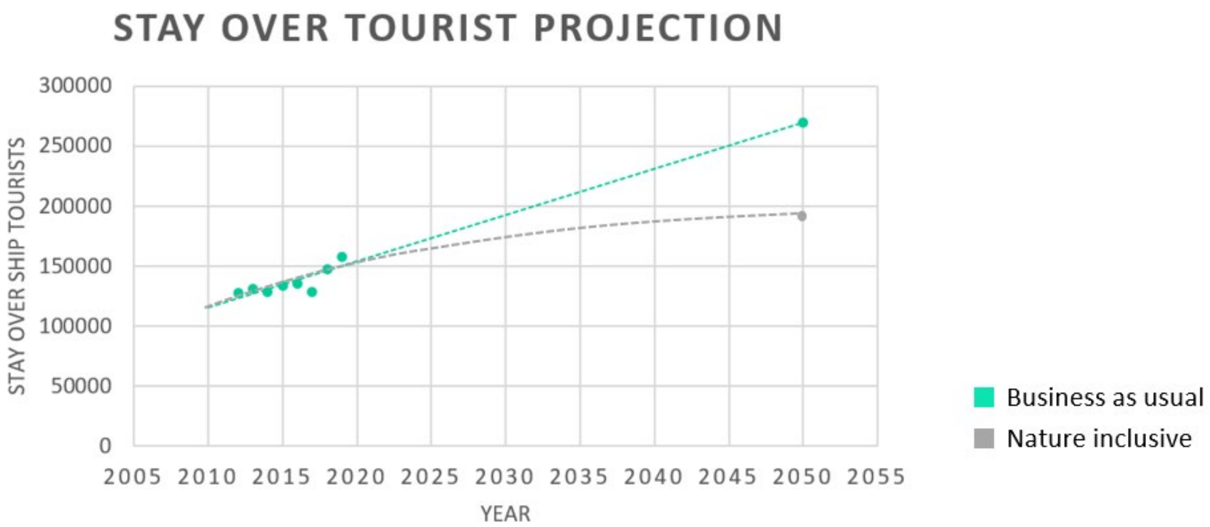

Figure 5 *Stay over tourist projection on Bonaire with the Business as Usual projection (green line) or Nature Inclusive projection (grey line).*

Cruise ship tourists

Since 2005, cruise ship tourism on Bonaire has strongly increased with a second wave of cruise increases since 2012 when Bonaire became a special municipality of the Netherlands (Central Bureau of Statistics Curacao; Verweij et al., 2020). In 2019, *457.000 c*ruise ship tourists visited the island (Statistics Netherlands, 2020).

Under the Business as Usual scenario (BaU), an increase to 2.4 million annual passengers is estimated based on trend extrapolation of census data from 2012 onwards (Statistics Netherlands, 2020), pre-COVID sold cruise tickets (TCB, 2021) as well as informed assumptions. These assumptions involve two full ships docking for 200 days a year (Bonaire is hardly influenced by the hurricane season) and, technological innovation leading to bigger ships of 6000 passengers each (DCNA, 2021). Growth is in line with the Tourism Recovery Plan that states '*Imagining cruise growth while maintaining the viability of natural ecosystems is possible*' (OLB[b], 2021). Van Bets et al (2017) signal the change from seasonal cruise ship tourism to year-round cruise ship tourism on Bonaire (Table 3). In 2050 the BaU scenario results in 2 400 000 annual cruise ship tourists (Figure 6). This will require infrastructural expansion, such as roads, harbour, services and urban expansion for housing servicing personnel.

Under the Nature Inclusive scenario, the number of cruise ship passengers will be downsized to 300 000 annual passengers by 2050. This will reduce pressure on the current urban infrastructure and environment (in line with Andrade et al., 2021; van Bets et al., 2017), as rising numbers of cruise ship passengers have led to heavy road congestion since the late 2010's (bonaire.nu, 2022). Cruise ship sizes will be limited to 3000 passengers for max 200 days per year, to decrease peak pressure.

Table 3 *Change in cruise ship passenger distribution throughout the year (after Statistics Netherlands, 2020).*

	Cruise ship passengers per month							
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
January	18%	25%	21%	17%	14%	12%	17%	16%
February	21%	16%	19%	17%	11%	14%	18%	9%
March	16%	14%	17%	15%	12%	14%	14%	11%
April	14%	10%	10%	6%	4%	6%	11%	9%
May	0%	0%	0%	0%	2%	5%	3%	5%
June	0%	0%	0%	0%	3%	3%	2%	4%
July	0%	0%	1%	1%	2%	4%	3%	4%
August	0%	0%	0%	2%	2%	3%	2%	5%
September	0%	0%	0%	2%	5%	4%	3%	5%
October	0%	0%	0%	9%	3%	5%	5%	6%
November	9%	10%	17%	15%	22%	16%	7%	11%
December	21%	24%	15%	16%	21%	16%	15%	15%

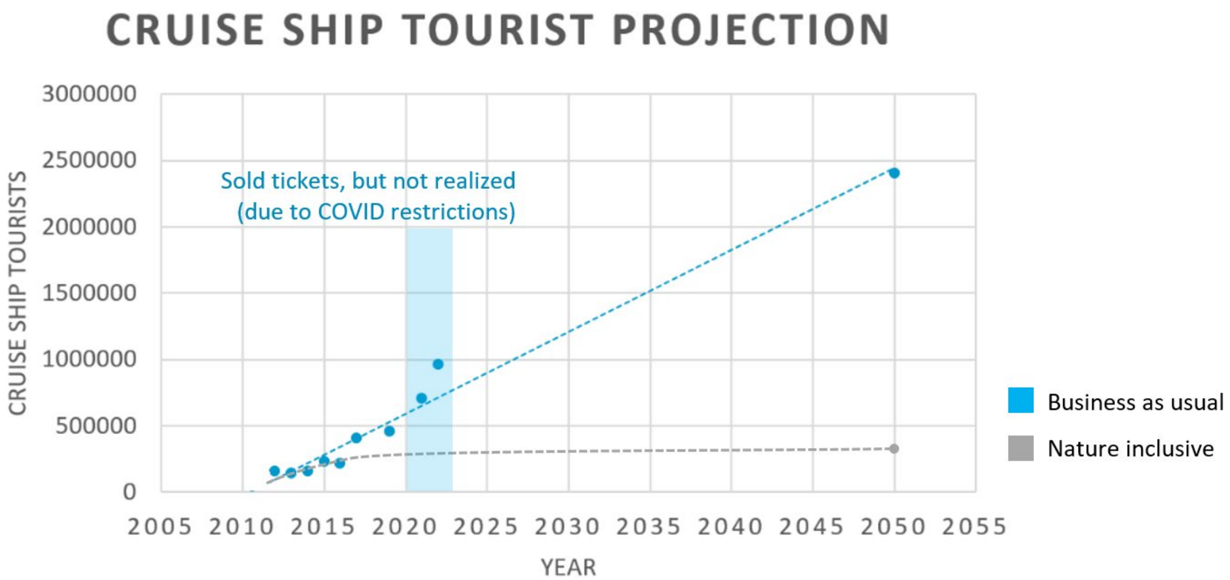

Figure 6 *Cruise shop tourist projection on Bonaire with the Business as Usual projection (blue line) or Nature Inclusive projection (grey line).*

3.3 Population

In 2019 the population of Bonaire was 20 104 (Statistics Netherlands, 2020). Population numbers have followed the growing trend along with annual stay-over tourism numbers on Bonaire with a respective ratio of 1:7 since 2012 (Table 4). Between 1990 and 2010 the ratio was 1:5 (Central Bureau of Statistics Curacao). This correlation can be explained by the growing economic dependency on (mostly stay-over) tourism. Increasing tourism is an incentive for immigrants set up more tourism-related services on Bonaire. By 2019, the population of Bonaire was 20 104 (Table 4, Statistics Netherlands, 2020).

Table 4 *Population on Bonaire and numbers of stay-over tourists (Statistics Netherlands, 2022).*

	2012	2013	2014	2015	2016	2017	2018	2019
Population (P)	16541	17408	18413	18905	19408	19179	19179	20104
Number of stay-over tourists (T)	127600	131000	128900	133400	135800	128500	147800	157800
Ratio P/T*100%	13	13	14	14	14	15	13	13

In the BaU scenario, population is predicted to grow following the trend extrapolation from 2012-2019 (Statistics Netherlands, 2020). The projected growth is accounted for within Bonaire's currently established spatial development plan (OLB[a], 2021), and the extrapolation of stay-over tourists (see section 3.2), and the 1:7 ratio (Table 4). OLB[a] (2021) predicts a population of 24.700 in 2027 and 26.500 in 2032 (Figure 7). If this trend projection continues, the Bonairean population will reach 35 000 by 2050.

Under the NI scenario the population will stabilize at 27 000. This prediction is a result of the maximum airport capacity being reached, and the stabilization of hotel and tourist numbers. Resulting policies will naturally stabilize the tourism-business related immigration, making it less attractive and less favourable to off-islanders settlers. By 2050, incentive will gradually be reduced for off-islanders to make a living on Bonaire in order to create a stable natural and economic environment suited to the capacity of the island.

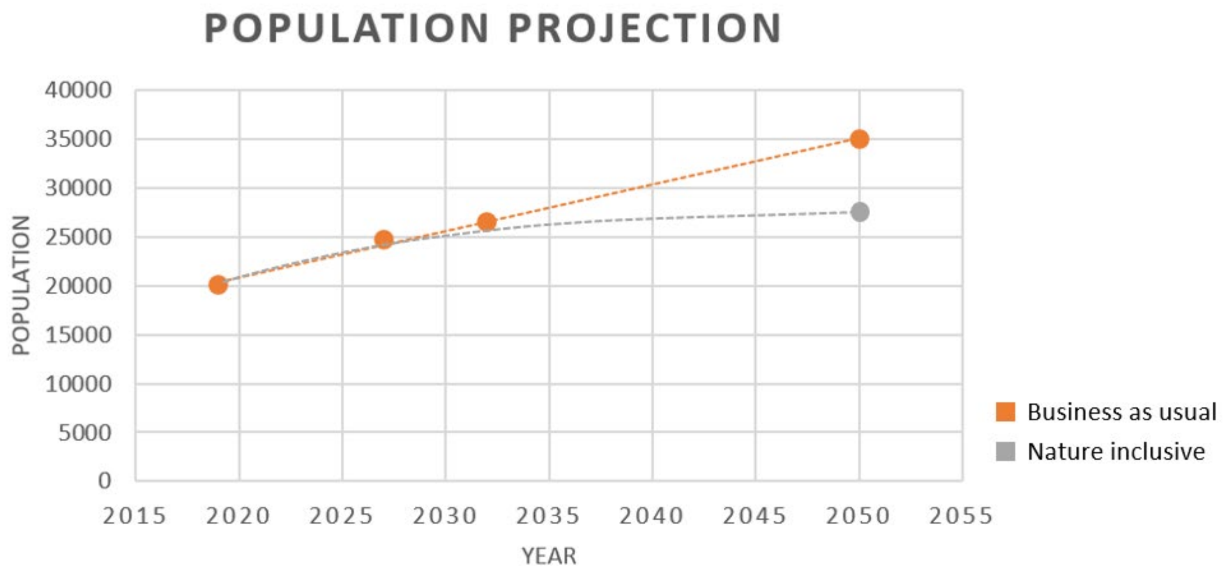

Figure 7 *Population projection on Bonaire with the Business as Usual projection (orange line) or Nature Inclusive projection (grey line).*

3.4 Infrastructure

Hotel and resort rooms for stayover tourists
Currently, the number of stay-over tourists (160.000, Statistics Netherlands, 2020) stay within the currently available hotel space (totalling 2.280 rooms, TCB, 2021).

Under the Business as Usual scenario, the projected airport capacity (Figure 5, Table 2) will dictate the number of tourists (according to the calculated airport passenger to tourist ratio of 80%, Table 2). This in turn leads to a corresponding increase of hotel rooms to 3.850 rooms by 2050.

Under the Nature Inclusive scenario, the number of rooms will also increase, proportionally to the stabilizing tourism numbers (Figure 5), while not exceeding the capacity of the current airport. The numbers of hotel rooms will increase, yet at a slower more manageable pace: to 2700 rooms based on the projected 190.000 tourists/year (see Table 1).

Areal demands for hotels and resorts
The hotel and resort area will also have to increase by 60ha in 2050 to accommodate above mentioned hotel room/tourism demand in the Business as Usual scenario. This estimation is based on the present-day average parcel size of 376m^2 (Annex 2) multiplied by the increase in number of stay-over tourists (270.000/year in 2050) (see Table 1, and Annex 2b for details).

In the Nature Inclusive scenario, denser urbanisation and smaller parcels, along with the stabilizing of the growing tourism industry results in a total increase of 20 hectares in hotel and resort area by 2050.

Areal demands for residential homes
In 2050, under the Business as Usual scenario the area allocated to residential homes will have to increase by 770 hectares for parcels to support the growing population. This is based on the present day average parcel size of 885m^2, multiplied by the increase in population (see Table 1, and Annex 2a for details).

While in the Nature Inclusive scenario, population increases which requires residential area, the housing plots will be smaller, and homes will have more floors encouraging vertical development. This is spatially and energy efficient. Average parcel sizes will be 75% of current averages and average house sizes are assumed 85% of current averages. This, in combination with the population increase, will lead to an additional areal demand of 290 hectares compared to the current situation.

Spatial allocation of areal demands for hotels, resorts and residential homes
There is not only a difference in areal demand size between the projections of the two described scenarios but also the spatial allocation of the areal demand.

By 2050 the built-up area under the Business as Usual projection increases by 850 hectares, consisting of 770 ha for residential homes and 60 hectares for hotels and resorts. Figure 8 shows a possible spatial allocation of built-up demands under the Business as Usual scenario. Hotels (blue polygons on the maps of Figure 8) are preferably built close to the coast, but at safe distance from flooding. These are specified as 1.5 m above flood line and 200 meter from the coastline (STINAPA, 2021). Residential homes are preferably built within existing neighbourhoods, densifying the built-up area (OLB, 2021[c]). 24% of the areal demand for residential homes under the Business as Usual scenario can be realised by densifying the built-up area (orange polygons on the maps of Figure 8). Urban expansion for the remaining 76% of the areal demand for residential homes (red polygons on the maps of Figure 8) will be realised within the current zoning plan, or adjacent to existing conglomerations, and preferably not on viable agricultural soils.

Under the Nature Inclusive scenario, the built-up area for 2050 increases by 310 hectares only, consisting of 290 ha for residential homes and 20 hectares for hotels and resorts. This means that almost two third of the areal demand for residential homes under the Nature Inclusive scenario will be met though densifying the built-up area. Also in this scenario all new buildings are constructed at least 200 meter from the projected coastline and at least 1.5 meter above the projected flood line.

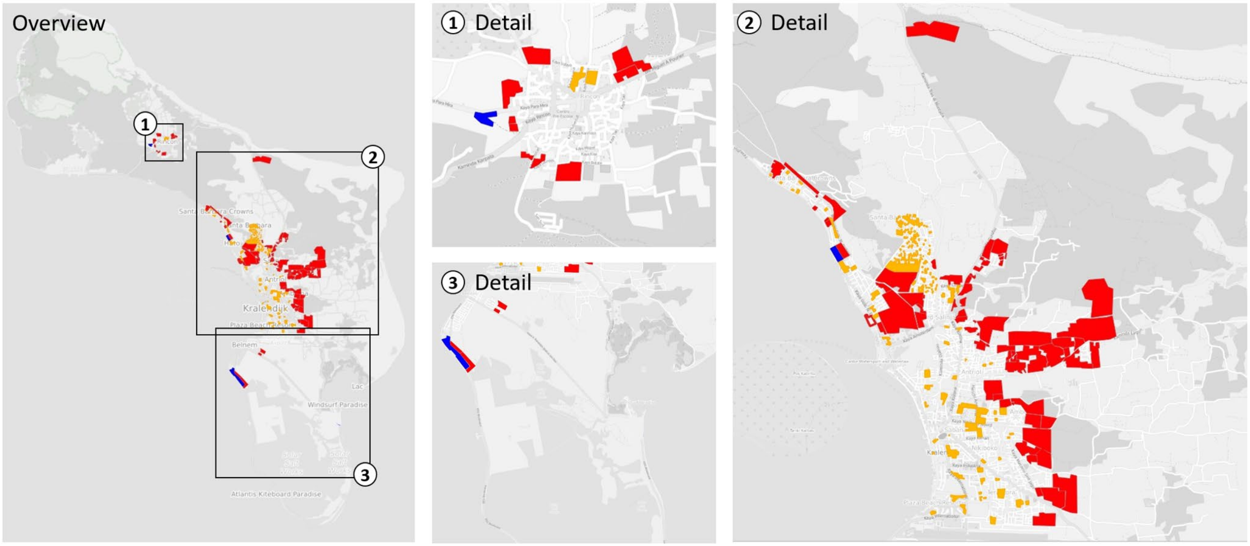

Figure 8 *Spatial allocation of built-up demands under the Business as Usual scenario, overview of all of Bonaire, with details for 1. Rincon, 2. Kralendijk and, 3. Southern Bonaire. Densifying residential in orange, expanding residential in red and, hotels and resorts in blue. Note, these maps mostly match current and foreseen policies and plans, although discrepancies have been identified by OLB during review of this document [3]. Potential urban expansion on the distant unspoiled east coast of Bonaire ('plantation Bolivia') (Antilliaans Dagblad, 2019) has been excluded as it remains highly contentious among the local residents.*

3.5 Resources

Water consumption

Currently the average water consumption for residents is 125 L/day/person of which 30% accounts for flushing the toilet (WEB, 2021[a]). This average consumption totals to 21.000x125=2625m^3/day for the population of Bonaire. Tourists use a lot more water: 400 L/day/person (average from different sources WEB, 2021[c] and Dorsch, 2002). Tourist water use is much higher than residential since swimming pools, washing dive gear, washing rental cars, etc., requires considerably more volumes. This amounts to a total consumption of 4449 000 L per day (with an actual production of 7200 000 L drinking water per day (WEB, 2021[b])).

Under the Business as Usual scenario, 7700 tourists are expected to stay-over each day, calculated from the average number of hotel rooms (3850) multiplied by an average of 2 people per room. With a population of 35.000, and equal water consumption figures compared to the current situation, the total water consumption will amount to 7455 000 L per day.

Under the Nature Inclusive scenario, 5400 are expected to stay-over each day (2700x2). The population (27000 inhabitants in 2050) will use water consciously, aware of the decrease in the amount of precipitation and the energy it takes to produce drinking water. Their average water use will decrease with 30% to 87.5 L/day/person. This will lead to a total water consumption of 4522 500 L per day.

Table 5 *Water consumption of residents and stay-over tourists for the present and future scenarios.*

Scenario:	**Present**		**Business as Usual 2050**		**Nature Inclusive 2050**	
	Stay-over tourist	***Population***	***Stay-over tourist***	***Population***	***Stay-over tourist***	***Population***
Individuals (No)	4560	21 000	7700	35 000	5400	27000
Average water use (L/day/person)	400	125	400	125	400	87.5
Total water use (L/day)	1824 000	2625 000	3080 000	4375 000	2160 000	2362 500
Total water use (L/day)	4449 000 (100%)		7455 000 (169%)		4522 500 (118%)	

3 Discrepancies with current and foreseen spatial plans and policies: too dense urbanisation at Ceru Grandi, missing urban expansion at Harbor Village, Suikerpalm in Belnem, Kaminda Lac and expansion between Kaya Korona and Kaya Neerlandia (OLB, 2022).

The volume of roof water capture

Roof top water harvesting is the measure most frequently mentioned by local experts, to address a variety of challenges in a nature-inclusive fashion (see Annex 5). These challenges are: drought and other extreme weather events; local produce and healthy diets; flourishing cultural heritage; and maintaining, enhancing and restoring nature.

This indicator depends on the amount of precipitation and the capturing capacity, i.e. roof surface, gutters, cisterns, plastic storage containers and pumps. Presently, very little water is captured through roof top water harvesting, as there are hardly any roofs with significant capture installations. However, it is interesting to know how much of the potential is not used, but might be used in the future under the different scenarios.

In the present situation there is a total of 161 hectares of roof area (OpenStreetMap, 2020) and 463 mm/year of precipitation (see Table 1, KNMI, 2017). The optimal annual water yield would therefore be around 745 million litres. Given the total water use of 4449 000 L/day, this covers 46% of the current daily need.

In 2050 under the Business as Usual scenario there will be no big changes in water harvesting anticipated. This results in even more water needing to be produced through the current methods of reverse osmosis.

However, if all roofs were to contribute to the collection of rainwater under the Business as Usual scenario, this would amount to a total roof area of 493 ha: 161 ha (present roof surface) + 332 ha (additional roof surface by 2050). This would result in a potential annual availability of 493x311 (reduced annual precipitation) = 1533 million litres. Given the total water use of 7455 000 L/day, this covers 56% of the daily need under the Business as Usual scenario.

In the Nature Inclusive projection, half of the buildings are estimated to capture water from their roofs. With a total roof area of 231 ha (161 ha (present roof surface) + 70 ha (additional roof surface by 2050)) this would result in an actual annual availability of 231x50%x311 (reduced annual precipitation)= 360 million litres. Given the total water use of 4523 000 L/day, this covers 22% of the daily need under the Nature Inclusive scenario.

The optimal annual water yield under the Nature Inclusive scenario would amount to 720 million litres if all roofs were to contribute to the collection of rainwater. This would cover 44% of the daily need under the Nature Inclusive scenario.

Energy produced by solar and wind

Currently wind turbines produce 32% of the energy on the island, while solar accounts for 1% and fossil fuels for 69% of energy production (van der Geest & Teles, 2019). Currently solar panels are only used on some rooftops.

Under the Business as Usual scenario, the lack of investments in installations (under SSP 5) and the growing population lower the fraction of energy from wind and solar installations to 10-15%.

There is a strong wish to produce 60% to 70% of all electricity through wind turbines within several years (WEB, 2021). This can be realized in the Nature Inclusive scenario by 2050, when investments will be made to create alternatives to fossil fuels. It is expected that political will and financial support will enable to produce most electricity through wind turbines and modern solar panels. New housing and developments will require rooftop solar and water collection installations and an investment in wind energy. Fossil fuels are however still used as a buffer in case the wind is down, or batteries which charged during day-time, are low on energy after sun set.

3.6 Land use

The interaction of the natural ecosystems with human activities is reflected in the land use. Land use helps to understand the environmental change dynamics. Land use maps are tools that provide vital information to aid policy development, urban planning, forest, agriculture and natural ecosystems. The maps below (Figure 9) represent the land use on Bonaire while Figure 10 displays the land use distribution in the present situation and both future scenarios.

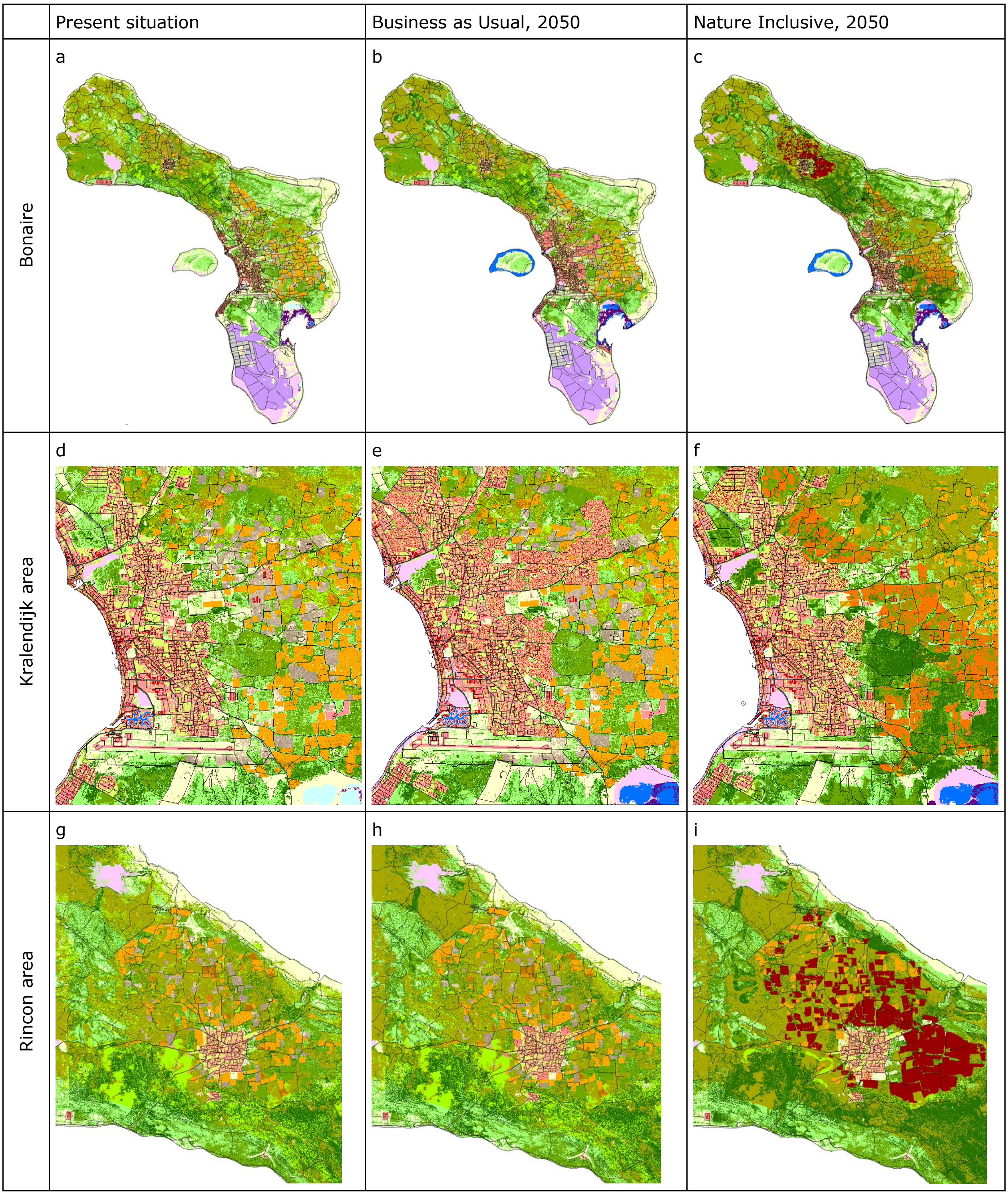

Figure 9 *Land use on Bonaire, with zoom-ins for Kralendijk and Rincon and their surroundings, for the current situation and for the two scenarios: Business as Usual and the Nature Inclusive projection. See Figure 10 for map legend.*

The future projections in Figures 9 and 10 incorporate the urban expansion, sea level rise, agricultural expansion, buffer zones around dry river beds and vegetation succession, taking future temperature and precipitation patterns into account. See Annex 7 for details on the creation of the maps.

Under the Business as Usual scenario, the urban and built-up areas increase, at the expense of pioneer and low scrub with cactus vegetation. Urban sprawl especially continues eastward from the current Kralendijk area (Figure 9e). Considering the projected population growth under this scenario, the current spatial development plan for all urban areas (OLBa) can host this growth without the need for extra urban zones.

Under the Nature Inclusive scenario, the island becomes greener overall (Figure 9c). This is especially apparent on the calcareous ancient forest plateau, the kunuku area and in the dry river beds ('rooien') of the north-east at the former plantation of Bolivia. The main driver for this change is the absence of free-roaming grazers which allows the vegetation to regrow. This regrowth allows for better water retention, soil restoration and protection against drought. Under the NI scenario more land is used for agriculture. Abandoned kunuku's are now maintained for local food production (orange spots in Figure 9f). Agriculturally viable soils are protected from urbanisation. A notable larger area around Rincon is used for agro-forestry under the NI scenario (dark red spots in Figure 9i). Considering the projected population growth under the Nature Inclusive scenario, the current spatial development plan for all urban areas (OLB[a]) can host both this growth (for example pictured in Kralendijk in Figure 9f) without the need for extra urban zones.

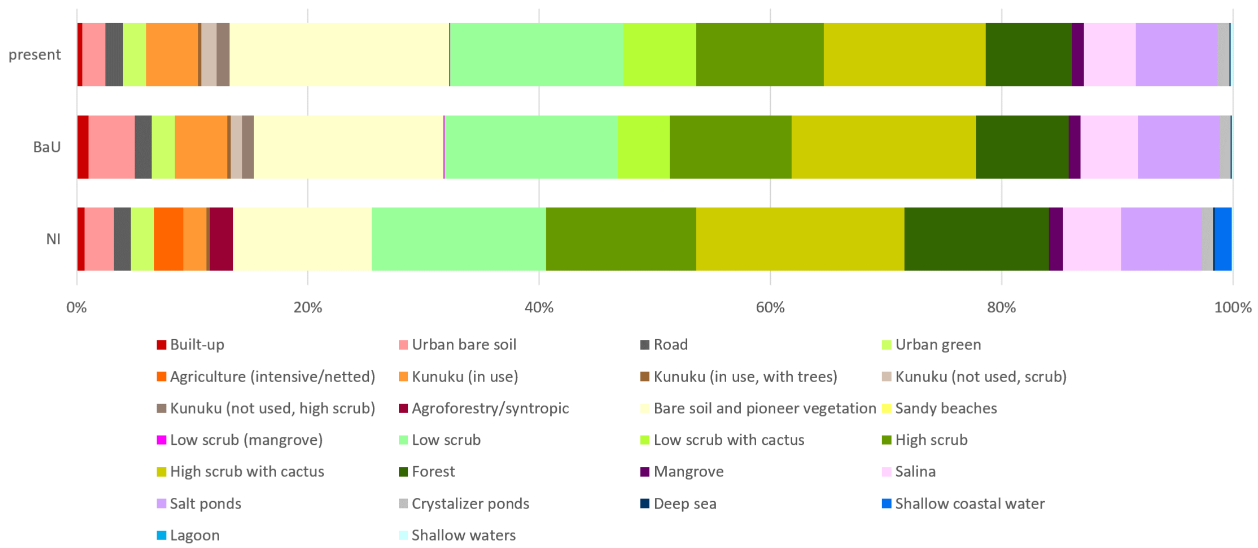

Figure 10 *Land use distribution on Bonaire currently and under two other scenarios: Business as Usual and the Nature Inclusive projection.*

The greenness index

The greenness index is a single number that can be used as proxy to estimate the amount of green vegetation (Clerici et al., 2012). For Bonaire the present greenness is derived from satellite measurements (NASA/USGS, 2021; Mucher et al., 2019). Mind: the greenness index does not represent all natural ecosystems. For example, the Bonairean open landscapes with cacti, or the saliñas are not represented by the greenness index.

For the future scenarios the average value of the vegetation type (at end stage after succession, see Annex 7) is used subtracted by the effect of reduced precipitation (Fensholt et al., 2013). See Annex 8 for maps showing the spatial distribution of the greenness index. In 2050 with the business as usual scenario, the areas of no green increase by 5% over the whole island and the areas over 80% decrease by 5% (Figure 11, BaU).

The main driver for the difference under the nature inclusive scenario is the absence of free roaming grazers. That leads to vegetation increase though regrowth, despite the reduction of rainfall. Regrowth also allows the soil to hold more water, increased vegetation increases shade which in turn reduces the levels of evaporation. This effect is visible in Figure 11 with the increase of areas that are 60-80% green and also areas with above 80% green.

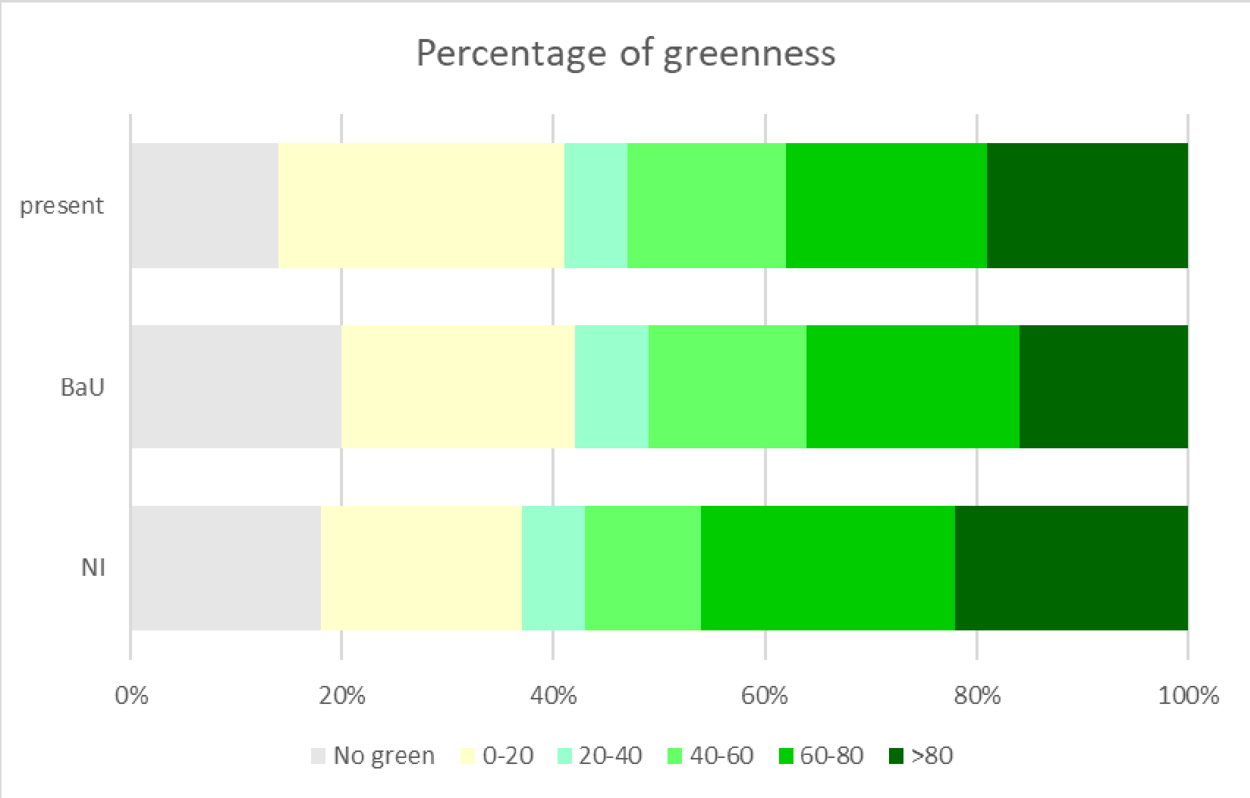

Figure 11 *Areal distribution of greenness for Bonaire for the present situation and the scenarios Business as Usual (BaU) and Nature Inclusive (NI). The total area is summarized per greenness intensity class: 0-20 (light yellow), 20-40 (light yellow/green), 40-60 (light green), 60-80 (green), 80-100 (dark green).*

Land based erosion

Erosion reduces soil fertility, increases pollution and sedimentation downstream, clogs waterways and negatively impacts plant and animal life. Erosion rates depend on a number of factors including slope, soil type and vegetation ground cover (Brooks and Spence, 1995; Tang et al., 2021). The vegetation stabilizes the soil and enhances infiltration (Munoz-Robles et al., 2011), thereby reducing run-off risk, also off coast and unto coral ecosystems (Álvarez-Romero et al., 2011; van der Geest et al., 2020).

Figure 12 represents the areal distribution of erosion risk for all of Bonaire currently, and in the two scenarios in 2050. Although the graph shows almost equal distribution for the present situation and BaU, the spatial distribution of the risk is different; the Washington Slagbaai Park in the northwest of Bonaire experiences erosion risk reduction from vegetation development as result of removal of free roaming cattle, urban sprawl replaces the (degraded) vegetation, see Annex 9 for the maps of erosion risk.

In the Nature Inclusive scenario, urban sprawl is reduced -through the encouragement of smaller yet taller buildings. There are more areas of vegetation regrowth on the island, both from reduction in free roaming cattle but also through increased agro forestry. Although not included in the calculations, runoff resulting from rain on infrastructure is halted through e.g. vegetated roadsides and permeable road pavements.

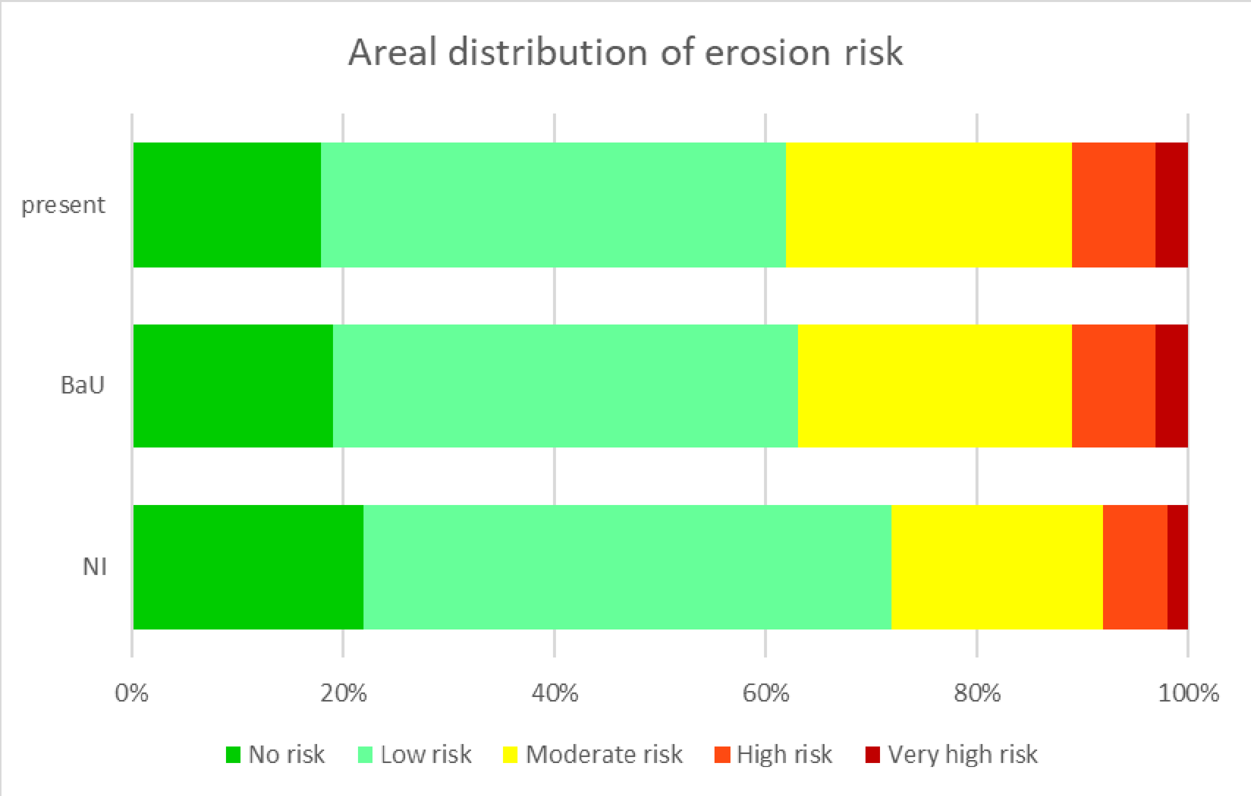

Figure 12 *Areal distribution of erosion risk for the present situation and the scenarios Business as Usual (BaU) and Nature Inclusive (NI). The total area is summarized per risk class: no risk (green), low risk (light green), moderate risk (yellow), high risk (orange), very high risk (dark red).*

Climate regulation

Climate regulation is an ecosystem service targeted at the moderation of temperature (Costanza et al., 1997). This service is provided by the vegetation, as green cover has a cooling effect. In this study, the climate regulation potential as provided by the vegetation is calculated as a product of land cover and greenness (both described above). See Annex 10 for details. This indicator does not reflect the measurable temperature, nor the temperature as perceived, but it is a rough proxy for the regulation by the vegetation only.

Due to the decrease in green cover under the BaU scenario, there is less of a cooling effect. Under the Nature Inclusive scenario, this cooling effect is greater than in the current situation, due to an increase in green cover.

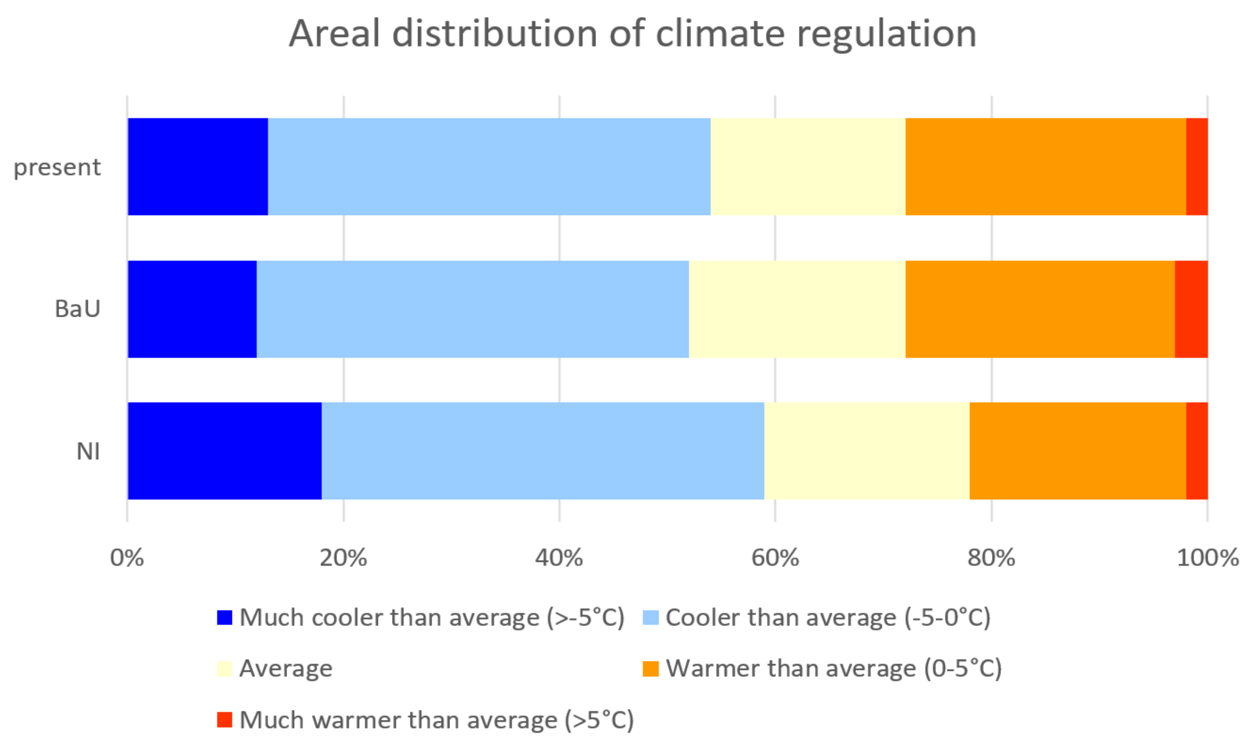

Figure 13 *Areal distribution of climate regulation for the present situation and the scenarios Business as Usual (BaU) and Nature Inclusive (NI). The total area is summarized per climate regulation class: much cooler than average (dark blue), cooler than average (light blue), average (light yellow), warmer than average (orange), much warmer than average (dark red).*

The mean species abundance

The mean species abundance (MSA) is a measure of 'biodiversity intactness'. It describes the average species population-level response to different stressors across a range of species. Although Bonaire is home to a rich marine biodiversity, in this study, the MSA has been calculated for the land mass only. Biodiversity on land and sea are interconnected. Improving the status of nature on land is likely to have a positive effect on marine biodiversity. Stressors include land use change, fragmentation and infrastructure (Alkemade et al., 2009; Schipper et al., 2020).

The mean species abundance was calculated using the InVEST GLOBIO model (Natural Capital Project, 2019) for the present and the future scenarios (Figure 14). See Annex 11 for detailed calculation results. The maps are calculated based on the land cover maps and the road network (Open Street Map, 2020). Although arguably the road network will change in the future to be extended to keep pace with urbanisation (especially in BaU), it was not changed for the scenarios.

The road network is an important driver for habitat fragmentation (and thus MSA). Under the BaU scenario, the MSA will especially decrease in the areas around Kralendijk, where urban expansion will take place.

Under the NI scenario, more land is used for agriculture. Abandoned Kunuku's are now maintained for local food production, which will lead to a decrease in species abundances in those areas, but since there will be no more free grazers on the island new areas will be allowed to regrow. Urban sprawl will also be reduced due to the vertical style of buildings.

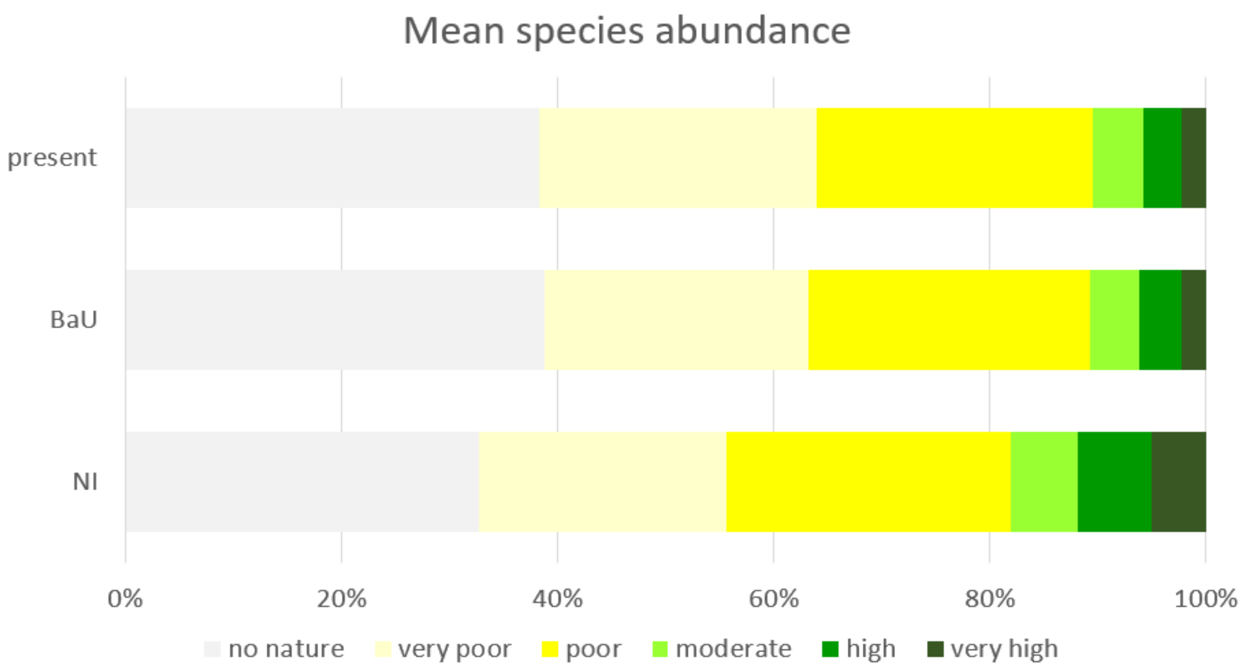

Figure 14 *Areal distribution of the mean species abundance within the present situation and as projected for the future scenarios Business as Usual (BaU) and Nature Inclusive (NI).*

4 Discussion and future perspectives

With this study, we shed light on measurable impacts to Bonaire if current trends continue as usual; and provided an alternative which can be visualized as a result of nature inclusive policies, actions and land use changes. However steering changes towards nature inclusivity is not only a change in land (and sea) use and indicator values, but to make it a reality it is a change in mindset of an entire community. This cannot happen without the awareness of the trade-offs that nature inclusive actions can bring to the many different stakeholders involved. In this discussion we make a case for the importance of nature inclusivity on Bonaire, and make a start towards a dialogue about the risks, trade-offs and opportunities that may lie ahead.

We have documented the current trends: Bonaire has experienced a quadrupling in population size over the past half century. Cruise tourism started growing exponentially in the mid-2000s, and stay-over tourism steadily increasing. All while access to freshwater with the climate change projections becomes more difficult and costly. While some Dutch Caribbean islands might have experienced a much more explosive increase in tourism and population than Bonaire (e.g. Aruba), other islands experience more stability (e.g. Saba). Anecdotal evidence from other islands (see Bonaire reporter, 2022), as well as the projections showcased in this report imply that if Bonaire wants to stay relevant as a tourist destination and support its growing population the island needs to focus on its long-term assets.

The scenarios in this report were described using indicators that progress along the trends and rates of the past several years. While these assumptions include some climate change parameters like gradual warming, and gradually reduced precipitation, they fail to consider implications of unforeseen natural disasters, or increasing severe weather conditions which will take a toll on the island. Neither do the scenario projections consider any changes in world trade processes for food or fuel. An honest look at the state of the island for the next 30 years under the Business as Usual projections indicates that sustaining such growth under the current (environmental or political) conditions of the planet are relatively short-lived, and are built on a set of fragile assumptions.

Naturally, trends described in the nature inclusive scenario imply (policy) choices with varying effects on each sector as shown using several indicators. In some cases, the rates compared to the BaU scenario will be slower (population growth due to immigrants, stay-over tourism, urbanisation), while with other indicators/sectors growth rates will increase (greenness, agricultural land, green and wind energy use and water collection). Specific implications of a scenario can be beneficial, while others can be unfavourable, depending on the agenda of each particular stakeholder. An example of such a trade-off is the extensive local food production under the nature inclusive scenario: in the foreseen closed agricultural system there is far less need for off-island nutrient imports. As fewer nutrients are brought onto the island, this reduces the harm from foreign particles to the environment and the reef. As such, the reef is more likely to stay healthy and can continue to be a major tourist attraction. Nevertheless, individuals currently working in the food import logistics sector may experience a decrease in business. This may be overcome by jobs created through the growing local food production industry, but awareness of this trade-off is important when instigating changes. Attractiveness of the nature inclusive scenario in the short-term depends on the stakeholder. While in the long-term, the implication of the nature-inclusive scenario is of an island prosperity that is inclusive for everyone and ensures sustainability. One which is much less dependent on the few precarious pillars on which it is currently built: food and fuel importation.

Another crucial trade-off of the nature inclusive scenario is the implication of water and waste collection. This requires significant infrastructural investments (sceptic tank collection, or rooftop collection installations, appropriate facilities and road ways to ensure this, and home fitting) which requires not only government support, but individual support and repeated actions. It means a change in routine, from linear to circular consumption. Routine is a difficult circuit to make or break. This will require a cultural understanding of the benefits and wholehearted will to change the norm. It may require a big investment in time and energy in the short-term to create a long term self-sustaining infrastructure.

Besides long-term self-reliance and climate resilience another benefit of the realization of a nature inclusive Bonaire is a return of cultural roots and pride. The development of systematic agriculture on the island could bring with it an influx of non-tourist-based entrepreneurship and local business opportunities. Land-use policies that prioritize the agriculturally viable soils to be free of urbanization can be promoted to start initiatives for community or school gardens. A shift in mindset and new green-technologies could make growing and working with the nature on and around the island a fulfilling use of resources and time as opposed to an exploitation for the use of off-island tourists.

Making the nature inclusive future a reality requires transformative actions and policies. With transformative ideas, it is important to simultaneously shift mindsets and create an enabling institutional environment that incentivizes change (Nel, 2021). A dialogue is necessarily from both angles: a top down, formal route (though policies, frameworks and regulations) and also from the bottom-up (knowledge exchange with local inhabitants and communities). Considering the findings in this report some of the top-down recommendations should be policy discussions regarding airport expansion, immigration, urban expansion, green energy, water collection, agricultural and natural land restauration. With regards to the bottom-up approach, social interactions with local communities could be organized to showcase the possible options for community gardens, consider solar and water capture roof installations, create possible education modules for schools, develop business opportunities for entrepreneurs in the food sectors, or gatherings for local kunuku holders. In every step, both top-down and bottom-up, there are opportunities for idea exchange and dialogue. These moments of stakeholder involvement and dialogue can create the foundation for sustainable changes. They ensure that the island communities and culture are intrinsic when making decisions for a nature inclusive future on Bonaire.

Visualizing scenarios as a part of the ‘foresight’ method is one important piece in creating awareness about the future. It allows us to shed light on the difficult to grasp long-term effects, and explicitly showcases current trends. It gives opportunities to imagine a future that looks different from the prognosis. While it is a powerful tool, it is also just a desk exercise. The steps that follow should be interactive with society and the stakeholders on the island. Gathering information about how these ideas are received and further elaborating new ideas together with all the actors is an essential part of creating a sustainable and desirable future.

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Annex 1 Photograph of inventoried system elements

System elements of Bonaire as identified by ten WUR experts with experience working on Bonaire during a workshop on May 2019 in Amsterdam, The Netherlands.

Participants: Katrine Soma, Diana Slijkerman, Anouk Cormont, Matthijs van der Geest, Peter Verweij, Dolfi Debrot, Michiel van Eupen, René Henkens

Annex 2 Areal demands

Residential homes
To estimate the area needed to house the increase in residents we analysed the current parcel sizes. In dialogue with local stakeholders (BONHATA, 2021) we divided current parcels of residential homes in three size categories:

House size category	Building area *[m²]*	Plot area (incl. house) *[m²]*
Small to average	Up to 125	Ca. 350
Large	125 - 375	Ca. 1000
Very large	Over 375	Ca. 2000

The house size categories were identified on a GIS-map of all buildings on Bonaire. This distinguishes many types of buildings, such as: church, shop, industry, house, etc. We selected only the categories 'residential', 'house' and 'apartment' to be included in the analyses. For these buildings we determined the polygon area and assigned the house size categories accordingly. From all houses we found 30% to be 'small to average', 62% 'large' and 8% 'very large', although these percentages differ per neighbourhood (see 15). By multiplying these percentages with the corresponding parcel areas the current average parcel area for a house is determined: 30%*350 + 62%*1000 + 8%*2000 = 885 m^2.

To house the increase of residents, OLB (2021a) expects 1.800 houses to be developed between 2021 and 2027, which equals 300 houses each year. Following that trend to 2050, 8.700 new houses are to be developed ((2050-2021) years * 300 houses)[4]. With an average plot area of 885m^2, 770 hectares of residential parcels are demanded.

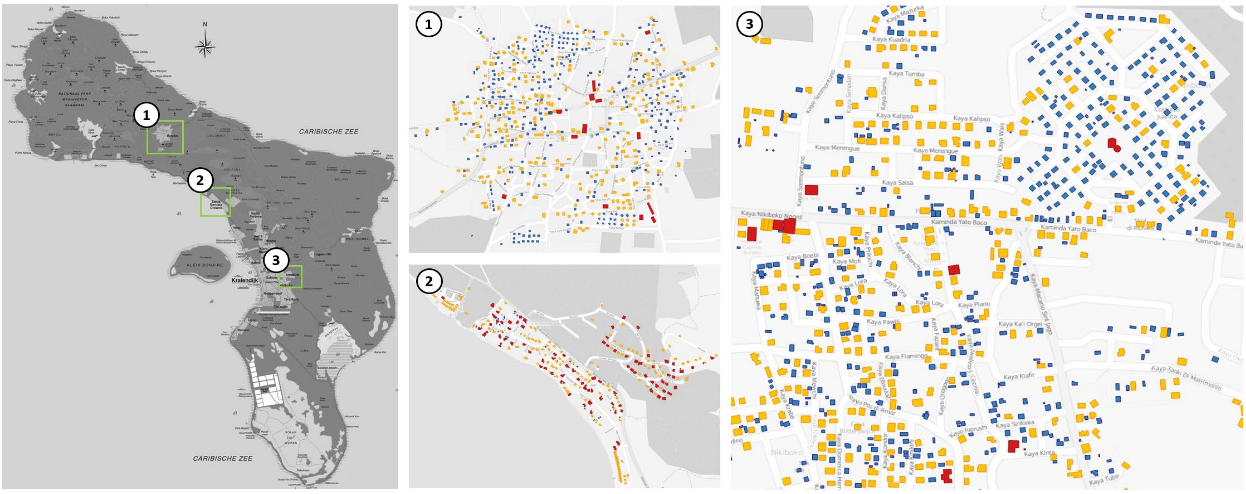


Figure 15 *House size categories for three neighbourhoods in Bonaire. Blue is 'small to average', orange is 'large' and red is 'very large'. 1. Rincon with respectively 53%/45%/2%, 2. Sabadeco and Santa Barbara Crowns 16%/55%/29% and Amboina and Nikiboko 61%/38%/1%.*

[4] Extrapolation of population growth and estimated demanded houses accounts for roughly 2 persons per household.

Hotels and resorts

To estimate the area needed to accommodate the increase in the demand for hotel rooms we analysed the current number of rooms (hotels.com, 2021) in relation to the area of those hotels and resorts. In dialogue with local stakeholders (DCNA, 2021; Engel, 2021) a number of hotels was selected and their property delineated by drawing boundaries in Google earth (see Figure 16). The property includes buildings, swimming pools, gardens, parking lots, etc.

Hotel name	Number of rooms	Property area *[m²]*
Divi Flamingo	129	21254
Marriot	111	22800
Delfin	84	18500
Ocean Breeze	76	17850
Buddy dive	73	23400
Hamlet Oasis	30	10400
Van der Valk	126	81228
Captain Don	40	27777
Sand dollar	31	40000
Total	700	263209

On average the property area per room is: 263209 / 700 = 376 m^2. Mind, this takes all services of the hotel into account, which is different from the room sizes that equals around 16 to 23m^2.

The estimated property area for all current rooms equals: 2280 rooms (see section Futures for Bonaire) * 376 = 85 hectare.

The estimated property area for 2050 equals: 3850 rooms (see section Futures for Bonaire) * 376 = 145 hectare, which is an increase of 60 hectares from now.

Figure 16 *Example of a property (van der Valk) delineated by drawing boundaries in Google earth.*

Annex 3 Food production

Several field visits were made to inventory potential food production methods: small-scale vegetable gardens for house-hold consumption (LVV, 2021; Beukeboom, 2021), netted agriculture (Bon Tera, 2021) and aquaponics (Bonaire DailyFresh, 2021). In aquaponics aquaculture (e.g. fish) are coupled with cultivating plants in water by which the nutrient rich aquaculture water is fed to hydroponically grown plants. Syntropic farming (Gietzen, 2019), a form of regenerative agro-forestry, has been suggested as a potential addition (Mangazina di Rei, 2021). See the pictures below for an impression of the field visits.

During the field visits semi-structured interviews were conducted with the objective to find key figures for production potential and resource use in terms of land area and water use. The table below lists the key figures.

Name	**assumptions**	**Area**	**Water use**
Vegetable garden (small, educational purposes)	100% netted, good Bonairean soil, absence of diseases, drip irrigation	1.125 m2/person/day	5 liter/person/day
Vegetable garden (practiced)	40% netted, 60% agro-forestry, good soil, drip irrigation, some diseases, vagrancy by lizards and rats	6.25/person/day	20 liter/person/day
Substrate cultivation	Netted agriculture	Total of 0.5 hectare	5 m^3/day
Syntropic (Andrade et al., 2020)	a single patch of at least 500 ha to enable the development of a micro-climate		A lot in the beginning, then less and less until maturity is reached. At maturity no irrigation is needed
Aquaponics	12.000 units a year of 45 different types of crops, mostly lettuce. 360 tilapia fishes a year of 700a800 gr. a piece. 1/3 can be used as filet (250 gr.).	Current: 110m^2	10 litre/lettuce

Demonstration vegetable garden at LVV. These vegetable gardens are used for educational purposes. The containers are 3 x 3 meters in size and are used to grow leafy vegetables only. Such a container provides a single household (4 persons) for two days of vegetables and requires at max 4 liter/day/m². Substrate cultivation uses around 1/6 of the water demand from drip irrigation in open field cultivation.

Bonaire DailyFresh
In the summer of 2022 it is expected that the entrepreneur in collaboration with LVV, will have increased its capacity to 1250 m^2 producing 200.000 units of fresh vegetables and 1500 kg Tilapia a year. The entrepreneur foresees continued upscaling, where each additional production greenhouse can provide 400,000 pieces of vegetables and 3,000 kg of Tilapia extra per year.

Private vegetable garden
A garden of 10x10 meter of which 40m² is made up of netted agriculture for growing melon, pumpkin, beans and lettuce. The remaining 60m² is agro-forestry. Tomato, paprika, pepper, eggplant, okra and herbs like basil and mint are located in the shade of the greenhouse and the trees. Two types of trees are found here, banana and papaya. The garden is watered on a daily basis via drip irrigation. This garden is used for growing vegetables and fruits (30%), flowers (10%), trees for a revegetation project (10%) and is widely setup with plenty of manoeuvring space (50%).

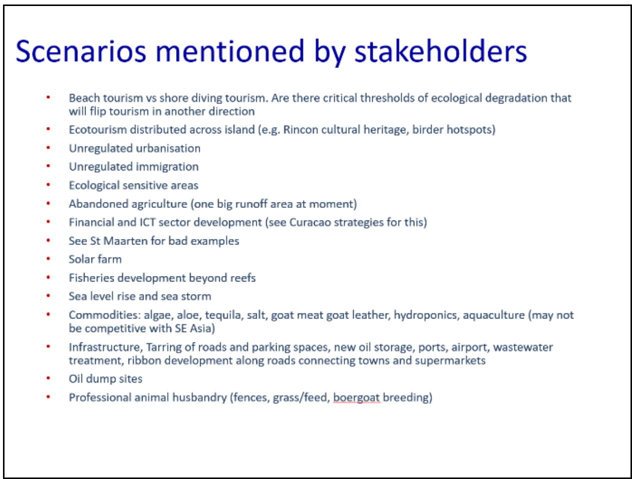
Bon Tera

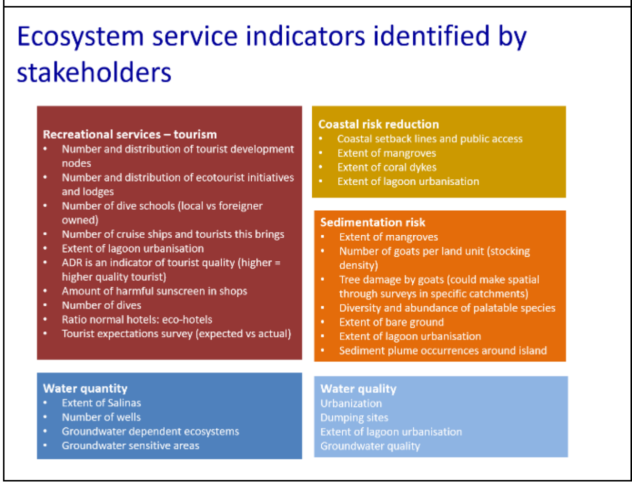
Annex 4 Summary of late 2019 scoping mission interview results

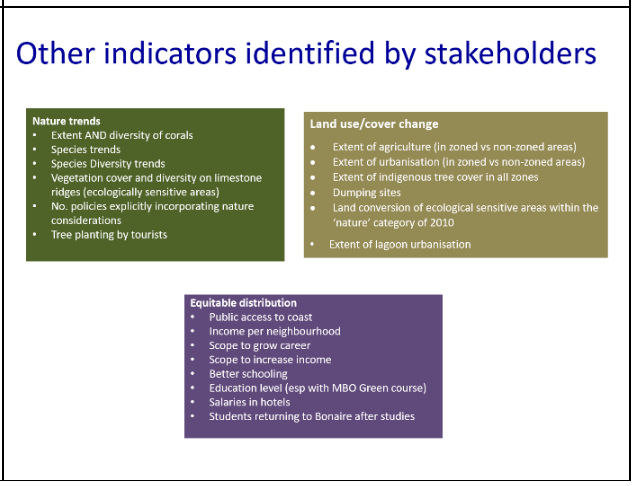
During one to two hour interviews local experts and stakeholders were asked to list relevant indicators for measuring impact of nature inclusive spatial plans. In addition they brainstormed on potential scenarios for how the future might look like. The below screenshots of a PowerPoint presentation summarize the findings.

Interviewers: Jeanne Nel, Peter Verweij

Interviewed individuals: Julianka Clarenda (ECHO), Yoeri de Vries (RCN), late Paul Hoetjes, (RCN), Caren Eckrich (STINAPA), Paulo Bertuol (STINAPA), Wijnand de Wolf (STINAPA), Frank v Slobbe (OLB), Delno Tromp (TCB), Jan Jaap van Almenkerk (Wayaka advies), Esther Meijer-Sedney (CBS), Henk van de Velden (CBS)







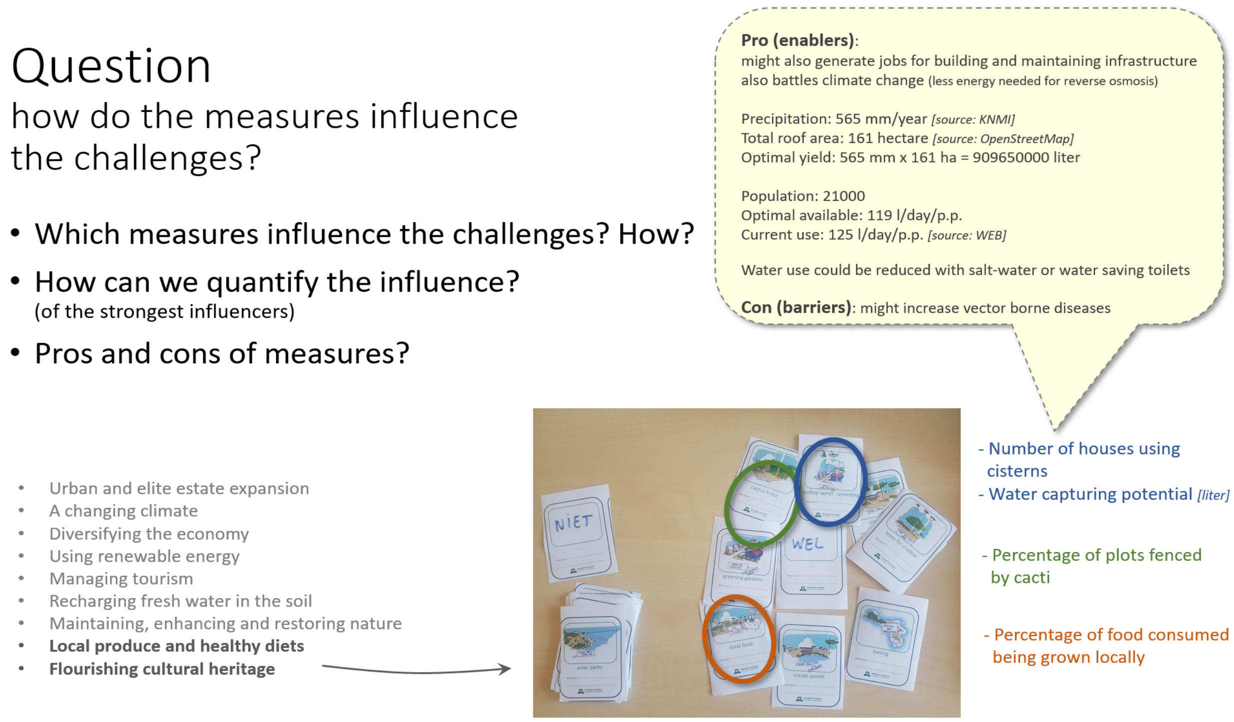
Annex 5 Summary of late 2021 mission interview results

During one to two hour interviews local experts and stakeholders were asked to; 1) select a challenge of their interest and knowledge; 2) identify measures contributing to resolving the challenge; 3) select the most effective measures; 4) name indicators with which to measure progress and; 5) what might be enablers and barriers for implementing the measures?

Selected priority measures influencing a high number of challenges were: rooftop water harvesting (5 challenges), local food production (3 challenges), wind energy (3), re-vegetation and feral exclusion (2), sediment traps (2), regulating wells (2), solar roofs and parks (2), coral restoration (2) and, shaded agriculture (2).

Selected (non-prioritized) measures influencing a high number of challenges were: local food production (8 challenges), planting trees in kunukus (8), zoning (7), shaded agriculture (7), rooftop water harvesting (7), greening gardens (7).

The below screenshots of a PowerPoint presentation display how the questions were introduced.



Interviewers: Peter Verweij, Michiel van Eupen

Interviewed individuals: Nolly Oleana (OLB/RCN), Quirijn Coolen (Bonberde), Maurice Adriaens (LVV), Wijnand de Wolf (STINAPA), Sherwin Pourier (BAABbv), Sabine Engel (Mangrove Maniacs), Caren Eckrich (STINAPA), Elesier Angel (TCB), Elsmarie Beukeboom, Danilo Christiaan (Mangazina di Rei), Hans Staring (WEB), Carolyn Caporusso (Clean Coast Bonaire), Henk van de Velden (CBS), Esther Meijer-Sedney (CBS), Yoeri de Vries (RCN), Bob Jansen (Bonaire DailyFresh), Marja Kooistra and Hans Bergsma (TogetherForTheBetterGood), Jan van de Ploeg (STINAPA), Frank van Slobbe (OLB), Veroesjka de Windt and Simone Rienks (BONHATA), Miles Mercera (TCB), Tadzio Bervoets (DCNA), Arie Boers (Bon Tera)

	prioritized by #sectors	influence for #sectors														
Challenge			Local produce		Nature			groundwater recharge	local produce		cultural heritage	Renewable energy	Tourism		diversifying economy	urban expansion
Expert			1	2	3	4	5	6	7	8	9	10	11	12	13 and 14	15
re-vegetation / feral exclusion	2	4			*	*	*	*								
planting mangroves (coral dike)		6														
planting mangroves (flat coast)		6														
sediment traps (coast)	1	4					*									
sediment traps (water bodies)	2	4			*		*									
dredge salinas		4														
regulating wells	2	5			*			*								
coral restoration	2	4											*	*	*	
inland tourism (yoga, birding)	1	4											*	*		
zoning (tourism)	1	7				*										
local food	3	8									*		*			*
cactus fence	1	5								*						
plant trees (kunuku)	1	8			*											
trees for shadow (crops)		4														
trees for shadow (goat)		5														
shaded agriculture	2	7		*						*						
create ponds (kunuku)	1	8						*								
agro forestry	1	6									*					
wind energy (kunuku)	1	6													*	
wind parks (cliff coast)	3	5										*	*		*	
wind parks (flat coast)		5														
wind parks at sea		1														
solar roofs	2	5										*			*	
solar parks (kunuku)	1	5													*	
solar parks (cliff coast)	2	3										*			*	
solar parks (flat coast)		5														
floating solar		1														
floating farms	1	1													*	
floating algae parks	1	4													*	
sea weed farms	1	3													*	
rooftop water harvesting	5	7		*			*			*	*					*
storm water harvesting	1	4					*									
greening gardens	1	7														*
buoy shading	1	4		*												
capture airco condense		4														
regulating soil sealing		2														
no fish zone	1	3					*									
fish farming																
home dining (at local's home)	1	3											*			
syntropic / food forest		3														
road on contourlines		3														
tour guide nature/culture	1	1												*		
green roofs	1	1														*
trees for urban cooling	1	1														*
shared urban agri		1														
plant conocarpus (e.g. edge salinas)						*										

Annex 6 Indicator framework

Author: Chassy Cahyani

Based on 18 expert and stakeholder interviews the system of tourism development and its environmental impact on Bonaire has been studied (Cahyani, 2022). The resulting Fuzzy Cognitive Map (FCM) represents a system model based on the mental representations of (part of) reality. FCM's use a mix of qualitative and quantitative approaches to include multiple and diverse sources to overcome the limitations of expert opinions (Kosko, 1986; Groumpos & Stylios, 2004; Jetter & Kok, 2014). FCM's are visualised through nodes (variables) and arrows (connections) that create networks showing causal-relationship between factors. Each arrow is accompanied by a weight that represents the strength of the relationship. The sign (positive or negative) indicates the nature of causality (respectively strengthening or weakening). The essential notion is that FCM's describes feedbacks that capture the dynamic relationship between all factors.

Identified factors are:

C0. Climate change	**Sea-level rise, increase of sea temperature**
C1. Number of international flights and cruises	The number of international flights and cruises per day
C2. Invasive alien species	Non-native species include sargassum and goats.
C3. Number of tourists	Residential tourist, one-day tourist, stay-over tourist
C4. Tourism infrastructure and urban expansion	Hotels, restaurants, accommodations, housing, airport, ports, roads, energy infrastructure
C5. Population growth	Local people, work-related immigrants, retirements
C6. Economic growth	GDP (investment+export+consumption+government spending), cost of growth (inflation, inequalities)
C7. The availability of groundwater resources	Groundwater that is linked to surface water for wildlife, groundwater for vegetation
C8. Waste volume	Wastewater, garbage, landfill
C9. Coral reef and mangrove health	
C10. Natural vegetation and wildlife	Native plants for food and feed (cacti, agave). Native animals (lizard, iguana, birds, flamingo, bats)
C11. Land degradation	Pollution from landfills and sewage, soil erosion, loss of soil biodiversity, soil compaction

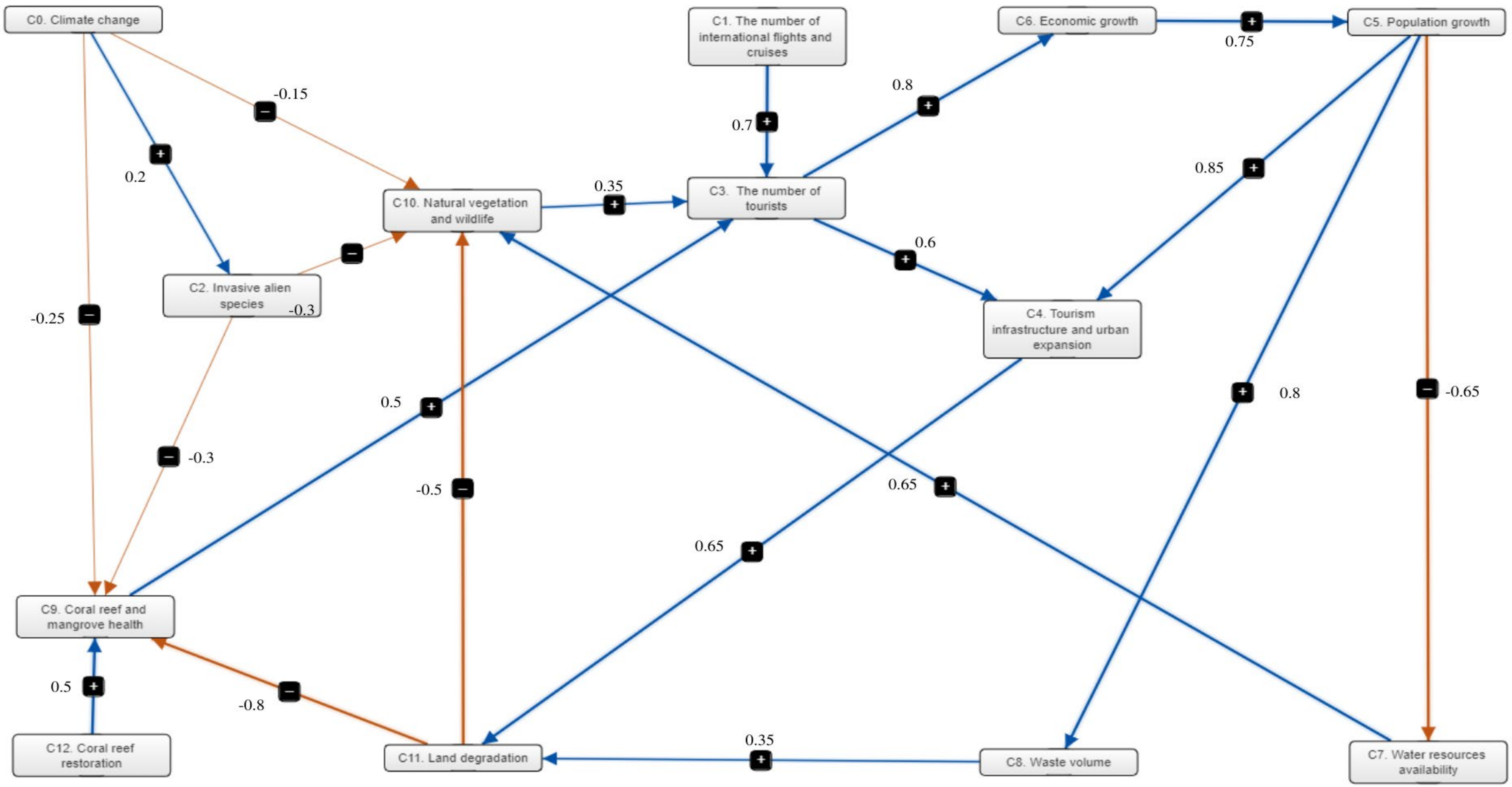
The highest relation, 0.85, was given to population growth, tourism infrastructure, and urban expansion. Both factors were visible through remote sensing and stakeholder daily observation. Tourists may contribute to urban expansion based on stakeholder valuation. However, only residential tourists and over-stay tourists increase urban expansion.

The second highest relation, 0.8, is given to population growth and waste. Both factors were tangible factors that were observed in daily activities. The third highest relation, 0.8, was given to the number of tourists and economic growth, even though the direct tourist spending is only 16.4%. According to OLB, tourism contributes more than 75% of GDP through various sectors that support tourism. Tourism sectors trigger a multiplier effect on the economy in Bonaire. This causal relationship was observed through the number of tourism-related businesses that increased over time by stakeholders.

The fourth highest relation, 0.8, is given to land degradation and coral reef and mangrove health. This is because coral reefs are the main tourist attraction in Bonaire. Coral reefs were monitored regularly, while erosion and sedimentation were well-researched by educational institutes.

The lowest relationship of 0.15 is given to climate change and natural vegetation and wildlife because climate change has a slow impact on terrestrial ecosystems. The impact is often not visible, for example, low humidity and irregular rainfall.

The interviewed experts and stakeholders were: Wageningen Environmental Research (Peter Verweij), STINAPA (Caren Eckrich and Roxanne-Liana Fransisca), BONHATA and ABC car rental (Luite Berkenbosch), Local resident and former Junior Ranger (Bonnie Roefs), OLB - advisor of Deputy H. Thielman (Orphaline Saleh), OLB – department of nature (Eva van Voskuijlen), Island Time Bonaire (Kristen Walker and her colleague), Sea Turtle Conservation (Kaj Schut), Tropical Travel Bonaire (Shou Lan Turin), Wolfs Company (Stijn Schep), Dive Friends Bonaire (Bart Linders), Wild Conscience (Fernando Simal), TCB (Elesier Angel), TU Delft (Jelle Oliemans), Dive tourists (Ingmar and Tyrza).



Some of the FCM's factors have been related to inclusive measures to combat the challenges of Bonaire. The tables below list: a) the measures for each landscape (after Verweij et al., 2019) and b) measures in relation to each challenge. In 'b' the factors have been reformulated to function as indicators for measuring impact of measures to combat challenges (Cahyani, in prep.).

Measure					Implemented in landscapes											
	Group	Type	InvestmentType	InvestmentEffort	Kralendijk urban fabric	Calm cliff coast	Calcareous ancient forest plateau	North western hills	Traditionl valley of Rincon	Kunuku	Caribbean Savanna	Windswept inhospitable northeast coast	Lac Lagoon	Southern flats	Scrubby southern limestone pavement	Unoccupied island of Klein Bonaire
agro-forestry	Agriculture	Investment	Private	High						x						
netted agri	Agriculture	Investment	Private	High						x						
goat farm	Agriculture	Investment	Private	High						x						
feed and fodder	Agriculture	Investment	Private	High						x						
shrimp and conch farm	Agriculture	Investment	Private	Medium										x		
cactus fencing (agri)	Agriculture	Re-greenin	Public	Medium					x							
greening gardens (hofitos)	Agriculture	Re-greenin	Private	Small	x				x	x						
livestock manure husbandry	Agriculture	Technical	Private	Small												
rooftop water harvesting	Energy and Wat	Technical	Private	Medium	x				x		x					
solar roofs	Energy and Wat	Technical	Private	Medium	x				x	x						
water harvesting in storage ponds	Energy and Wat	Technical	Public	High					x							
wind for cooling houses	Energy and Wat	Technical	Public	Small	x				x	x						
wind turbines	Energy and Wat	Technical/I	Public/Pr	High						x		x				
septic tank (safe from disease)?	Energy and Wat	Technical	Private	Small	x				x							
restore dams	Nature	Technical	Public	High					x							
salt water for flushing toilet	Energy and Wat	Technical	Public	High	x				x							
mangrove expansion	Nature	Re-greenin	Public	High									x	x		
restore healthy seagrass beds	Nature	Re-greenin	Public	High									x			
dig flow canals in mangrove	Nature	Re-greenin	Public	Medium									x			
restoring salinas	Nature	Technical	Public	High				x								
sediment traps	Nature	Technical	Public	High	x			x				x				
coral restoration	Nature	Technical?	Public	High	x									x		x
protect turtle nest habitats	Nature	Zoning	Public	Small										x		
protect wetlands	Nature	Zoning	Public	Small										x		
revegetation	Nature	Re-greenin	Public	High		x		x	x		x	x	x		x	x
forest restoration	Nature	Re-greenin	Public	High		x		x							x	
remove grazing pressure	Nature	Re-greenin	Public	High			x			x	x				x	
greening gardens	Nature	Re-greenin	Public	Small	x					x	x					
replant Sabal palm	Nature	Re-greenin	Public	High											x	
cactus fencing	Nature	Re-greenin	Public	Medium			x				x			x	x	
local cuisine and outdoor dining	Tourism	Investment	Private	Medium	x	x			x	x						
caverns and tours	Tourism	Investment	Private	Medium			x									
park tours	Tourism	Investment	Private	Small			x									
exploration track	Tourism	Investment	Private	Small											x	
bking and hiking paths	Tourism	Investment	Public	Medium			x	x								
landscape park	Tourism	Zoning	Public	Small								x				
public parks	Tourism	Zoning	Public	Small	x											
public coast	Tourism	Zoning	Public	Small	x											
birdwatching	Tourism	Zoning	Public	Small			x	x								
snorkling and diving	Tourism	Zoning	Public	Small				x								
recerational zoning	Tourism	Zoning	Public	Small									x			
regulate number of visitors	Tourism	Zoning	Public	Small					x							x
guesthouses/homestay	Tourism	Investment	Private	Medium	x				x	x						

Measure	Contribution towards managing challenges																											
	Regulating urban and elite estate expansion		Coping with changing climate				Diversifying the economy		Tourism				Fresh water in the soil				Nature/ecosystem condition					Healthy fresh food				Cultural heritage		
	Landuse or zoning map	Built/ impervious surface area	Carbon sequestration	Temperature and humidity regulation	Renewable energy supply	GHG emission	Employment (numbers)	New job markets	Landscape/seascape aesthetics	Temperature regulation (shade)	Number of tourists by interest group	Accessibility/ road network	Soil water retention (capacity)	Capturing capacity of salinas	Water quality (salinity, grey/black water)	Alternative water sources supply	Greenness Index	Erosion risk	Reef Health Index	Species conservation status	Keystone species habitat quality	Soil quality (organic carbon)	Crops production	Livestock production	Fisheries production	Authenticity/originality index (Pre-oil industry)	Preservation status of cultural/heritage sites/traditions	Local dishes/food availability
feed and fodder			*																					*				
shrimp and conch farm	*						*		*		*														*			*
cactus fencing (agri)	*		*	*					*	*			*				*					*				*		
greening gardens (hofitos)		*	*	*					*	*			*				*					*	*			*		
livestock manure husbandry	*					-*	*															*	*					
rooftop water harvesting									*							*							*					
solar roofs	*				*		*		*																			
water harvesting in storage ponds																*												
wind for cooling houses				*					*																			
wind turbines	*				*		*		*																			
septic tank (safe from disease)?															*													
restore dams	*								*							*										*		
salt water for flushing toilet															*	*												
mangrove expansion	*		*	*					*	*			*		*		*		*	*	*				*	*		
restore healthy seagrass beds			*						*										*	*	*				*	*		
dig flow canals in mangrove	*		-*	*					*																			
restoring salinas	*								*					*	*					*	*	*				*		
sediment traps	*		*												*				*		*	*			*	*		
coral restoration	*								*										*	*	*				*	*		
protect turtle nest habitats	*								*		*									*	*					*		
protect wetlands	*		*						*	*	*			*	*		*			*	*	*				*		
revegetation	*		*	*					*	*			*	*	*		*				*	*				*		
forest restoration	*		*	*					*	*	*		*		*		*			*	*	*				*		
remove grazing pressure			*						*	*			*		*		*			*	*	*	*			*		
greening gardens			*	*					*	*			*	*	*		*			*	*	*				*		
replant Sabal palm			*	*					*	*	*		*	*			*			*	*	*				*		
cactus fencing	*		*	*					*	*			*		*		*			*	*	*				*		
local cuisine and outdoor dining	*	-*					*	*	*		*															*	*	*
caverns and tours	*						*	*			*															*		
park tours							*	*			*															*		
exploration track	*										*	*																
bking and hiking paths	*	*							*		*	*																
landscape park	*						*		*	*	*						*											
public parks	*	*							*	*	*	*					*											
public coast	*	*					*		*		*	*																
birdwatching	*						*				*																	
snorkling and diving	*						*																					
recerational zoning	*	*							*			*																
regulate number of visitors	*	*				*															*							
guesthouses/homestay	*	-*					*		*		*															*	*	

Annex 7 Land cover maps

Land use and land management practices have a major impact on natural resources including water, soil, nutrients, plants and animals. Land use information can be used to develop solutions for natural resource management issues such as salinity and water quality' (Stephens et al., 2019). Land use is one of the most important drivers of change of the environment (Meyfroidt et al., 2018) on which humans depend for their livelihoods. Land use (and land cover) is there for a crucial foundation for the assessment of the present situation and the future scenarios within this report.

Satellite imagery form the basis for the land cover map of Bonaire (Mucher & Verweij, 2020). Figure 17 illustrates how kunuku use (agricultural plots) was added for the present situation and how that was consequently updated to incorporate scenario specific elements.

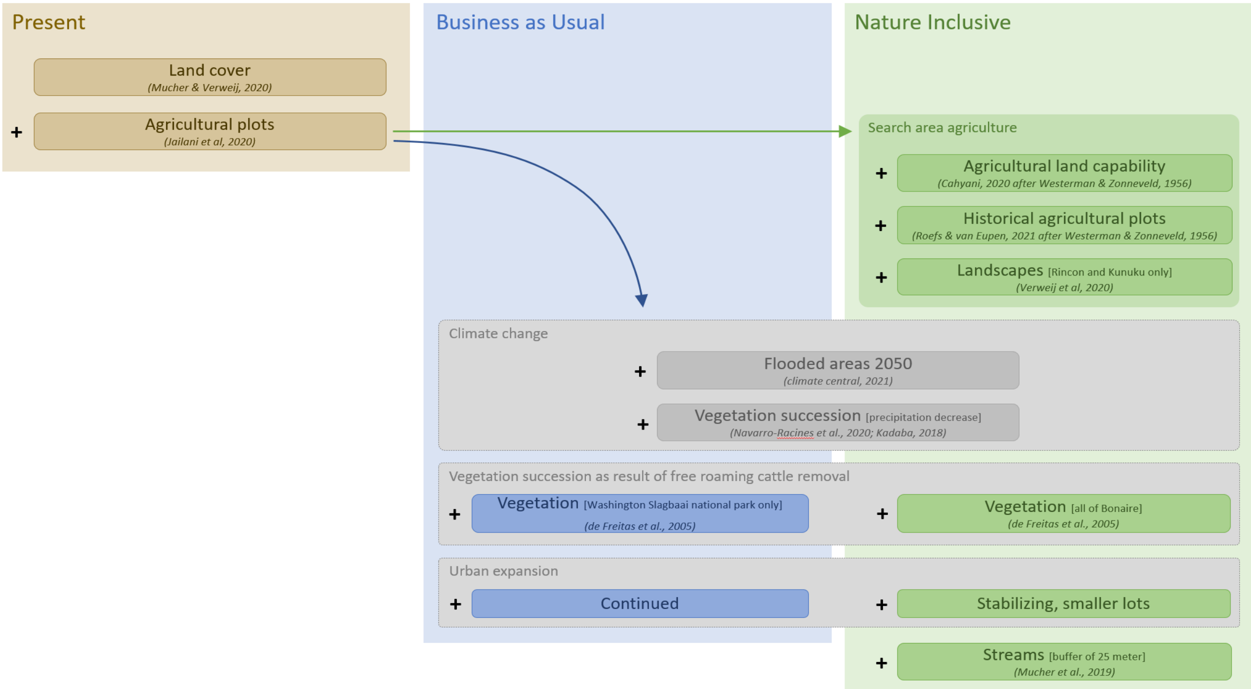
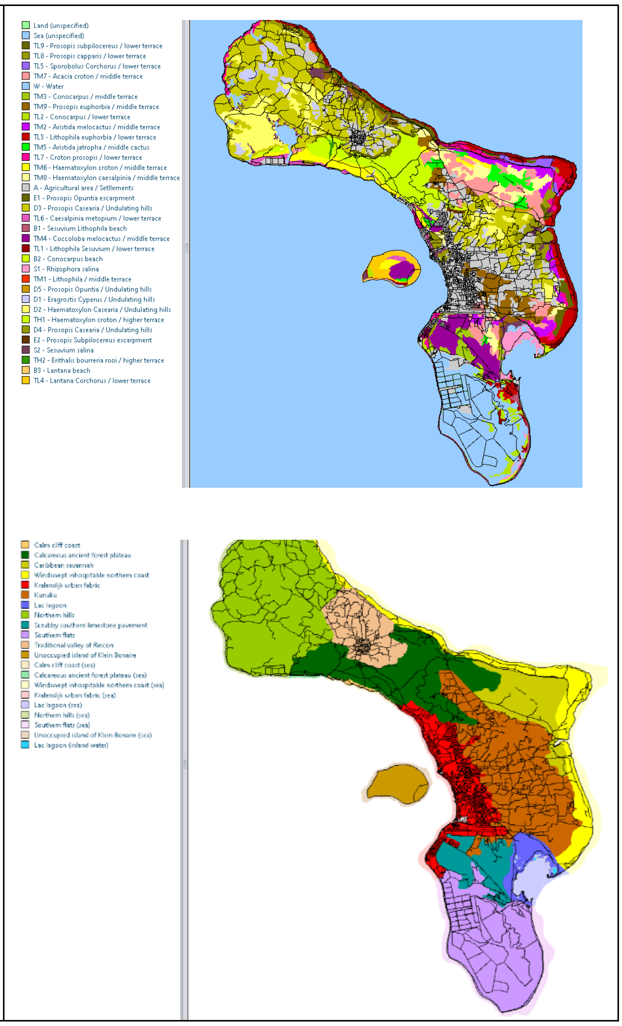


Figure 17 *Flow diagram depicting the derivation of the land use maps for the present situation (brown), the BaU scenario (blue) and the NI scenario (green). The grey boxes represent modification steps for both of the BaU and the NI scenario.*

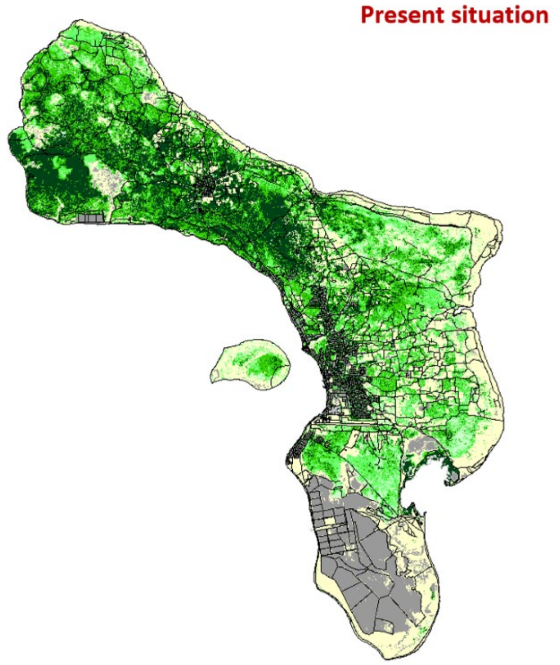
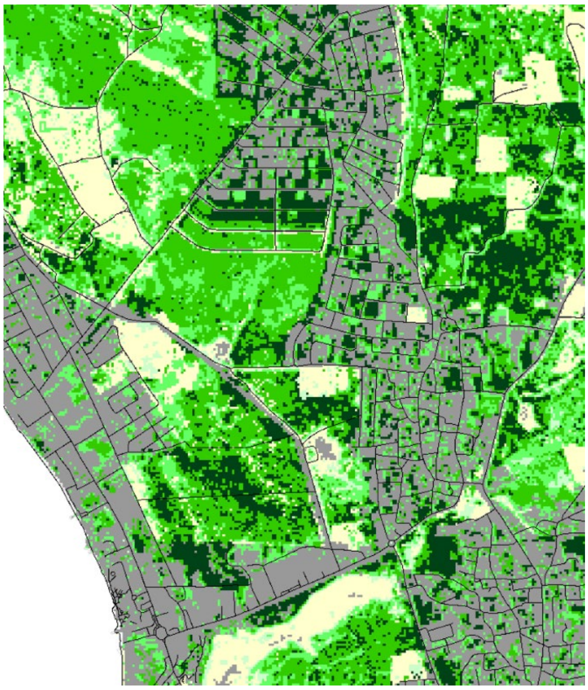
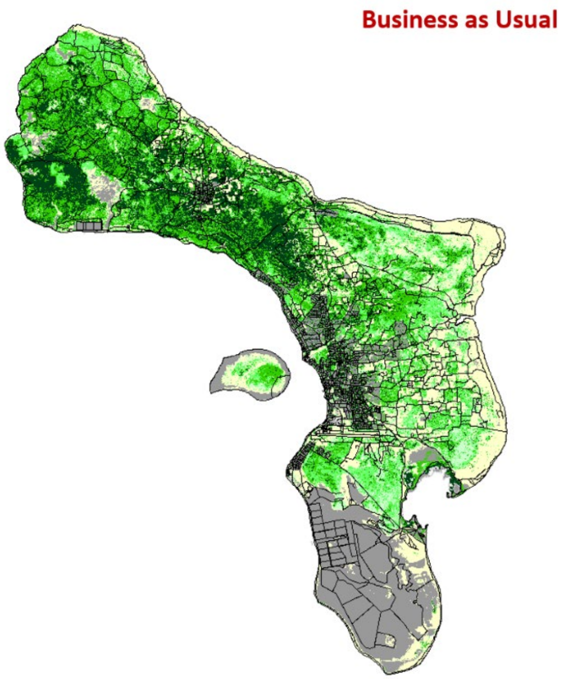
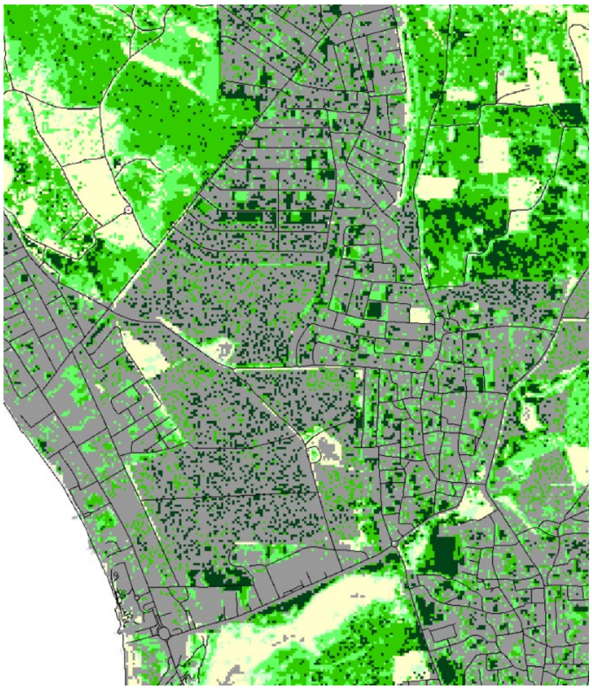
Vegetation succession is assumed to take place after eradication of free roaming cattle. In 2050 the vegetation end stage is assumed to have been reached.

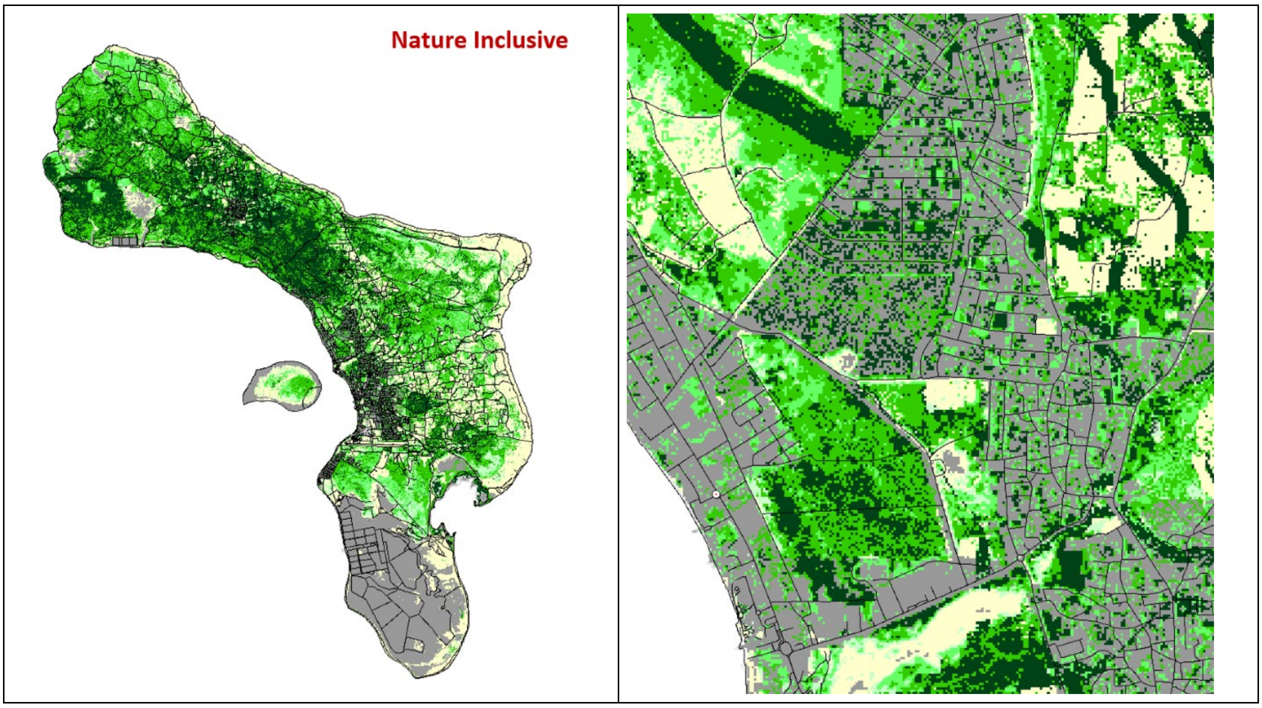
	Calcareous ancient forest plateau	Other landscape
Land (unspecified)	No change	No change
Sea (unspecified)	No change	No change
TL9 - Prosopis subpilocereus / lower terrace	To Forest	To high shrub
TL8 - Prosopis capparis / lower terrace	To Forest	To Forest
TL5 - Sporobolus Corchorus / lower terrace	No change	No change
TM7 - Acacia croton / middle terrace	To Forest	To Forest
W - Water	No change	No change
TM3 - Conocarpus / middle terrace	No change	No change
TM9 - Prosopis euphorbia / middle terrace	To Forest	To Forest
TL2 - Conocarpus / lower terrace	No change	No change
TM2 - Aristida melocactus / middle terrace	No change	No change
TL3 - Lithophila euphorbia / lower terrace	No change	No change
TM5 - Aristida jatropha / middle cactus	No change	No change
TL7 - Croton prosopis / lower terrace	To Forest	To high shrub
TM6 - Haematoxylon croton / middle terrace	No change	No change
TM8 - Haematoxylon caesalpinia / middle terrace	No change	No change
A - Agricultural area / Settlements	No change	No change
E1 - Prosopis Opuntia escarpment	No change	No change
D3 - Prosopis Casearia / Undulating hills	To Forest	To high shrub
TL6 - Caesalpinia metopium / lower terrace	No change	No change
B1 - Sesuvium Lithophila beach	No change	No change
TM4 - Coccoloba melocactus / middle terrace	No change	No change
TL1 - Lithophila Sesuvium / lower terrace	No change	No change
B2 - Conocarpus beach	No change	No change
S1 - Rhizophora salina	No change	No change
TM1 - Lithophila / middle terrace	No change	No change
D5 - Prosopis Opuntia / Undulating hills	To Forest	To Forest
D1 - Eragrostis Cyperus / Undulating hills	To Forest	To Forest
D2 - Haematoxylon Casearia / Undulating hills	No change	No change
TH1 - Haematoxylon croton / higher terrace	To Forest	To Forest
D4 - Prosopis Casearia / Undulating hills	To Forest	To high shrub
E2 - Prosopis Subpilocereus escarpment	No change	No change
S2 - Sesuvium salina	No change	No change
TH2 - Erithalis bourreria rooi / higher terrace	To Forest	To Forest
B3 - Lantana beach	No change	No change
TL4 - Lantana Corchorus / lower terrace	No change	No change



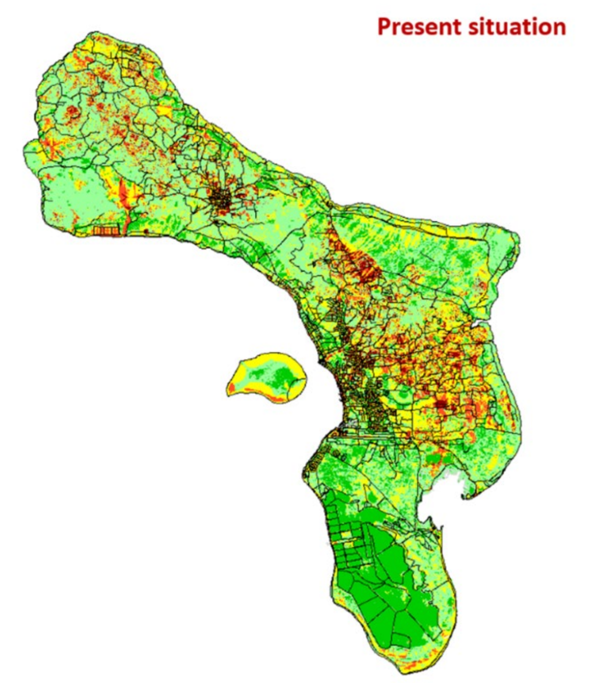
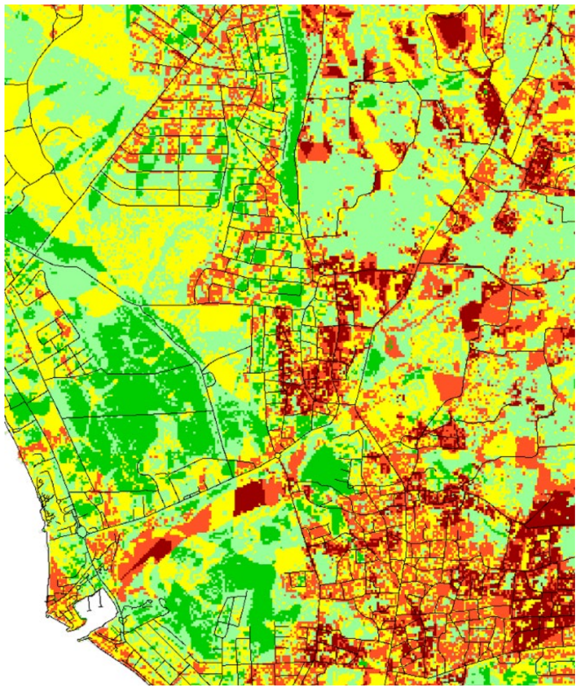
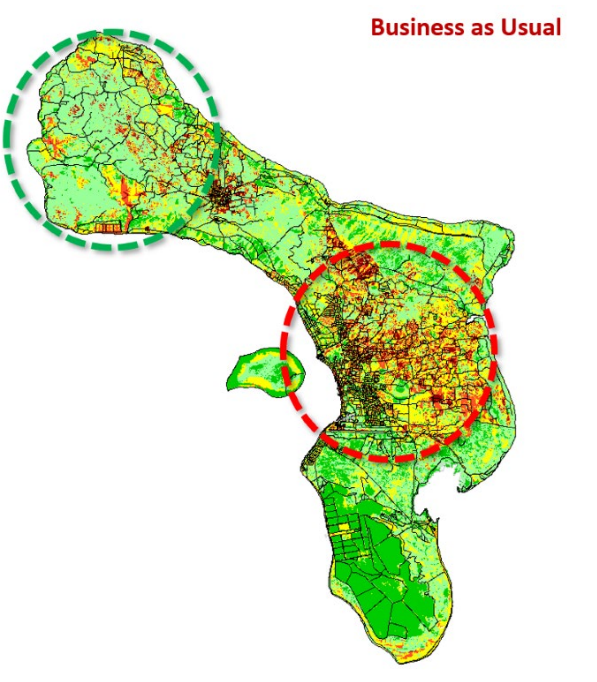
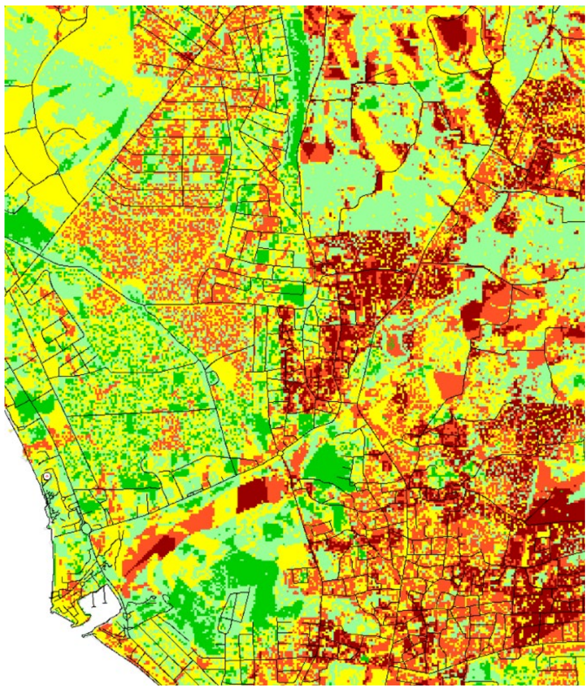
Rule for determining vegetation succession (after dialogue with BonBerde, 2021). The left column illustrates the rule. The right column displays the vegetation map (de Freitas, 2005) and the landscape map (Verweij et al., 2020) on which the rule is applied.

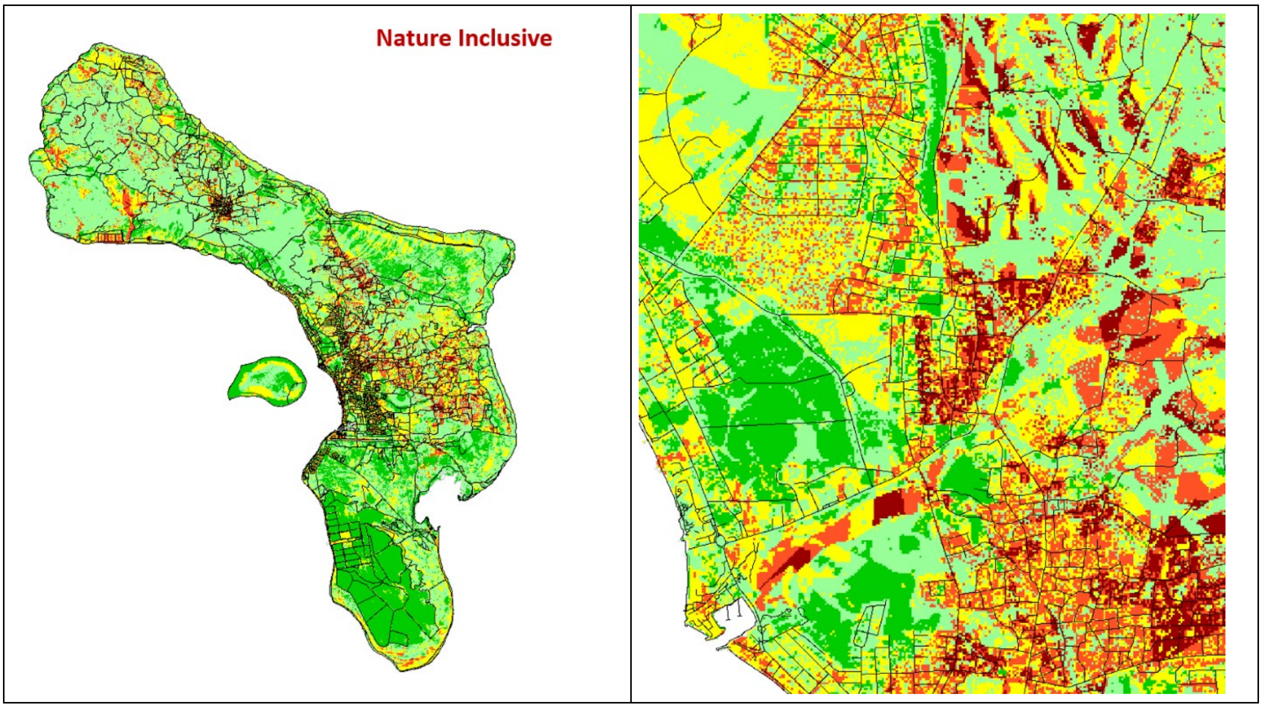
Annex 8 Greenness index maps

Legend for the maps in this table: No green 0-20 20-40 40-60 60-80 >80	
	
	


Nature Inclusive

Annex 9 Erosion Risk maps

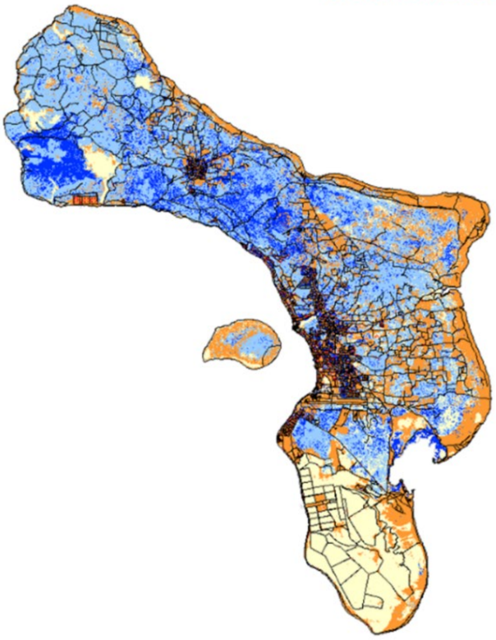
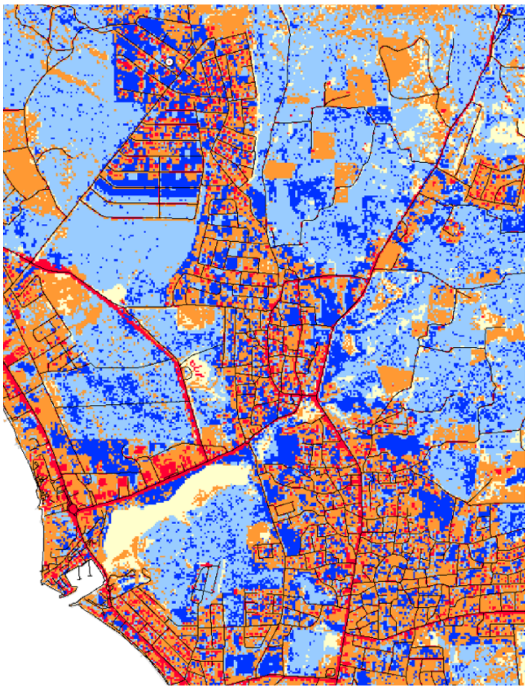
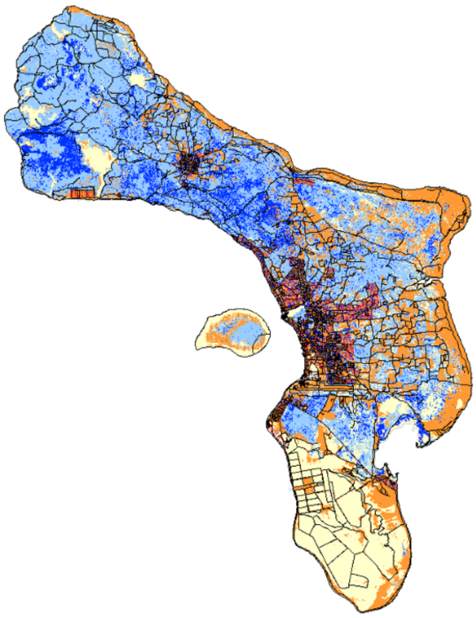
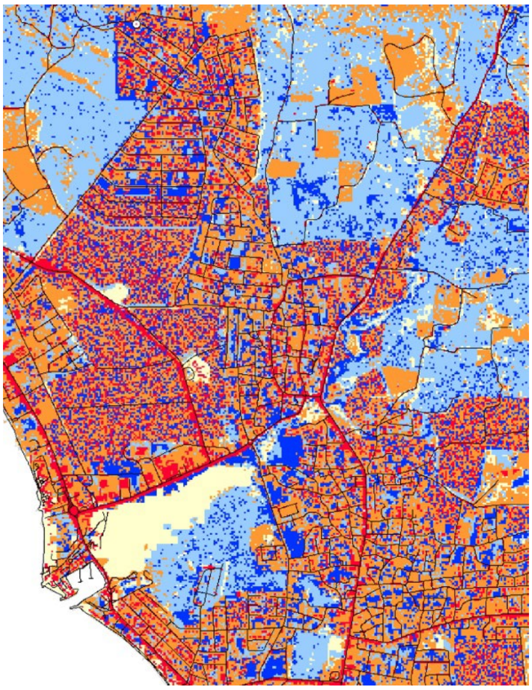
Legend for the maps in this table: No risk Low risk Moderate risk High risk Very high risk	
	
	

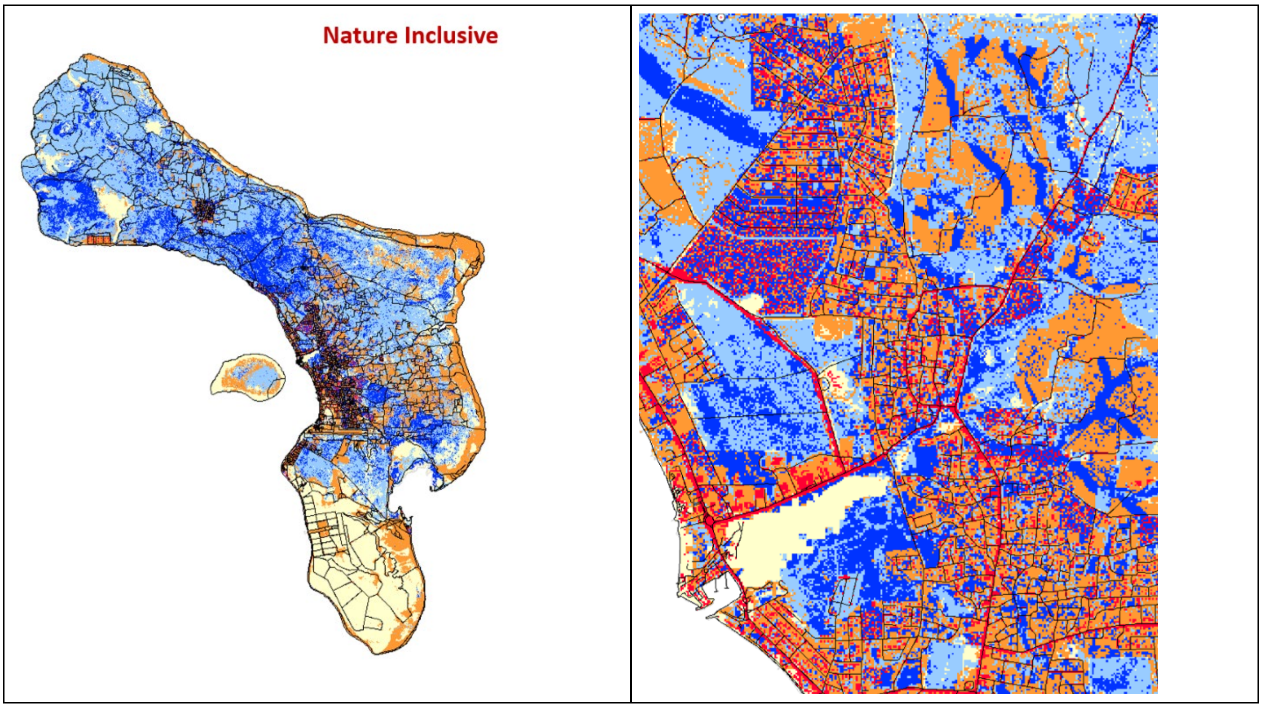

Nature Inclusive

Annex 10 Temperature regulation

Legend for the maps in the table:

- Much cooler than average (>-5°C)
- Cooler than average (-5-0°C)
- Average
- Warmer than average (0-5°C)
- Much warmer than average (>5°C)

Present situation 	
Business as Usual 	



LandCover \ Greenness (quali) : Temperature regulations	Land (unspecified)	Sea (unspecified)	No green	0-20	20-40	40-60	60-80	>80
Built-up	Much warmer than average (>5 d...	Cooler than average (-5-0 degC)	Much warmer than average (>...	Warmer than average (0-5 degC)	Average	Average	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)
Urban bare soil	Warmer than average (0-5 degC)	Cooler than average (-5-0 degC)	Warmer than average (0-5 deg...	Warmer than average (0-5 degC)	Average	Average	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)
Road	Much warmer than average (>5 d...	Cooler than average (-5-0 degC)	Much warmer than average (>...	Warmer than average (0-5 degC)	Average	Average	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)
Urban green	Average	Cooler than average (-5-0 degC)	Average	Average	Average	Cooler than average (-5-0 degC)	Much cooler than average (>-5 de...	Much cooler than average (>-5 de...
Agiculture (intensive / netted)	Much warmer than average (>5 d...	Cooler than average (-5-0 degC)	Much warmer than average (>...	Warmer than average (0-5 degC)	Average	Average	Average	Average
Kunuku (in use)	Warmer than average (0-5 degC)	Cooler than average (-5-0 degC)	Warmer than average (0-5 deg...	Warmer than average (0-5 degC)	Average	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)
Kunuku (in use, with trees)	Warmer than average (0-5 degC)	Cooler than average (-5-0 degC)	Warmer than average (0-5 deg...	Average	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Much cooler than average (>-5 de...
Kunuku (not used, scrub)	Warmer than average (0-5 degC)	Cooler than average (-5-0 degC)	Warmer than average (0-5 deg...	Average	Average	Average	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)
Kunuku (not used, high scrub)	Warmer than average (0-5 degC)	Cooler than average (-5-0 degC)	Warmer than average (0-5 deg...	Average	Average	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)
Agroforestry / syntropic	Warmer than average (0-5 degC)	Cooler than average (-5-0 degC)	Average	Average	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)
Bare soil and pioneer vegetation	Warmer than average (0-5 degC)	Cooler than average (-5-0 degC)	Warmer than average (0-5 deg...	Warmer than average (0-5 degC)	Average	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)
Sandy beaches	Warmer than average (0-5 degC)	Cooler than average (-5-0 degC)	Warmer than average (0-5 deg...	Warmer than average (0-5 degC)	Average	Average	Average	Average
Low scrub (mangrove)	Average	Cooler than average (-5-0 degC)	Average	Average	Average	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)
Low scrub	Average	Cooler than average (-5-0 degC)	Average	Average	Average	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)
Low scrub with cactus	Average	Cooler than average (-5-0 degC)	Average	Average	Average	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)
High scrub	Average	Cooler than average (-5-0 degC)	Average	Average	Average	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Much cooler than average (>-5 de...
High scrub with cactus	Average	Cooler than average (-5-0 degC)	Average	Average	Average	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)
Forest	Average	Cooler than average (-5-0 degC)	Average	Average	Average	Cooler than average (-5-0 degC)	Much cooler than average (>-5 de...	Much cooler than average (>-5 de...
Mangrove	Average	Cooler than average (-5-0 degC)	Average	Average	Average	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Much cooler than average (>-5 de...
Salina	Average	Cooler than average (-5-0 degC)	Average	Average	Average	Average	Average	Average
Salt ponds	Average	Cooler than average (-5-0 degC)	Average	Average	Average	Average	Average	Average
Crystalizer ponds	Average	Cooler than average (-5-0 degC)	Average	Average	Average	Average	Average	Average
Deep sea	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)	Cooler than average (-5-0 degC)

Knowledge rule for deriving temperature regulation as a product of land cover and greenness.

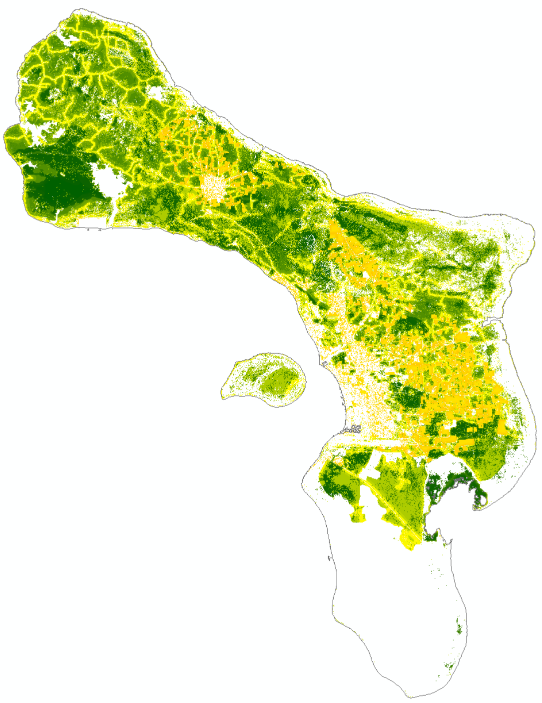
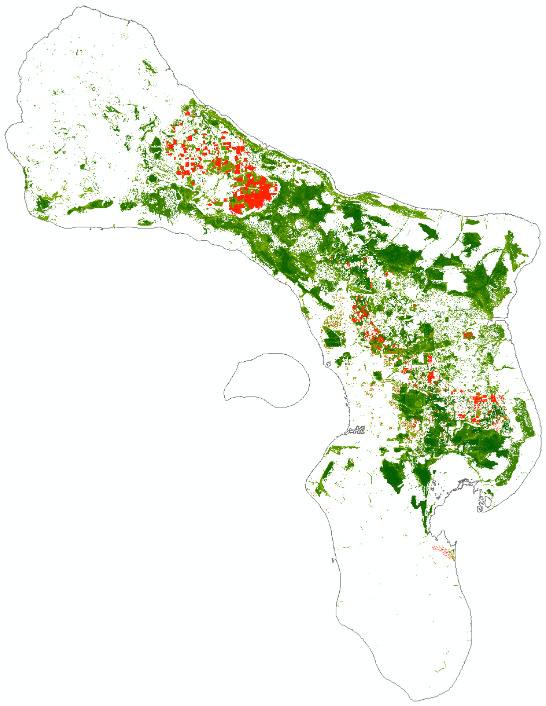
Annex 11 Mean Species Abundance

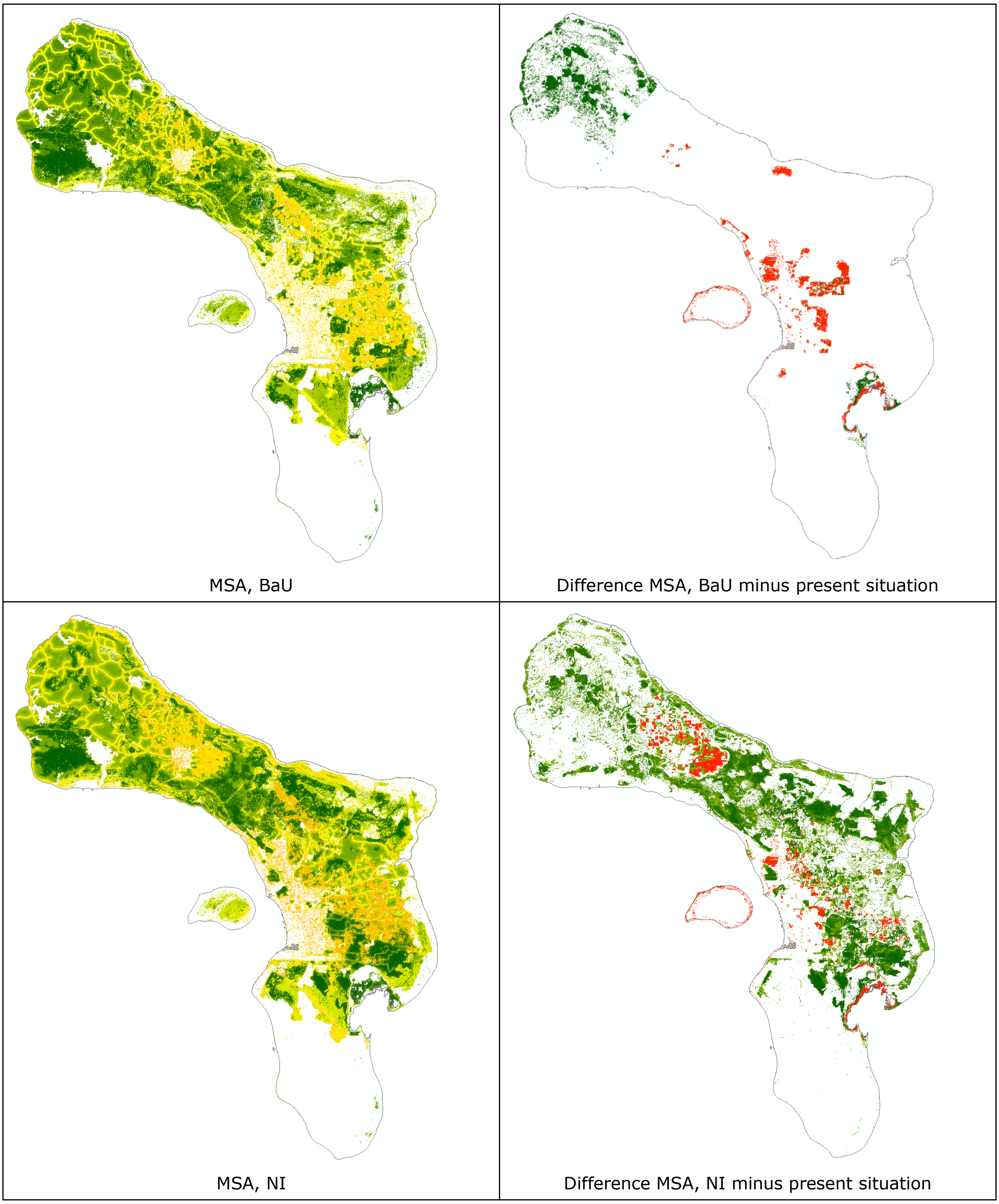
Author: Petros Panteleon

The table below shows two columns. In the left columns maps are displayed on the state of the Mean Species Abundance (MSA). MSA is expressed as an index ranging from 0 to 1, where 0 corresponds to ‘poor’ (yellow) and 1 to ‘very high’ species abundance (dark green). The right column displays difference maps of two states of MSA. Red areas indicate a decrease in MSA. Green areas indicate an increase in MSA. Dark green indicate a strong increase in MSA.

The maps are created by running the GLOBIO model (Natural Capital Project, 2019) on the basis of the land cover maps as described in Annex 7 and the road network (Open Street Map, 2020). Although arguably the road network will change in the future to be extended to keep pace with urbanisation (especially in BaU), it was not changed for the scenarios. The road network is an important driver for habitat fragmentation (and thus MSA). Road quality (e.g. dirt road or tarmac) and traffic pressure variety and their influence on erosion and road-kills have been ignored in this study.

Although Bonaire is home to a rich marine biodiversity, in this study, the MSA has been calculated for the land mass only. Land management (and thereby terrestrial ecosystem health) greatly influences the marine environment (erosion, contamination, nutrification, etc.). The marine environment is also influenced by direct pressures that have not been included (e.g. fisheries, ship and diver activity, water temperature).

	
MSA of present situation	Difference MSA, NI minus BaU

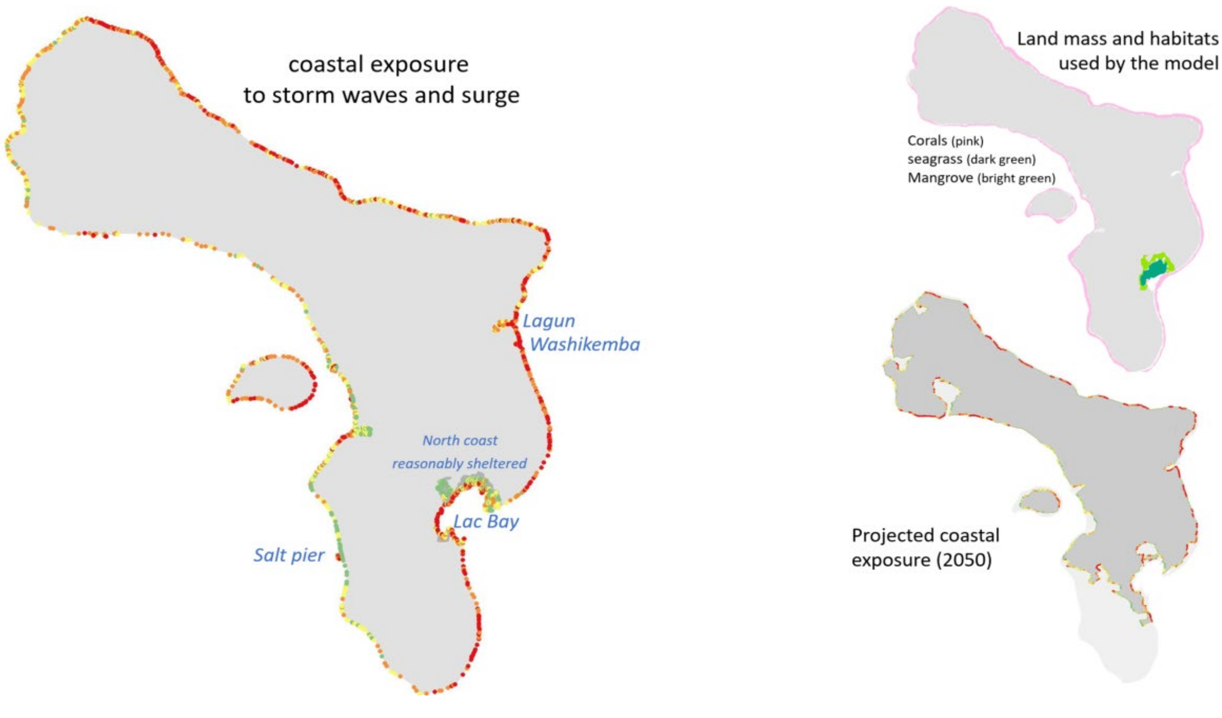

MSA, BaU
Difference MSA, BaU minus present situation
MSA, NI
Difference MSA, NI minus present situation

Annex 12 Coastal exposure to storm waves and surge

Author: Petros Panteleon

Coastal areas that are exposed to storm waves and surges are prone to damage (Aucelli et al., 2018). These areas are mapped using the InVEST model (Natural Capital Project, 2019) for the current situation and 2050. The model uses a map of the land mass of Bonaire to determine the coast line, a global database for prevailing wind direction and wave characteristics (Natural Capital Project, 2019), elevation model (Mucher et al., 2017), bathymetry (Dienst der hydrografie, 2018), and natural coastal habitats that buffer the impact: corals, (Mucher et al., 2017), seagrass and mangroves. Seagrasses and mangroves were digitized from satellite imagery. Corals and mangroves were modelled to have a four times as high protection value then seagrasses. For 2050, part of Bonaire's land mass was modelled to have been disappeared as result of sea level rise (climate central, 2021) and failing flood protection as result of seepages and upwelling in the low lying karst area (Rooth, 1965). The Figure below illustrates the coastal exposure in red (heavily exposed) to green (not exposed).

The model output for the present situation has been validated by local experts (from STINAPA). Overall the map fits historic events, but several locations have been incorrectly modelled to be exposed (south east of Klein Bonaire and Te amo beach), while others are incorrectly modelled to be not to mildly exposed (Salina di Vlijt, Carl's hill and punt Vierkant that all have been hit severely by hurricanes in 1999, 2008 and 2016).



Wageningen Environmental Research
P.O. Box 47
6700 AA Wageningen
The Netherlands
T 0317 48 07 00
wur.eu/environmental-research

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Wageningen Environmental Research
P.O. Box 47
6700 AB Wageningen
The Netherlands
T +31 (0) 317 48 07 00
wur.eu/environmental-research

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