Landscape ecological vegetation map of St. Maarten (Lesser Antilles)

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ABSTRACT

Vegetation maps are a primary and essential tool in biodiversity science, conservation, management, and monitoring as well as in land-use management planning. In this study a semi-detailed landscape-based vegetation map (scale: 1: 46,000) is presented for the 34 km^2 Dutch half of Lesser Antillean island of St. Martin (St. Maarten). A vegetation map is especially critical in biodiversity context as St. Maarten lies in a key biodiversity hot spot and is habitat to more than 100 regional endemic animal and plant species of which 12 are island endemic species found only on St. Maarten. The map is based on a total of 56 vegetation plots that were sampled in 1999 using a stratified random sampling design and analysed using TWINSPAN cluster analysis. Two hundred and twenty (220) plant species, representing 40 % of the total known flora (544 species), were recorded in the sample plots.

A total of four main and eleven different sub-landscape types were distinguished based on geology, geomorphology and the eleven distinguished vegetation types. The most dominant landscape type was the hilly landscape type for which seven sub-landscapes were distinguished. The 11 vegetation units we describe represent an important decline from the 16 vegetation types distinguished by STOFFERS (1956). Large changes have clearly occurred in the coverage and composition of the vegetation types of the island. Between the early 1950s and 1999 the total coverage of vegetated areas in St. Maarten declined from 67% to 42% representing a loss of 25% of the total vegetated surface of St. Maarten. Five of the vegetation units of STOFFERS (1956) have disappeared beyond recognition. These are: *Hippomane* woodland, Vegetation of the salt flats, Strand scrub community, Littoral woodland and Vegetation of the rock pavement. While *Hippomane* woodland has in part likely been lost due to hurricane impacts, most vegetation loss and degradation has been due to massive urbanization and touristic development especially in the lower and coastal parts of the island. As a consequence the vegetation types of the higher and steeper sections of the island have remained among the least disturbed and degraded. Some vegetation units described by STOFFERS (1956) have also disappeared due to actual vegetation regeneration and succession to a more diverse state due to the decline in agriculture and livestock grazing. Goat grazing remains especially high in two of the eleven vegetation types we described (50 – 80 % presence of dung in the study plots). The highest goat presence was recorded in a “new” vegetation unit (type 6) that has developed based on the domination of the invasive plants *Leucaena leucocephala* (jumbie bean, lead tree) and *Antigonon leptopus* (coral vine).

The main threats to the vegetation of St. Maarten we discern based on this mapping project are 1) the massive scale of urbanization and touristic development the island has undergone, 2) continued uncontrolled livestock grazing, 3) invasive plant species, and 4) hurricane impacts. Unless actions are taken to stem the loss of and help restore natural vegetations, we predict that the island will continue to lose its plant diversity, and along with it the fauna which depends on that vegetation. Continued loss of natural vegetation will further exacerbate erosion, loss of freshwater, soil quality and

environmental resilience to climate change, as well as sedimentation in the marine environment and the concomitant loss of shallow marine habitats like seagrass beds and coral reefs.

To help prevent this scenario from developing further, we recommend several practical measures: 1) implement land-use planning and designate protected areas to preserve the native flora and fauna, 2) limit and control roaming livestock, 3) legally protect endangered and ecologically critical plant species, 4) connect protected areas by means of ecological corridors, 5) implement measures to control and limit invasive species and 6) implement long-term vegetation monitoring.

CONTENTS

CHAPTER 1

INTRODUCTION

Terrestrial plant assemblages form a critical component of the biodiversity of a region and in turn also greatly influence other components of the local biodiversity. Not only do they serve as a critical source of food and shelter for terrestrial animals but they also are important in moderating environmental extremes, and creating microhabitats (e.g. SMITH ET AL. 2010; TOMS ET AL. 2012). They have large influence on soil properties, erosion and water retention within the terrestrial environment and thereby also indirectly exercise important influence on surrounding aquatic environments whether rivers, lakes or shallow seas (e.g. ROBERTS ET AL. 2017). Plant assemblages further are not only in part a result of biogeographical and human land-use history but also clearly influence biogeographical history itself (STOFFERS 1956; FORMAN & HAHN 1980; HORWITH& LINDSAY 1999; DUNPHY ET AL. 2000; LUGO 2000; VAN BLOEM ET AL. 2005; WILLIG ET AL. 2012; ATKINSON & MARÍN-SPIOTTA 2015; RAMOS DE ANDRADE 2015). Finally, thorough quantitative knowledge about vegetations also provides the necessary framework and context for broader scientific understanding of ecological processes (such as animal movements, migrations and habitat use at a landscape level) (TANNER ET AL. 1991; HELMER ET AL. 2002; NIJMAN ET AL. 2009; STEADMAN ET AL. 2009; DE FREITAS 2010; LUKE ET AL. 2016; DE FREITAS ET AL. 2018; HU & SMITH 2018). Therefore, it is not surprising that vegetation maps are a primary and essential tool in biodiversity science, conservation, management, and monitoring as well as in land-use management planning.

Land-use planning has been given more attention in the Dutch Caribbean since the 1980s. The seminal paper on the vegetations of the six Dutch Caribbean islands (Aruba, Bonaire, Curaçao, Saba, St. Eustatius and St. Maarten) by STOFFERS (1956) was not only largely qualitative but also quite outdated, with as a consequence that new quantitative vegetation maps for these islands have been a high priority to achieve. Following the quantitative landscape level vegetation map for Curaçao (BEERS ET AL. 1997), our team has followed with similar maps for Bonaire (DE FREITAS ET AL. 2005), St. Eustatius (DE FREITAS ET AL. 2014) and Saba (DE FREITAS ET AL. 2016). We here now present a similar map for the Dutch side of the Caribbean island of St. Martin. All these landscape level vegetation map projects are based on aerial photo-interpretation and stratified quantitative sampling following the ITC method (International Training Center for Aerial Survey, University of Twente) developed by ZONNEVELD (1979, 1988a, 1988b).

The Caribbean island of St. Martin is located in the Outer Arc of the Lesser Antilles. It has a surface of about 85 km^2 and its greatest length and width are 15 km and 14 km respectively (STOFFERS 1956). The island is divided into a Dutch part (approx. 34 km^2) and a French part both of which falls under separate national jurisdictions. The Dutch side of the island is named St. Maarten. Together with Saba and St. Eustatius, St. Maarten forms a cluster referred to as the Dutch Windward Islands (or “SSS” islands). The distance between St. Maarten and Saba is 48 km and between St. Maarten and St. Eustatius is 63 km (ROJER 1997).

The flora of the island has been studied quite extensively (BOLDINGH 1909, 1913; STOFFERS 1981, 1963-1984; HOWARD 1974-1989; ROJER 1997) but an up-to-date quantitative vegetation map remained critically lacking for conservation and land-use planning purposes. BOLDINGH (1909) described the vegetation of the three Dutch Windward Islands (Saba, St. Eustatius and St. Maarten) only in general terms as 'that of a tropical zone without any pronounced dry season'. He stated that based on the amount of rain on the islands, the vegetation would be in potential that of a tropical rainforest; he considered determinant factors affecting the state of vegetation development to be the persistent wind, the presence or lack of humus in the soil, the high extent of deforestation and the many introduced species.

STOFFERS (1956) was the first to provide a vegetation map for St. Maarten, in which he described 17 vegetation types. His map was a low-resolution map (scale 1:37,000) based on limited qualitative observations and the classification system developed by BEARD (1944, 1949, 1955). Albeit on a rough scale, the earlier descriptive mapping work of STOFFERS (1956) offers a unique opportunity to compare and assess developments in vegetation characteristics over a 50 year period during which the natural vegetation will have been impacted significantly by both natural and man-mediated impacts such as habitat loss for tourism development and housing, erosion, feral livestock grazing, hurricanes, the rapid rise of invasive species and the decline of agricultural cultivation.

In this report we finalize the presentation of the results of a quantitative vegetation survey of St. Maarten, including the description of terrain characteristics, vegetation structure, species composition and spatial patterns in the landscape, which has been available but unfinalized as based on field data collection from 1999. While we expect that in the past 20 years changes will have continued to take place in the detailed species composition of the vegetation units described, our results provide a major update compared to STOFFERS' (1956) vegetation description and a quantitative reference point for future studies on vegetation development for the island. In particular, the last 20 years has seen a massive increase in urban sprawl, in the number of exotic invasive species (VAN DER BURG ET AL 2012.) and in the intensification of hurricane impacts as predicted by global climate change. Therefore, this vegetation map provides a very valuable, relatively early biodiversity reference point before the most recent major surge in adverse impacts to the vegetations of the island.

The semi-detailed scale (LOTH 1990) we chose for the landscape ecological vegetation map of St. Maarten is 1:46,000. Its units are delineated and characterized on the basis of landscape-forming factors, such as geology, geomorphology, soil characteristics and vegetation. The quantitative approach we used will facilitate the possibility to track future changes in the vegetation types and their distribution over time. A comparison between the nearby islands of St. Eustatius and Saba is also possible because of the fact that the vegetation maps for St. Eustatius and Saba were made using the identical methodology (DE FREITAS ET AL. 2014, 2016).

CHAPTER 2

THE ISLAND OF ST. MAARTEN

2.1 GEOGRAPHY

The arc of islands stretching between the Virgin Islands and Venezuela consists of an inner and an outer arc. St. Martin[1] is part of the outer arc that runs from Anguilla to Barbados. The outer arc is made up of relatively low, flat islands whose limestone surfaces overlie older volcanic or crystalline rocks. The islands of the inner arc on their turn are of younger geological age than those of the outer arc and consist of geologically young volcanoes that are absent in the islands of the outer arc.

St. Maarten is situated between 18◦0’ and 18◦8’N latitude and between 63◦1” and 63◦10’W longitude (STOFFERS 1956). Since 1648, the island has been shared by two countries. The northern part of the island is under French jurisdiction, whereas the southern part of ca. 34 km^2 is part of the Dutch Caribbean. St. Maarten includes a few small uninhabited islets: Pelican Key (Guana Key), Molly Beday (Mal Aborder), Hen and Chicken and Cow and Calf along the eastern coast and Little Key in the Simpson Bay Lagoon.

The landscape of St. Maarten is dominated by hills with the exception of the western part of the island where the low limestone area of the ‘Low Lands’ became attached to the main island through the formation of sandbanks (‘tombolos’) in the Holocene. The topography of the hilly part is characterized by two ranges verging SSW-NNE and -going from east to west- can be described as follows:

a) The eastern range that goes from Pointe Blanche to Oyster Pond in which Naked Boy Hill (296 m) is the highest point.
b) The western range that goes from Little Bay to Pic Paradis (424 m); the latter is located in French St. Martin. In the Dutch part of the island this range further contains a number of the highest hills of the island, e.g. Flagstaff (386 m), Sentry Hill (341 m), St. Peter Hill (316 m) and Mount William (264 m).

Along the coast there are various bays with sandy beaches, but the eastern windward coast is steep and rugged in many places. Some of the bays have been separated from the sea by a sand bar and must be categorized as lagoons, e.g. the Great Salt Pond just above the capital Philipsburg. Simpson Bay is the largest lagoon of the island (STOFFERS 1956).

[1] When we use St. Martin in this report we mean the whole island, i.e. the two parts (Dutch and French) together. When St. Maarten is used, this refers to the Dutch part only.

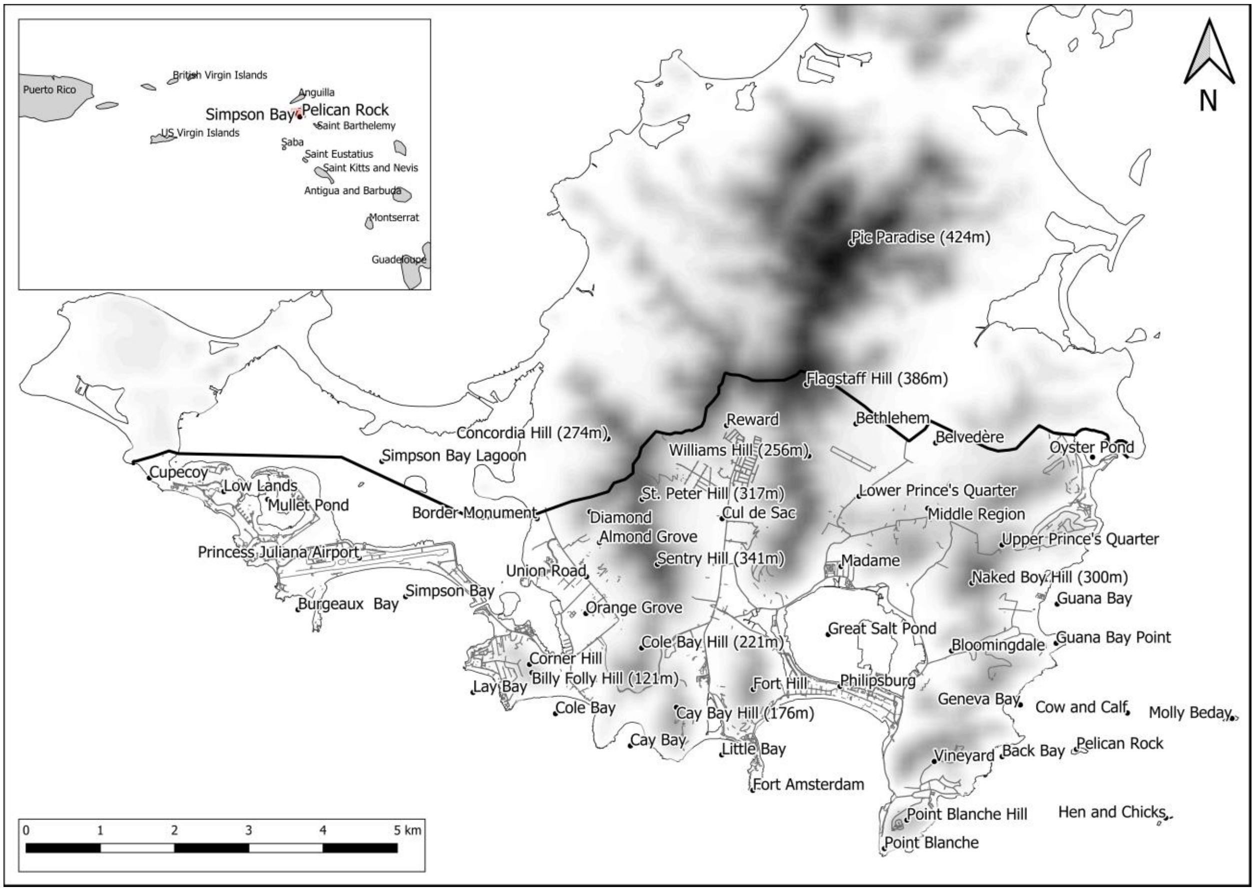

Figure 1. Map of St. Maarten with main topographical features and the location of the island in the chain of the Lesser Antilles.

2.2 CLIMATIC DATA

2.2.1 CLIMATE CATEGORIZATION

According to the KÖPPEN (1931) system of climate classification, the tropical climate of St. Maarten falls in the A-category, because the mean temperature of the coldest month exceeds 18°C (AUGUSTINUS ET AL. 1985). The amount and distribution of the precipitation determines the subdivision of the A-climate:

- Af: tropical rainforest climate with at least 60 mm precipitation every month;
- Am: tropical monsoon climate with a short dry season and the driest month with rainfall less than 60 mm;
- Aw: tropical savannah climate with a pronounced dry season, with the driest month having precipitation less than 60 mm.

Precipitation is very erratic and differs from year to year and month to month, and long droughts may occur. There is more precipitation on the windward slopes than on the leeward slopes of the hills. Precipitation also varies locally: 'In Cul-de-Sac valley it has often been noticed that clouds discharged on the western slopes facing eastward, while there was no rain a few hundred yards to the east.' (VEENENBOS 1955). So even at such a small spatial scale hills create apparent "rain shadow" effects that can be expected to locally influence vegetation composition and phenology. The Low Lands area of St. Maarten probably have the lowest rainfall of all three SSS Islands (VEENENBOS 1955), in particular because of the afore-mentioned rain shadow effect.

Table 1 shows the monthly rainfall data of St. Maarten for the period of 1879-1889 and 1892-1933 and also the monthly average temperature data for the period 1920-1933 (STOFFERS 1956).

Table 1. Selected climatic data of St. Maarten.

	Yr/Period	Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Yr total/Av.
Rainfall (mm)	1879-1889 & 1892-1933[a]	79.3	36.4	37.2	47.3	84.1	145	93.9	118	176	146.8	87.7	75.6	1027
Temperature (°C)	1920-1933[b]	24.7	24.7	25	25.9	26.9	27.5	27.7	27.9	27.7	27.5	26.5	25.5	26.5
Rainfall (mm)	1995[c]	19.4	74.9	33.8	16	18.6	24.4	70.3	120.4	308.4	98.8	73.5	178.8	1037.3
Rainfall (mm)	1996[c]	77.2	27.9	74.9	62.6	22.4	64.7	171.5	61	103.7	105.9	124.7	79.9	976.4
Rainfall (mm)	1997[c]	90.2	89.1	29.1	17.7	127.8	25.7	137.9	73.4	158.9	170.1	42.5	14	976.4
Rainfall (mm)	1998[c]	83.8	19.8	8.4	84.4	115.5	39.7	64.5	99.1	103.6	144	269.5	154.4	1226.7
Rainfall (mm)	1999[c]	64.1	31.4	15.5	40.3	22.2	191.5	78.3	144.9	108.2	357.2	594.3	153.2	1801.1

[a] Source: STOFFERS (1956); Station: Phillipsburg.
[b] Source: BRAAK 1935 in STOFFERS (1956); Station: Phillipsburg.
[c] Source: MDC (pers. comm.); Station: Princess Juliana Internat. Airport.

VEENENBOS (1955) and STOFFERS (1956) concluded that the climate of St. Maarten lies somewhere between the monsoon forest climate (Am) and savannah climate (Aw).

2.2.2 RAINFALL AND TEMPERATURE DATA IN THE PERIOD 1971-2000 AND THE CORRESPONDING WALTER CLIMATE DIAGRAM

The annual average rainfall on St. Maarten as measured at the Princess Juliana Airport (at about 3 m above sea level) for the period 1971-2000 was 1047 mm (see Appendix 1). This is comparable to the average value of 1027 mm for the combined period of 1879-1889 and 1892-1933 (STOFFERS 1956). For the period 1879 up to and including 1980 the long-term annual average was 1061.7 mm (MDNA 1982).

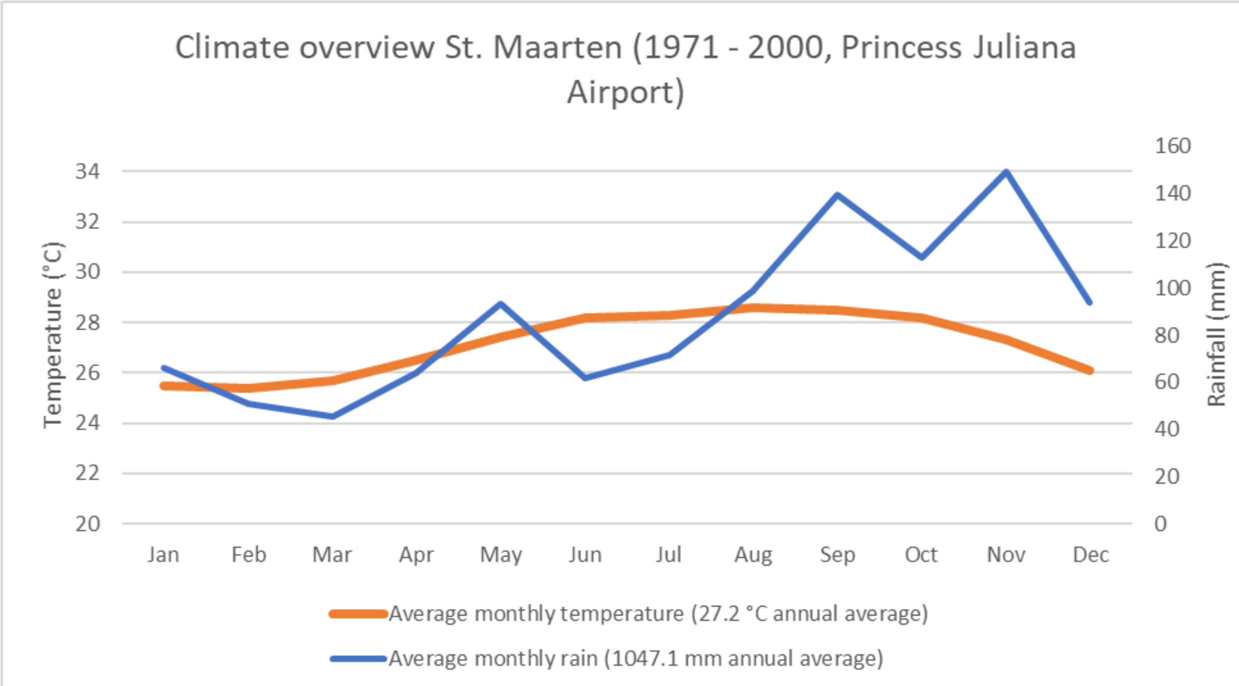

Figure 2. Walter climate diagram for the island of St. Maarten (period 1971-2000).

From the 1971-2000 data (Appendix 1) it can be deduced that the last five months of the year account for 57% of the annual average rainfall (see Appendix 1). The data show that In the months August, September, October and November the rainfall is 100 mm or more. Rainfall of 100 mm is considered the critical point below which evaporation exceeds precipitation in tropical areas (BEARD 1949; NIX 1983). The months with the lowest rainfall (in mm) are the first four months of the year. A combination of monthly rainfall and temperature data (see the Walter climate diagram in Fig. 2) show that the critical months for the survival of plants in general are the months June and July. The rainfall data show that the long-term average annual rainfall in the period 1971-2000 has changed very little and that there are still three months with a monthly average rainfall of less than or very close to 60 mm.

Table 1 provides data on monthly and annual average rainfall in the four years preceding and including the year in which the fieldwork was carried out (1999). The data show that both 1998 and 1999 were years with an above average rainfall.

2.2.3 TRADE WIND AND HURRICANES

There is a continuous, predominantly easterly trade wind, varying between ENE (60°) and ESE (120°) (MDNA 1982). The average wind speed (at 10 m height) on St. Maarten is 4.8 m/sec (Appendix 1)). St. Maarten is located within the hurricane belt. The “official” Atlantic hurricane season extends from June 1 through November 30. Almost every year at least one tropical cyclone occurs within a range of 100 miles of the SSS Islands and on the average once every 4-5 years hurricane conditions are experienced (MDC 2018). In 1995, St. Maarten was badly hit by hurricane Luis, whereas in 1999 the hurricanes José and Lenny caused serious damage (MDC 2018). Appendix 2 gives an overview of hurricanes that have passed within 185 km of any of the SSS islands up to 1999.[2]

2.3 GEOLOGY AND GEOMORPHOLOGY

2.3.1 GEOLOGY

Fig. 3 shows a schematic geological map of both parts of the island (WESTERMANN 1957. The oldest rock strata dates from about 50 million years ago (Young Eocene/Old Tertiary strata) (WESTERMANN 1957). These strata, evolved via eruptions and erosion of volcanoes as well as sedimentation of marine materials, and consist of series of tuffs and tuffoid rocks intruded with a diorite batholith. In the Oligocene tectonic forces folded and lifted these strata of the Pointe Blanche Formation temporarily above sea level. In several phases magma came up and came in partial contact with the Pointe Blanche Formation, but did not reach the surface. In areas where there was contact the Point Blanche Formation underwent changes and is characterized by depositions of several kind (e.g. iron and manganese). The crystallization of the different magmatic intrusions resulted in the formation of dolerites, porphyrites and quartz diorites. Because of the tectonic forces the older formation was lifted which resulted in eventual erosion of these parts.

In the early part of the Miocene (30 to 16 million years ago) a marine transgression occurred, during which marls and limestones were deposited on the shallow and flat sea-bottom. This formation is called ‘Low Lands formation’ and can be found e.g. in the Low Lands area and Lay Bay (and also the islet of Tintamarre on the French side). The late Miocene and Pliocene periods were characterized by the presence of tectonic forces and absence of sedimentation (marine or otherwise). The former can be deduced from the fact e.g. that the layers of the Low Lands formation at different localities no longer occur in a horizontal position. The tectonic forces caused the older volcanic and magmatic formations to rise above sea level and be subjected to erosion and fractioning. The very hard tuffoid rocks of the Point Blanche Formation offers the relatively most resistance to those degrading forces and it is therefore no surprise that the highest hills of the island consist of the Point Blanche Formation. These hills are found in two parallel SSW-NNO oriented hill chains. The magmatic intrusions were also exposed but are less resistant to erosion and weathering but there is variation in the different types: Mount William (264 m) consists of dolerite, which is more resistant to erosion than the diorite found in the low Middle Region and Belle Plain. In the latter areas the diorite has eroded to round blocks and rock piles.

The Pleistocene (first part of the Quaternary) is characterized by a series of glacial periods which resulted in a lowering of the sea level around St. Maarten of at least 36 m (and possibly

[2] In the 21th century several strong hurricanes passed near the island: Omar (2008), Earl (2010), and Irma and Maria (2017). Irma caused enormous damage on the island.

even up to maximally 100 m lower than at present). Anguilla, St. Barts and St. Maarten were then part of one large island. On this island a giant rodent (*Amblyrhiza inundata*) once lived (WESTERMANN 1957; McFARLANE ET AL. 1998). Remains of this animal were found in St. Maarten as well as on Anguilla. In this period of low sea level there was acceleration in the erosion and weathering of the old formations of the larger (Pleistocene) island. In that period a large and wide valley was formed at the location of the present Great Salt Pond and Great Bay. At the end of the Pleistocene (± 10.000 years ago) the ice and snow masses melted and sea level rose. The large island was flooded and as the result of crumbling only the highest parts, viz. the present islands of St. Maarten, Anguilla, and St. Barts remained above sea level. Since then these three islands have remained connected by an underwater plateau, with a maximum depth of 36 meters, which is called the 'Anguilla Bank' (WESTERMANN 1957). The valley of the Great Salt Pond and Great Bay areas were inundated and a young marine shell layer was deposited on the older surface of the valley. Other bays and lagoons of St. Maarten are also such "drowned" valleys. The youngest rocks (limestone; Holocene) were formed in the sea. They are coral reefs, which due to the uplift of the island are now situated 5 to 6 meters above sea level. They cover small areas and are mainly found in the eastern coast of the island. The youngest geological formations are the recent sand bars in several bays that act to largely shut the bays off from the sea.

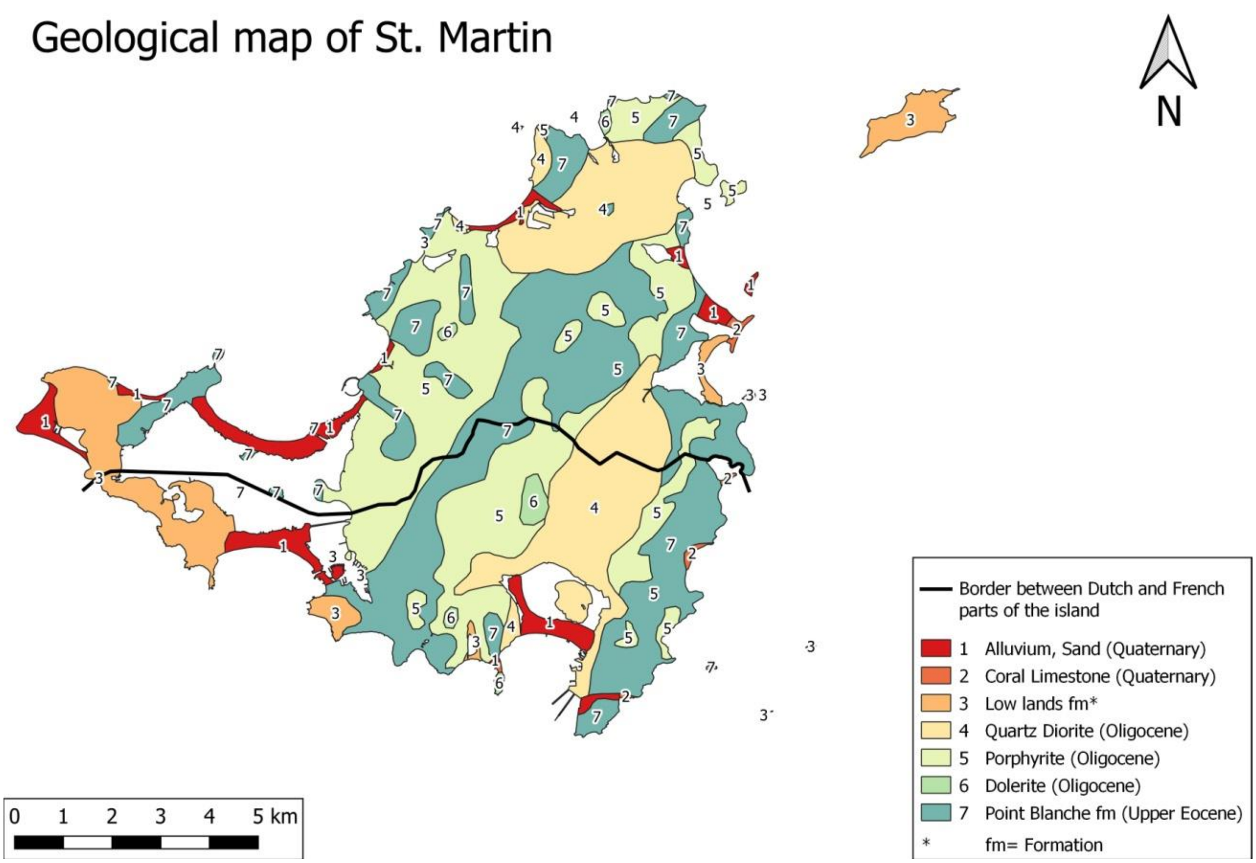

Figure 3: Schematic geological map of St. Maarten (Source: WESTERMANN 1957).

2.3.2 GEOMORPHOLOGY

The greater part of the island is occupied by hills and low mountains. The western part of the island is generally flat ('Low Lands').The coastline of St. Maarten has an irregular shape due to the many larger and smaller bays and lagoons. The windward coast is steep and rugged in many places, whereas along the leeward side several shallow-sloping beaches and bays are found. Sand bars occur at several points along the coast. The capital Philipsburg is built on such a sand bar. The sandbars partially close the lagoons off from the sea, e.g. Great Bay and Simpson Bay. Simpson Bay Lagoon, in the south, is the largest lagoon on the island.

2.3.3 SOIL TYPES

As a result of the relatively dry climate on St. Maarten, the soils are in a young stage of development, as is reflected by their shallowness, the poor development of subsoils and the grippiness of the surface soil (VEENENBOS 1955). The shallowness is also in part caused by erosion due to man-made factors such as deforestation and overgrazing. The soil map of St. Maarten is shown in Fig. 4.

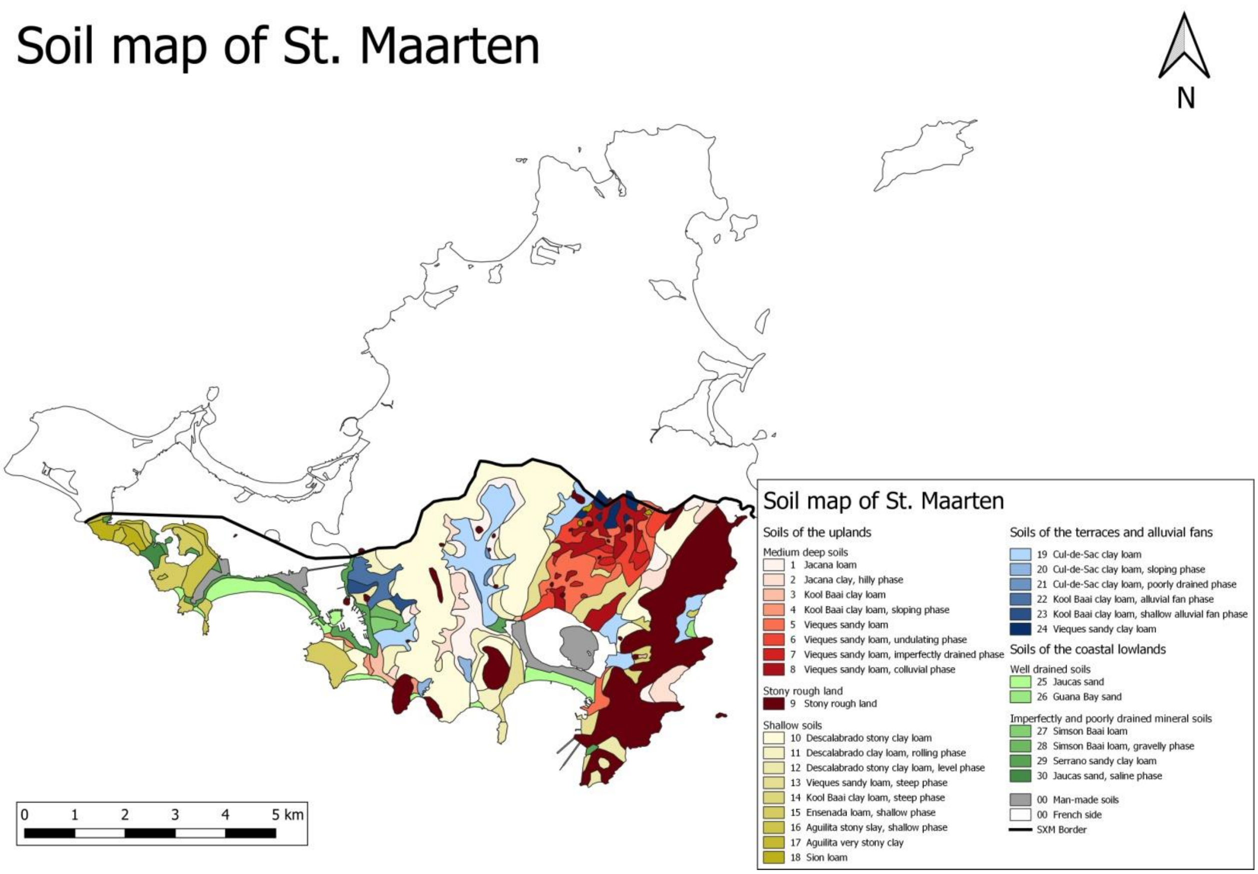

Figure 4. Soil map of St. Maarten (source: slightly adapted from VEENENBOS 1955)

The soil development in the Pointe Blanche Formation is so slow that nothing more than rough and stony land has formed. On the less hard porphyritic rocks, soil formation is a little more rapid. A very stony and shallow lithosolic Descalabrado[3] clay loam soil (although very stony) developed here, the solum of which often shows a heavier and compact subsoil. Soil formation on the hard limestone of the Low Lands Formation (WESTERMANN 1957) is generally very poor as well. Here only a few centimeters of soil have formed (Ensenada loam series). In some small pockets an accumulation of red clay occurs. On the soft limestone a somewhat more pronounced soil formation can be seen, though still only poor and shallow (Aguilita clay soils[4]). The soil formation over the relatively soft calcareous intercalations and their fans in the older Pointe Blanche Formation is rather different. In these places the soils are deeper, less alkaline, better developed and less stony as well (Kool Baai series). The strongest soil formation took place over quartz-diorite and on the lower hillsides and foothills of the porphyritic rocks and their debris (Vieques sandy loam, Jacana soils, and Cul-de-Sac clay loam).

The soils of St. Maarten can be classified into three principal groups (VEENENBOS 1955):

1. Soils of the uplands;
2. Soils of the terraces and alluvial fans;
3. Soils of the 'coastal lowlands'.

All information provided in the paragraphs 2.3.3.1, 2.3.3.2, 2.3.3.3 and 2.3.3.4 is based on VEENENBOS (1955).

2.3.3.1 <u>Soils of the uplands</u>
The soils of the uplands are mostly residual or sometimes colluvial soils found at altitudes up to approximately 427 m elevation. Relief is predominantly undulating, hilly or steep. They are derived from tuffs, limestones, porphyrites and quartz-diorites of the older volcanic and intrusive formations and from hard or soft limestones and marls of Middle to Young Tertiary age. Different soils developed under rather uniform, sub-humid climatic conditions, according to composition and hardness of the parent material. Three subgroups are distinguished according to effective depth: a) Medium deep soils of the uplands ('Jacana loam', 'Jacana clay hilly phase', 'Kool Baai clay loam', 'Kool Baai clay loam sloping phase', 'Vieques sandy loam', 'Vieques sandy loam undulating phase', 'Vieques sandy loam imperfectly drained phase', and 'Vieques sandy loam colluvial phase'); b) Shallow soils of the uplands ('Descalabrado stony clay loam', 'Descalabrado clay loam rolling phase', 'Descalabrado stony clay level phase', 'Vieques sandy loam steep phase', 'Kool Baai clay loam steep phase', 'Ensenada loam shallow phase', 'Aguilita stony clay shallow phase' and 'Aguilita very stony clay'); c) Stony rough land. The medium deep soils occur at lower hillsides over porphyritic parent material and Pointe Blanche soft limestone or are derived from quartz-diorite. The soils can consist of loam or clay as well as clay loam or sandy loam materials. The group with shallow soils represents the steeper and/or stony areas where several soils derived from Pointe Blanche rocks, porphyrites or Middle-Upper-Tertiary limestone occur. These soils can be stony clay or stony clay loam, clay loam or sandy loam as well as

[3] Lithosols are soils with a significant amount of rubble; Descalabrado ('shallow soils of the uplands'; VEENENBOS 1955) are clay loams that are less than 50 cm deep over bedrock.
[4] The Aguilita series consists of gently sloping to steep, well-drained soils that are shallow over soft limestone or marl.

loamy. The soils grouped in the 'Stony rough land' subgroup are very stony and are mostly found on Pointe Blanche parent material (VEENENBOS 1955).

2.3.3.2 Soils of the terraces and alluvial fans

This subgroup comprises all types with gravelly subsoil derived from upland wash (adjacent hills) on a gently sloping to sloping relief. The term terrace is used in a general sense, since true geomorphological terraces (due to uplift of the island) are lacking. These medium friable soils occur in narrow valleys and form flat, cone-shaped fan formations. Two categories are important for the present study: a) 'Cul-de-Sac silty clay loam' and b) 'Vieques silty clay loam'. The 'Cul-de-Sac silty loam' type is derived from wash from the porphyrite hills and occurs on gravelly deposits in the valley bottoms. Its greatest extension is found in Cul-de-Sac. These soils are 60-80 cm deep and the slope ranges from nearly level to gently sloping or undulating (1 - 8%). There is no typical profile, because a complex of soils is formed by erosion and deposition. Both internal drainage and runoff are medium. The soils therefore have a good moisture-holding capacity.

'Vieques sandy clay loam' occurs between Belvedere and Bethlehem in the north as separate areas (1.2-3 m high) surrounded by the colluvial phase of 'Vieques sandy loam' (Vc). It has a 10-15 cm, somewhat gritty, or even gravelly, sandy clay loam surface soil, which is plastic when wet and dries to dense, very hard, clods. The subsoil is a 35-37.5 cm deep, mostly very firm, impermeable, plastic, clay loam, which becomes sandier and grades at a depth of 75 cm into disintegrated parent material. Drainage is imperfect and the land periodically gets swampy (VEENENBOS 1955).

2.3.3.3 Soils of the 'coastal lowlands'

All soils within this group occur near the sea and lagoons. These soils include all recent marine deposits such as sand, loams and clays. According to the depth of the groundwater these soils are divided into two subgroups: a) well drained sandy soils of the 'coastal lowlands'; b) imperfectly and poorly drained mineral soils of the 'coastal lowlands'.

The well drained soils consist of non-coherent sandy soils, adjacent to or near the beach. They include 'Jaucas sand' and 'Guana Bay sand'. The 'Guana Bay sand' is a very fine, sandy deposit. The surface soil, to a depth of 35-45 cm, consists of loose, single-grained, non-coherent, brown, fine sand, which with depth, gradually becomes yellowish-white.

The second subgroup includes the imperfectly drained lagoon soils of the 'Simpson Baai series' and the poorly drained lagoon deposit of clays, loams and sands of the 'Serrano series'. The 'Serrano sandy clay loam' occupies narrow strips of salty lagoon deposits along the coast. It consists of clays, fine sand and loam which are grey, wet and very poorly drained. It is a level soil, partly barren and partly overgrown with mangrove (VEENENBOS 1955).

2.3.3.4. Detailed characteristics of the relevant soil types in the present study

Jacana loam (Jl) occurs on lower hillsides or low foothills in 8-15 % sloping land. This soil is derived from porphyrites and in general is 60-80 cm deep. It has an 20-30 cm surface soil of friable, granular, slightly acid or neutral loam or clay loam which is rather plastic when wet. The subsoil consists of a 25-40 cm very firm, compact clay or silty loam, which is plastic and sticky when wet and which gradually merges into tuffaceous rock. Hard bedrock occurs at a depth of

70-100 cm. This soil is moderately drained while internal drainage is medium and external drainage is rapid. There is a rather close relation between soil formation in the Jacana series and the ‘Descalabrado series’. The Jacana soils are more deeply weathered; they always have a well-developed, stiff, clay subsoil, which, in the ‘Descalabrado soils’, only occurs locally. The ‘Jacana’ surface soil has a somewhat more plastic consistence but looser structure as compared to the ‘Descalabrado series’.

‘Jacana clay, hilly phase’ (Ja) is found in areas of Jacana clay with slopes of 15-25 %. In general, these soils are stony and have suffered rather severely from sheet erosion and therefore they have a somewhat heavier texture. Runoff on these soils is very rapid, but gully erosion is rare. This soil is less productive than the typical Jacana soil.

‘Vieques sandy loam’ (Vs) occurs in the Middle Region and is derived from coarse-grained quartz-diorite in a hilly area. There is an 20-40 cm deep soft loam or sandy loam surface soil. Soil drainage is rather on the high side. The subsoil is 15-25 cm deep and consists of a firm but permeable gritty, sandy clay loam which is slightly plastic when wet. Solid bedrock is found at a depth of 70-100 cm.

‘Vieques sandy clay loam’ (Vz) occurs only locally in the Belle Plain as ‘islands’ surrounded by the colluvial phase of ‘Vieques sandy loam’. It has a 10-15 cm slightly acid, somewhat gritty (or even gravelly), sandy clay loam surface soil, which is plastic when wet and dries to dense, very hard clods. The subsoil is a 35-37.5 cm deep, mostly very firm, impermeable, plastic, slightly more acid, clay loam, which gradually becomes sandier and grades at a depth of 75 cm into disintegrated parent material (including some gravel). Drainage is imperfect and the land periodically gets swampy.

‘Vieques sandy loam, colluvial phase’ (Vc) is called “wash mould”, occurs in the lower altitudes and is partly colluvial and partly alluvial. It is 35-50 cm thick and consists of loose, single-grained, gritty, sandy loam or very friable, fine, sandy loam (which contains a moderate amount of organic matter locally). The subsoil consists of some 40 cm of gritty, plastic, sandy clay loam. When the subsoil is lacking, the surface soil rests immediately on coarse-grained, disintegrated quart-diorite. The soil has a good moisture-holding capacity. Most of the area is well drained.

‘Cul-de-Sac loam’ (Uc) occurs on gravelly deposits in the valley bottoms and has its greatest extension in Cul-de-Sac. These soils are normally 60-80 cm deep, but sometimes less deep. There is no typical profile because it is a complex of soils formed by erosion and deposition. The surface soil is 20-30 cm deep, medium acid, medium friable, granulated clay loam, sandy clay loam or even sandy loam, overlying a somewhat stiff, neutral, medium permeable clay, or clay loam subsoil of 20-40 cm. This category has a good moisture holding capacity.

‘Descalabrado stony clay loam’ (Dm) is derived from Pointe Blanche rocks and porphyrites. It occurs on the steep higher parts of the hills (> 30° slope). In general these slopes are very stony. The surface soil consists of a 15-25 cm layer of firm, semi-granular, slightly acid, grippy clay loam, plastic when wet, and overlying a substratum of decomposed, fragmental, tuffaceous rock. The surface soil also contains an abundance of minute rock fragments which give the soil its grippy character. Where a compact subsoil is present, the surface soil is more friable. In these features the ‘Descalabro soils’ resemble the ‘Jacana soils’.

‘Descalabrado stony clay loam, level phase’ (Dx) is the level phase of the typical soil and is discerned for the nearly level, but very shallow, stony and grippy soils over decomposed, rotten rock. Mostly these rocks do not occur in uplands, other than those on hard Pointe Blanche rock.

It is a 15-20 cm thick, stony, grippy surface soil that overlies parent material. Where the parent material consists of rotten, bluish rock this material is worked up into the surface soil.
‘Aguilita stony clay, shallow phase’ (Aa) occurs in the Low Lands area on somewhat higher elevations than ‘Ensenada loam, shallow phase’ (En). It is derived from soft, Young-Tertiary limestone, and has a rolling to hilly relief. The topsoil ranges from about 15 cm to over 30 cm in thickness. No distinct subsoil has been observed. Internal drainage is rapid. The soil is a permeable clay, calcareous, moderately alkaline, semi-granular, often soft and dusty, gravelly or stony, which feels like sandy loam when dry and is only slightly plastic when wet. Locally, it may be very stony.
‘Ensenada loam, shallow phase’ (En) occurs mostly in the Low Lands area and is little more than bare rock covered with only one or two inches of soil. It is derived from hard, Young-Tertiary, coral limestone and has a gently sloping or undulating relief. The soil has a very rapid internal drainage.
‘Kooi Bay clay loam’ (Kc) is derived from Pointe Blanche relatively soft calcareous rocks and occurs on level to gently sloping land (1-5 %). It has a 15-20 cm deep, loose, very friable and slightly acid, granular clay-loam surface soil, which is plastic when wet. When dry, this soil shows small cracks. The subsoil of 20-25 cm thickness, is a hard, subangular, blocky, very slightly acid or neutral clay-loam or clay. The friable, more alkaline, calcareous substratum of 10-30 cm, merges into parent material. The latter lies at a depth of 60-70 cm below the surface. These soils are imperfectly drained while internal drainage is slow and the surface soil has a tendency to flow. After rains, the land remains wet for a long time.
‘Guana Bay sand’ (Gs) occurs on the windward shore of St. Maarten at Guana Bay. The surface soil, to a depth of 35-45 cm, consists of loose, single-grained, non-coherent, brown, fine sand, which with depth, gradually becomes yellowish-white. The land is hummocky.
‘Serrano sandy clay loam’ (Sd) occupies narrow strips of salty lagoon deposits along the coast. It is a level soil, partly barren, partly overgrown with mangrove. The soil consists of clays, fine sand and loam which are grey, wet and very poorly drained (VEENENBOS 1955).

2.4 FLORA AND VEGETATION

BOLDINGH (1909) considered the vegetation on the three SSS islands to be generally identical but on each of the three islands a particular formation is predominant. According to BOLDINGH (1909) the vegetation of St. Martin is different from that of the other two islands and chiefly composed of a *Croton* vegetation that is much more developed than on St. Eustatius; the tropical woods that are found on St. Eustatius and Saba do not occur on St. Martin. Due to the fact that a greater part of St. Martin is being cultivated, ruderal plants are dispersed in almost the whole island, along the roads and on the plantations and meadows, but not in the typical *Croton* vegetation. The latter changes gradually into a well-developed littoral vegetation in the outer parts of St. Martin (BOLDINGH 1909).

BOLDINGH (1909) distinguished the following four vegetation types (‘formations’) on St. Martin: 1) ‘Vegetation of the tops of the hills’ (could also be called ‘*Eriodendron* vegetation’ which is a greenish woody vegetation); 2) ‘Vegetation of the level parts of the island and of the lower slopes of the hills’ (could also be called ‘*Croton* vegetation’); 3) ‘Vegetation of the seashore and the rocky parts' (could also be called 'Littoral vegetation'); 4) 'Vegetation of the cultivated region' (BOLDINGH (1909) considered this type almost synonymous with the '*Croton* vegetation' and in some cases the '*Eriodendron* vegetation' intermixed with and partly replaced by ruderal plants). The whole aspect of St. Martin was determined by the '*Croton* vegetation' together with the 'Littoral vegetation' (BOLDINGH 1909). Only where the hills were a little higher, the '*Eriodendron* vegetation' (similar to that found in the northern part of St. Eustatius) occurred. The vegetation found bordering the salt ponds consisted of species not found on St. Eustatius or Saba.

VEENENBOS (1955) made some relevant remarks with respect to the vegetation of St. Maarten: 'The natural vegetation of these islands consists for the greater part of low, semi-deciduous seasonal forest. When vegetation began anew after earlier cultivation, thorny brush and cactus invaded the land, rendering whole areas almost impenetrable. Scattered remnants of the original vegetation are found mainly at higher elevations. Generally, the leeward slopes are covered with forest to a greater extent than the windward slopes. The latter are exposed to the prevailing trade winds and receive a greater amount of precipitation. Hence, they were formerly cultivated more intensively. In French St. Martin nearly all hilltops have been deforested. Primary and secondary natural vegetation in the various islands vary from place to place. Altitude plays an important role.'…..'The Low Lands and the tops of the hills on the island proper are covered with brush and low forest of a predominantly semi-deciduous seasonal type. The lower two-third of the slopes is covered with Guinea grass or secondary thickets of low thorny brush and cactus. Most of the land in secondary brush is abandoned crop or pasture land. The brush country is sparsely grazed by cattle. Locally, subsistence crops are grown on terraced spots. The windward slope of the easternmost range is for the greater part steep, rough and stony, and covered with thorny shrubs and cactus. The hills are dissected by guts which carry water only after heavy rains.' …. 'Since most of the guts are very short, there is little opportunity for holding the rainwater by building dams, with the possible exception of the deep and narrow Ravine Rouge in the easternmost range, and the shallow valley along the Netherlands-French border draining into the Oyster Pond.'

STOFFERS (1956) on his turn made the following comments on the vegetation of St. Maarten in his introduction to the vegetation of the SSS Islands: 'The island was formerly under very active cultivation and consequently the present vegetation is secondary, except for some scattered remnants of the original vegetation in the highest parts, e.g. the top of Sentry Hill. The beach vegetation is very well developed along several bays. The secondary communities are characterized by the absence of a definite structure and great variation in composition.'
The combined known flora of the three SSS islands today consists of 857 species. The flora of St. Maarten consists of 544 species (including naturalized species)[5] in 339 genera and 95 families. The main plant families of the flora of St. Maarten are: *Gramineae* (65 spp.), *Compositae* (31 spp.), *Euphorbiaceae* (30 spp.), *Fabaceae* (28 spp.), and *Malvaceae* (21 spp.). Compared to St. Maarten the main plant families on Saba and St. Eustatius are somewhat different: *Gramineae*, *Polypodiaceae*, *Compositae*, *Rubiaceae* and *Fabaceae* (DE FREITAS ET

[5] For the purpose of comparison: the flora of semi-arid island Curaçao consists of 492 plant species (BEERS ET AL. 1997).

AL. 2014, 2016). The data in Table 2 show the grade of (dis)similarity among the (current) floras of the three SSS islands.

Table 2. Similarity of the floras of the SSS islands of St. Maarten, St. Eustatius and Saba.

	% of total of 857 spp. shared
All three islands	32%
Saba and St. Eustatius	10%
Saba and St. Maarten	7%
St. Eustatius and St. Maarten	9%
Part of the 857 spp. that only occur on one of the three islands	42%

Most of the species of St. Maarten (50 %) have a wide American distribution, followed by the species with a worldwide distribution (33 %). Next are the West-Indian species (14 %), the species restricted to the Lesser Antilles (3 %) and finally the island endemics (< 1 %). This last group consists of two species: *Calyptranthes boldinghii* (*Myrtaceae*) and *Galactia nummelaria* (*Fabaceae*). Both of these may already have gone extinct as the last confirmed records date from 1909 (BOLDINGH 1909; STOFFERS 1979, 1982).

2.5 HUMAN INFLUENCE ON FLORA AND VEGETATION

It can be assumed that before the settlement of Europeans on St. Maarten around 1630 (DE PALM, 1985) human influence on the flora and vegetation was relatively limited. In the colonial period the island developed into an important island for salt production due to the presence of the saline areas of the lagoons (STOFFERS 1956). Besides this activity, agriculture and trading were also important subsistence activities. In the middle of the 17th century St Maarten had extensive sugar plantations. In 1789, there were 92 plantations on the island and 35 of these had sugar cane as the main product, while the remainder was focused on livestock breeding and food crops for local consumption (DE PALM 1985). At the beginning of the 19th century, sugar cane was grown almost to the top of the hills in St. Maarten (TEENSTRA 1836 in STOFFERS 1956). After the abolition of slavery in the middle of that century, sugar cultivation decreased significantly and ceased over time. Early in the 20th century, sea-island cotton was planted in St. Maarten, but it ceased over time due to diseases attacking the crop and the low prices for that product on the world market. Emigration in the 1920s of many men (to work in the oil refineries of Aruba and Curaçao) resulted in the further decline of agricultural activities (STOFFERS 1956). In the 1950s, only small patches of land were in use for the production of subsistence crops and cattle. The latter was somewhat on the increase in that period. The livestock present on St. Maarten in 1947 consisted of 75 horses, 60 donkeys, 719 cattle, 315 goats, 612 sheep and 170 pigs (STOFFERS 1956).

In 1672, the population consisted of 1075 people. In 1816, the population had increased to 9.000 persons (TEENSTRA 1837). During the first half of the 20th century, many people, especially men, emigrated to Curaçao and Aruba in search of work (DE PALM 1985). The number of inhabitants in 1937, 1949, 1952 and 1960 were respectively 2350, 1500, 1550 and 2,728 (STOFFERS 1956; DE PALM 1985). In 1980 and 1995, the numbers were 13,156 and 38,567 respectively (CBS 1996). Since the mid of the 1960s tourism has become the main economic activity of St. Maarten and is the cause of the steep rise over time of the number of inhabitants of the island due to the return of former inhabitants and immigration of other nationalities (DE PALM 1985).

In 1963, 13,419 stay-over tourists visited the island while over the years it has kept increasing. The number of stay-over tourists in 1980, 1983, 1986 and 1999 were respectively: 171,000, 304,048, 385,000 and 444,824[6] (DE PALM 1985; INTERDEPARTMENTAL WORKING GROUP 1987; ST. MAARTEN TOURIST BUREAU: https://www.onecaribbean.org/wp-content/upoads/St.-Maarten-2004.pdf).

[6] In 2016 the highest number of stay-over tourists up till now was reached: 528,153 (http://stat.gov.sx/tourism; consulted on January 16, 2020).

CHAPTER 3

METHODS

3.1 PHOTO-INTERPRETATION AND FIELDWORK

For the survey of the (semi)-natural vegetation areas of St. Maarten, we used the landscape guided method, developed at the International Institute for Aerospace Survey and Earth Sciences (ITC). The principle of this method is a combination of aerial photo-interpretation (API) and stratified sampling (ZONNEVELD 1979; 1988a; 1988b; VAN GILS ET AL. 1985; GROTEN ET AL. 1991). Stereoscopic photo-interpretation was based on true-colour aerial photographs of the island (scale approximately 1:8,000) that were taken in March, April and December 1991 and served as basis for field sampling. The photo-interpretation was based on analysis of differences in photo-features, such as tone, texture and spatial pattern, using the landscape as guiding principle. The resulting units of the photo-interpretation were then drawn on a 1:10,000 topographic map (1982; NETHERLANDS ANTILLES CADASTRAL SURVEY DEPARTMENT). This map was used as the base map for field-truthing and final determination of the location of the sample plots used. Sample plots were selected in each mapping unit of the base map. At each site of a unit, the plot was haphazardly selected in a representative area of the unit. A varying number of sample plots ('relevé's') were taken in each of the (preliminary) mapping units. Plot sizes used, were based on the guidelines of the ITC method, but in the present study slightly modified for herbaceous vegetation types (1), woodlands (4) and heterogeneous higher vegetation (5) (VAN GILS ET AL. 1985; LOTH 1990), see below.

A total of 56 plots were sampled. Taking into account the homogeneity of the vegetation the following plot sizes were used:

1.	Short grass and herb vegetation:	3 m x 3 m
2.	Low shrub vegetation (<1 m):	5 m x 5 m
3.	High shrub vegetation (> 1 m):	7 m x 7 m
4.	Woodland:	10 m x 10 m
5.	Very open heterogeneous higher vegetation:	15 m x 15 m

3.2 DATA COLLECTION

The fieldwork was done in August, September and November 1999. (August 24-September 10 & 10-16 November). All data collected for each sample plot were recorded on standard ITC relevé sheets (see e.g. LOTH 1990). These data included:

Terrain characteristics: information on geology; relief type; slope type (steepness and exposure (compass direction of the slope of the plot and its direct surroundings)); percentage of surface stoniness or rock outcrops.

Soil and water characteristics: pH of the top layer (using Hellige indicator solution) and relative calcium-carbonate content (using HCl with the following potential outcomes: "-", "+" or "±"; n.m.= not measured); soil colours (assessed with Munsell colour charts); coverage of the soil or rocks with plant litter (as percentage of the sample plot).

Grazer presence: in order to have an assessment of the impact of disturbance on the vegetation, goat (or any other exotic grazer) presence (or absence) based on presence (or absence) of dung or signs of grazing in or adjacent to the sample plot was recorded.

Human disturbance: this term refers to the presence of direct human disturbance such as the felling of trees, vegetation clearing in the past, trails, littering or dumping.

Vegetation structure and floristic composition: total cover; cover and height (average and maximum) of each stratum. The average height was calculated by multiplying the height of each layer that was distinguished with their percentage cover and dividing that sum by the sum of the cover percentages (decimals). In the description of the types the dominant structural layer will be indicated.

When it was difficult to distinguish between a shrub layer and a tree layer or a shrub and a herb layer, these were then considered as one layer. Sometimes the tree and/or shrub layer could be divided into a higher and lower layer. In each plot, all species were recorded for each stratum and their abundance or coverage was estimated. Coverage estimates were transformed to the decimal scale for vegetation analysis according to LONDO (1976).

The following publications were used for the identification of the plant species: BOLDINGH (1913); HITCHCOCK (1936); STOFFERS (1963-1984); LITTLE & WADSWORTH (1964); PINTO-ESCOBAR & MORA-OSEJO (1966); LITTLE ET AL. (1974); GODFREY & WOOTEN (1979); HOWARD (1974-1989a,b); CORREL & CORRELL (1982); LIOGIER (1985-1997). Dr. Frank Axelrod (Herbarium Collections Manager of the Herbarium of the University of Puerto Rico) also helped with the identification of a number of species based on plant material collected during the field work. Nomenclature of the plant species is based on HOWARD (1974, 1977, 1979, 1988, 1989a & 1989b), except for species not treated by HOWARD in which case we used STOFFERS (1981). Where necessary these names were updated using AXELROD (2011, 2017). For the genus *Cuscuta* it proved difficult to identify the species in the field, and therefore the extension *spec.* is used.

3.3 DATA PROCESSING

A total of 220 plant species was recorded in the 56 sample plots used. This represents 40% of the total flora (544 spp.; DE FREITAS 2014, 2016). Table 3 shows the conversion of the 14 categories of the LONDO (1976) scale to a scale of nine scores as required for input into the clustering program scores TWINSPAN (Two-Way Indicator Species Analysis; HILL 1979).

Table 3. Decimal scale for abundance / coverage after LONDO (1976) and the conversion values applied for the TWINSPAN clustering program.

Londo [a]	r	p	a	m	1	2	3	4	5	6	7	8	9	10
Twinspan	1	2	3	3	4	5	6	7	7	8	8	9	9	9

Legend
[a] Overall cover <5%: r = rare, sporadic, p = rather sparse, a = plentiful, m = very numerous; overall cover ≥5%: 1 = 5-15%; 2 = 16-25%, etc. .; 9 = 86-95%; 10= 96-100%.

After constructing the final vegetation table via TWINSPAN, a synoptic table was made with the program CLUTAB (WAGENINGEN AGRICULTURAL UNIVERSITY 1994) to help characterize the vegetation types further (Appendix 3.). In the synoptic table, the presence or absence in a vegetation type is indicated for each of the 220 plant species found and a presence scale of I-V is used as an index of species presence. When the average coverage of a certain species within a cluster is 16 % or more it is indicated with an asterisk (*). A distinction is made between “differentiating” species, “common” species, “other” species and “rare” species (BOKKESTIJN & SLIJKHUIS, 1987; BEERS & VAN DER HAVE, 1989; BEERS ET AL. 1997; DE FREITAS ET AL. 2005; DE FREITAS ET AL. 2014; DE FREITAS ET AL. 2016). In Appendix 3, differentiating species as determined using TWINSPAN are indicated in bold. The cut-level used for the differentiating species is occurrence in at least 41% of sample plots of a vegetation type. ‘Common species’ include species that are present in minimally four clusters (of the total of 11) with at least one presence category III or in five clusters with a low presence category (< III). ‘Other species’ refers to species that occur in maximally three clusters or in four categories with a low presence category (< III)). ‘Rare species’ occur in maximally two clusters with a low presence (I or II).

Each vegetation type was characterised by the presence or absence of (a combination of) certain species and was given a binary name. The first part of that name was based on a common species with a high presence category. The second part of the binary name was a differentiating species, which occurred in at least 41% of the sample plots of that type (for a justification of the selected species used we refer to Appendix 3). When no differentiating species was present in a type, species with the highest presence category combined with a relative high abundance (cover) category in the common species group and ‘other species’ group was used: in vegetation type 7 the binary names was based on two common species and in vegetation type 5 a common species and an accompanying species (“Other species”) were used. In selecting the species, the predominant structural layer of the vegetation type was also taken into account. With the description of each vegetation type an average (and range) of several parameters (number of species, total real cover, height of the characteristic layer, slope percentage, exposure, soil pH, goat presence) are given and are based on the field data collected for the relevant plots.

3.4 FINAL MAP COMPILATION

After classification of all sample points into the present vegetation types, each sample point (relevé) was labelled with a code corresponding to the specific vegetation type to which it belongs. By plotting these codes onto the aerial photographs, the photo features could be compared for each plant community, and used as a basis for classification of the interlying unsampled areas.

The hierarchical guiding principle in the construction of the names of the land types in the final legend was: (1) geology and land type (see paragraph 2.3); (2) terrain form (hills, lowlands, cliffs, beach); (3) vegetation structure and floristic composition (vegetation types). The subdivision of land types is based on the differences in the associated vegetation of the subunits. The names of the legend units thus refer to both terrain features and vegetation types.
After preparation of the final legend, the aerial photographs were checked where necessary for the preparation of the final map. The re-interpretation was scanned and then edited in ARCGIS. This map was made by combining the main topographical features (landscape units) and vegetation units in ARCGIS into which also all information on topography, geology, landscape, soil characteristics and vegetation types were stored. Because of practical reasons the scale of The final map scale is 1:46,000, which is a semi-detail scale (VAN GILS ET AL, 1985; LOTH, 1990; GROTEN ET AL. 1994) and serve for comparing our results with those of STOFFERS (1956).

CHAPTER 4

RESULTS

4.1 VEGETATION TYPES

Cluster analysis of 56 sample plots resulted in a total of 11 vegetation types. The synoptic table of the 11 vegetation types (Appendix 3) gives the presence of each species in each vegetation type. The 11 vegetation types are described in detail below and summarized in Table 4. The sequence in which the vegetation types are described below follows their sequence in the synoptic table (Appendix 3). At the end of the description of each vegetation type, values are given for the soil pH, signs of goat presence, substrate surface slope and exposure, average number of species for each vegetation type, cover and average height of the vegetation. Each value for a parameter represents the average of all sample plots of a type, followed by the observed range between brackets. Table 5 shows the correlation between the 11 vegetation types and the soil (and land) types as described in VEENENBOS (1955) and shown in Figure 4.

1 *GUAPIRA FRAGRANS-CAPPARIDASTRUM FRONDOSUM* TYPE (6 RELEVÉS)

This vegetation type has the highest number of plant species and highest average cover of all vegetation types in the present study. The highest trees (9 m and 7.2 m) were found in two of the plots of the present type. The shrub layer or combined tree/shrub layer has the highest contribution to cover. No dominant species were found while deciduous and evergreen species are about equally represented. The four differentiating species are two shrub/tree species (*Capparidastrum frondosum* and *Eugenia biflora*), one vine (*Dolichondra unguis-cati*) and a herb (*Lasiacis divaricata*). Tree/shrub species that are always present and have the highest abundance are *Bourreria succulenta, Erythroxylum rotundifolium*, *Guapira fragrans*, *Leucaena leucocephala*, *Pisonia subcordata*, and *Senegalia riparia*. *Megathyrsus maximus* was dominant in the herb layer. The shrubs *Comocladia dodonaea* and *Euphorbia tithymaloides* are always present just like the vine *Stigmatophyllon emarginatum*. This type has the highest number of species of vines (16) and is the only type in which an *Araceae* species (*Anthurium*), an orchid species (*Oncidium*) and fern species[7] (*Polypodium*) occur but these are (very) rare. A few of the characteristic plant species of the Semi-evergreen seasonal forest are found in type 1: *Nectandra coriacea*, *Eugenia monticola*, *Casearia decandra*, and *Guettarda parviflora* (BEARD, 1949 in STOFFERS, 1956). This vegetation type is found on the leeward side of the two western hill ranges, but not on the southern hills of Cay Bay hill, Cole Bay hill and Fort William hill. Half (50%) of the plots shows signs of both hurricane damage and human disturbance.

Type 1 has the highest average terrain slope values. The soil pH is relatively high while the soil type is usually a shallow Descalabrado (stony) clay loam (Dm), which is very susceptible to

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[7] It is possible there were more than one species due to the fact that not all plants could be collected due to the height at which some plants occur.

Table 4. Summary overview of mean biotic and abiotic community characteristics for the 11 vegetation types distinguished.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Parameters	Guapira-Capparidastrum	Bourreria-Eugenia	Erythroxylum-Cynophalla	Krugiodendron-Amyris	Pisonia-Eugenia	Leucaena-Antigonon	Botrhiochloa-Melochia	Lantana-Talinum	Ruellia-Melocactus	Laguncularia-Conocarpus	Canavalia-Ipomoea
Number of plots	6	3	6	6	4	5	5	4	9	6	2
pH	7.7	6.7	6.9	7.6	6	6.7	6.7	8.1	6.2	8.3	8.5
Slope (◦)	33 °	30 °	27 °	11 °	20 °	11 °	15 °	7 °	30 °	4 °	5 °
Exposure direction	se-wsw-nnw	se-sw-w	nnw-e-ssw	s-ssw	wnw-ne-sse-ssw	n-se	e-se-s	s-ssw-w	n-e-s	s-nnw-n	ssw
Goat presence (%)[1]	0	33	50	0	0	80*	20	0	0	17	0
# of species	43	32	31	30	28	25	16	13	12	9	10
Total real cover (%)	76	61	69	73	58	72	61	63	50	46	36
Height of vegetation (m)	2.1	2.3	2	2.6	2.5	1.7	0.8	0.7	0.3	1.9	0.9
Cover by wood & leaf litter (%)	54 (25-80)	25 (10-40)	38 (20-50)	63 (35-80)	58 (35-90)	30 (20-50)	30 (20-50)	8 (5-10)	18 (0-40)	20 (0-50)	45 (30-60)
Cover by loose stones (%)[2]	25 (5-70)	35 (5-90)	37 (20-56)	15 (0.5-30)	7 (5-8)	9 (0-30)	17 (1-40)	6 (0-15)	15 (0-40)	0.3 (0-0.5)	15 (0-30)
Cover by solid rock (%)[3]	1 (0-5)	1 (0-2)	38 (20-80)	6 (0-30)	44 (0-70)	0.3 (0-1)	1 (0-5)	1 (0-4)	26 (0-100)	17 (0-100)	0

* 50% of the plots in which grazing was found, this was caused by exotic grazers other than goats (viz. by pig and cow)

[1] 63 % of all cases in which goat presence was determined, was based on signs of goat presence in the direct vicinity of the plots.

[2] Cover of soil surface by loose stones

[3] Percentage of soil surface that consists of solid rock.

Table 5. Correlation between the classification of vegetation types and the classification of soil and land types according to VEENENBOS (1955). Results are based on plot and map data.

	SOIL and LAND TYPE / COVER														
	Soils of the uplands											Soils of the terraces and alluvial fans		Soils of the coastal lowlands	
	Medium deep soils					Stony rough land	Shallow soils							[a]	[b]
	Jl	Ja	Kc	Vs	Vc	Rs	Dm	Dx	Vs	En	Aa	Uc	Vz	Gs	Sd
VEGETATION TYPE															
Guapira-Capparidastrum type	2						8								
Bourreria-Eugenia type	3					3			3						
Erythroxylum-Cynophalla type				2		5	2		2						
Krugiodendron-Amyris type											10				
Pisonia-Eugenia type										8	3				
Leucaena-Antigonon type				2	2		2					2	2		
Botriochloa-Melochia type			3			4	2								
Lantana-Talinum type								10							
Ruellia-Melocactus type		7				3									
Laguncularia-Conocarpus type		2									3			2	3
Canavalia-Ipomoea type														10	

[a] Well drained soils

[b] Imperfectly and poorly drained mineral soils

Legend: + = cover less than 5%, 1 = cover 5-14%, 2 = 15-24% etc. 10 = 95-100%.
Column: Jl = Jacana loam; Ja = Jacana clay; Kc = Kool Baai clay loam; Vs = Vieques sandy loam; Vc = Vieques sandy loam, colluvial phase; Rs = Stony rough land; Dm = Descalabrado (stony) clay loam; Dx = Descalabrado stony clay loam, level phase; En = Ensenada loam; Aa = Aguilita stony clay, shallow phase; Uc = Cul-de-Sac clay loam; Vz = Vieques sandy clay loam; Gs = Guana Bay sand.

drought. The Jacana loam (Jl), a medium deep soil with well-developed subsoil and moderately drained, occurs only rarely (VEENENBOS 1955).

pH	7.7
HCl	-
slope	33° (19-43°)
exposure	se-wsw-nnw
# of species	43 (30-57)
total real cover	76 % (55-97 %)
height of shrubs/trees	2.1 m (0.1-3.4 m)

2 *BOURRERIA SUCCULENTA-EUGENIA PROCERA* TYPE (3 RELEVÉS)

This vegetation type resembles type 1, but is less diverse. The combined tree and shrub layer is the most important layer in cover percentage and is characterized by the presence of both deciduous and evergreen species. The only differentiating species is *Eugenia procera* (evergreen shrub/small tree) that occurs further only in type 1. Species in type 2 that are always present are: *Bourreria succulenta* (tree), *Cephalocereus royenii* (columnar cactus), *Commelina elegans* (herb) and *Randia aculeata* (tree/shrub). *Quadrella indica* (tree), *Leucaena leucocephala* (shrub/tree) *and Senegalia riparia* (shrub/tree) are also always present but are relatively less abundant. The following evergreen species have their highest presence in type 2: *Morisonia americana* (tree), *Schaefferia frutescens* (shrub/tree) and *Quadrella cynophallophora* (tree). Epiphytic *Tillandsia spp.* were common while herbs were rare. Only a limited number of species of vines occurs in type 2 which occurs on the lower parts of the steep slopes of the two most western hill ranges. All plots showed signs of hurricane damage while 70% had signs of human disturbance.

Three soil types occurred in about the same presence: Stony rough land (Rs), Vieques sandy loam, steep phase (Vs) or Jacana loam (Jl). A loose structure characterizes the shallow soils of the Vieques sandy loam soils and these soils are therefore more susceptible to erosion. The Jacanda soils at lower hillsides are medium deep (VEENENBOS 1955).

pH	6.7
HCl	-
slope	30° (27-35°)
exposure	se-sw-w
# of species	32 (29-35)
total real cover	61 % (55-70 %)
height of trees/shrubs	2.3 m (1.8-3.0 m)

3 *ERYTHROXYLUM ROTUNDIFOLIUM–CYNOPHALLA HASTATA* TYPE (6 RELEVÉS)

The relatively low combined tree and shrub layer is the most important layer. Two species are differentiating: *Cynophalla hastata* (shrub/tree) and *Pavonia spinifex* (herb). The following species are always present and have the highest abundance: *Erythroxylum rotundifolium* (tree/shrub), *Randia aculeata* (tree/shrub), and *Samyda dodecandra* (shrub/tree). *Guapira fragrans* (tree) and *Cephalocereus royenii* (columnar cactus) are also always present but relatively less abundant. The invasive *Leucaena leucocephala* (tree/shrub) occurs frequently while the shrubs *Lantana camara* and *Croton astroites* are highly concentrated in type 3. A significant number of vine species are important and three occur often: *Stigmatophyllon emarginatum*, *Rhynchosia reticulata* and *Centrosema virginianum*. The herb layer is of little significance while *Megathyrsus maximus* (grass species) is dominant and has its highest cover in type 3. The main *Tillandsia* species found in our sampling (*T. utriculata* and *T. recurvata*) play only a minor role. This vegetation type is found in the southern part of the middle and the whole eastern hill ranges. The presence of goats was detected in 50% of the plots and their direct surroundings. A third of the plots showed signs of past hurricane damage. No signs of human disturbance were noted probably due to lack of human habitation in the direct surroundings.

The main soil type is Stony rough land (Rs). Descalabrado (stony) clay loam (Dm) and less frequently also two types of Vieques sandy loam (Vs medium deep soils and Vs shallow soils) (VEENENBOS 1955).

pH	6.9
HCl	-
slope	27° (16-41°)
exposure	nnw-e-ssw
# of species	31 (16-44)
total real cover	69 % (58-86 %)
height of trees/shrubs	2.0 m (1.2-2.8 m)

4 *KRUGIODENDRON FERREUM-AMYRIS ELEMIFERA* TYPE (6 RELEVÉS)

Types 4 and 5 occur on limestone soils and have many (36) species in common. Type 4 is restricted to the calcareous Low Lands area and has the highest average height of all vegetation types in the present study. Six species are confined to types 4 and 5: *Eugenia procera* (shrub/tree), *Ipormoea eggersii* (vine), *Erithalis fruticosa* (shrub/small tree) *Jacquinia berteroi* (shrub/tree), *Scleria lithosperma* (Cyperaceae) and *Sideroxylon obovatum* (tree). Evergreen tree and shrub species play an important role in the combined tree and shrub layer that had the highest contribution to cover in type 4. The evergreen tree species *Krugiodendron ferreum* is dominant. Type 4 has the highest number of differentiating species. Five of the differentiating species are always present: *Amyris elemifera* (tree/shrub), *Eugenia foetida* (shrub/tree), *Maytenus elliptica* (tree), *Pithecellobium unguis-cati* (tree/shrub) and *Jacquinia berteroi* (tree). The other three differentiating species are also less common: *Gyminda latifolia* (shrub), *Passiflora suberosa* (a vine) and *Sideroxylon obovatum* (tree). *Plumeria alba* (tree) and *Tabebuia heterophylla* (tree) are concentrated in types 4 and 5. *E. foetida* and *G. latifolia* are exclusive species for type 4. Three other common species are also found: *Argithamnia candicans* (shrub), *Bourreria succulenta* (tree), and *Lantana involucrata* (shrub). The herb layer is very sparse (max. 2% cover) and consists mainly of a few grass species and seedlings of dicotyledons. The epiphyte *Tillandsia utriculata* is frequently present and abundant. Signs of past hurricane damage were detected in 60% of the plots. No presence of exotic grazers or human disturbance was detected.

The soil type is only Aguilita stony clay (shallow phase) (Aa), derived from soft (Young-Tertiary) limestone and has no distinct subsoil. It has a rapid internal drainage and the thickness of the topsoil ranges from about 6 inches to over one foot and locally may be very stony. During long dry periods it suffers severely from drought (VEENENBOS 1955).

pH	7.6
HCl	±
slope	11° (0-25°)
exposure	s-ssw
# of species	30 (23-35)
total real cover	73 % (60-90 %)
height of trees/shrubs	2.6 m (1.9-3.4 m)

5 *PISONIA SUBCORDATA-EUGENIA RHOMBEA* TYPE (4 RELEVÉS)

This type is found in the Low Lands area as well as on Billy Folly. This type has no differentiating species. A combined tree and shrub layer is the most important structural layer in cover percentage. The average vegetation height and cover are lower n comparison with type 4. Type 5 is very similar to type 4 in number of plant species and has many species (36) in common with type 4. Six species that are confined to types 5 and 4 (see type 4). *Plumeria alba* (tree) and *Tabebuia heterophylla* (tree) are concentrated in types 5 and 4. Type 5 lacks however three (evergreen) species that are differentiating in type 4: *Eugenia foetida* (tree), *Maytenus laevigata* (tree), and *Gyminda latifolia* (shrub). The deciduous trees *Pisonia subcordata* and *T. heterophylla, the evergreen shrub/tree Eugenia rhombea* and the columnar cactus *Cephalocereus royenii* play a more important role in type 5 as compared to type 4. *Eugenia rhombea* and *Pisonia subcordata* are dominant in type 5. *Bourreria succulenta* (tree), *Lantana involucrata* (shrub) and *T. heterophylla* (tree) are abundant. The herb layer has a very low cover (2-5 %). 75 % of the plots showed past hurricane damage while no signs were observed of grazing by exotic grazers. Signs of human disturbance were noted in 25 % of the plots.

Type 5 occurs on two soil types of which the Ensenada loam (En) is much more prominent than the Aguilita stony clay (Aa). Ensenada loam occurs mostly in the Low Lands area and is derived from hard coral limestone (Young Tertiary) and has a gently sloping or undulating relief. Generally speaking it is little more than bare rock covered with only 2.5 or 5 cm of soil. The soil has a very rapid internal drainage (VEENENBOS 1955). Billy Folly consists of the Ensenada loam and has the two lowest pH values measured (pH 4) and this is probably the result of the influence of the humus layer on the thin soil. Aguilita stony clay occurs on higher elevations and is deeper as compared to the Ensenada loam and has a rapid internal drainage (VEENENBOS 1955).

pH	6.0
HCl	-
slope	20° (10-42°)
exposure	wnw-ne-sse-ssw
# of species	28 (24-35)
total real cover	58 % (52-63 %)
height of trees/shrubs	2.5 m (2.0-3.2 m)

6 *LEUCAENA LEUCOCEPHALA-ANTIGONON LEPTOPUS* TYPE (5 RELEVÉS)

The combined tree and shrub layer is the layer with the highest contribution to cover in this type that is characterized by the presence of substantial numbers of spiny species and vine species. The average total real cover of type 6 is among the three highest of the present vegetation types. There are four differentiating species: *Petiveria alliacea* (herb), *Pisonia aculeata* (woody vine), *Antigonon leptopus* (vine) and *Vachellia macracantha* (tree). *Leucaena leucocephala* (tree/shrub) is the dominant species and reaches its highest cover in the present type The herb layer is relatively open. Type 6 represents a highly degraded vegetation due to the following three factors: 1) the presence of several invasive species (*L. leucocephala*, *A. leptopus* and *Jasminum fluminense* (vine)) (LANGELAND ET AL. 2008); 2) 80 % of the plots had signs of exotic grazers (goats/cows/pigs) in or just outside the plots; and 3) 40 % of the plots showed signs of human disturbance. With respect to hurricane damage it must be said that this was detected in 60 % of the plots; 4) absence or poor representation of characteristic tree species.

This vegetation type occurs mainly in the valley of Belvedère, but also in other lower parts of the Hills landscape (see paragraph 4.2). Five soil types are equally important as substrate for the present vegetation type. Both the typical Vieques sandy loam (Vs) and its colluvial phase (Vc) are present besides the Vieques sandy clay loam (Vz), Descalabrado stony clay loam (Dm), and Cul-de-Sac clay loam (Uc) (VEENENBOS 1955).

pH	6.7
HCl	n.m.
slope	11° (0-30°)
exposure	n-se
# of species	25 (17-37)
total real cover	72 % (64-83 %)
height of trees/shrubs	1.7 m (0.9-2.4 m)

7 *BOTHRIOCHLOA PERTUSA-MELOCHIA TOMENTOSA* TYPE (5 RELEVÉS)

The combined shrub and herb layer is the most important layer in this type. Type 7 has no differentiating species and is characterized by the presence of a significant number of herb species. The two species that has the highest cover in this type are grass species: *Bothriochloa pertusa* and *Megathyrsus maximus*. The vine *Stigmatophyllum emarginatum* is abundant while the shrub *Melochia tomentosa* occurs frequently. In type 7 *M. tomentosa* reaches its highest abundance. The low shrub *Ayenia pusilla* has its highest presence and abundance in type 7. This type is found in patches in the hilly parts of St. Maarten and often on former pasture land.

Signs of past hurricane damage were detected in 33 % of the plots and signs of grazing in 20 % of the plots. Signs of human disturbance were found in 17% of the plots.

The main soil type is Stony rough land (Rs) (VEENENBOS 1955), but type 7 is also found on Kool Baai clay loam (Kc) and less on Descalabrado (stony) clay loam (Dm).

pH	6.7
HCl	n.m.
slope	15° (0-29°)
exposure	e-se-s
# of species	16 (4-25)
total real cover	61 % (35-80 %)
height of shrubs/herbs	0.8 m (0.4-1.2 m)

8 *LANTANA INVOLUCRATA-TALINUM FRUTICOSUM* TYPE (4 RELEVÉS)

The herb layer is the layer with the highest cover. However, shrubs, especially spiny species, together with herb species determine the appearance of this low vegetation type. Type 8 is restricted to the península of Fort Amsterdam and has five differentiating species: *Talinum triangularis* (herb), *Opuntia triacanthos* (cactus), *Commicarpus scandens* (herb) *Vachellia tortuosa* (shrub/tree) and *Cuscuta spec.* (vine). *T. triangularis* is exclusive of type 8 and dominant in the herb layer. *Lantana involucrata* is dominant in the shrub layer while *Stigmatophyllon emarginatum* (vine) and the herbs *Commicarpus scandens* and *O.triacanthos* are always present. *Melochia tomentosa* is frequently present. The abundance of *O. triacanthos* and *V. tortuosa* in type 8 is indicative of grazing by exotic grazers and other anthropogenic activities (COBLENTZ 1978; BEERS ET AL. 1997; DEBROT & DE FREITAS 1993). Signs of past hurricane damage were seen in 50 % of the plots. Signs of human disturbance were observed in 50 % of the plots but no signs of grazing by exotic mammals were seen at present. The latter can be explained by the isolated position of the peninsula.

The soil is of the Descalabrado stony clay loam type (Dm), which is very susceptible to drought (VEENENBOS 1955). The relatively high pH indicates the presence of calcareous materials.

pH	8.1
HCl	-
slope	7° (5-8°)
exposure	s-ssw-w
# of species	13 (11-14)
total real cover	63 % (40-80 %)
height of shrubs/herbs	0.7 m (0.3-1.0 m)

9 *RUELLIA TUBEROSA-MELOCACTUS INTORTUS* TYPE (9 RELEVÉS)

The herb layer is the main structural layer because it contributes most to cover. Type 9 represents a low herb and grass vegetation of coastal plains and cliffs with an eastern exposure that stretches from Guana Bay Point to Pointe Blanche. The vegetation has relatively high cover percentages on the coastal plains but is very open (≤ 5 % cover) on the cliffs. There are three differentiating species: *Galactia dubia* (vine), *Melocactus intortus* (cactus) and *Portulaca teretifolia* (herb). The latter species is exclusive to type 9. The herb *Ruellia tuberosa* is the only species that is always present, but the grass *Sporobolus virginicus* is the species with the highest cover. Signs of past hurricane damage are present in 11 % of the plots. Human disturbance was noted in 44 % of the plots.

Type 9 is found on two soil types. The main soil type is a medium deep Jacana clay soil (Js), while Stony rough land (Rs) is of lesser importance. Run-off is very rapid on the first-mentioned soil type that suffers rather severely from sheet erosion (VEENENBOS 1955).

pH	6.2
HCl	-
slope	30° (8-65°)
exposure	n-e-s
# of species	12 (1-24)
total real cover	50 % (<1-90 %)
height of herbs/shrubs	0.3 m (0.1-1.0 m)

10 *LAGUNCULARIA RACEMOSA-CONOCARPUS ERECTUS* TYPE (6 RELEVÉS)

The combined tree/shrub layer is the layer that contributes most to cover. The low species number is characteristic for the mangrove vegetation in the Caribbean area. The common New World mangrove species are also found in the mangrove areas of St. Maarten: *Rhizophora mangle*, *Avicennia germinans*[8] and *Laguncularia racemosa*. It is mainly found in the Low Lands area and near the Boundary Monument. There are two differentiating species: *L. racemosa* (tree) and *Conocarpus erectus* (tree). Two other characteristic mangrove tree species (*R. mangle and A. germinans*) have a very low presence in this type. *A. germinans* is only found near the Boundary Monument and is dominant there. A number of halophytes (herbs and woody species) are found in the drier parts of this type. *Thespesia populnea* is a naturalised species (WARRIER 2010) that is often associated with mangrove ecosystems as is the case in the present type. The average pH of type 10 is the second highest within the present study. In a large portion (83 %) of the plots dead mangrove trees were seen as the result of damage by hurricane Luis (1995) (ROJER 1997). This is partially reflected by the relatively low average cover (see BEERS ET AL. 1997; DE FREITAS ET AL. 2005).

Type 10 occurs on four soil types: Serrano sandy clay loam (Sd), Aguilita (very) stony clay (Aa), Guana Bay sand (Gs) and Jacana clay types (Ja). The Serrano sandy clay loam is a very poorly drained soil. The Guana Bay sand is a very fine sandy deposit, where the land appears hummocky (VEENENBOS 1955).

[8] Old name of this species is *Avicennia nitida* (AXELROD 2011).

pH	8.3
HCl	+
slope	4° (0-14°)
exposure	s-nnw-n
# of species	9 (3-16)
total real cover	46 % (16-70 %)
height of trees/shrubs	1.9 m (0.2-2.9 m)

11 *CANAVALIA ROSEA-IPOMOEA PES-CAPRAE* TYPE (2 RELEVÉS)

This type is characterized by a combined shrub and herb layer. This beach vegetation type has a very low species diversity and is only found in Guana Bay. Two vines are the differentiating species: *Canavalia rosea* and *Ipomoea pes-caprae*. The first one is the dominant species while *I. pes-caprae* is abundant. Three other shrubs play a role of significance in type 11: *Cynophalla flexuosa*, *Coccoloba uvifera* and *Solanum bahamense*. STOFFERS (1956) indicated that *C. uvifera* is a prominent species of the littoral woodland. *Hippomane mancinella* was only found in this type. All plots show signs of past hurricane damage and may explain the low height of the shrubs. Especially category five hurricane Luis (1995) was devastating to the island of St. Maarten. No signs of grazing or other disturbance are present in this type.

The soil is only of the Guana Bay sand type (Gs) and had the highest pH value of all types.

pH	8.5
HCl	+
slope	5° (0-9°)
exposure	ssw
# of species	10 (7-12)
total real cover	36 % (30-42 %)
height of shrubs	0.9 m (0.7-1.0 m)

4.1.1 ADDITIONAL REMARKS ON THE RELATIONSHIP BETWEEN THE DESCRIBED VEGETATION TYPES AND SOIL TYPES

Three of our vegetation types turn out to be strictly soil specific (Table 7): *Krugiodendron-Amyris* type (type 4) is only found on Aguillita stony clay, shallow phase that only occured in the Low Lands area; *Lantana-Talinum* type (type 8) is confined to Descalabrado stony clay loam, level phase; and the *Canavalia-Ipormoea* type (type 11) is only found on Guana Bay sand. The majority of vegetation types in St. Maarten occur on non-calcareous soils but deep soil profiles are lacking on St. Maarten (VEENENBOS, 1955). The medium-deep soils occur in the valleys and were formerly planted with sugar cane and later with food crops and later also taken up by urban development. It is not clear to what extent the shallowness of the soils on the hills has hampered the development of real forest on those hills (see e.g. DUNPHY ET AL. 2000). Of the three hill ranges the eastern range is the one with the least soil development (Stony rough land; VEENENBOS, 1955). It is not clear to what extent the low stature of the *Erythroxylum-Cynophalla* type (type 3) in this area is influenced by the shallowness of the soil or that other factors also play a role or are determinant (e.g. trade wind, hurricanes, grazing by mammalian grazers and/or anthropogenic activities).

4.2 DESCRIPTION OF THE FINAL LEGEND UNITS

Based on the results obtained the main legend of the landscape ecological vegetation map of St. Maarten is divided into four different landscape types (Hills, Low Lands, Cliffs and Beaches), which are subdivided on the basis of differences in the vegetation (Fig. 5). The names of the legend units refer to both terrain features and vegetation types. Table 6 gives a summary of the relative occurrence of the vegetation types in each (sub-)landscape type.

Below we describe the landscape and legend units that we have distinguished. A photo of each is presented in Appendix 4.[9] The surface area of each unit is shown in Appendix 5.

H HILLS

The largest part of St. Maarten consists of hills. These rather steep hills are arranged in three parallel north-south oriented ranges with a maximum height of 380.6 m, enclosing the two valleys of Cul-de-Sac and Middle Region. On significant parts of the hills, infrastructure is developed, gradually pushing the edge of the areas of natural vegetation higher.

H1 *GUAPIRA-CAPPARIDASTRUM HILLS*

This sub-landscape is found on the higher parts of the two most western hill ranges and a few relatively (much) smaller areas in the eastern hill range. H1 occurs on the western and eastern side of the Sentry Hill range, while on the Williams Hill range it is mostly found on the western (leeward) side. The dense vegetation consists of the *Guapira-Capparidastrum* type (type 1).

H2 *ERYTHROXYLUM-BOURRERIA HILLS*

The *Erythroxylum-Bourreria* landscape is restricted to the southern part of the Williams Hill range. The vegetation consists of shrubs and small trees overtopped with some scattered higher trees. It consists of the *Erythroxylum-Cynophalla* type (type 3) and to a lesser extent of the *Bourreria- Eugenia* (type 2) and *Leucaena-Antigonon* type (type 6).

H3 *ERYTHROXYLUM-PISONIA HILLS*

This sub-landscape is widespread on the island and is found on Billy Folly, on Fort Hill and on the western and eastern hill ranges. The mostly shrubby vegetation of these areas differs in composition. On Billy Folly a limestone vegetation of the *Pisonia-Eugenia* type (type 5) occurs, while on the Sentry Hill range and Cay Bay Hill a *Bourreria-Eugenia* vegetation (type 2) is present. An *Erythroxylum-Cynophalla* vegetation (type 3) is found on Fort Hill and on the most

[9] Photos were taken by VROM personnel based on a number of GPS coordinates of the units on our map.

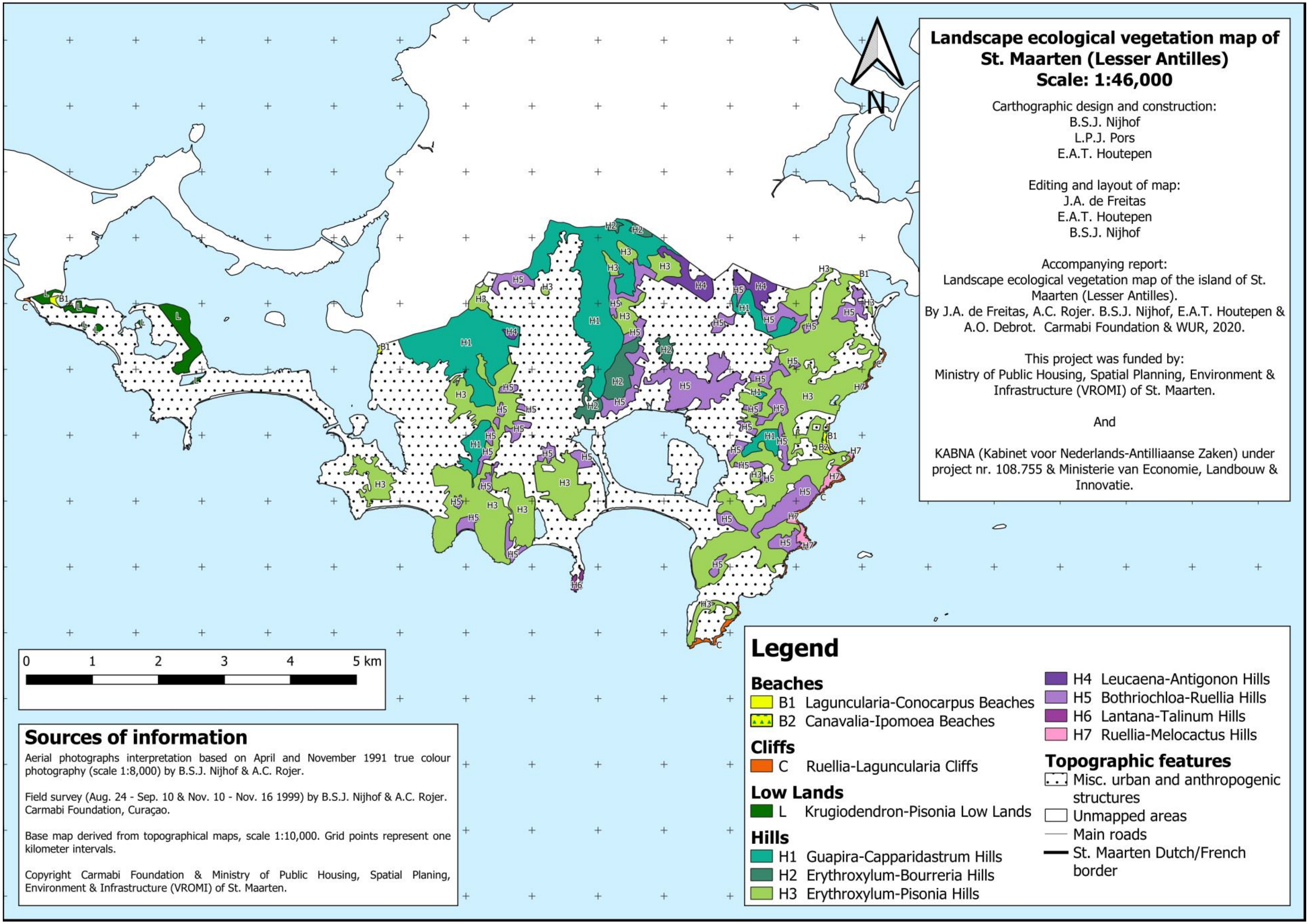

Figure 5. Landscape ecological vegetation map of St. Maarten (1:46,000).

Table 6. Estimated cover of plant communities in the different (sub)landscape units. Based on plot data, field observations and photo-interpretation.

		Vegetation Type										
		Guapira-Capparidastrum type	Bourreria-Eugenia type	Erythroxylum-Cynophalla type	Krugiodendron-Amyris type	Pisonia-Eugenia type	Leucaena-Antigonon type	Botriochloa-Melochia type	Lantana-Talinum type	Ruellia-Melocactus type	Laguncularia-Conocarpus type	Canavalia-Ipomoea type
		1	2	3	4	5	6	7	8	9	10	11
Landscape Unit	**symbol**											
Guapira-Capparidastrum Hills	H1	10										
Erythroxylum-Bourreria Hills	H2		3	5			2					
Erythroxylum-Pisonia Hills	H3		3	4		3						
Leucaena-Antigonon Hills	H4						10					
Bothriochloa-Ruellia Hills	H5			1			1	6		2		
Lantana-Talinum Hills	H6								10			
Ruellia-Melocactus Hills	H7							1		9		
Krugiodendron-Pisonia Lowlands	L				7	3						
Ruellia-Laguncularia Cliffs	C									7	3	
Laguncularia-Conocarpus Beach	B1										10	
Canavalia-Ipomoea Beach	B2										3	7

Legend: + = cover less than 5%, 1 = cover 5-14%, 2 = 15-24% etc.; 10 = 95-100%.

eastern hill range of Naked Boy Hill. The difference in the occurrence of the vegetation types is a reflection of the differences in soil types.

H4 *LEUCAENA-ANTIGONON HILLS*

This sub-landscape is restricted to the lower parts of Bethlehem and Belvédère, which are situated between the most northern parts of the Williams Hill range and Naked Boy Hill range. It consists entirely of an open high spiny shrub vegetation of the *Leucaena-Antigonon* type (type 6) that is characterized by the frequent presence of vines. During the rainy season parts of this area become swampy.

H5 *BOTHRIOCHLOA-RUELLIA HILLS*

This sub-landscape occurs all over the hilly areas of St. Maarten. It is mostly found as smaller areas bordering urban areas. The main vegetation is the low shrubby *Bothriochloa-Melochia* type (type 7). Three other vegetation types occur rarely: the low herbaceous *Ruellia–Melocactus* type (type 9) and two of the higher woody vegetation: *Leucaena-Antigonon* (type 6) and *Erythroxylum-Cynophalla* type (type 3).

H6 *LANTANA-TALINUM HILLS*

This sub-landscape is restricted to the peninsula of Fort Amsterdam. The aspect of the low *Lantana-Talinum* type (type 8) is characterized by herbaceous and spiny species.

H7 *RUELLIA-MELOCACTUS HILLS*

This *Ruellia-Melocactus* landscape is only found along the eastern coast on the lower parts of the most eastern hill range (Naked Boy Hill range, near Guana Bay Point, and just behind the cliff area between Back Bay and Geneve Bay). A low herb vegetation determines the appearance of this sub-landscape. It consists almost exclusively of the *Ruellia-Melocactus* type (type 9) and rarely of the *Bothriochloa-Melochia* type (type 7).

L LOW LANDS

The Low Lands area is found on the western leeward side of St. Maarten, surrounding Simpson Bay Lagoon. It is characterized by relatively low hills with a flat appearance, many bays and a calcareous soil. In large areas significant development of urban and industrial infrastructure has taken place and this explains why this landscape is very fragmented.

L1 *KRUGIODENDRON-PISONIA LOW LANDS*

This sub-landscape type occurs in the Low Lands area and has its most significant presence to the east of Mullet Pond. It represents fragments of the original landscape. The relatively high and dense vegetation mainly consists of the *Krugiodendron-Amyris* type (type 4) and sometimes of the *Pisonia-Eugenia* type (type 5).

C CLIFFS

C *RUELLIA-LAGUNCULARIA CLIFFS*

The Cliffs landscape occurs for the largest part along the eastern coast of St. Maarten. The steepness and elevation of the terrain varies widely. The vegetation cover is low and consists mainly of the *Ruellia-Melocactus* type (type 9). In its lower parts this landscape is characterized by the occasional presence of the *Laguncularia-Conocarpus* type (type 10).

B BEACHES

The Beach landscape is found along Simpson Bay Lagoon and some parts of the eastern coast. In the past beach areas occurred more extensively but over time these areas were disturbed due to their use for recreation. Along the eastern coast of the island we have mapped this type in the coastal areas of Guana Bay and Oyster Pond. Two small sub-landscape types have been distinguished.

B1 *LAGUNCULARIA-CONOCARPUS BEACHES*

This sub-landscape is found bordering water, e.g. near Cupecoy, the Boundary Monument and Oyster Pond. The vegetation consists of only the *Laguncularia-Conocarpus* type (type 10), and is flooded every now and then.

B2 *CANAVALIA-IPOMOEA BEACHES*

The *Canavalia-Ipomoea* sub-landscape is only found along the eastern coast of the island near Guana Bay, on the lower parts just behind a sandy beach. Its vegetation is mainly of the *Canavalia-Ipomoea* type (type 11) and in the wetter parts of the area of the *Laguncularia-Conocarpus* type (type 10).

CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1 STATUS OF TERRESTRIAL NATURE ON ST. MAARTEN

St. Maarten is part of the Caribbean biodiversity hotspot (Fig. 6), one of the 25 biodiversity hotspots in the world (CINCOTTA & ENGELMAN 2000; MYERS ET AL. 2000; HELMER ET AL. 2002; BOS ET AL. 2018). The SSS islands and Saba Bank together possess 223 endemic animals and plants (32 subspecies, 191 species) of which 35 are endemic to the SSS islands and Saba Bank, 15 are endemic to the Northern lesser Antilles, 110 to the Lesser Antilles and 58 to the Greater and Lesser Antilles combined (BOS ET AL. 2018).

Fig. 6. Caribbean "biodiversity hotspot" (incl. St. Maarten). (Source:http://www.biodiversityhotspots.org/xp/Hotspots/-caribbean/Pages/default.aspx)

The type of dry lowland forests (woodlands) present on St. Maarten further belongs to the most threatened ecosystems in Latin America and worldwide (CEBALLOS & GARCIA 1995; IMBERT & PORTECOP 2008; TOMS ET AL. 2012; FRANKLIN ET AL. 2015; VAN ANDEL ET AL. 2016) and has also been insufficiently studied (MURPHY & LUGO 1986; DUNPHY ET AL. 2000; MILES ET AL. 2005; TOMS ET AL. 2012; FRANKLIN ET AL. 2015). The high species richness and endemicity is further accompanied by a large and complex foodweb in the terrestrial ecosystem (GOLDWASSER & ROUGHGARDEN 1993). This uniqueness, and complexity at a small island scale likely makes the ecosystem and the species depending on it especially vulnerable to factors such as habitat loss, loss of key species, climate change, and invasive species which also interact with each other and help to exacerbate negative effects (DEBROT & BUGTER 2010, BRANDEIS ET AL. 2009).

5.2 COMPARISON OF STOFFERS' (1956) PLANT COMMUNITIES AND THOSE OF THE PRESENT STUDY

STOFFERS (1956) used the classification of BEARD (1944, 1949) for the tropical vegetation of the broader Caribbean region and divided the plant communities of the three Dutch Windward Islands (Saba, St. Eustatius and St. Maarten) in two main categories of climax communities, namely: "Climatic climax communities" and "Edaphic climax communities". For St. Maarten STOFFERS (1956) distinguished 17 different vegetation types of which he classified eight as primary climax communities: "Semi-evergreen seasonal forest", "Evergreen bushland", "Littoral woodland", "Mangrove woodland", "Herbaceous strand community", "Strand scrub community", "Vegetation of the salt flats" and "*Hippomane* woodland".

A comparison is possible between our results and STOFFERS' (1956) results despite the differences in methods used. This comparison (see Table 7) reveals that three vegetation types in the present research correspond very well with one secondary community and two climax communities of STOFFERS (1956), both in structure and ecological specialization as well as in species composition. Type 3 (*Erythroxylum-Cynophalla* type) fits STOFFERS' Woodland derived from dry evergreen forest, type 4 (*Krugiodendron-Amyris* type) corresponds well with the dry Evergreen bushland and type 10 (*Laguncularia-Conocarpus* type) corresponds with the Mangrove woodland (STOFFERS 1956). Other vegetation types correspond with STOFFERS' (1956) communities only in certain aspects.

In the present study we found an abundance of *Opuntia triacanthos* only in vegetation type 8. Low presence of this species was seen in five other vegetation types in the present study. A possible explanation for the difference in abundance of *Opuntia* plants between the present study and STOFFERS' is the introduction and impact of the cactus moth *Cactoblastis cactorum* in St. Maarten. Between 1957 and 1970 this insect was introduced in Nevis, Montserrat, Antigua and Grand Cayman with the purpose to control *Opuntia* spp. which were considered noxious weeds on those islands. From those islands it spread possibly in a natural way to different other Caribbean islands including St. Maarten (FRANK & McCOY 1995; ZIMMERMAN ET AL. 2000; ZIMMERMAN ET AL. 2004) and may account for the apparent reduction in prevalence of this species.

Types 1 and 2 fit quite well STOFFERS' (1956) 'Secondary woodland derived from deciduous seasonal formations'[10]. According to STOFFERS (1956) the majority of the species of the shrubby lower trees are evergreen and a few have simple leaves. He also states that the majority of the higher trees are evergreen while a few have compound leaves. We did not find a higher tree layer in the present study. However, we quite often found in the tree/shrub layer three of the six species of STOFFERS' higher layer in type 1 (*Guapira fragrans*, *Morisonia*

[10] For this type of vegetation on the slopes of Cul de Sac, STOFFERS (1956) specifically remarks: 'This area was undoubtedly once covered by a type of seasonal forest, which was probably intermediate between semi-evergreen and deciduous in character.'

americana,and *Tabebuia heterophylla*) and two in type 2 (*G. fragrans* and *M. americana*). The trees in the combined tree/shrub layer of both types in the present study are shrubby and evergreen and this is in accordance with the characteristics of the lower trees in STOFFERS' (1956) community. *Myrtaceae* spp. are frequently found in the shrub layer according to STOFFERS (1956). In the present study *Myrtaceae* are rather well-represented in type 1 in the shrub layer or combined tree/shrub layer with four species, but less in type 2 (only one species). *Tillandsia utriculata* and *T. recurvata* occurs frequently in both types and this coincides with STOFFERS' finding that epiphytes occur at higher elevations. However, *Tillandsia* spp. are also found at lower elevations in the present study. We did not find the abundance of *Opuntia* plants that STOFFERS (1956) reported. We only found *Opuntia triacanthos* to occur occasionally in type 2. In conformity with the findings of STOFFERS (1956) we also found the occurrence of common weeds among the herbs and lower shrubs.

The relative high cover and shrubby character of type 3 fits STOFFERS' (1956) Woodland derived from dry evergreen forest in structure and ecological specialization and species composition. A good deal of the trees and shrubs are evergreen and this is also in conformity with STOFFERS' (1956) description. All tree and shrub species mentioned by STOFFERS (1956) in the general description of this woodland are present in type 3 with the exception of *Pithecellobium unguis-cati*. Hence type 3 fits STOFFERS' (1956) community notably well.

Type 4 closely fits STOFFERS' category of 'Dry evergreen bushland' while type 5 less so. In conformity with STOFFERS (1956) we also found that many species have shiny, hard or fleshy leaves and that both types occur on limestone and lack a definite stratification. STOFFERS (1956) mentioned the following characteristic species for the evergreen bushland: *Canella winterana*[11], *Jacquinia berteroi*, *Phyllanthus epiphyllanthus*, *Samyda dodecandra*, *Coccoloba krugii* and *Ernodea littoralis*. We did not find *S. dodecandra* nor *E. littoralis* in the present study. *J. berteroi* and *P. epiphyllanthus* were found in both types, while *C. winterana* and *C. krugii* occur in type 4 but not in type 5. STOFFERS (1956) mentioned that *Tillandsia* is the only epiphyte in the evergreen bushland, and in the present study this is true for type 4; in type 5 we found also two other bromeliad species but with a (very) low presence. The presence of a limited number of vines and prickly species mentioned by STOFFERS (1956) was also found during the present research, although type 5 has twice more spiny species as compared to type 4. STOFFERS (1956) found only a few spiny species and we found these in types 4 and 5: *Comocladia dodonaea*,[12] *Pithecellobium unguis-cati* and *Sideroxylon obovatum*[13]). One *Acacia* species was only found in type 5 but with a low presence. The three deciduous species *Plumeria alba*, *Bursera simaruba* and *Tabebuia heterophylla*, mentioned by STOFFERS (1956) are also abundantly present in types 4 and 5. In conformity with STOFFERS (1956), we also found that the herb layer in both types is poor in cover and consists mainly of a few grass and/or sedge species.

[11] Old name of this species is *Canella alba* (HOWARD 1989a).
[12] Old name of this species is *Comocladia ilicifolia* (AXELROD 2017).
[13] Old name of this species is *Bumelia obovata* (AXELROD 2017).

Based on its structure and species composition we can conclude that type 6 corresponds quite well with STOFFERS' (1956) 'Thorny woodland derived from seasonal formations'. Abundance of *Vachellia macracantha*[14] and the presence of two other *Acacia* species[15] in the present study are in accordance with the important role of *Acacia* species in this woodland as described by STOFFERS (1956). A high number of other spiny species also occurs in type 6. STOFFERS (1956) noted that *Malpighia emarginata*[16] and *Randia aculeata* can be abundant. In the present study both species are present, but only *R. aculeata* is abundant. *Opuntia* is absent in type 6 and this differs from STOFFERS (1956).

The *Bothriochloa-Melochia* type (type 7) and *Lantana-Talinum* type (type 8) resemble '*Croton* thickets derived from seasonal formations' (STOFFERS 1956) rather well in structure (including height and cover) but not much in floristic aspects. These thickets are considered the most impoverished of communities that are found on the driest, poorest and most degraded sites (STOFFERS 1956). In the present study *Croton spp.* are not abundant but the principal species of the shrub layer are *Melochia tomentosa (types 7 and 8) and Lantana involucrata* (type 8). *Croton astroites* was present in low frequencies in both types, while *Croton flavens* was absent. In conformity with STOFFERS (1956) *Solanum racemosum* was present in both types (with a low presence). The presence of *Opuntia* in types 7 and 8 fits STOFFERS' findings. *Conocarpus erectus* was described by STOFFERS (1956) as a very occasional species, but did not form part of any of the two types in our study. *Melocactus* was described by STOFFERS (1956) as an associated species of this community. In the present study *M. intortus* is occasionally present in type 8 but absent in type 7. '*Corchorus*' is mentioned as an associated species by STOFFERS (1956) and at present *C. aestuans* is occasionally present in types 7 and 8 but *Corchorus hirsutus* is absent. According to STOFFERS (1956) the shrubs were overtopped by a few scattered specimens of *Acacia*, *Plumeria* and *Malpighia*. Two species of *Vachellia*[17] are found in both types in the present study while the abundance of one of the two *Vachellia* species in type 8 is opposite to the absence of *Acacia* spp. STOFFERS (1956) described. The*Vachellia* spp. in the present study are lower in height than in STOFFERS (1956). Finally, *Plumeria alba* is not present in any of our two types while *Malpighia* occurs with a low frequency in both types.

Type 9 has some resemblance to STOFFERS' (1956) Vegetation of the rocky slopes. Type 9 is less variable in structure as compared to STOFFERS (1956) and contains fewer trees. Of the species and genera mentioned by STOFFERS (1956) we only found the following species in the present study: *Opuntia triacanthos*, *Melocactus intortus*, *Croton astroites*, *C. flavens*, *Plumeria alba* and *Jacquinia armillaris*[18]. *Euphorbia petiolaris* occurred in STOFFERS' (1956) category frequently but is absent in our type 9. *Ruellia tuberosa* is abundant in type 9 but is not mentioned in STOFFERS (1956) for the category considered.

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[14] Old name of this species is *Acacia macracantha* (AXELROD 2017).
[15] *Vachellia tortuosa* and *Senegalia riparia* (AXELROD 2017)..
[16] Old name of this species is *Malpighia punicifolia*.
[17] Old name used by STOFFERS (1956) is *Acacia*.
[18] Old name of this species is *Jacquinia barbasco* (Axelrod 2017).

Vegetation type 10 corresponds well with the Mangrove woodland of STOFFERS (1956). In the better-developed mangrove systems *Rhizophora mangle* occupies the pioneer zone in the shallow and calm water. According to STOFFERS (1956) dominance of *Laguncularia racemosa* might be the result of anthropogenic activities, a factor that according to him has strongly affected the mangrove system on St. Maarten We found dominance of *L. racemosa* in our type 10 and this likely reflects the fact that the mangroves on St. Maarten at present are still subjected to anthropogenic activities. *Avicennia germinans* occurs in the present study only near the Boundary Monument. In conformity with STOFFERS (1956) we also found that the mangrove ecosystem on St. Maarten is associated with halophytic shrub and herb species of which we found quite a number. We found two of the three halophytic species specifically mentioned by STOFFERS (1956) (*Batis maritima* and *Sporobolus virginicus*) but we did not find *Eleocharis geniculata*[19] in the present study.

Type 11 corresponds somewhat with STOFFERS' category of Herbaceous strand community. STOFFERS (1956) mentions that this category on the SSS islands is best developed in St. Maarten. We found *Ipomoea pes-caprae* and *Canavalia rosea*[20] as the two prominent species and this fits STOFFERS' (1956) description. We did not find *Cakile lanceolata* nor *Lepidium virginicum* which are associated species specifically mentioned by STOFFERS (1956). Two other prominent associated species at present are worth mentioning: *Coccoloba uvifera* and *Hippomane mancinella*. *C. uvifera* is sometimes dominant in the present study and is a characteristic species of the Littoral woodland (e.g. STOFFERS 1956; BEERS ET AL. 1997).

In the present research we did not find a number of STOFFERS' (1956) communities. This might have been due to their being too small or disturbed to be mapped. These communities are the '*Hippomane* woodland', 'Strand scrub community', 'Vegetation of the rock pavement' and 'Vegetation of the salt flats'. These are largely at low elevations and close to the coast in areas most vulnerable to disturbance by man. Anthropogenic activities on St. Maarten resulting in negative impacts on nature is in a large part the result of the impact of development pressure based on the explosive growth of tourism as main economic development and related population growth.

Table 7. Comparison of the plant communities as described by STOFFERS (1956) with the ones found in the present study.

CLIMATIC COMMUNITIES (STOFFERS 1956)	**PRESENT STUDY**
Seasonal formations	
Semi-evergreen seasonal forest (XI)	
Secondary woodland derived from seasonal formations	Megathyrsus-Capparidastrum type (Type 1) Bourreria-Eugenia type (Type 2)
Thorny woodland (XIII)	Leucaena-Antigonon type (Type 6)
Leucaena thicket (XIV)	Related to types 1, 3 and 6

[19] Old name of this species is *Eleocharis caribaea* (Axelrod 2011).
[20] Old name of this species is *Canavalia maritima* (Axelrod 2017).

	Croton thickets (XV)	Bothriochloa-Melochia type (Type 7) Lantana-Talinum type (Type 8)
Dry evergreen formations		
	Woodland derived from dry evergreen forest (XVII)	Erythroxylum-Cynophalla type (Type 3)
	Evergreen bushland (XVIII)	Krugiodendron-Amyris type (Type 4) Pisonia-Eugenia type (Type 5)
	Thorny woodland (XIX)	
	Croton thickets (XX)	
	Littoral woodland (XXI)	related to Type 11
	Vegetation of the rock pavement (XXII)	
	Vegetation of rocky slopes (XXIII)	Ruellia-Melocactus type (Type 9)
EDAPHIC COMMUNITIES		
	Mangrove woodland (XXIV)	Laguncularia-Conocarpus type (Type 10)
	Herbaceous strand community (XXV)	Canavalia-Ipomoea type (Type 11)
	Strand scrub community (XXVI)	
	Hippomane woodland (XXVIII)	
	Vegetation of the salt flats (XXVII)	

5.3 COMPARISON OF OUR MAP WITH THE MAP OF STOFFERS (1956)

What follows is a comparison of our map (Fig. 5) with that of STOFFERS (1956). In the Low Lands area in the west of the island STOFFERS (1956) found quite large areas of ‘Dry evergreen bushland’ and ‘Thorny woodland derived from dry evergreen formations’. At present only a few small areas that include the two vegetation types (of Landscape unit ‘L’ on our map) that correspond with STOFFERS’ (1956) Dry evergreen bushland remain. It is clear that the whole area of Thorny woodland derived from dry evergreen formations in the Low Lands area has disappeared and has been replaced by residential areas and infrastructure for tourism and recreational use. Two other areas of this formation can be found on STOFFERS’ (1956) map: to the north of Cay Bay and to the west of Oyster Pond. On our map these areas are mainly H3 areas with a few relatively smaller H5 areas. Based on the vegetation type found in H3 to the north of Cay Bay we can conclude that the character of the vegetation at present is no longer that of a ‘Thorny woodland derived from dry evergreen formations’ but that of a ‘Secondary woodland derived from seasonal formations’ (STOFFERS 1956). The H5 areas are characterized in most instances by a relatively low, shrubby vegetation with occasionally some scattered lower trees and in very few cases prevalence of thorny species. We found type 3 in the H3 areas to the west of Oyster Pond and this fits STOFFERS’ (1956) ‘Woodland derived from dry evergreen forest’ that he found in that area. The H5 areas here are characterized by low shrubs and herbs and some scattered lower trees. The area west of Oyster Pond at present includes small areas that since STOFFERS (1956) have been taken up by human habitation.

Mangrove areas in Mullet Pond and the southern part of Simpson Bay Lagoon are no longer present. The strand vegetation and littoral woodland to the northeast of Burgeux Bay and the

strand vegetations in the Low Lands area and at Cole Bay have been lost or are too small to be mapped.
The ‘Thorny woodland derived from seasonal formations’ near Lay Bay (Billy Folly) has disappeared for a large part due to urbanization and tourism infrastructure development. In the present study the remainder of the vegetation has developed into one that is comparable with STOFFERS’ (1956) ‘Dry evergreen woodland’. The ‘*Hippomane* woodland’ and also the ‘Thorny woodland derived from seasonal formations’ near Orange Grove, Almond Grove, and Diamond (to the west of Union Road and partially to the east of it) on STOFFERS’ (1956) map have disappeared completely. At present these areas are occupied by human habitation. To the east of those Thorny woodlands (Concordia Hill, Saint Peter Hill, Sentry Hill, Cole Bay Hill, Cay Bay Hill) STOFFERS (1956) described a large area of ‘Secondary woodland derived from seasonal formations’. Based on the vegetation types we have found there in the present study it can be concluded that the vegetation of that large area has remained the same with the exception of some small areas that have degraded into a more disturbed shrubby vegetation (in H5) characteristic for areas formerly used as pasture land. Near the top of Sentry Hill STOFFERS (1956) found a small area of semi-evergreen seasonal forest (the only seasonal primary climax community on St. Maarten by STOFFERS 1956). This area was too small to be recognized by the (landscape) approach used in the present study and was not visited during our fieldwork. Consequently we do not know if it still exists.

The large area of ‘Thorny woodland derived from seasonal formations’ and ‘Secondary woodland derived from seasonal formations’ in the central hill range (STOFFERS 1956) coincides on our map mainly with a large H1 area. This H1 area is accompanied by smaller H3, H5 and H2 areas. Based on the vegetation of H1 we can conclude that the area of ‘Thorny woodland derived from seasonal formations’ of STOFFERS (1956) at present is a less thorny woodland vegetation in the central hill range. It is difficult to come with a verdict as to what vegetation development the H3 areas represent when compared to STOFFERS (1956) due to the fact that H3 contain both evergreen woodland vegetation types as a deciduous woodland vegetation type. The small dispersed H5 areas on our map along the eastern edge of the mentioned hill range are characterized here by a thorny (disturbed) woodland vegetation type. This means that the corresponding areas of STOFFERS’ (1956) ‘Secondary woodland derived from seasonal formations’ have been disturbed over time. The H2 areas in the central hill range area on our map have overall a more evergreen woodland vegetation. This would mean that these areas have developed from a seasonal formation (STOFFERS 1956) towards a more evergreen woodland vegetation at present.

More to the east at Oyster Pond the area of Mangrove woodland (STOFFERS 1956) still exists at present although *Rhizophora mangle* is more prominent at present than at the time of STOFFERS (1956). However, the area of ‘Vegetation of the Rock pavement’ at Oyster Pond (STOFFERS 1956) at present is occupied by tourism infrastructure. The largest part of the ‘Dry evergreen woodland’ and ‘Thorny woodland derived from seasonal formations’ on STOFFERS’ (1956) map in the eastern hill range correspond with H3 areas on our map. Based on the vegetation of H3 (type 3) in the eastern hill range it can be concluded that the evergreen character of the woodland vegetation described by STOFFERS’ (1956) is still present. For the large area of ‘Thorny woodland derived from seasonal formations’ in the eastern hill range (STOFFERS 1956) that falls in the H3 area this means that the vegetation has a more evergreen character at present in comparison to STOFFERS (1956). On our map we also see a few H1 areas in the eastern hill range and therefore it can be said that these areas consist of a vegetation type that is comparable to ‘Secondary woodland derived from deciduous formations’. The H1 areas correspond on STOFFERS’ (1956) map with both areas of ‘Dry evergreen woodland’ and ‘Thorny woodland derived from seasonal formations’. There are a number of dispersed H5 areas in the eastern hill range. From north to south in the eastern hill range there are a small number of dispersed H5 areas. On STOFFERS’ (1956) map these occur in areas of ‘Dry evergreen woodland’, ‘Thorny woodland derived from dry evergreen formations’ and ‘Thorny derived from seasonal formations’. Type 7 is the main vegetation type we found in H5 in the eastern hill range. Type 7 is comparable to STOFFERS’ ‘*Croton* thickets’ and this indicates that the corresponding areas on STOFFERS’ (1956) map have been disturbed since possibly as the result of use as pasture land. The H5 areas to the west of Geneva Bay are even more disturbed because it consists of a relatively low herbaceous vegetation.

STOFFERS (1956) mapped on Naked Boy Hill an area of Secondary woodland derived from seasonal formations while on our map this is a H3 area (with type 3). The H1 area more to the south (in Bloomingdale) on our map would be comparable to that Naked Boy Hill vegetation in STOFFERS (1956).

At Guana Bay STOFFERS (1956) mapped a significant area of ‘*Hippomane* woodland’. However, we conclude that this is wrong due to the fact that he describes in his section of ‘Description of the regions investigated’ a ‘Littoral woodland’ at Guana Bay and does not mention the Guana Bay area in his list of areas with *Hippomane* woodland’ in St. Maarten. ROJER (1997) found a small area with *Hippomane* trees at Guana Bay, but all the *Hippomane* trees were dead due to the impact of hurricane Luis (ROJER 1997). In the present study we found only a few young specimens of *H. mancinella* at Guana Bay. Due to the openness of the vegetation caused by hurricane Luis a number of plant species typical for our *Canavalia-Ipomoea* vegetation type (‘Herbaceous strand community’ in STOFFERS 1956) entered this zone. We conclude that the vegetation at present has some characteristics of a ‘Littoral woodland’ (STOFFERS 1956) intermingled with species of our *Canavalia-Ipomoea* vegetation type (STOFFERS’ ‘Herbaceous strand community’).

Most of the area that goes from Vineyard Hill to the Point Blanche Hill more to the south on our map consists of urban and industrial areas. On STOFFERS’ (1956) map these were areas of ‘Secondary woodland derived from seasonal formations’ (Vineyard Hill), ‘Dry evergreen woodland’ and ‘*Croton-Lantana-Cordia* thicket derived from dry evergreen formations’. At present only on the lower parts of the northern and eastern slopes of the Point Blanche Hill a H3 area (with a type 3 vegetation) is present. This is thus comparable to STOFFERS’ (1956) map. On our map a *Ruellia-Laguncularia* Cliff area occurs in the coastal areas of Guana Bay Point, Geneve Bay and Point Blanche. On STOFFERS’ (1956) map these areas have been mapped as ‘Secondary woodland derived from dry evergreen formations’ and a small part as ‘*Croton-Lantana-Cordia* thicket derived from dry evergreen formations’.

5.4 THREATS TO THE TERRESTRIAL VEGETATION OF ST. MAARTEN

Habitat loss and fragmentation and invasive species are the main immediate threats to nature on islands (HARRIS & SILVA-LOPEZ 1992; PUEYO ET AL. 2006; NIJMAN ET AL. 2009; JESSE ET AL. 2020), while climate change is the main long-term threat. From our map it is clear that habitat loss and fragmentation has taken place in all parts of the island since STOFFERS (1956). Since the 1960s the population of St. Maarten has grown explosively as the result of tourism development on the island (PALM 1985; CBS 2003, 2004).[21] Based on our landscape ecological vegetation map we conclude that approximately 42 % of the surface of St. Maarten consists of vegetated areas, whereas at the time of STOFFERS (1956) vegetated areas amounted to 67 % of the surface of the island. In our study 19 % of areas with natural vegetation consist of areas marked as disturbed on STOFFERS'(1956) map but showed regeneration of their vegetation at the time of our survey. Based on our calculation we have estimated that approximately 43 % of the vegetation areas of STOFFERS (1956) have been destroyed and converted into urban areas. The landscapes of the island have been impacted since colonial times (PALM 1985). A large part of the island -with the exception of hill tops- was used for centuries for the cultivation of agricultural products (e.g. sugar cane and cotton). Over time, significant numbers of livestock animals were kept (mostly as free roaming animals) but the importance of this activity decreased with tourism becoming the main source of income. At present the most notorious and common of these animals are the free roaming goats although their numbers have also decreased over time (STOFFERS 1956; PALM 1985; ROJER 1997). In the present study, goat presence or signs of grazing by introduced livestock were recorded in or in the direct vicinity of 18 % of the total number of sample plots. This corresponds with grazing by livestock in five of the eleven vegetation types described. Type 6 (80%) and type 3 (50%) had the highest percentages of presence of grazing mammals while in type 2, type 7 and type 10 signs of grazing were found in or in close proximity of a third or less of the sample plots. Evidence of the presence of introduced grazers was found in the following areas: Bethlehem, Lower Prince's Quarter, Middle Region, Reward, Bloomingdale, Cupecoy, Fort Hill and Williams Hill. The detrimental effects of goats and other introduced grazers on island ecosystems have been demonstrated and discussed by numerous authors (COBLENTZ 1978; HAMANN 1979; NOY-MEIR 1990; KEEGAN ET AL. 1994; DEBROT & DE FREITAS 1993; CAMPBELL ET AL. 2004; FERNANDEZ-LUGO ET AL. 2009; CARRION ET AL. 2011). Goats have a broad diet in the region and species eaten include canopy, mid-canopy and understory species (MELENDEZ-ACKERMAN ET AL. 2008). It has also been demonstrated that continued grazing greatly reduces the recovery potential of the vegetation (ALBALADEJO ET AL. 1998; STEEN 1998). Goats especially favor the spread of plant species that are characteristic of earlier successional stages. These plant species fill, in a sense, the void created by overutilization of more palatable (preferred) plant species (COBLENTZ 1980). Consequently, goat control, removal and eradication are being adopted worldwide and are nowadays among the most important tools used for biodiversity recovery and rehabilitation (CAMPBELL & DONLAN 2005).

[21] 458,000 stay-over arrivals in 1998 (https://www.indexmundi.com/facts/sint-maarten(-dutch-part)/international-tourism)

STOFFERS (1956) indicated that there were 23 introduced plant species on the island, while in BURG ET AL. (2012) this number has increased to 38. In the 56 sample plots, we documented the presence of 14 exotic plant species with a significant presence in at least one vegetation type: *Alysicarpus vaginalis*, *Antigonon leptopus*, *Bothriochloa pertusa*, *Cordia sebestena*, *Dactyloctenium aegyptium*, *Gossypium hirsutum*, *Guilandina bonduc*, *Indigofera tinctoria*, *Jasminum fluminense*, *Leucaena leucocephala*, *Megathyrsus maximus*, *Sesbania bispinosa*, *Thespesia populnea* and *Triphasia trifolia*. Three prominent (LANGELAND ET AL 2008) and in the present study common invasive plant species (see Appendix 3) are: *Megathyrsus maximus* (guinea grass), *Leucaena leucocephala* (jumbie bean; lead tree) and *Bothriochloa pertusa* (pitted beard grass; hurricane grass). *Antigonon leptopus* (coral vine) is abundant but occurrs only in type 6. *M. maximus*, *L. leucocephala* and *A. leptopus* were already found on St. Maarten at the beginning of the 20th century (BOLDINGH 1909). *M. maximus* is a perennial grass species native to Africa and has been introduced to many countries as a promising fodder crop. It has become a problematic invader in many countries resulting in decreased plant diversity and transformation of native ecosystems (LANGELAND ET AL. 2008). *L. leucocepha*la is native to southern Mexico and northern Central America and has been introduced worldwide for its many uses, amongst which importantly as livestock fodder (LANGELAND ET AL. 2008). *B. pertusa* is a perennial grass species native to eastern and southern Asia that has been introduced to several continents for use as a forage grass. It is believed that it was introduced from southern Europe to the Caribbean. For the Caribbean there are records from 1896 in St. Croix, 1917 in Jamaica and from 1943 in Puerto Rico (CABI 2019). On St. Eustatius this invasive species is called ‘Donna grass’ because it is believed to have reach the island with hurricane Donna (1960) (VAN DER BURG ET AL. 2012; DE FREITAS ET AL. 2014). *A. leptopus* is native to Mexico and northern Central America and was introduced as an ornamental plant across the Caribbean and other warm, tropical climates around the world. This vine is tolerant of many soil types and has become a very problematic invader in a number of countries (KAIRO ET AL. 2003; LANGELAND ET AL. 2008; FREITAS ET AL. 2014; JESSE ET AL. 2020). Invasive plant species will cause effects that will change and degrade the whole ecosystem they have invaded (KAIRO ET AL. 2003; ATKINSON & MARÍN-SPIOTTA 2015; JESSE ET AL. 2020; WALLER ET AL. 2020). Vegetation degradation further also affects the competitive balance towards invasive species and loss of regenerative capability due to loss of variation of microhabitats (FORMAN & HAHN 1980; DE FREITAS ET AL. 2014; FRANKLIN ET AL. 2015; VAN ANDEL ET AL. 2016).

It must be further mentioned that in almost all vegetation types (with exception of types 10 and 11) human disturbance was also noted in the form of trash and sometimes felled trunks (the latter was observed in 13 % of all sample plots). This is an additional threat because most probably evergreen (hardwood) tree species are the target for use in charcoal burning.

Climate change is also considered a serious threat to especially dry forests in the Americas (MILES ET AL. 2006; TOMS ET AL. 2012; SMITH ET AL. 2014). St. Maarten and the other two Dutch Windward islands (Saba and St. Eustatius) experience hurricane conditions once every three years on average (see Appendix 2). It is remarkable that STOFFERS (1956) does not mention or discuss the effects of hurricanes on the vegetation of St. Maarten despite e.g. the passing of the strong hurricane Dog in September 1950 (MDC 2018). In recent years there have been several hurricane events that brought considerable damage to the islands. One of the most catastrophic ones for the SSS Islands was Hurricane Luis in 1995 (MDC 2018). Another devastating hurricane named Lenny hit St. Maarten after the survey of this study was done (ROJER & DE FREITAS 2002). SOLOMON ET AL.(2007) predict with a chance of over 60% an increase in the intensity of large tropical storms (larger peak wind speeds and more precipitation) in the future in our region as the result of global warming. Hurricane damage in Caribbean dry forests at least in part helps to maintain the dense, low canopy structure of this category of vegetation due to the fact that the main damage is the breakage of larger branches (and trees) and induction of basal sprouting (ROJER & DE FREITAS 2002; VAN BLOEM ET AL. 2005; LUKE ET AL. 2016). Data indicate that hurricane damage to Caribbean dry forest structure is less compared to most wet tropical forest. This difference is due to the fact that tree mortality in the former forest category is relatively low due to the multi-stemmed nature of trees and relatively low canopy height (VAN BLOEM ET AL. 2005). As the result of this characteristic structure of Caribbean dry forests, stem mortality is relatively low. Damage by hurricane Lenny to two vegetation types with an evergreen character[22] was less compared to other woodland vegetation types (ROJER & DE FREITAS 2002). Remnants of better developed vegetation types found on hill tops of St. Maarten contain in comparison to more disturbed vegetation types less multi-stemmed tree species (ROJER & DE FREITAS 2002) and are therefore more vulnerable to the impact of hurricanes. This is a hindrance for these vegetation types to reach higher successional stages (i.e. higher development stages). Publications show that damage is greater at windward and more exposed sites as compared to more protected leeward sites (REILLY 1991; LUKE ET AL 2016). On St. Maarten damage levels were highest in areas on slopes that for a certain period of time were perpendicular to the direction of the hurricane winds (ROJER & DE FREITAS 2002). In analyzing hurricane damage to natural vegetation it must be taken into account that in the case of relatively frequent hurricanes of higher or intermediate ecological effects, spatial heterogeneity will be maintained or increased and thereby enhance coexistence of several types of plant species[23], especially at more exposed sites (PAINE ET AL. 2011; LUKE ET AL. 2016; HU & SMITH 2018). Lowering of species richness can occur in areas that are frequently exposed to hurricanes due to the fact that plant species requiring more time to reach maturity become locally extinct. Conversely, there are areas in which storms are sufficiently infrequent and an increase in their frequency could lead to a rise in local species richness (VANDERMEER ET AL. 2000).

5.5 OVERALL ASSESSMENT AND RECOMMENDATIONS

Based on a comparison of STOFFERS' (1956) map with our map we conclude that in 1999 the total cover of natural areas has declined with 25 % since 1956. Comparable to the findings of STOFFERS (1956) our results show that most vegetation types in the present study represent secondary or sub-climax vegetation (Table 9). Although there has been some regeneration, the overall process witnessed for St. Maarten is that of loss of natural and semi-natural vegetated

[22] One type falls in STOFFERS' (1956) category of 'Dry evergreen bushland' and the second one falls in STOFFERS' (1956) category of 'Woodland derived from dry evergreen forest.

[23] Plant spp. will react differently to hurricane exposure (LUKE ET AL. 2016).

areas. Comparison of the two studies shows that the species composition of the units comparable to each other has changed in varying degrees over time. We have noted major changes with respect to the *Croton* thickets derived from seasonal formations. We see furthermore that due to a number of factors several of STOFFERS' (1956) communities do not occur anymore or are strongly reduced in area: 'Semi-evergreen seasonal forest', 'Thorny woodland derived from dry evergreen forest' '*Croton* thickets derived dry evergreen formations', 'Littoral woodland', 'Vegetation of the rock pavement', 'Strand scrub community' and '*Hippomane* woodland' . In descending order of importance, the most diverse vegetation types in the present study are types 1, 2, 3, 4 and 5. The more diverse vegetation types have a relatively high resilience capacity to outside environmental stressors due to the inherent micro-environmental heterogeneity (FORMAN & HAHN 1980; HARRIS & SILVA-LOPEZ 1992; TOMS ET AL. 2012; ELMQVIST ET AL. 2015; RAMOS DE ANDRADE ET AL.2015).Their conservation is therefore important but also the conservation of representative habitats of a country. Loss of vegetation (quality) also impacts negatively on faunal biodiversity.

MACRAE & NISBETH (2008) proposed the following three natural areas as having special conservation value: 1) The Emilio Wilson Estate, a 90 ha piece of land that goes from the road through Cul de Sac to the top of Sentry Hill; 2) An area of approximately 100 ha that runs below Guana Bay Point to the Back Bay in the south. Its value is based on the lack of construction in this area; 3) The Hill Tops that consists of the areas above the 200 m height contour of Cole Bay Hill, Sentry Hill, St. Peters Hill, Concordia Hill, Marigot Hill, Waymouth Hill and Williams Hill.

The characteristics of type 1 give landscape unit H1 a high conservation value. The Hill Tops conservation area of MACRAE & NISBETH (2008) lies for a great deal in our H1 areas. The Hill Tops conservation area in the north also covers our H2 areas there. The Emilio Wilson Estate as a proposed conservation area by MACRAE & NISBETH (2008) can be seen as an extension of the Hill Tops conservation area due to its location on the eastern slope of Sentry Hill. On our map the Emilio Wilson Estate falls into areas of H3 and H5. When comparing the proposed conservation area of the Hill Tops with our map we see that in the eastern hill range they miss out on an important part of the H1 areas. These should be included as part of a conservation area with as much as possible of the surrounding H3 areas to serve as buffer zones. Buffer zones are considered important for protecting biodiversity values of core areas (DEBROT & DE FREITAS 1991; ELMQVIST ET AL. 2015). The Guana Bay Point to Back Bay conservation area (MACRAE & NISBETH 2008)) also falls into H3 and H5 areas on our map. This area is also mentioned as an important natural area including its value as a potential habitat for one of the endemic plant species (*Galactia nummularia*) of St. Maarten (ROJER 1997).

We consider it as a priority to realize protection of as much as possible of what is left on our map of the' L' landscape in the calcareous Low Lands area. We have seen that the vegetation of the L unit fits STOFFERS' (1956) 'Dry evergreen bushland' (a primary climax community). We also propose to protect the remaining vegetation on Billy Folly, together with Corner Hill the only two higher limestone hills of St. Maarten. The vegetation of both hills fits STOFFERS' (1956) 'Dry evergreen bushland' in certain aspects. It is important to protect this unique habitat on St. Maarten.

We also propose to protect the landscape areas B1 and B2 that harbors vegetation types that fit respectively STOFFERS' (1956) 'Mangrove woodland' and 'Herbaceous strand community' (two primary climax communities). Mangroves are found in the present study at Cupecoy, Boundary Monument and Oyster Pond. In the present study, a vegetation type that fits STOFFERS' (1956) 'Herbaceous strand community' has been found at Guana Bay.

In addition to the above site-specific conservation interventions, we like to emphasize the importance of several broader measures needed to lay a sound basis for terrestrial nature management on the island.

1) Protected terrestrial areas network
   St. Maarten currently has no protected terrestrial habitat even though plans for a 'hillsides national park' have been talked about since the mid 1990s (ECOVISION & AIDEnvironment 1996; ROJER 1997). We have discussed above here the three conservation areas proposed by MACRAE & NISBETH (2008) and mentioned additionally several important natural areas that should also receive protection. We want to emphasize also the importance of including buffer zones in order to ensure adequate protection of the core areas. In order to prevent further habitat fragmentation it is advisable to connect natural areas through natural corridors (FORMAN & GODRON 1986; BAERSELMAN & VERA 1989). If necessary, more-degraded areas could be protected and restored to function as corridors to connect several existing natural areas. Reforestation can help enhance biodiversity and ecological values. As a mitigation strategy for hurricane-prone areas LUGO (2000) recommends to have a diverse set of connected natural areas in order to minimize the negative consequences of hurricanes on biodiversity. Important for supporting this strategy is also improved land use planning in order to minimize the negative effects of development projects on the integrity of natural areas. An example is e.g. preventing landslides by better planning of road constructions.

   It is also important to set up management plans for all areas to be protected and managed. This is also relevant in order to prevent trails from passing through sensitive areas of high conservation value and with rare plant species like e.g. the semi-evergreen deciduous forest and provide active management.

2) Control of roaming livestock
   Goat control, removal and eradication is being adopted worldwide as one of the most important tools used in biodiversity recovery today (CAMPBELL & DONLAN 2005). Important vegetation types in which the presence of goats was registered in the present study were type 2 (33 %: Williams Hill) and type 3 (50 %: Fort Hill, Middle Region, and Lower Prince's Quarter). There should be a general prohibition for free roaming goats on the island in order to ensure protection of valuable vegetation types from the negative impact of exotic mammalian grazers.

3) Protection of endangered plant species

The protection of indigenous species could be fortified by setting up a list of protected plant species (see e.g. the Eilandsverordening natuurbeheer Bonaire, A.B. 2008, no. 23) and Eilandsbesluit natuurbeheer Bonaire, A.B. 2010, no. 15) starting out with the plant species protected based on the SPAW Protocol (CARTAGENA Convention) to which St. Maarten is a party. In this context it would also be necessary to have botanists do an extensive search to hopefully rediscover the two St. Maarten endemics (*Calyptranthes boldinghii* and *Galactia nummularia*). If these rare endemics can still be found, a program for their artificial reproduction and replanting in suitable habitat would be highly recommended. Reforestation with other rare plant species is also of importance. Replanting of mangrove seedlings in suitable habitats is also important considering the important functions of mangroves. MACRAE & NISBETH (2008) mention such a plan by the St. Maarten Nature Foundation and it is therefore important to support this plan.

4) Invasive species action plan

Considering the negative impact of invasive plant species, it is important for the government of the island to have an invasive plant species policy plan. Such a plan should be used to manage where possible the existing invasive plant species, prevent the introduction of (potential) new invasive plant species or prevent the spreading of species that over time develop invasive characteristics (SMITH ET AL. 2014).

5) Long-term vegetation monitoring

In order to better understand the effects of hurricanes on different landscape units and vegetation types and their recovery it is necessary to establish a system of permanent plots (VAN ‘T RIET 1997; IMBERT & PORTECOP 2008; WILLIG ET AL. 2012) in at least the vegetation types in which the tree/shrub layer is the dominant layer (types 1, 2, 3, 4, 5, 6 and 10 in the present study). Due to the fact that the vegetations described in the present study correspond to the situation of vegetations of more than 20 years ago, a good starting point would be to do a new vegetation assessment to examine the extent of any more-recent changes that have taken place in the vegetations of St. Maarten.

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APPENDIX 1. Climatological data for St. Maarten (Philipsburg) in the period 1971-2000 (MDC 2020).

METEO CURACAO

Princess Juliana Airport, Sint Maarten (18°03'N 63°07'W) Summary of Climatological Data, Period 1971-2000

Element	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Avg. Air Temperature	°C	25.5	25.4	25.7	26.5	27.4	28.2	28.3	28.6	28.5	28.2	27.3	26.1	27.2
Avg. Maximum Temperature	°C	28.6	28.7	29.2	29.8	30.4	31.3	31.6	31.7	31.6	31.2	30.2	29.2	30.3
Abs. Maximum Temperature	°C	32.7	31.6	32.6	33.6	33.5	33.9	34.2	35.1	34.8	34.3	33.9	32.1	35.1
Avg. Minimum Temperature	°C	23.2	23.1	23.5	24.1	25.1	25.2	26.1	26.2	26.0	25.7	24.9	23.9	24.8
Abs. Minimum Temperature	°C	18.6	19.2	19.5	19.3	20.2	22.3	22.1	21.4	22.0	22.1	21.2	20.0	18.6
Avg. Seawater Temperature	°C	26.0	25.9	25.8	26.1	27.1	27.5	27.9	28.2	28.3	28.4	28.0	27.2	27.2
Avg. Air Pressure (-1000)	hPa	16.9	17.0	16.4	15.6	15.7	17.0	17.1	15.9	14.5	13.8	13.9	15.7	15.8
Avg. Vapour Pressure	hPa	24.3	23.3	24.2	25.7	27.6	28.6	28.8	29.3	29.4	29.1	27.7	25.9	27.0
Avg. Relative Humidity	%	74.7	74.1	73.6	75.0	75.9	75.1	74.8	75.4	76.3	76.8	77.4	76.6	75.5
Avg. Dewpoint Temperature	°C	20.6	20.4	20.6	21.8	22.9	23.4	23.6	23.8	24.0	23.7	23.1	21.9	22.5
Avg. Daily Evaporation	mm	4.7	5.5	6.3	6.6	6.7	7.0	7.1	6.7	6.4	5.6	4.7	4.4	6.0
Avg. Monthly Rainfall	mm	66.0	50.7	45.2	64.0	93.3	61.8	71.6	98.8	139.6	113.0	149.3	93.8	1047.1
Avg. Hours with Rainfall	hours	62.3	50.0	45.2	42.6	54.1	35.4	60.8	65.4	62.5	77.0	81.5	68.3	705.1
Avg. Days with Rain > 1,0 mm	days	11.9	9.3	9.0	11.8	10.3	8.4	12.2	13.9	13.5	13.8	14.8	13.3	142.0
Highest Rainfall in 24 hours	mm	40.7	75.8	42.5	101.2	117.5	109.8	65.0	89.6	258.4	122.4	254.2	123.2	258.4
Avg. Days with Thunder	days	0.2	0.1	0.1	0.3	1.1	1.4	2.2	3.0	3.9	3.5	1.9	0.5	18.2
Avg. Cloud Coverage	%	37.3	39.6	37.8	41.1	49.0	47.3	46.1	45.3	47.5	45.7	44.0	40.7	43.4
Avg. Sunshine Duration	%	73.5	72.7	72.2	70.6	62.4	62.0	63.2	67.7	62.8	67.0	68.3	71.4	67.8
Avg. Sunshine Duration	hours	257.2	235.2	271.6	265.4	251.0	245.1	257.2	268.1	232.4	244.6	235.0	246.7	3009.4
Avg. Global Radiation	kWh/m^2	144.0	144.9	187.7	195.0	190.4	182.6	181.1	197.3	170.3	155.6	128.9	135.1	2013.7
Avg. Wind Direction	degrees	093	099	100	103	110	106	094	097	100	112	089	084	097
Avg. Wind Speed (at 10 m)	m/sec	4.9	4.9	4.8	4.8	4.8	5.2	5.3	5.0	4.6	4.2	4.5	4.7	4.8
Avg. Maximum Wind Speed	m/sec	11.6	11.5	11.1	10.6	10.6	11.8	12.7	11.8	11.2	10.1	11.3	11.2	11.3
Strongest Gust	m/sec	20.4	20.9	19.9	20.9	20.9	23.0	35.7	28.6	50.5	44.4	45.9	25.5	50.5
Persistency of the Wind	%	87.2	88.1	86.6	78.9	81.9	94.7	92.9	85.7	89.7	80.0	81.4	83.5	87.5

APPENDIX 2. Tropical storms (ts) and hurricanes (hu; period 1956-1999) passing through the SSS Islands within 100 N.M. (185 km) of 18.5° N, 63.0° W. Only hurricanes and tropical storms with maximum sustained surface wind speed (one minute mean) of minimally 50 mph.

Year	**Month / day**	**Name hurricane**	**Storm intensity** (mph)	**Hurricane /storm**
1956	11-Aug	Betsy	90	hu
1959	18-Aug	Edith	50	ts
1960	4-Sep	Donna	145*	hu
1963	27-Oct	Helena	50	ts
1964	22-Aug	Cleo	100	hu
1965	28-Aug	Betsy	55	ts
1966	26-Aug	Faith	90	hu
1966	27-Sep	Inez	130	hu
1975	14-Sep	Eloise	35^	ts
1979	29-Aug	David	150	hu
1979	3-Sep	Frederic	75^	hu
1989	3-Aug	Dean	85	hu
1989	17-Sep	Hugo	140*	hu
1990	6-Oct	Klaus	75	hu
1995	27-Aug	Iris	65	ts
1995	5-Sep	Luis	145*	hu
1995	12-Sep	Marilyn	95*	hu
1996	8-Jul	Bertha	80	hu
1998	21-Aug	Bonnie	50	ts
1998	21-Sep	Georges	100*	hu
1999	20-Oct	José	75*	hu
1999	18-Nov	lenny	115*	ts

* Hurricanes that caused considerable damage to the SSS Islands.

^These two events caused prolonged extensive flooding because of their associated torrential rainfall of more than 250 mm within 24 hours.

Source: Meterological Department Curaçao (2018).

Appendix 3. Synoptic table of the vegetation types of St. Maarten

Vegetation type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Number of sample plots:	6	3	6	6	4	5	5	4	9	6	2
Average number of species:	42.8	31.7	30.8	29.5	28.3	25.0	16.0	13.3	12.1	8.7	9.5
Standard deviation:	8.1	2.5	9.4	4.0	4.1	7.4	7.5	1.3	6.0	5.0	2.5

Differentiating species (at least 40% difference)

Capparidastrum frondosum	**V (2)**	II (3)	II (1)	-	-	I (4)	-	-	-	-	-
Lasiacis divaricata	**IV (3)**	-	I (4)	-	-	I (3)	-	-	-	-	-
Eugenia biflora	**V (2)**	-	II (3)	-	-	-	-	-	-	-	-
Dolichandra unguis-cati	**IV (1)**	-	-	-	-	I (1)	-	-	-	-	-
Eugenia procera	I (1)	**V (3)**	-	-	-	-	-	-	-	-	-
Pavonia spinifex	II (2)	-	**IV (2)**	-	-	I (2)	-	-	-	-	-
Cynophalla hastata	I (2)	-	**V (2)**	-	-	-	-	-	-	-	-
Passiflora suberosa	I (2)	-	I (1)	**IV (1)**	-	I (1)	-	-	-	-	-
Maytenus laevigata	II (1)	-	I (1)	**V (3)**	-	-	-	-	-	-	-
Pithecellobium unguis-cati	III (1)	II (1)	-	**V (3)**	II (1)	-	-	-	-	-	-
Amyris elemifera	II (3)	II (4)	-	**V (3)**	III (4)	-	I (1)	-	-	-	-
Eugenia foetida	-	-	-	**V (3)**	-	-	-	-	-	-	-
Gyminda latifolia	-	-	-	**IV (1)**	-	-	-	-	-	-	-
Jacquinia berteroi	-	-	-	**V (2)**	III (3)	-	-	-	-	-	-
Sideroxylon obovatum	-	-	-	**IV (1)**	II (2)	-	-	-	-	-	-
Pisonia aculeata	I (1)	-	II (1)	-	-	**IV (3)**	-	-	-	-	-
Petiveria alliacea	-	II (2)	-	-	-	**IV (3)**	-	-	-	-	-
Antigonon leptopus	-	-	-	-	-	**IV (5)***	-	-	-	-	-
Vachellia macracantha	-	II (1)	I (1)	-	II (1)	**IV (3)**	I (1)	II (4)	II (1)	-	-
Vachellia tortuosa	I (1)	-	I (1)			I (1)	I (4)	**IV (4)**	-	-	-
Opuntia triacanthos	-	II (2)	II (2)	-	II (1)	-	I (1)	**V (3)**	II (2)	-	-
Talinum ruticosum	-	-	-	-	-	-	-	**V (4)**	-	-	-
Commicarpus scandens	-	-	-	-	-	-	-	**V (3)**	-	-	III (2)
Cuscuta spec.	-	-	-	-	-	-	-	**IV (2)**	I (2)	-	-
Galactia dubia	-	-	I (3)	-	II (2)	-	-	II (1)	**IV (3)**	-	-
Melocactus intortus	-	-	-	-	II (2)	-	-	II (1)	**IV (2)**	-	-
Portulaca teretifolia	-	-	-	-	-	-	-	-	**IV (2)**	-	-
Laguncularia racemosa	-	-	-	-	-	-	-	-	-	**V (5)***	-
Conocarpus erectus	-	-	-	-	-	-	-	-	-	**IV (4)**	-
Ipomoea pes-caprae	-	-	-	-	-	-	-	-	I (1)	I (1)	**V (3)**
Canavalia rosea	-	-	-	-	-	-	-	-	I (1)	-	**V (4)**

Vegetation type	1	2	3	4	5	6	7	8	9	10	11
Number of sample plots:	6	3	6	6	4	5	5	4	9	6	2
Average number of species:	42.8	31.7	30.8	29.5	28.3	25.0	16.0	13.3	12.1	8.7	9.5
Standard deviation:	8.1	2.5	9.4	4.0	4.1	7.4	7.5	1.3	6.0	5.0	2.5

Common species (Occur in minimally 4 clusters with at least one presence category of III)

Euphorbia petiolaris	II (2)	IV (1)	II (1)	-	III (1)	-	-		-	-	-
Tillandsia recurvata	IV (3)	IV (3)	I (3)	-	II (3)	-	-	-	-	-	-
Erythroxylon rotundifolium	V (3)	IV (2)	V (3)	-	II (1)	III (1)	-	-	-	-	-
Randia aculeata	V (2)	V (3)	V (3)	-	II (1)	IV (3)	-	-	-	-	-
Commelina erecta	II (2)	V (3)	III (2)	-	II (3)	II (3)	II (2)	-	-	-	-
Guapira fragrans	V (3)	IV (2)	V (2)	-	-	I (1)	-	-	-	-	-
Senegalia riparia	V (3)	V (2)	I (1)	-	-	I (5)*	-	-	-	-	-
Tragia volubilis	III (3)	II (2)	I (1)	-	-	I (2)	-	-	-	-	-
Coursetia caribaea	III (2)	II (1)	II (3)	-	-	I (1)	I (1)	-	-	-	-
Rhynchosia reticulata	IV (2)	II (3)	IV (4)	-	-	I (3)	II (3)	-	-	-	-
Melochia tomentosa	I (1)	II (1)	III (1)	-	-	I (2)	IV (3)	IV (2)	II (3)	-	-
Samyda dodecandra	III (2)	V (1)	V (3)	-	-	-	I (1)	-	-	-	-
Lantana camara	I (2)	II (1)	IV (2)	I (1)	-	I (1)	-	-	-	-	-
Comocladia dodonaea	V (2)	V (1)	II (1)	V (2)	V (2)	-	-	-	-	-	-
Tillandsia utriculata	V (2)	IV (2)	III (3)	IV (3)	V (4)	-	-	-	-	-	-
Krugiodendron ferreum	IV (3)	IV (3)	I (1)	V (4)	IV (1)	-	-	-	-	-	-
Argythamnia candicans	IV (3)	II (3)	I (2)	V (3)	V (2)	-	-	II (4)	-	-	-
Pisonia subcordata	V (3)	IV (3)	II (1)	III (2)	V (4)	-	-	-	-	I (1)	-
Bursera simaruba	IV (2)	V (1)	II (1)	V (2)	V (2)	-	-	-	-	I (1)	-
Bourreria succulenta	V (3)	V (3)	I (1)	V (3)	V (3)	I (1)	-	-	-	-	-
Cynophalla flexuosa	IV (2)	IV (1)	I (1)	II (1)	IV (1)	II (2)	-	II (1)	I (1)	-	V (1)
Quadrella indica	V (2)	V (2)	V (1)	III (1)	III (1)	II (1)	-	-	-	-	-
Pilosocereus royenii	III (2)	V (3)	V (2)	II (3)	V (2)	II (1)	-	II (1)	I (2)	-	-
Quadrella cynophallophora	III (2)	IV (2)	II (1)	III (2)	III (2)	I (1)	-	-	I (4)	I (1)	-
Leucaena leucocephala	V (3)	V (2)	IV (3)	I (2)	II (1)	V (4)	I (1)	-	-	-	-
Megathyrsus maximus	V (4)	IV (4)	V (5)*	IV (3)	IV (3)	III (3)	III (5)*	-	-	-	-
Stigmaphyllon emarginatum	V (2)	V (1)	V (2)	V (2)	IV (3)	IV (2)	V (2)	V (2)	III (4)	I (1)	III (2)
Solanum bahamense	III (1)	II (1)	-	V (2)	V (1)	II (2)	I (1)	II (1)	-	II (2)	III (4)
Croton betulinus	I (1)	IV (1)	-	III (3)	IV (2)	-	-	-	-	-	-
Portulaca oleracea	I (1)	II (1)	-	-	-	-	-	-	II (2)	-	III (2)
Centrosema virginianum	III (1)	-	IV (2)	II (2)	III (3)	I (1)	I (2)	-	III (3)	-	-
Ipomoea tiliacea	II (2)	-	II (3)	III (2)	-	II (2)	-	-	-	-	-
Sida glabra	I (1)	-	II (2)	-	-	III (2)	I (2)	II (2)	-	-	-
Desmanthus virgatus	III (1)	-	I (2)	-	-	III (2)	III (2)	-	III (2)	-	-
Bastardia viscosa	I (1)	-	II (2)	-	-	-	I (3)	III (3)	-	-	-
Tabebuia heterophylla	III (1)	-	-	IV (3)	V (3)	-	-	-	-	I (1)	-
Teramnus labialis	I (2)	-	-	-	-	III (1)	II (3)	-	I (4)	-	-
Lantana involucrata	-	II (1)	III (2)	V (3)	V (3)	-	-	V (4)	-	II (2)	-
Justicia sessilis	-	IV (2)	IV (2)	-	-	III (2)	II (3)	II (3)	-	-	-
Exostema caribaeum	-	II (4)	-	V (2)	II (4)	-	I (1)	-	-	-	-
Plumeria alba	-	II (1)	-	IV (1)	IV (1)	-	-	-	I (1)	-	
Crossopetalum rhacoma	-	II (1)	-	III (2)	II (1)	-	-	-	-	I (1)	
Ayenia insulicola	-	II (1)	-	I (2)	II (1)	-	III (3)	-	I (2)	-	-
Croton astroites	-	-	IV (2)	II (1)	III (3)	I (1)	II (1)	II (4)	I (4)	-	-
Jacquinia armillaris	-	-	I (1)	II (1)	III (1)	-	-	-	I (1)	-	III (1)
Setaria setosa	-	-	I (3)	I (3)	-	-	-	III (4)	I (3)	-	-
Ruellia tuberosa	-	-	I (1)	-	-	II (1)	III (2)	III (5)*	V (3)	-	-
Bothriochloa pertusa	-	-	I (3)	-	-	II (4)	IV (5)*	III (5)*	III (4)	-	-
Tournefortia volubilis	-	-	-	II (2)	III (2)	-	I (2)	III (2)	I (2)	I (1)	-

Vegetation type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Number of sample plots:	6	3	6	6	4	5	5	4	9	6	2
Average number of species:	42.8	31.7	30.8	29.5	28.3	25.0	16.0	13.3	12.1	8.7	9.5
Standard deviation:	8.1	2.5	9.4	4.0	4.1	7.4	7.5	1.3	6.0	5.0	2.5

Other species (Occur in 3 clusters or max. 4 with low presence (<III)

Piscidia carthagenensis	IV (1)	II (1)	II (2)	-	-	-	-	-	-	-	-
Margaritopsis microdon	I (2)	II (1)	I (1)	-	-	-	-	-	-	-	-
Guettarda odorata	III (1)	II (4)	II (3)	-	-	-	-	-	-	-	-
Indigofera tinctoria	III (2)	II (1)	III (2)	-	-	-	-	-	-	-	-
Argythamnia fasciculata	I (4)	II (2)	II (2)	-	-	-	-	-	-	-	-
Morisonia americana	IV (2)	IV (3)	I (1)	-	-	-	-	-	-	-	-
Schaefferia frutescens	III (1)	IV (2)	I (1)	-	-	-	-	-	-	-	-
Cissus verticillata	I (1)	II (1)	II (1)	-	-	II (2)	-	-	-	-	-
Jasminum fluminense	III (3)	-	I (2)	-	-	IV (3)	-	-	-	-	-
Melochia nodiflora	III (2)	-	I (1)	-	-	II (2)	-	-	-	-	-
Abrus precatorius	III (1)	-	II (1)	-	-	-	-	-	-	-	-
Eugenia ligustrina	II (1)	-	III (3)	-	-	-	-	-	-	-	-
Chiococca alba	III (1)	-	I (1)	-	-	-	-	-	-	-	-
Wedelia calycina	IV (3)	-	II (4)	-	-	-	-	-	II (3)	-	-
Euphorbia tithymaloides	V (2)	-	II (2)	III (3)	-	-	-	-	-	-	-
Lepidaploa glabra	III (2)	-	-		II (3)	I (1)	-	-	-	-	-
Picramnia pentandra	III (3)	-	-	-	-	I (4)	-	-	-	-	-
Triphasia trifolia	III (1)	-	-	-	-	I (1)	-	-	-	-	-
Rivina humilis	I (1)	-	I (1)	-	-	I (2)	-	-	-	-	-
Rauvolfia viridis	-	II (1)	-	-	-	II (3)	I (1)	-	-	-	-
Citharexylum spinosum	-	-	II (1)	-	II (1)	I (1)	-	-	-	-	
Sidastrum multiflorum	-	-	I (3)	-	-	I (1)	II (3)	-	-	-	-
Desmodium incanum	-	-	I (2)	-	-	II (1)	I (3)	-	-	-	-
Malphigia emarginata	-	-	II (5)	-	-	II (1)	I (1)	II (4)	I (1)	-	-
Eugenia rhombea	-	-	-	V (2)	V (4)	-	-	-	-	-	-
Ipomoea eggersii	-	-	-	III (2)	IV (2)	-	-	-	-	-	-
Erithalis fruticosa	-	-	-	III (2)	III (1)	-	-	-	-	-	-
Scleria lithosperma	-	-	-	III (2)	II (3)	-	-	-	-	-	-
Pseudabutilon umbellatum	-	-	-	-	-	I (1)	I (3)	II (1)	-	-	-
Jatropha gossypiifolia	-	-	-	-	-	I (2)	II (1)	II (2)	-	I (1)	-
Guilandina bonduc	-	-	-	-	-	II (3)	-	-	-	I (1)	III (1)
Hippomane mancinella	-	-	-	-	-	I (1)	-	-	-	-	III (1)
Boerhavia coccinea	-	-	-	-	-	-	I (1)	-	I (2)	-	III (3)
Sporobolus virginicus	-	-	-	-	-	-	-	-	IV (6)*	I (4)	III (3)
Corchorus hirsutus	-	-	-	-	-	-	-	-	II (1)	-	III (2)
Evolvulus convolvuloides	-	-	-	-	-	-	-	-	III (3)	-	-
Coccoloba uvifera	-	-	-	-	-	-	-	-	-	I (1)	III (6)*

Vegetation type	1	2	3	4	5	6	7	8	9	10	11
Number of sample plots:	6	3	6	6	4	5	5	4	9	6	2
Average number of species:	42.8	31.7	30.8	29.5	28.3	25.0	16.0	13.3	12.1	8.7	9.5
Standard deviation:	8.1	2.5	9.4	4.0	4.1	7.4	7.5	1.3	6.0	5.0	2.5

Rare species (Occur in max. 2 clusters with low presence (I or II)

Anthurium grandifolium	II (2)	-	-	-	-	-	-	-	-	-	-
Gouania lupuloides	II (2)	-	-	-	-	-	-	-	-	-	-
Bernardia corensis	I (3)	-	-	-	-	-	-	-	-	-	-
Celtis iguanaea	II (1)	-	-	-	-	-	-	-	-	-	-
Cissampelos pareira	II (2)	-	-	-	-	-	-	-	-	-	-
Aechmea lingulata	II (4)	-	-	I (1)	-	-	-	-	-	-	-
Cardiospermum halicacabum	I (1)	-	-	-	-	-	-	-	-	-	-
Phlebodium aureum	I (1)	-	-	-	-	-	-	-	-	-	-
Eugenia monticola	I (3)	-	-	-	-	-	-	-	-	-	-
Cordia sebastena	I (1)	-	-	-	-	-	-	-	-	-	-
Porophyllum ruderale	I (3)	-	-	-	-	-	-	-	-	-	-
Sida cordifolia	I (1)	-	-	-	-	-	-	-	-	-	-
Talinum paniculatum	I (3)	-	-	-	-	-	-	-	-	-	-
Casearia decandra	I (2)	-	-	-	-	-	-	-	-	-	-
Nectandra coriacea	I (1)	-	-	-	-	-	-	-	-	-	-
Justicia eustachiana	I (2)	-	-	-	-	-	-	-	-	-	-
Tolumnia variegata	I (2)	-	-	-	-	-	-	-	-	-	-
Psychotria nervosa	I (1)	-	-	-	-	-	-	-	-	-	-
Senna spectabilis	I (1)	-	-	-	-	-	-	-	-	-	-
Bidens cynapiifolia	I (1)	-	I (1)	-	-	-	-	-	-	-	-
Rhynchosia minima	I (2)	-	I (2)	-	-	-	-	-	-	-	-
Tillandsia usneoides	I (3)	-	I (3)	-	-	-	-	-	-	-	-
Senna bicapsularis	II (2)	-	-	-	-	II (2)	-	-	-	-	-
Ditaxis argothamnoides	-	II (1)	-	-	-	-	-	-	-	-	
Bunchosia glandulifera	-	II (4)	-	-	-	-	-	-	-	-	
Callisia repens	-	II (3)	-	-	-	-	-	-	-	-	-
Erythroxylum havanense	-	II (4)	-	-	-	-	-	-	-	-	-
Forestiera eggersiana	-	II (2)	I (1)	-	-	-	-	-	-	-	-
Zanthoxylum punctatum	-	-	II (1)	-	-	-	-	-	-	-	-
Amaranthus dubius	-	-	I (1)	-	-	-	-	-	-	-	-
Panicum trichoides	-	-	I (4)	-	-	-	-	-	-	-	-
Solanum agrarium	-	-	I (2)	-	-	-	-	-	-	-	-
Myrcianthes fragrans	-	-	I (4)	-	-	-	-	-	-	-	-
Commelina erecta	-	-	I (3)	-	-	-	-	-	-	-	-
Abutilon indicum	-	-	I (2)	-	-	I (1)	-	-	-	-	-
Annona muricata	-	-	I (1)	-	-	I (1)	-	-	-	-	-
Eugenia axillaris	-	-	II (3)	-	-	I (1)	-	-	-	-	-
Peperomia humilis	-	-	I (2)	-	-	-	I (1)	-	-	-	-
Sida jamaicensis	-	-	I (3)	-	-	-	II (2)	-	-	-	-
Waltheria indica	-	-	I (1)	I (1)	-	-	-	-	-	-	-
Coccoloba krugii	-	-	-	II (3)	-	-	-	-	-	-	-
Guaiacum officinale	-	-	-	I (1)	-	-	-	-	-	-	-
Gynandropsis gynandra	-	-	-	I (2)	-	-	-	-	-	-	-
Gymnanthes lucida	-	-	-	I (4)	-	-	-	-	-	-	-
Exostema caribaeum	-	-	-	I (2)	-	-	-	-	-	-	-
Hypelate trifoliata	-	-	-	I (1)	-	-	-	-	-	-	-
Cenchrus polystachios	-	-	-	I (3)	-	-	-	-	-	-	-
Canella winterana	-	-	-	I (1)	-	-	-	-	-	-	-
Guettarda scabra	-	-	-	I (3)	-	-	-	-	-	-	-
Croton flavens	-	-	-	I (1)	-	-	-	-	II (3)	-	-
Phyllanthus epiphyllanthus	-	-	-	II (3)	II (1)	-	-	-	-	-	-
Tetramicra elegans	-	-	-	I (3)	II (3)	-	-	-	-	-	-
Stenostomum acutatum	-	-	-	-	II (1)	-	-	-	-	-	-
Zanthoxylum flavum	-	-	-	-	II (1)	-	-	-	-	-	-
Euphorbia hypericifolia	-	-	-	-	II (1)	-	-	-	-	-	-
Rondeletia anguillensis	-	-	-	-	II (2)	-	-	-	-	-	-
Catopsis floribunda	-	-	-	-	II (3)	-	-	-	-	-	-
Rochefortia acanthophora	-	-	-	-	II (1)	-	I (1)	-	-	-	-
Stylosanthes hamata	-	-	-	-	II (2)	-	II (3)	-	-	-	-

Vegetation type	1	2	3	4	5	6	7	8	9	10	11
Number of sample plots:	6	3	6	6	4	5	5	4	9	6	2
Average number of species:	42.8	31.7	30.8	29.5	28.3	25.0	16.0	13.3	12.1	8.7	9.5
Standard deviation:	8.1	2.5	9.4	4.0	4.1	7.4	7.5	1.3	6.0	5.0	2.5

Rare species continued (Occur in max. 2 clusters with low presence (I or II)

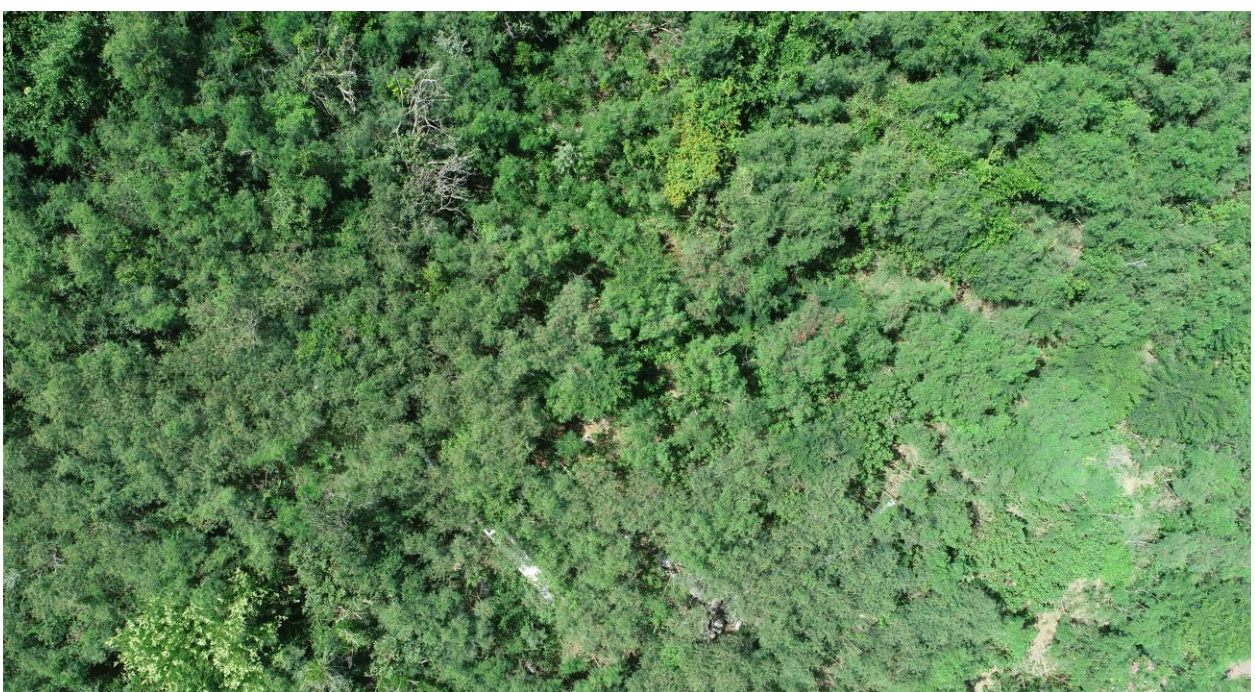
Cordia obliqua	-	-	-	-	-	II (1)	-	-	-	-	-
Trichostigma octandrum	-	-	-	-	-	II (2)	-	-	-	-	-
Ziziphus mauritiana	-	-	-	-	-	II (2)	-	-	-	-	-
Panicum ghiesbreghtii	-	-	-	-	-	I (1)	-	-	-	-	-
Galactia longiflora	-	-	-	-	-	I (3)	I (1)	-	-	-	-
Astraea lobata	-	-	-	-	-	I (1)	-	-	-	-	-
Melicoccus bijugatus	-	-	-	-	-	I (4)	-	-	-	-	-
Mitracarpus hirtus	-	-	-	-	-	I (1)	II (2)	-	-	-	-
Herissantia crispa	-	-	-	-	-	-	I (2)	-	-	-	-
Ipomoea nil	-	-	-	-	-	-	I (1)	-	-	-	-
Sida abutifolia	-	-	-	-	-	-	I (3)	-	-	-	-
Arivela viscosa	-	-	-	-	-	-	I (1)	-	-	-	-
Wissadula hernandioides	-	-	-	-	-	-	I (1)	-	-	-	-
Phyllanthus amarus	-	-	-	-	-	-	II (3)	-	I (3)	-	-
Stachytarpheta jamaicensis	-	-	-	-	-	-	II (2)	-	II (2)	-	-
Corchorus aestuans	-	-	-	-	-	-	II (2)	-	II (3)	-	-
Cyperus confertus	-	-	-	-	-	-	I (1)	-	II (3)	-	-
Chloris barbata	-	-	-	-	-	-	I (9)*	-	II (3)	-	-
Cyanthillium cinereum	-	-	-	-	-	-	I (1)	-	-	I (3)	-
Heliotropium angiospermum	-	-	-	-	-	-	-	II (1)	-	-	-
Capraria biflora	-	-	-	-	-	-	-	-	II (4)	-	-
Desmodium procumbens	-	-	-	-	-	-	-	-	II (3)	-	-
Sida ciliaris	-	-	-	-	-	-	-	-	II (2)	-	-
Tephrosia cinerea	-	-	-	-	-	-	-	-	II (2)	-	-
Alysicarpus vaginalis	-	-	-	-	-	-	-	-	I (3)	-	-
Hymenocallis caribaea	-	-	-	-	-	-	-	-	I (1)	-	-
Pectis linearis	-	-	-	-	-	-	-	-	I (3)	-	-
Pectis humifusa	-	-	-	-	-	-	-	-	I (1)	-	-
Alternanthera geniculata	-	-	-	-	-	-	-	-	I (3)	-	-
Mollugo nudicaulis	-	-	-	-	-	-	-	-	I (3)	-	-
Batis maritima	-	-	-	-	-	-	-	-	-	II (2)	-
Avicennia germinans	-	-	-	-	-	-	-	-	-	I (7)*	-
Rhizophora mangle	-	-	-	-	-	-	-	-	-	II (4)	-
Sesuvium portulacastrum	-	-	-	-	-	-	-	-	-	II (2)	-
Thespesia populnea	-	-	-	-	-	-	-	-	-	II (2)	-
Fimbristylis dichotoma	-	-	-	-	-	-	-	-	-	II (4)	-
Heliotropium curassavicum	-	-	-	-	-	-	-	-	-	II (3)	-
Euphorbia mesenbrianthemifolia	-	-	-	-	-	-	-	-	-	II (1)	-
Dactyloctenium aegyptium	-	-	-	-	-	-	-	-	-	I (3)	-
Gossypium hirsutum	-	-	-	-	-	-	-	-	-	I (1)	-
Launaea intybacea	-	-	-	-	-	-	-	-	-	I (1)	-
Sesbania bispinosa	-	-	-	-	-	-	-	-	-	I (3)	-
Strumpfia maritima	-	-	-	-	-	-	-	-	-	I (1)	-
Euphorbia serpens	-	-	-	-	-	-	-	-	-	I (1)	-
Sporobolus pyramidatus	-	-	-	-	-	-	-	-	-	I (2)	-

Appendix 4. Recent photos of the landscape units described in the present study.

H HILLS

H1 *GUAPIRA-CAPPARIDASTRUM HILLS*

H2 *ERYTHROXYLUM-BOURRERIA HILLS*



H3 *ERYTHROXYLUM-PISONIA HILLS*

H4 *LEUCAENA-ANTIGONON HILLS*

H5 *BOTHRIOCHLOA-RUELLIA HILLS*

H6 *LANTANA-TALINUM HILLS*

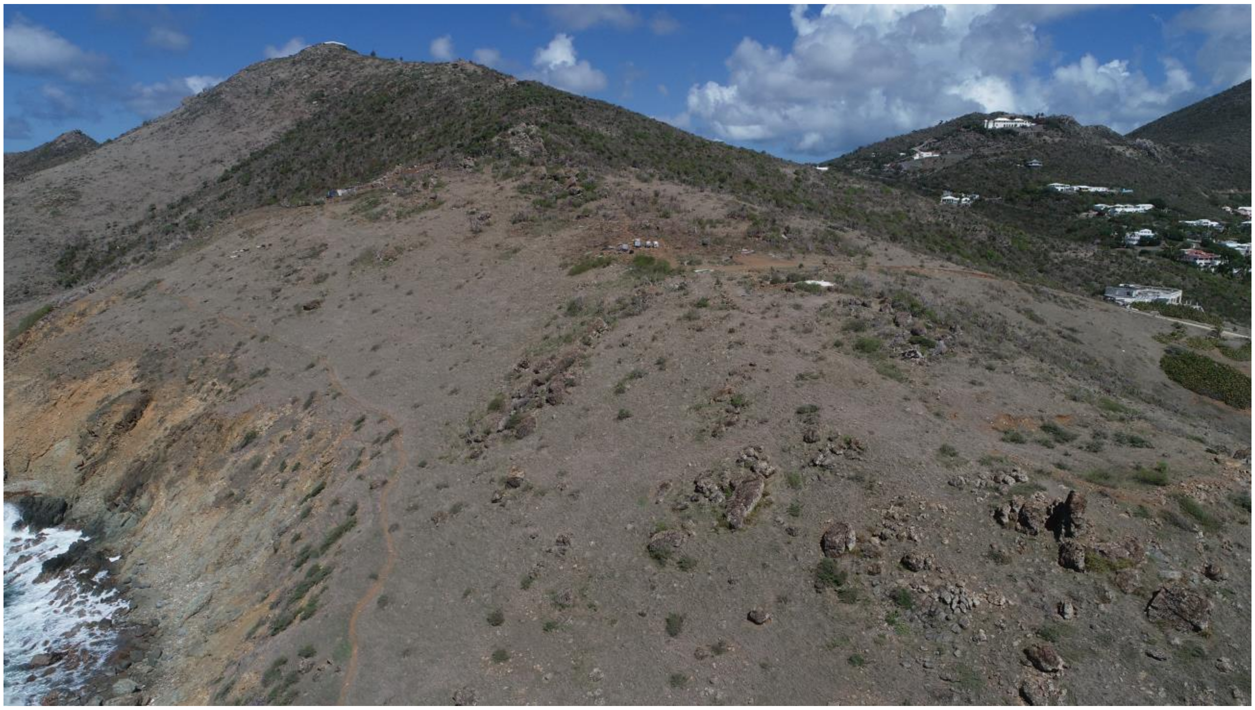
H7 *RUELLIA-BOTHRIOCHLOA HILLS*

L LOW LANDS

L1 *KRUGIODENDRON-PISONIA LOW LANDS*

C CLIFFS

C *RUELLIA-LAGUNCULARIA CLIFFS*



B BEACHES

B1 *LAGUNCULARIA-CONOCARPUS BEACHES*

B2 *CANAVALIA-IPOMOEA BEACHES*

APPENDIX 5. Surface area of each landscape unit in square meters and as percentage of total surface area of St. Maarten and of the sum of all units.

Landscape units	Area (m^2)	Area (km^2)	Percentage of total surface SxM	Percentage of total landscape units
B1	36798	0.04	0.1	0.2
B2	26836	0.03	0.1	0.2
C	135838	0.14	0.4	0.9
H1	3714101	3.71	11.7	23.8
H2	533488	0.53	1.7	3.4
H3	7177271	7.18	22.6	46
H4	419015	0.42	1.3	2.7
H5	3012655	3.01	9.5	19.3
H6	34891	0.03	0.1	0.2
H7	133468	0.13	0.4	0.9
L	388504	0.39	1.2	2.2
Urban areas	16103307	16.10	50.8	
SUM All	31716172	31.7	100	
Total of landscape units	15612865	15.6	49.2	