A landscape ecological vegetation map of Saba (Lesser Antilles)

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Contents

Abstract

A semi-detailed landscape-based vegetation map (scale: 1: 37,500) is presented for the 13 km^2 Lesser Antillean steep volcanic island of Saba, Netherlands Caribbean. The map is based on a total of 49 vegetation plots that were sampled in 1999 using a stratified random sampling design and analysed using TWINSPAN cluster analysis. Three hundred and fourteen (314) plant species, representing 56% of the total known flora (565 species), were recorded in the sample plots. The principal lower sections of the island possess a tropical savannah climate whereas the upper slopes reaching a maximum altitude of 870 m can best be characterized as a tropical rainforest climate.

A total of two main and nine different sub-landscape types were distinguished based on geology, geomorphology and nine distinguished vegetation types. In Saba, sharp contrasts in soil, geomorphology and climatic factors are found on a small spatial scale and this meant that compared to the other islands of the Dutch Caribbean there is little mixing and merging of vegetation types at the landscape vegetation level. Consequently, vegetation type translates relatively directly into landscape vegetation units. Aside from important contrasts in vegetation that correspond to what is known about differences in soil and climate, our study also shows that large vegetation changes have taken place on the island since the survey by STOFFERS, five decades earlier. These largely appear to be due to three major forces: a) hurricane impacts; b) natural succession made possible due to diminished agricultural activity and; c) invasive plants and plant pest species.

The most recent hurricane, hurricane Georges, which struck the island one year before this study, clearly caused much damage to the vegetation, especially high on Mount Scenery. As a consequence, the elfin woodland vegetation has virtually disappeared, while remnant sections have been radically altered. Based on studies elsewhere in the region, the elfin woodland can be expected to take very long (if at all) to gradually recover. The impact of various hurricanes in the last 60 years has clearly caused major disturbance of the vegetation throwing it back into earlier stages of succession. The development of the “Tree fern brake” into “Pioneer forest” vegetation must be seen as a positive change where a secondary community had entered a higher stage in the sequence of succession. The virtual disappearance of the formerly prominent secondary shrub communities like *Miconia* thickets, *Piper dilatatum* thickets and *Leucaena* thickets can also be seen as likely evidence of natural successional forces thanks to diminished agriculture and woodcutting. Invasive species was the third major force of change that clearly appears to have been active on Saba in recent decades. The lasting impacts of insect invaders which have decimated formerly prominent *Opuntia* (cactus) and *Tabebuia* (tree) populations testify to the impact of invasive species as a major driver of recent vegetation changes on Saba.

Our field data show that most wilderness areas of Saba remain strongly affected by roaming grazing goats even though the contribution of goats to the local island economy is negligible. Goat dung or traces of grazing were recorded in or adjacent to 46% of the sample plots. Grazing by exotic mammals reduces the resilience of natural vegetation types and interferes with natural succession. Highest livestock densities and impacts seem to be in the more vulnerable coastal arid zones along the western and southern sections of the island with poor soil conditions and more open and shrubby vegetation. The development of ‘Dry evergreen woodland’ under similar conditions on the more remote, windy and salt spray-affected, but less-grazed, northern sectors of the island, suggest that those disturbed areas of the southern and western coastal zones should have potential for woodland recovery if and when goat grazing is reduced. Therefore, a key priority for terrestrial conservation in Saba should be to reduce feral grazer densities to allow vegetation recovery and reduce vulnerability to erosion. We suggest the use of pilot demonstration projects for grazer exclusion as a useful way to help build stronger arguments and public support for tackling the roaming goat problem in Saba.

1. Introduction

The Dutch Caribbean volcanic island of Saba has a surface area of about 13 km^2 (De PALM 1985) and is located in the north-eastern Caribbean (17°37'-17°39' N, 63°13'-63°15' W). It is the smallest of the three islands of the Windward Dutch Caribbean (STOFFERS 1956). Its greatest length and width are 5 and 4 km respectively (STOFFERS 1956).

The flora and vegetation of the island have been studied quite extensively 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'. According to him, determinant factors affecting the state of vegetation development were 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 Saba, in which 13 vegetation types were described. His map was a low-resolution map (scale ca. 1:37,000) based on limited qualitative observations and the classification system developed by BEARD (1944, 1949, 1955). When land-use planning in the Dutch Caribbean began in the early 1980s, the need arose for up-to-date quantitative vegetation maps for all islands. After vegetation mapping projects for Curaçao (BEERS ET AL. 1997), Bonaire (FREITAS ET AL. 2005) and St. Eustatius (FREITAS ET AL. 2014), we here provide a landscape ecological vegetation map for Saba using identical methods. These were based on aerial photo-interpretation and stratified quantitative sampling, and involved 49 sample plots distributed around the island (ZONNEVELD 1979; 1988a; 1988b). Albeit on a rough scale, the earlier descriptive mapping work by STOFFERS (1956) offered a unique opportunity to compare and assess developments in vegetation over a 40 year period during which the natural vegetation might have been affected significantly by both natural and man-mediated impacts such as erosion, feral livestock grazing, hurricanes, the rapid rise of invasive species and the decline of agricultural cultivation.

This study describes the results of a quantitative vegetation survey of Saba, which includes the description of terrain characteristics, vegetation structure, species composition and spatial patterns in the landscape. The semi-detailed scale (LOTH 1990) for the landscape ecological vegetation map of Saba is 1:37,500. Its units are delineated and characterized on the basis of landscape-forming factors, such as geology, geomorphology, soil characteristics and vegetation. The quantitative approach used will facilitate the possibility to track future changes in the vegetation types and their distribution in landscape units over time.

2. The island of Saba

2.1 Geography

Saba is the northernmost volcanic island in the active arc of the Lesser Antilles island-arc chain (Fig. 1). The presence of Tertiary, Quaternary or (rarely) recent volcanoes is characteristic for these inner arc islands. The highest peak of Saba is the 870.4 m high Mount Scenery (also called 'The Mountain') (Fig. 1) and is of Pleistocene origin (ROOBOL & SMITH 2004). It is the top of a dormant volcano resting on a sea-bottom more than 600 m deep. The population of the island was about 1010 persons in 1982 (DE PALM 1985) and 1381 persons in 1999 (CBS 2009). At present (2015) the population amounts to about 1811 persons (www.cbs.nl).
Saba lies approximately 50 km to the south-west of St. Maarten and approximately 30 km to the northeast of St. Eustatius (DE PALM 1985). The capital of Saba is The Bottom.

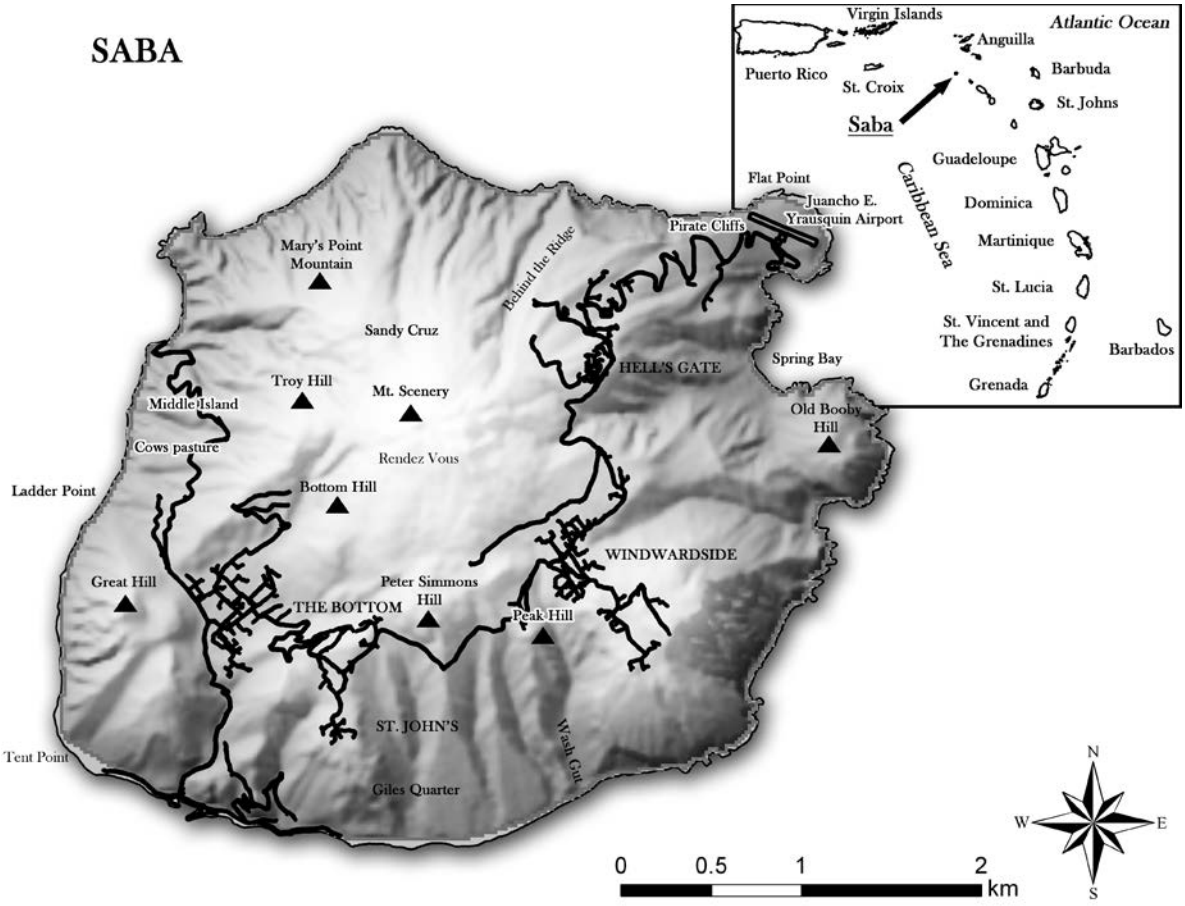


Fig. 1. *Map of the island of Saba with main topographical features, site names used in the text and the location of the island in the Lesser Antilles. (courtesy of David Haberkorn).*

Surrounding the main peak of Mount Scenery, several smaller hills can be found, like Troy (586 m), Mary's Point Mountain (566 m), Peter Simon's Hill (557 m), Great Hill (423 m), Peak Hill (401 m) and Old Booby Hill (223 m). The slopes of the peaks and domes are steep, in places exceeding 60° or are even nearly perpendicular. Several fairly straight to slightly curved, V- or U-shaped, steep-sided valleys or ravines (locally called "guts") run down the slopes of Mount Scenery (WESTERMANN & KIEL 1961). Some small, fairly level plateaus can be found and have been formed by accumulation of erosional material (valley of The Bottom, flats of Little and Big Rendez-Vous) or are essentially

remnants of watersheds (Windward Side, Spring Bay Field). The largest ones are the valleys of The Bottom and Flat Point. Protruding portions along the coast represent lava domes (e.g. Booby Hill, Old Booby Hill). The peninsula of Flat Point (where the landing strip is situated) is an example of a fan-shaped lava flow having descended even below sea level. The coast of the island consists of very steep, almost perpendicular escarpments that are either sea-washed or which have a very narrow, pebbly beach at the foot of the cliff. To the south of Flat Point there are two bays of which Spring Bay is the most southern one and is the only permanent (partly) sandy beach of the island.

2.2 Climatic data

The annual average rainfall on Saba as measured at the airport at about 30 m above sea level is 760.5 mm (1971-2000) (METEOROLOGICAL SERVICE OF THE NETHERLANDS ANTILLES & ARUBA: Appendix 1). This is over 30% lower than the averages given for The Bottom which lies at altitudes of about 250 m (STOFFERS (1956): 1133.5 mm (1947-1952); and BRAAK (1935): 1124 mm (1891-1898 & 1901-1933)). According to VEENENBOS (1955) precipitation is higher on the slopes of Mount Scenery and surpasses 2000 mm. This is e.g. reflected in more lush vegetation types above 500 m.

The most recent rainfall data (METEOROLOGICAL SERVICE OF THE NETHERLANDS ANTILLES & ARUBA: http://www.meteo.an/include/climate2/documents/clim_sum_Saba.pdf) shows that in recent times, the last five months of the year account for 50% of the annual rainfall. Only in the months November (134.5 mm) and May (95.9 mm) is the average monthly rainfall respectively above or close to 100 mm, which is the critical point below which evaporation exceeds precipitation in tropical areas (BEARD 1949; NIX 1983). STOFFERS (1956) described a situation where the last five months of the year all had monthly average rainfall figures above 100 mm. The driest months in STOFFERS (1956) were February, March, April, May and June, while at present these appear more spread out (January, March, April, June and October; METEOROLOGICAL SERVICE OF THE NETHERLANDS ANTILLES & ARUBA: http://www.meteo.an/include/climate2/documents/ clim_sum_Sab.pdf). It can thus be concluded that at present the rainfall pattern is totally different (and much drier) than the situation described by STOFFERS (1956). Fig. 2 shows the climate diagram for Saba for the period 1971-2000.

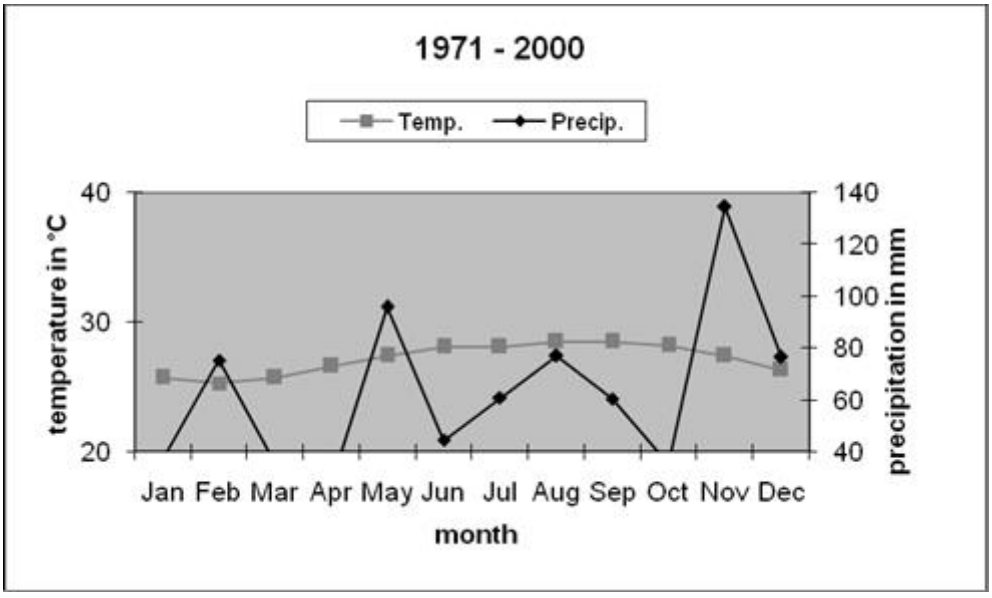


Fig. 2. *Walter climate diagram for the island of Saba (period 1971-2000). Source: Meteorological Department Curaçao.*

According to the KÖPPEN (1931) system of climate classification, the tropical climate of Saba falls in the A-category because the mean temperature of the coldest month exceeds 18 °C (AUGUSTINUS ET AL. 1985). A further classification of the A-category is based on the amount and distribution of the precipitation:

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.

According to VEENENBOS (1955) the climate of Saba lies somewhere between Am and Aw, which is also in accordance with the recent climatic data presented above. However, the top of Mount Scenery (above 800 m), should be characterized as an Af-climate based on estimated annual rainfall levels above 2000 mm (VEENENBOS 1955). This is the result of the fact that the top is almost continuously hidden in a cloud cap, raising the amount of precipitation and relative humidity significantly (AUGUSTINUS ET AL. 1985). This is a typical feature of the mountain peaks in Caribbean islands: a great billowy mass of “trade wind clouds” which remains upon them, masking their summits day after day and only dissipated in very dry or very still weather (BEARD 1949). This is reflected by the development of rainforest vegetation, palm brakes and elfin woodland at these heights.

Saba is situated in the zone of the north-eastern trade winds. Consequently, there is a continuous, predominantly easterly trade wind blowing over the island. The most frequently occurring wind directions are northeast (ne), east-northeast (ene) and east (e); together they account for 80% of the wind direction frequency (VERSTAPPEN ET AL. 1972).

The average wind speed at 10 m height is 5.2 m/s (1971-2000; METEOROLOGICAL DEPARTMENT CURACAO; Appendix 1). Saba is also located within the hurricane belt. The “official” Atlantic hurricane season extends from June 1 through November 30. Almost every year at least one hurricane passes within a range of 100 miles and on the average once every 4 to 5 years hurricane conditions are experienced (METEROLOGICAL SERVICE NERTHERLANDS ANTILLES AND ARUBA 2010; Appendix 2). Hurricanes that have caused significant damage to the nature of Saba more recently include Hugo (1989), Luis (1995), Marilyn (1995), Georges (1998), José (1999) and Lenny (1999). NIELSEN (2007) points out that in the 50 year period up to Hugo in 1989, only two major hurricanes had affected the islands.

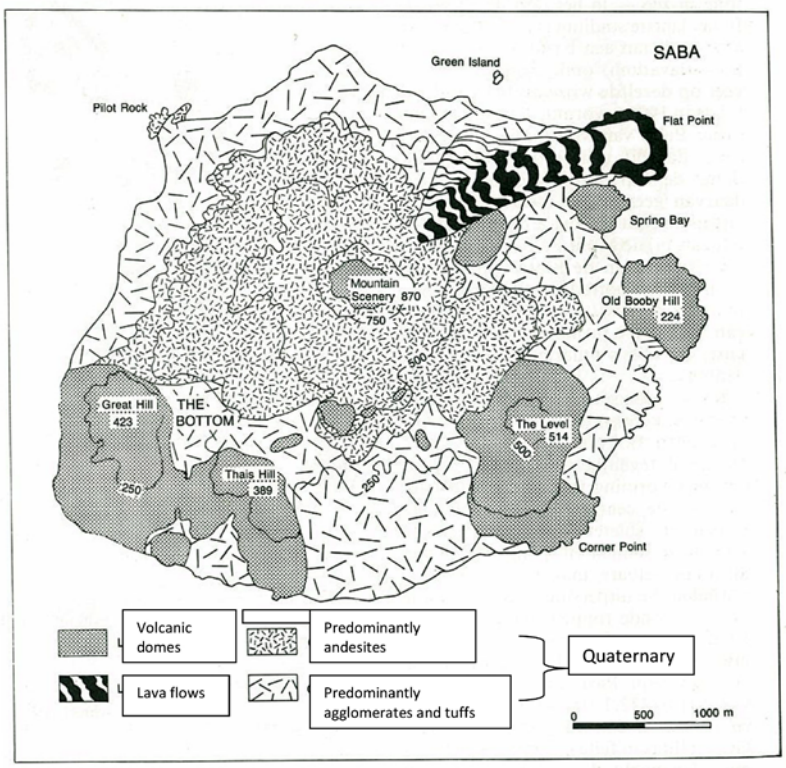
The average air temperature varies between 23.6 °C (February) and 26.5 °C (September) and the average maximum temperature varies between 27.7 °C (February) and 30.9 °C (August) (1971-2000; METEOROLOGICAL SERVICE OF THE NETHERLANDS ANTILLES & ARUBA, http://www.meteo.an/include/climate2/documents/clim_sum_sab.pdf). The hottest months are August and September, while January, February and March are the coldest. The temperature decreases with increasing height while precipitation increases. On the windward slopes there is heavier cloud formation and less sunshine (VEENENBOS 1955; STOFFERS 1956). According to VERSTAPPEN ET AL. (1972) this is not only the case for the windward slopes but also for the whole top of such conical hilltops (see also BEARD 1949).

2.3 Geology and geomorphology

2.3.1 Geology

Saba is a volcano of which three-fifths are above sea level. The first eruptions, starting the submarine phase, date back from the Middle or Upper Pleistocene (estimated at maximally 500.000 years ago). The last real volcanic phenomena lasted until approximately 500 years ago (Holocene) (ROOBOL & SMITH 2004).

A number of geological units can be distinguished on Saba (WESTERMANN & KIEL 1961; see Fig. 3). The basal formation consists of agglomeritic and tuffaceous strata with some intercalated andesitic beds (former lava flows). On the higher parts of the upper formation of The Mountain there is a combination of (less-exposed) andesitic lava rocks (main formation) and agglomerates and tuffs. In north-east Saba, there are the lava flows of Flat Point and Behind the Ridge. These are younger than the basal unit of the volcano. The volcanic domes and isolated volcanic dikes around Mount Scenery are young members of the volcanic sequence which have forced their way through the rocks of the older formations. During the formation of the dome in the crater of Mount Scenery hot volcanic ash, dust and gas (nuées ardentes) were produced and were deposited near Wash Gut. The only recent evidence of post-volcanic activity is the presence of some warm-water springs on the beach between Ladder Point and Tent Point (ROOBOL & SMITH 2004).



Geologische kaart van Saba.

Fig. 3. *Schematic geological map of Saba (adapted from: DE PALM 1985).*

By far the largest part of Saba is characterized by slopes exceeding 15º. Some parts, especially along the coast, have slopes steeper than 45º. The moderately-steep slopes of Mount Scenery (15º-45º) are covered with weathered and broken basaltic andesitic rocks. Steep-sided valleys or ravines locally called “guts”, run straight to slightly curved down the slopes of Mount Scenery. They only discharge water during and after heavy rainfall (‘intermittent guts’; WESTERMANN & KIEL 1961). V- and U-shaped guts can be distinguished. The V-shaped guts occur on the southern slopes. They developed in the basal unit dominated by agglomerates and tuffs. The U-shaped guts are characteristic for the western and northern parts of Saba. They are not restricted to the basal unit, but also occur in the

higher unit of predominantly andesites. According to the topography of the agglomeritic deposits, the coast of Saba can be divided in an eastern and south-eastern section and a northern and western section. The latter section is characterized by high steep cliffs, while the slopes of the former coastal areas are less steep. Lithological differences have led to an alternation of promontories (andesites) and bays (agglomerates and tuffs), especially along the eastern coast.

2.3.2 Soil types

A soil map for Saba (by VEENENBOS 1955) is presented in Fig. 4. Soil formation of any significance is only found above the 460 m contour and increases with height. Just below the 630 m contour soil formation is minor. The main soil type categories found on Saba from the top of Mount Scenery downwards are: 'clay loam' on the top of Mount Scenery, followed by various intergrading degrees of 'very stony loam' and 'cherty sandy loam'. In the eastern and southern sections of the island in different areas the 'cherty sandy loam' is replaced by 'very steep stony land' (VEENENBOS 1955).

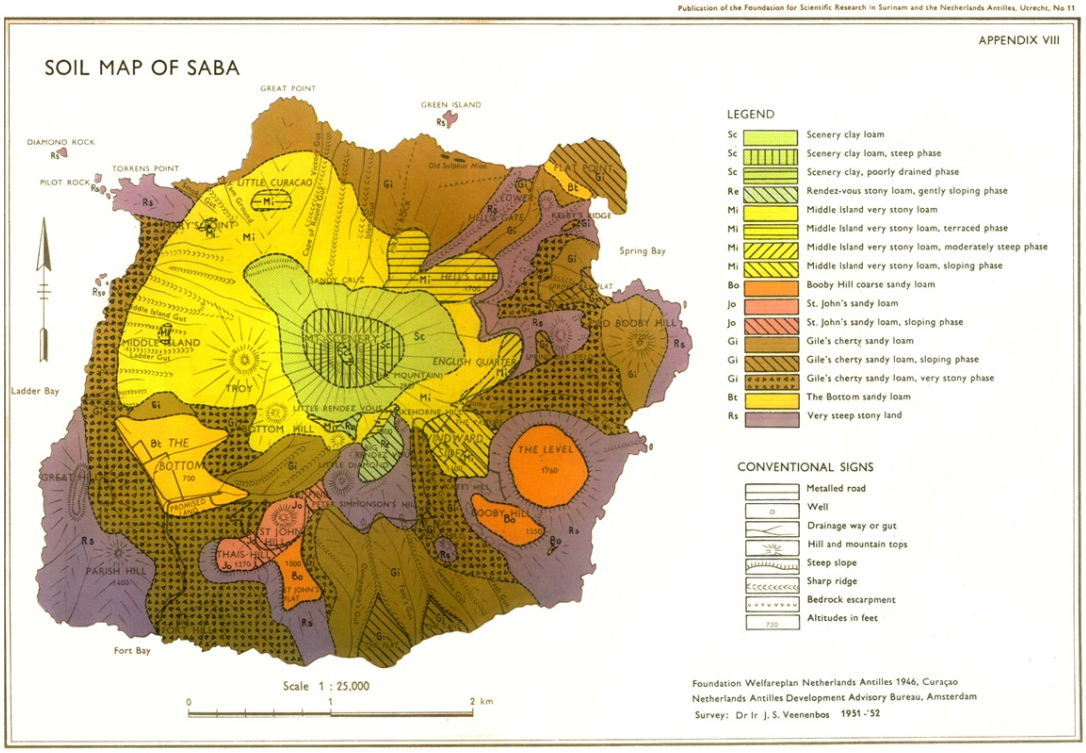


Fig. 4. *Soil map of Saba (source: VEENENBOS 1955).*

With exception of the poorly drained phase of the 'clay loam' in the bottom of the Mount Scenery (crater) depression, there is no great variance in the nutrient relations of the soils of Saba. With the exception of a slightly alkaline pH on the level areas, most soils on Saba are slightly acidic to neutral (VEENENBOS 1955). The rate of soil solution of nutrients is very high and noticeably higher than on St. Eustatius and St. Maarten. On the top of Mount Scenery the 'Scenery clay loam soils' are grown with palm brake and are only present in more or less level places of the rim of the depression. These soils developed under good drainage conditions in a very damp atmosphere. In the depression itself, a dark-coloured, poorly-drained clay soil occurs, rich in organic matter. Lower down the outer slope, an eroded phase of the typical Scenery soil, mapped as the 'Scenery clay loam, steep phase', is present. Still further down, both in the surface layers and deeper in the solum, the soil gets somewhat stony. These soils, as well as the 'Rendez-vous stony loam' soils located further down the slope and into which they intergrade, developed under good external drainage.

The 'Middle Island very stony loam', lacks a well-defined subsoil. On the eastern and southern slopes this soil series goes down no further than about the 460 m contour, due to exposure to the drying effect of the sun. On the more shady western and northern slopes it reaches as far down as the 265 m

contour. The ‘Gile’s soils’, forming the dryer equivalent of the ‘Middle Island soils’, have very shallow top soils over stony parent material and are therefore susceptible to sheet erosion. The parent material consists of cemented, closely packed rock debris. In the ‘Middle Island soils’ of the more shadowed western and northern slopes, weathering goes much deeper, and the rock debris is embedded in a loamy matrix. Largely outcropping rocks occupy the ‘Very steep stony land’.

So, with exception of the ‘Scenery clay loam’, the availability of nutrients are generally medium to very high, in the soil types on Saba (VEENENBOS 1955).

Looking at moisture conditions the following soil orders can be distinguished on Saba (SOIL SURVEY STAFF 1975; AUGUSTINUS ET AL. 1985):

1. Inceptisols (form quickly through alteration of parent material)
2. Alfisols (typically form under hardwood forests with distinct aluminium and iron content)
3. Mollisols (soils of grasslands with a thick dark surface horizon)
4. Entisols (from unaltered parent material and with no profile development)

With a few exceptions, the climatic variation with altitude causes a well-developed soil sequence (Table 1). With increasing altitude the availability of water increases, which is expressed in a better development of the soil profiles.

Table 1
The relationship between altitude, soil moisture regime and soil order on Saba (AUGUSTINUS ET AL. 1985).

Altitude (m a.s.l.)	Soil moisture regime	Soil order
± 600 - 875 m	Udic*	Inceptisols***
± 250 - ± 600 m	Udic	Mollisols***
below ± 50 m	Ustic**	Entisols***

* udic = The udic moisture regime implies that in most years the soil moisture control section is not dry in any part for as long as 90 cumulative days (SOIL SURVEY STAFF 1975).

** ustic = The ustic moisture regime is intermediate between the aridic and the udic regimes. It is one of limited moisture, but the moisture is present when the conditions are suitable for plant growth. If the mean annual soil temperature is 22°C or higher, or if the mean summer and winter soil temperatures differ by less than 5°C at a depth of 50 cm the soil moisture control section is dry in some or all parts for 90 or more cumulative days in most years. But the soil moisture control section is moist in some part for more than 180 cumulative days, or it is continuously moist in some parts for at least 90 consecutive days (SOIL SURVEY STAFF 1975).

*** Alfisols are locally developed in small patches throughout the three main soil orders.

2.4 Flora and vegetation

The flora and vegetation of Saba have been studied quite extensively, although the information is quite dispersed over a number of publications (BOLDINGH 1909, 1913, 1914; ARNOLDO 1964, 1967, 1971; STOFFERS 1956, 1963-1984, 1981; HOWARD 1974-1989; WIERSMA 1984). More recently, a biological inventory of the island was conducted (ROJER 1997), the New York Botanical Garden developed a digital flora of Saba and launched a website for this (MORI ET AL. 2007), and some additional work has been done on specific plant groups (LELLINGER 2002, CHIPKA and IZQUIERDO 2005; CHIPKA 2009a,b,c; BOEKEN 2014). BOLDINGH (1909) considered the vegetation of the three Windward Islands (St. Eustatius, Saba and St. Maarten) to be generally identical to each other with a particular formation being predominant on each island. BOLDINGH (1909) distinguished four vegetation types on Saba.

Vegetation of:

1. Top and slopes of Mount Scenery
2. Arid hills.
3. Seashore and rocky localities
4. Cultivated areas.

The conical shape of the island of Saba results in the fact that there are almost only steep slopes on the island. These slopes are covered by the *Eriodendron* vegetation. This vegetation is a greenish woody vegetation (BOLDINGH 1909). The top part of Mount Scenery higher than 500 m a.s.l. has a very well-developed tropical rainforest that is characterized by a great number of fern trees (contrary to St. Eustatius). This rainforest is also home to an abundance of ruderal plants. In contrast the lower arid hill vegetation is generally poor in plant species and contains species that are predominantly characteristic for disturbed sites. It is also here that the *Croton* vegetation is found, but this vegetation only has a limited distribution on Saba compared to St. Eustatius. The total surface area covered by seashore and rocky vegetation is very limited and does not play a role in the determination of the general aspect of the vegetation of the island. The vegetation of the cultivated areas is found in all areas apt for cultivation and in combination with human habitation. This vegetation type is often intermixed with the *Eriodendron* vegetation.

The vegetation study of STOFFERS (1956) of Saba, St. Eustatius and St. Maarten resulted in the description of 28 different vegetation types. These types were clustered in the following three main groups: primary climatic climax communities, primary edaphic climax communities and secondary and sub-climax communities. This classification system is based on earlier work by BEARD (1944, 1949 and 1955; see also HOWARD 1973). For Saba, STOFFERS (1956) distinguished 13 different vegetation types from the primary climatic climax communities and secondary and sub-climax communities. Of these, only eight plant communities were actually mapped by STOFFERS (1956). Those that were not mapped are the following: *Miconia* thickets, *Piper dilatatum* thicket, Pioneer forest, *Leucaena* thicket and *Croton* thickets derived from seasonal formations. According to STOFFERS (1956) the vegetation types of the Dutch Windward Islands were mainly determined by climatic factors.

This study and previous publications so far on the flora of Saba (BOLDINGH (1909, 1913, 1914); ARNOLDO (1964, 1967, 1971); STOFFERS (1956, 1963-1984, 1981); HOWARD (1974-1989); WIERSMA 1984; ROJER 1997; LELLINGER 2002, CHIPKA and IZQUIERDO 2005; CHIPKA 2009a,b,c; BOEKEN 2014) have served to determine that the flora of the island consists of about 565 species in 342 genera and 106 families; 20% of the species does not occur on either St. Eustatius (21 km^2) or St. Maarten (34 km^2). The flora of St. Eustatius and St. Maarten, both significantly larger islands, are less than this, respectively, 505 and 544 species.

The main families of the flora of Saba are: *Gramineae* (51 spp., 28 genera*), Polypodiaceae* (43 spp., 15 genera), *Compositae* (34 spp., 23 genera), *Rubiaceae* (23 spp., 15 genera) and *Fabaceae* (22 spp., 15 genera). These same families are also the most important plant families on nearby St. Eustatius, albeit in a slightly different sequence of importance. For sister island St. Maarten the most important plant families are not completely the same. The sequence in descending order of importance is as follows: *Gramineae* (65 spp.), *Compositae* (31 spp.), *Euphorbiaceae* (30 spp.), *Fabaceae* (28 spp.) and *Malvaceae* (21 spp.). The data in Table 2 show the grade of (dis)similarity among the (current) floras of the three Dutch Windward Islands.

Table 2

Similarity of the flora of the three Dutch Windward islands of Saba, St. Eustatius and St. Maarten.

	% 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. found only on a single island	42%

When grouped by region of current distribution, about 51% of plant species have a respectively wide distribution on the American continent, 30% have a world-wide distribution, 14% are restricted to the West-Indies, and 5% are restricted to the Lesser Antilles. Saba (for so far known) lacks island endemics, but some species present are Lesser Antilles and West-Indian species that have a very limited geographic distribution:

- *Bunchosia jamaicensis* occurs only on Saba and Jamaica (STOFFERS 1984)
- *Mitracarpus polycladus* is found only on Saba and Puerto Rico (HOWARD 1989b)
- *Eupatorium macranthum* is limited to Saba, St. Eustatius, St. Kitts and Nevis (HOWARD 1989b).
- *Begonia retusa* is found only on Saba, St. Eustatius, St. Kitts, St. Barth's and Montserrat (HOWARD 1989a)
- *Myrcia citrifolia* var. imrayana is restricted to the Dutch Windward islands, St. Vincent, Grenada, Guadeloupe and Martinique (HOWARD 1989a (part2)).
- *Agave karatto* is limited to Saba, Antigua, Barbuda, St. Kitts, Montserrat and La Désirade (HOWARD 1979).
- *Charianthus purpureus* var. *crinitus* is confined to Saba and St. Kitts (STOFFERS 1982).

2.5 Human influence on flora and vegetation

It may be assumed that before the arrival of Europeans around 1640 on Saba (DE PALM 1985), human influence on flora and vegetation was relatively limited. Nevertheless, the pre-colonial native inhabitants of the Caribbean widely transported animals and plants of value as food (BERMAN & PEARSALL 2000; HOFMAN & HOOGLAND 2003). Undoubtedly a number of tree species of food value, such as possibly *Annona muricata, A. squamosa* and others, must have been introduced. Suitable land for agriculture has always been scarce on Saba (DE PALM 1985) and practically limited to small, more or less level areas found at higher altitudes and totalling slightly over 200 ha (DE PALM 1985). The relatively extensive farming in the colonial period and use of exotic plants resulted in many ruderal plants today forming part of the vegetation of the higher hills on the island (rainforest vegetation) (BOLDINGH 1909; STOFFERS 1956). During STOFFERS' study he noted the following exotic plants being cultivated in (semi-) natural areas: yams, sweet potatoes, potatoes, cabbage, pineapple, lettuce, peppers, breadfruit and cassava. In the 1980s only 64 ha of the land suitable for agriculture was still in use (DE PALM 1985).

3. Methods

3.1 Photo interpretation and fieldwork

For the survey of the (semi)-natural vegetation areas of Saba, 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 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 49 plots was 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

Fieldwork was done in October and November 1999. 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 slope)); 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); 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 presence or absence based on excrement or signs of grazing in or adjacent to the sample plot was recorded.

Vegetation structure and floristic composition: total real cover; cover and height (average and maximum) of each stratum. The average height of the highest structural layer (if constantly present in (most) sample plots) was taken as the average height of the vegetation in the plot.

When it was difficult to distinguish between a shrub layer and a tree layer or a shrub and a herb layer, these were considered as one layer. Sometimes the tree and/or shrub layer could be divided into a higher and a lower layer. In each plot, all plant 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); ARNOLDO (1964); STOFFERS (1963-1984); LITTLE & WADSWORTH (1964); PINTO-ESCOBAR & MORA-OSEJO (1966); LITTLE ET AL. (1974); GODFREY & WOOTEN (1979); HOWARD (1974, 1977, 1979, 1988, 1989a & b); CORREL & CORRELL (1982); and LIOGIER (1985-1997). Nomenclature of the plant species is based on HOWARD (1974, 1977, 1979, 1988, 1989a & b), except for species not treated by HOWARD, in which case we used STOFFERS (1981). Where necessary these names were updated using AXELROD (2011). Names for the fern species are based on PROCTOR (1977, 1989) and AXELROD (2011). Some plant species proved difficult to identify; when only the genus could be determined, the genus name is followed by the extension 'spec.'.

3.3 Data processing

A total of 314 plant species was recorded in the 49 sample plots used. This represents about 56% of the total known flora (565 species). 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 TWINSPAN (Two-Way Indicator Species Analysis; HILL 1979) that served to distinguish the vegetation types. 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 314 plant species and a frequency scale of I-V is used as an index of species presence. A distinction was made between differentiating species, common species, "other" species and rare species. In this appendix highly differentiating species, as determined using TWINSPAN are indicated in bold. "Common species" include species that are present in more than three clusters (of the total of nine) with at least a presence category of III, or in more than five clusters with a low presence category (< III). "Other species" refer to species that occur in maximally three clusters with at least a presence category of III or in maximally five clusters with low frequency categories (< III). "Rare species" occur in maximally two clusters in low presence (I or II) (DE FREITAS ET AL. 2014; BOKKESTIJN & SLIJKHUIS 1987). Each vegetation type is characterized by the presence or absence of (a combination of) certain species and was given a binary name. The first part of the binary name represents a common and often dominant species with a high coverage. The second part of the binary name is a differentiating or accompanying species, occurring in at least 41% of the sample plots of that type (for justification of specific choices please see Appendix 3). When no differentiating species were present, the second most important (and characteristic) species was taken to define the type. In one case (type 8) there was an (almost) exclusively dominant species, and in this case only the name of this species was used to denominate the type.

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

3.4 Final map compilation

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

The hierarchical ordering principle in the construction of the names of the land types in the final legend was (1) geology and land type; (2) terrain form (mountains, cliffs, beach); and (3) vegetation structure and floristic composition (vegetation types). The subdivision of land types is based on differences in the associated vegetation. The names of the legend units 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 later-on edited in ArcGIS into which also all information on topography, geology, landscape, soil characteristics and vegetation types were stored. The final map was made with ArcGIS, by combining the main topographic features and the vegetation communities. Because of practical reasons, the scale of the final map was not set at 1:16,000, as would be the case considering the ideal 1:2 ratio of aerial photographs and final map (VAN GILS ET AL 1985; LOTH 1990), but at 1:20,000 to be at a semi-detailed scale for best comparison with the map of STOFFERS (1956).

4. Results

4.1 Vegetation types

Cluster analysis of the 49 sample plots resulted in a total of nine vegetation types. The synoptic table of the nine vegetation types (Appendix 3) gives the presence of each species in each vegetation type. The nine vegetation types are described below and summarised 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 nine vegetation types of the present study and their correlation with the soil and land types of VEENENBOS (1955). The accompanying soil map by VEENENBOS (1955) can be used to find a correlation between the vegetation types and soil- and land types.

Table 4

Summary overview of mean biotic and abiotic community characteristics for the nine vegetation types distinguished. For further details see individual vegetation types below.

	Vegetation type								
	1	2	3	4	5	6	7	8	9
	Heliconia - Charianthus	*Philodendron - Marcgravia*	*Philodendron - Cordia*	*Inga - Pharus*	*Coccoloba - Myrcianthus*	*Swietenia - Leucaena*	*Wedelia - Plumbago*	*Bothriochloa*	*Aristida - Mitracarpus*
Number of plots	4	6	9	4	6	4	3	5	8
pH	5	6.2	6.8	6	6	6.5	7	6.5	7.3
Slope (°)	25	32	42	49	40	30	41	30	41
Exposure direction*	nw	var	var	nw	n	nnw	var	ene	var
Goat presence (%)	25	17	22	0	33	75	100	100	75
# of species	44	38	41	47	31	32	30	13	10
Total real cover (%)	94	89	87	82	73	73	50	63	28
Height of vegetation (m)	1.5	3.4	3.8	7.2	5	4.4	3.3	0.4	0.3

* (exposure = compass direction of the slope of the land; "var" refers to vegetation types that occurred on locations with a variety of slope exposures in this study.

1 *HELICONIA BIHAI - CHARIANTHUS PURPUREA* TYPE (4 RELEVÉS)

This species-rich vegetation type is found on the top of Mount Scenery. Its average total real cover (94 %) is the highest of the vegetation types occurring on Saba. The high cover percentage is the result of the dense and mostly combined shrub/ herb layer. The tree layer is very open and consists of only a few species. The most important tree species is *Prestoea montana*, while *Freziera undulata* has become noticeably scarce since STOFFERS (1956). The differentiating species are *Nephrolepis rivularis* (a fern), *Cecropia schreberiana* (a tree), *Rubus rosifolius* (an introduced shrub), *Peperomia emarginella* (a herb), *Charianthus purpurea* (a shrub), *Besleria lutea* (a shrub), *Hymenophyllum hirtellum* (a fern) and *Pilea obtusata* (a herb). The latter three species occur exclusively in this vegetation type. In the higher shrub layer the pioneer *Cecropia schreberiana* is present while *Heliconia bihai, Cyatheaceae spp.* and *Piper dilatatum* have the highest cover. The following species are prominent in the herb layer: *Paspalum conjugatum, Begonia retusa, Besleria lutea, Pilea obtusata* and *Panicum trichoides*. Few dicotyl climbers are found and of the three climbing *Araceae* found, *Philodendron giganteum* is the most conspicuous in all structural layers. Orchids and ferns are well-represented in this vegetation type (BOEKEN 2014). The latter group forms a diverse group in the present vegetation type of which *Thelipteris reticulata, Hymenophyllum hirtellum* and *Nephrolepis*

rivularis are the most prominent elements both in presence and cover. Epiphytic mosses are abundant. The low cover of the tree layer as well as the low average height of the vegetation and the high cover of the shrub/herb layer have to do with the impact of hurricane Georges (1998; VAN'T HOF 2010) on this habitat (pers. obs. T. van 't Hof). The soil in this vegetation type has the lowest pH of all vegetation types studied. This probably is the result of the fact that this clayey soil, due to its location in the depression of Mount Scenery, has a poor drainage and is rich in organic matter.

pH	5.0
Slope	25 ° (15-40°)
Exposure	w-nw-n
Goat presence	25%
# of species	44 (35-47)
Total real cover	94 % (90-98 %)
Height of shrubs/herbs	1.5 m (0.7-2.0 m)

2 *PHILODENDRON GIGANTEUM - MARCGRAVIA UMBELLATA* TYPE (6 RELEVÉS)

On the higher slopes of Mount Scenery, often covered in clouds, this rather high vegetation type is found. An open tree layer usually overtops the well-covering but not always distinct shrub and herb layer. Principal species of the tree layer are *Prestoea montana*, *Citharexylum spinosum* and different species of *Cyatheaceae. Philodendron giganteum* is the dominating species in the shrub/herb layer, followed by *Heliconia bihai*. Types 2 and 1 are the only vegetation types in which *Cyatheaceae spp.* are found, whereas there are also other species that only occur in either of these two vegetation types. Comparing these two vegetation types shows that type 2 is higher because of the presence of a tree/shrub layer, but the species richness in type 2 is on average lower. *Nectandra krugii* is only found in this vegetation type. The epiphytic bromeliad *Vriesea ringens* and the low shrub *Gonzalagunia spicata* are always present as are fields of the fern *Blechnum occidentale*. Among the climbers and vines, *Monstera adansonii, Ipomoea tiliacea* and *Passiflora rubra* are common. Mosses are always present on trees and stones. Former agricultural fields that have been overgrown can still be recognized within this vegetation type. Based on slope angle values measured for all vegetation types it can be concluded that the range of values of the slope angle measured for this type is intermediate. The soil type is mostly 'Rendez-vous stony loam' followed by 'Scenery clay loam'. 'Rendez-vous stony loam' has a slow internal drainage while run-off is rapid (VEENENBOS 1955).

pH	6.2
Slope	32 ° (20-50°)
Exposure	sw-wnw-n-e
Goat presence	17%
# of species	38 (30-45)
Total real cover	89 % (70-100 %)
Height of shrubs/trees	3.4 m (1.4-9.0 m)

3 *PHILODENDRON GIGANTEUM - CORDIA SULCATA* TYPE (9 RELEVÉS)

This vegetation type occurs adjacent to type 2 but lower on the slope of Mount Scenery. There is a dense tree and shrub layer or a combined tree/shrub layer, dominated by the climber *Philodendron giganteum*. In common with types 1 and 2, type 3 has a high presence of *Heliconia bihai* and *Prestoea montana*, but the cover of these species is significantly lower. Among the most important higher trees are *Byrsonima spicata, Inga laurina* and the differentiating *Cordia sulcata*. In the lower trees/high shrubs layer, *Myrcia splendens* and *Clusia major* have the highest cover. *Piper dilatatum, Miconia laevigata* and *Blechnum occidentalis* are important species in the (lower) shrub layer. Vines are well represented with e.g. *Ipomoea tiliacea* and *Melothria pendula.* Fruit trees that were planted in former times, such as *Mangifera indica*, *Citrus limon*, *Psidium guajava* and *Carica papaya* are found. Ferns occur always, but epiphytic *Bromeliaceae* are uncommon. Mosses are always present and lichens mostly. The following characteristic species of the secondary rainforest have their highest presence in

this type: *Clusia major*, *Cordia sulcata* and *Tabernaemontana citricifolia*. *C. sulcata* is differentiating for this type. *Ocotea leucoxylon* is also found mainly in this vegetation type on Saba. Noticeable is the relatively higher presence of loose stones averaging about 34% of the ground cover. The variation in soil slope angles in this type is the largest of all vegetation types. The topography is hilly to steeply dissected. The soil is mostly of the 'Middle Island very stony loam' type, followed by the 'Rendez-vous stony loam' type. Root penetration can go deep between the stones present which facilitates the growth of large trees. Overall drainage can be considered adequate (VEENENBOS 1955).

pH	6.8
Slope	42 ° (28-90°)
Exposure	ssw-nw-nne
Goat presence	22%
# of species	41 (30-46)
Total real cover	87 % (80-96 %)
Height of trees/shrubs	3.8 m (1.5-6.0 m)

4 *INGA LAURINA - PHARUS LAPPULACEUS* TYPE (4 RELEVÉS)

This vegetation type is found on the mid sections of the western and southern slopes of Mount Scenery. In this type, the highest number of plant species was recorded. The tree layer attains both on average and maximally the greatest heights of all types. Tree species are most abundant. The trees *Inga laurina, Myrcia splendens, Coccoloba swartzii* and *Guettarda scabra* have their highest cover here. The first two, as well as *Allophylus racemosus*, *Nectandra coriacea, Picrasma excelsa* and *Pisonia fragrans,* are common. Many ferns and vines can be encountered but *Bromeliacaea* are scarce. In the relatively open herb layer *Piperaceae* occur frequently while *Psychotria nervosa* is the only common low shrub. *Araceaea* are common on the ground and in the trees. The following species are differentiating: *Pharus lappulaceus* (a grass)*, Adiantum tenerum* (a fern) and *Smilax guianensis* (a vine). *Thelypteris tetragona*, *Smilax guaianesis*, *Oeceoclades maculata*, *Picrasma excelsa* and *Tragia volubilis* occur mainly in this type. Lichens are often present, while mosses are abundant. The average slope value is the highest of all vegetation types described for Saba while the variance is very small. The soil is mostly of the 'Middle Island very stony loam' type, followed by 'Very steep stony land'. The former is characterized by the possibility of deep root penetration between the many stones and an adequate drainage (VEENENBOS 1955).

pH	6.0
Slope	49 ° (45-53°)
Exposure	w-nw-nnw
Goat presence	0%
# of species	47 (36-55)
Total real cover	82 % (77-85 %)
Height of trees	7.2 m (5.8-10.0 m)

5 *COCCOLOBA SWARTZII - MYRCIANTHUS FRAGRANS* TYPE (6 RELEVÉS)

This vegetation type is found on the lower north-western and northern to eastern slopes of Mount Scenery and represents a drier habitat. The average number of species as well as the average total real cover is considerably lower than in the preceding vegetation types. The combined tree and shrub layer is rather high, and dominated by the trees *Coccoloba swartzii* and *Guettarda scabra*. These species reach their highest cover/presence in this type. Other species that are common in this layer are *Casearia decandra*, *Daphnopsis americana* and the differentiating *Annona muricata*, *Maytenus laevigata, Ardisia obovata* and *Myrcianthus fragrans*. *A. muricata* is a common fruit tree that is generally ascribed to colonial introduction but may well have been introduced by preceramic Amerindians that occupied Saba as early as 3300 BP (HOFMAN & HOOGLAND 2003). In the usually open herb layer, *Peperomia myrtifolia* is always present and reaches its highest cover in this type. The majority of the tree species present are evergreen with the exception of some common deciduous

trees: *Randia aculeata, Pisonia subcordata* and *Bursera simaruba*. Climbers and vines are scarce with the exception of *Philodendron giganteum* and *Cissus verticillata.* Sometimes ferns and bromeliads are present. Mosses and lichens can be found on trees and rocks. The soil type is mostly 'Gile's cherty sandy loam' and with a lesser role for 'Middle Island very stony loam'. The 'Gile's cherty sandy loam' soils have very shallow top soils over stony parent material, consisting of cemented, closely packed rock debris. Root penetration below the topsoil is difficult, contrary to the 'Middle island very stony loam', which restricts average tree size. The Middle island soils are considered the moister equivalent of the 'Gile's soils'.

pH	6.0
Slope	40 ° (33-48°)
Exposure	nw-n-ne
Goat presence	33%
# of species	31 (28-41)
Total real cover	73 % (67-84 %)
Height of trees	5.0 m (4.0-7.5 m)

6 *SWIETENIA MAHAGONI - LEUCAENA LEUCOCEPHALA* TYPE (4 RELEVÉS)

This vegetation type is restricted to the gentle lower western slopes of Saba in the area called 'Cow Pasture' and both north and south of it. The characteristic layer is the combined tree and shrub layer. *Swietenia mahagoni* is obviously dominant, occurring in all plots and having a very high cover compared to other species within this vegetation type and also compared to any other dicotyl species within other vegetation types. At the same time this species is differentiating together with *Leucaena leucocephala* and *Capparis baducca. Eugenia axillaris* and *Pimenta racemosa* are common and have a high cover. The (fruit) tree *Melicoccus bijugatus* is only found in this vegetation type, but occurs in a very low cover. Herbs are usually very scarce. No *Araceae* are present and only a few *Bromeliaceae*, dicotyl climbers and ferns occur. Mosses and lichens are found on trees and rocks. The slopes of Cows Pasture are among the gentlest slopes of Saba. The soil consists for the largest part of the 'Middle Island very stony loam' and in the lower parts of the 'Gile's cherty sandy loam'. Root penetration between the stones in this soil type is seriously hampered (VEENENBOS 1955).

pH	6.5
Slope	30 ° (23-34°)
Exposure	nw-nnw-n
Goat presence	75%
# of species	32 (15-50)
Total real cover	73 % (70-75 %)
Height of trees/shrubs	4.4 m (3.5-5.0 m)

7 *WEDELIA CALYCINA - PLUMBAGO SCANDENS* TYPE (3 RELEVÉS)

This is the second-most open vegetation type of all the types described for Saba (vegetation type 9 being the most open with only 28% average cover). In this type, the tree layer has the highest cover while the shrub layer has the highest number of species. Differentiating species are *Plumbago scandens* (a shrub) and *Iresine diffusa* (a herb). Dominant in the tree layer is *Pisonia subcordata* (but at low absolute coverage) while *Eugenia axillaris* is a frequent species. *Wedelia calycina* is dominant in the shrub layer (with highest absolute coverage) while *Croton astroites*, and *Lantana camara*, are frequent in this layer. *Bryophyllum pinnatum* (an exotic species) and *Justicia sessilis* are frequent in the herb layer. The herb layer is relatively open but reasonably speciose. Mosses are nearly always present, whereas lichens are mostly absent. This vegetation type is transitional between the woodlands and low grass vegetation. It is found on the lower slopes of the southern and south-western hills and on Pirate Cliff. Compared with the other vegetation types, the percentage of rocks is the largest. The soil is only of the 'Gile's cherty sandy loam' type.

pH	7.0
Slope	41 ° (38-46°)
Exposure	nnw-ene-sse
Goat presence	100%
# of species	30 (17-37)
Total real cover	50 % (36-69 %)
Height of trees/shrubs	3.3 m (1.2-7.0 m)

8 *BOTHRIOCHLOA PERTUSA* TYPE (5 RELEVÉS)

An invasive grass species is dominant and differentiating in this vegetation type: *Bothriochloa pertusa*. This type has a low species diversity. *Croton astroites*, *Lantana camara* and *Urechites lutea* are common in the open to rather well-covering shrub layer. This vegetation type occurs on the lower slopes of Saba, areas that are preferred as grazing areas by roaming livestock. Mosses are nearly always present, while lichens occur only sporadically. The relief of the terrain varies from undulating to very flat. The soil is of the 'Gile's cherty sandy loam' type.

pH	6.5
Slope	30 ° (17-43°)
Exposure	n-ene-se
Goat presence	100%
# of species	13 (6-26)
Total real cover	63 % (32-80 %)
Height of herbs/shrubs	0.4 m (0.1-1.0 m)

9 *ARISTIDA ADSCENCIONIS – MITRACARPUS POLYCLADUS* TYPE (8 RELEVÉS)

This vegetation type occurs bordering the often-steep cliff areas found almost all around Saba and is characterized by the presence of a relatively high number of *Gramineae* and *Cyperaceae*. This vegetation has the lowest cover and lowest number of species. *Aristida adscencionis* occurs mainly in this type. The fern *Pitogramma calomelanos* is characteristic for the rubble slopes within this vegetation type. Mosses and lichens are sometimes found. The most alkaline soils (average pH: 7.3) of the island were found in this type. The soil is mostly a 'Gile's cherty sandy loam', with small amounts of 'Very steep stony land'. The sloping phase of 'Gile's cherty sandy loam' here often has the lowest rate of solution and therefore of available nutrients (VEENENBOS 1955).

pH	7.3
Slope	41 ° (15-65°)
Exposure	nne-ese-wsw
Goat presence	75%
# of species	10 (4-27)
Total real cover	28 % (7-57 %)
Height of shrubs/herbs	0.3 m (0.1-0.5 m)

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 **VEGETATION TYPE**	**Sc**	**Re**	**Mi**	**Gi**	**Rs**
Heliconia - Charianthus type	10				
Philodendron - Marcgravia type	2	8			
Philodendron - Cordia type		2	7		1
Inga - Pharus type			8		2
Coccoloba - Myrcianthus type			3	7	
Swietenia - Leucaena type			8	2	
Wedelia - Plumbago type				10	
Bothriochloa type				10	
Aristida - Mitracarpus type				9	1

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

Column: Sc = Scenery clay loam; Re = Rendez-vous stony loam; Mi = Middle Island very stony loam; Gi = Gile's cherty sandy loam; Rs = Very steep stony land.

4.2 Description of the final legend units

The main legend of the landscape ecological vegetation map of Saba is divided into two different landscape types (Fig. 5). Table 6 gives a summary of the relative occurrence of the vegetation types in each of the listed (sub-) landscape types.

Table 6

Estimated cover of plant communities in the different (sub-)landscape units (based on plot data, field observation and photo-interpretation).

		Vegetation Type	Heliconia- Charianthus type	Philodendron - Marcgravia type	Philodendron - Cordia type	Inga - Pharus type	Coccoloba - Myrcianthus type	Swietenia - Leucaena type	Wedelia - Plumbago type	Bothriochloa type	Aristida - Mitrcarpus type
		#	1	2	3	4	5	6	7	8	9
Landscape Unit	**symbol**										
Heliconia - Charianthus Mountains	M1		10								
Philodendron - Marcgravia Mountains	M2			10							
Philodendron - Inga Mountains	M3				6	3	1				
Swietenia Mountains	M4							10			
Coccoloba - Wedelia Mountains	M5						8		2		
Coccoloba - Inga Mountains	M6				2	3	3		2		
Aristida - Bothriochloa Mountains	M7								2	3	5
Bothriochloa Mountains	M8									10	
Aristida Cliffs	C										10

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

The following landscapes and legend units were distinguished:

M MOUNTAINS

The whole island of Saba, except for the cliffs along the coast, is defined as the landscape type ‘Mountains’. The Mount Scenery (870.4 m) in the middle of the island is surrounded by several lower hills. Deep guts intersect the slopes of Mount Scenery. This landscape includes a range of vegetation types that goes from the vegetation on the top of the Mount Scenery described as cloud forest to the grassy vegetation in the more coastal areas. This is related to the variation in altitude between the different zones.

M1 *HELICONIA - CHARIANTHUS MOUNTAINS*

Only one vegetation type is found in and is also restricted to this sub-landscape: the *Heliconia - Charianthus* type (type 1). M1 is restricted to the highest parts of Mount Scenery, in the depression as well as on the rim and on the first stretch down the slope of the mountain.

M2 *PHILODENDRON - MARCGRAVIA MOUNTAINS*

The *Philodendron - Marcgravia* sub-landscape consists completely of the *Philodendron - Marcgravia* vegetation (type 2). It is found lower on the slopes of Mount Scenery than the *Heliconia - Charianthus* Mountains (M1). On the northern and western slopes, this sub-landscape type continues downwards to lower altitudes (app. 500 m) than on the eastern and southern slopes (app. 600 m). Downwards on the slopes the soil eventually changes from a 'Scenery clay loam' to a 'Rendez-vous stony loam type'.

M3 *PHILODENDRON - INGA MOUNTAINS*

This sub-landscape is dominated by the *Philodendron - Cordia* type (type 3), but with the *Inga - Pharus* type (type 4) occasionally, and *Coccoloba - Myrcianthus* type (type 5) more rarely present. This sub-landscape is characteristic for the higher hilltops around Mount Scenery, e.g. Mary's Point Mountain, Troy Hill and Bottom Hill. On the western slopes its lower limit is approximately at 200 m a.s.l., and on the eastern slopes its lower limit is at approximately 500 m. The area of this sub-landscape consists mainly of the 'Middle Island very stony loam' soil.

M4 *SWIETENIA MOUNTAINS*

This sub-landscape consists only of the *Swietenia - Leucaena* type (type 6).This vegetation type is only found in the M4 landscape type which is limited to the area of Cows Pasture on the more protected parts of the lower western slope of Mount Scenery.

M5 *COCCOLOBA - WEDELIA MOUNTAINS*

This sub-landscape covers a wide area in the northern part of Saba. The more northwestern section of it is occurrence is relatively more exposed to the influence of the wind. These *Coccoloba - Wedelia* Mountains occur on the lower slopes of Mount Scenery, along the cliffs. The main soil types are the 'Middle island very stony loam' and 'Gile's cherty sandy loam'. The *Coccoloba - Myrcianthus* vegetation type (type 5) is dominant while the *Wedelia - Plumbago* type (type 7) is less frequent.

M6 *COCCOLOBA - INGA MOUNTAINS*

This sub-landscape is found in an area of the lower parts of Saba that stretches from the lower south-western and southern sides to the north-eastern side of Saba. The more eastern parts of this sub-landscape area are more exposed to the influence of the predominant wind. The vegetation is a mosaic of four vegetation types that are of approximately the same importance: *Coccoloba - Myrcianthus* (type 5), *Inga - Pharus* type (type 4), *Philodendron - Cordia* (type 3) and *Wedelia - Plumbago* type (type 7).

M7 *ARISTIDA - BOTHRIOCHLOA MOUNTAINS*

This Aristida - *Bothriochloa* landscape occurs on the lowest slopes of Saba in a relatively extensive and sun-exposed zone that extends from Parish to the area between Windward Side and The Level and then north to Flat Point. The *Aristida - Mitracarpus* type (type 9) is the main vegetation type with a lesser role for the *Bothriochloa pertusa* (type 8) and *Wedelia - Plumbago* types (type 7).

M8 *BOTHRIOCHLOA MOUNTAINS*

This sub-landscape is restricted to a small area north of Deep Gut and west of the old sulphur mine, situated directly above the seaboard cliffs. Only one vegetation type is found in this sub-landscape, namely the *Bothriochloa pertusa* type (type 8).

C CLIFFS

C *ARISTIDA CLIFFS*

A steep seaboard surrounds most of the island of Saba. This cliff is a mostly barren steep slope, partly rubble and partly rocky. A very sparse and scattered cover of the *Aristida* - *Mitracarpus* type (type 9) vegetation is found in these areas.

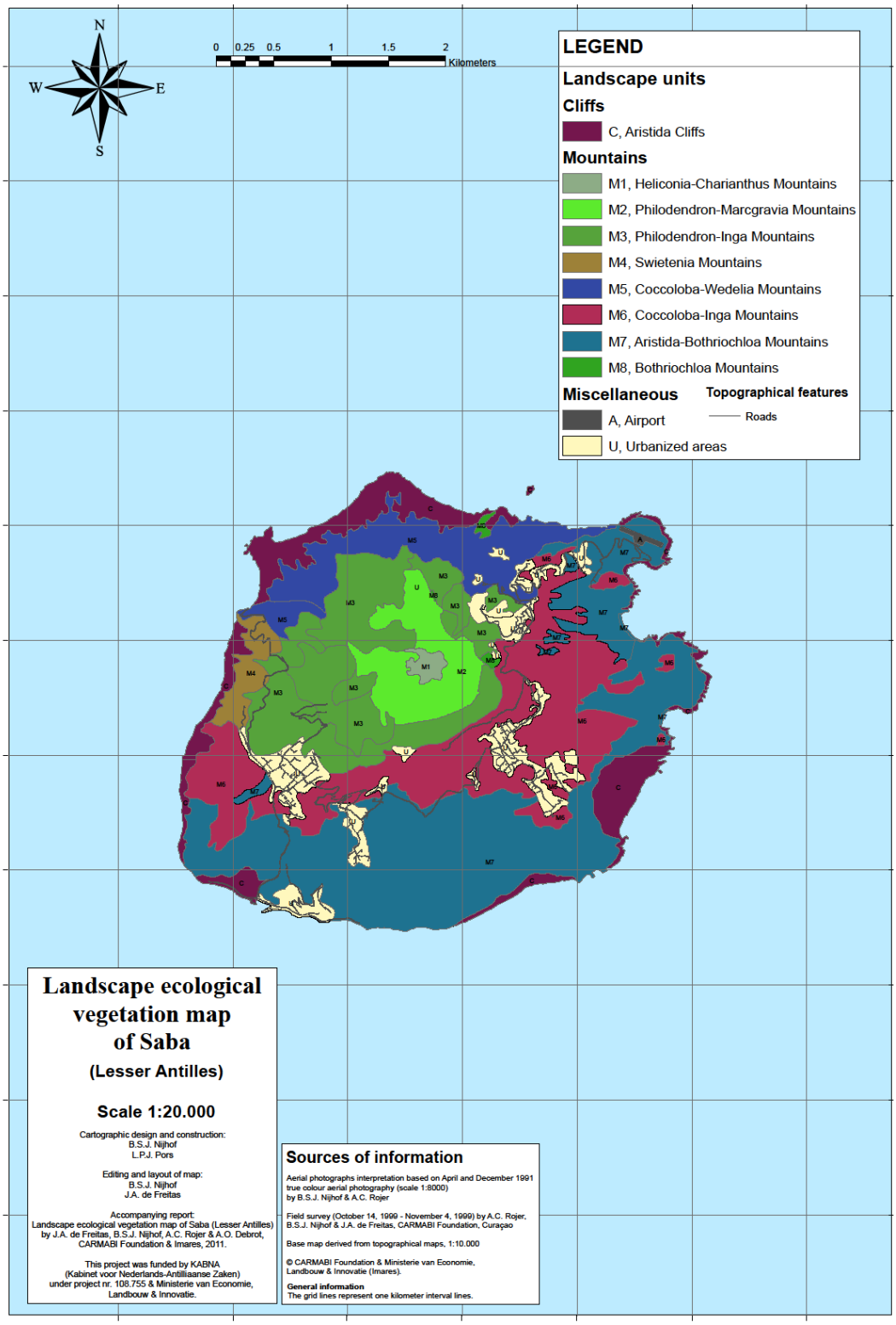


Figure 5. *Vegetation map of Saba.*

5. Discussion and concluding remarks

During this study we mapped more than ninety percent of the surface of Saba as the extent of urban development remains limited due to the inhospitable erosion-prone and steep terrains that characterize this island (CIVIL ENGINEERING CARIBBEAN 1994; DEBROT & SYBESMA 2000). In the last decades, residential areas have expanded but agricultural lands have diminished but grazing goats still roam at large in significant numbers. In the present study goat dung or traces of grazing were recorded in or adjacent to 46% of the sample plots. This was the case even for sample plots high on Mount Scenery. In general, our findings indicate that the most diverse vegetation types had the lowest goat presence (e.g. types 2, 3 and 4) whereas the low-diversity vegetation types (with also typically lower canopy height and located at lower elevations, e.g. vegetation types 6, 7, 8 and 9) showed high goat presence (Table 4). The detrimental effects of goats on island ecosystems has 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). It has also often been demonstrated that continued grazing reduces the recovery potential of the vegetation (ALBALADEJO ET AL. 1998; STEEN 1998). Consequently, goat control, removal and eradication is being adopted world-wide and is one of the most important tools used in biodiversity recovery today (CAMPBELL & DONLAN 2005).

On the basis of BEARD's (1944, 1949) classification system, STOFFERS (1956) divided the communities of the Windward Islands of the Netherlands Antilles in primary climax communities and secondary and sub-climax communities. The primary climax communities were divided in: 'Climatic climax communities' and 'Edaphic climax communities'. On Saba STOFFERS (1956) recognized 13 different communities, of which 3 climactic climax communities: Rain forest, Elfin woodland and Palm brake. A comparison is possible between our results and STOFFERS' (see Table 7) despite the difference in methods used. STOFFERS did not find edaphic communities on Saba and neither did we find any in this study. Only one vegetation type of the present study corresponds well with one of the climatic communities STOFFERS distinguished on Saba. The *Swietenia* - *Leucaena* type (type 6) fits STOFFERS' description of woodland derived from dry evergreen forest, both in species composition as well as in structure and ecological specialization. Other vegetation types correspond partly either in species composition or structural aspects but not both. Two vegetation types we describe show no similarity to any of the communities STOFFERS (1956) described. The low similarity between our described vegetation types and STOFFERS' communities indicates substantial changes in the vegetation since the survey of STOFFERS (Table 7).

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
Optimal formation	*Vegetation type*
Rain forest (I)	
Secondary rain forest (II)	*Philodendron - Cordia* (type 3)
Tree-fern brake (III)	
Miconia thickets (IV)	related to type 3
Piper dilatatum thicket (V)	related to types 1 and 3
Pioneer forest (VI)	*Philodendron - Marcgravia* (type 2) and related to types 1 and 3
Montane formations	
Palm brake (VIII)	
Elfin woodland (IX)	
Seasonal formations	
Woodland derived from seasonal forest	*Wedelia - Plumbago* (type 7)
Leucaena thicket (XIV)	related to type 6
Croton thickets* (XV)	
Dry evergreen formations	
Woodland derived from dry evergreen forest (XVII)	*Coccoloba - Myrcianthus* (type 5) *Swietenia - Leucaena* (type 6)
Croton thickets** (XX)	*Bothriochloa* (type 8) *Aristida - Mitracarpus* (type 9)

* derived from deciduous seasonal forest

** derived from dry evergreen forest/bushland

The two most distinct vegetation types we describe are *Heliconia-Charianthus* type (type 1) and *Inga laurina-Pharus lappulaceus* type (type 4). Type 1 was found on the top of Mount Scenery. This area used to be covered with Elfin Woodland when STOFFERS did his survey. However, in September 1998 a devastating hurricane, named Georges, caused massive damage to the Elfin woodland and destroyed most large trees, therewith degrading its structure and altering its dominating species. At the time of our field data collection in 1999, the tree layer was low and very open making the shrub/herb layer the defining layer. *Freziera undulata* was no longer a dominant species. Most *Freziera*-trees died and *Prestoea acuminata* var. *montana* have subsequently become the most important tree species. At the same time, tree ferns (*Cyatheaceae spp.)* gained importance and some other pioneer species such as *Acnictus arborescens* and *Cecropia peltata* appear to have increased. In spite of that, typical species of the former Elfin woodland (*Freziera undulata, Myrsine coriacea, Marila racemosa and Charianthus purpurea)* were still present while small climbers and epiphytes were still abundant, an important feature of Saba's Elfin woodland (STOFFERS 1956).

As pointed out by FREITAS ET AL. (2014) before, the Elfin woodland is a very delicate system that is characterized by important limitations for regeneration. These characteristics include limited plant diversity, reduced root respiration due to saturated soils, high winds, lower temperatures and the limited production of seeds by key species (BYER & WEAVER 1977). Recovery may be only very slow or maybe even impossible in light of ongoing climate change (DEBROT & BUGTER 2010). The *Inga laurina-Pharus lappulaceus* type (type 4) occurred principally on the western slopes of Mount Scenery where 'Secondary rainforest' changes into 'Dry evergreen woodland' on the map of STOFFERS (1956). This vegetation type resembled the 'Semi-evergreen forest' as described by BEARD (1949). Nearly all important tree species of type 4 were components of this community. It seems to be the logical intermediate between type 3, corresponding to STOFFERS' (1956) 'Secondary rainforest' located

higher on the slope, and type 6, corresponding to 'Woodland derived from dry evergreen forest' found at a lower elevation.

None of the vegetation types we found corresponded to STOFFERS' Elfin woodland, Rain forest, 'Tree fern brake' or Palm brake. There are no indications that the 'Secondary rain forest' has yet reached the stage of Rain forest in the 50 year period since the early 1950s. Recovery time-scales for tropical Caribbean forests are very long and are calculated to be on the order of several hundred years (WEAVER 2000, 2008; LUGO & HELMER 2004; MOLINA COLON & LUGO 2006). The two small patches of original Rain forest STOFFERS found on Saba probably were too small to be distinguished by the (landscape) approach used in the present study. Palm brake may be present on Saba in small patches, but were not recognized at the landscape level we used in this study. According to BEARD (1949) Palm brake is a sub-climax community of 'Montane thicket' on very steep, geologically young slopes, liable to frequent landslides. Steep unstable slopes do occur on Saba. Therefore, Palm brake is expected to be found but only locally.

While the *Philodendron-Marcgravia* type (type 2) occurred exactly in the area of 'Tree fern brake' on the map of STOFFERS (1956), tree ferns had only occasionally a high cover within this type. This is likely in part due to the effects of hurricane Georges. An observer reported large numbers of broken palms and ferns in this zone after this hurricane (VAN 't HOF, pers. comm., 1998) and these appear to have not yet recovered when the data were collected for this study in 1999. There were more notable differences as well. While the 'Tree fern brake' of STOFFERS (1956) lacked a shrub and herb layer, these layers had significant cover and number of plant species in our *Philodendron-Marcgravia* type. We therefore surmise that many of the shrubs and young trees in these layers must have been present already before the hurricane and only got their chance as a result of the opening of the canopy layers due to the breakage of the palms and tree ferns. Some pioneer tree species like *Acnictus arborescens, Cecropia peltata, Cordia sulcata* and *Byrsonima spicata* were present, although with low cover. All remaining tree species were species of the rain forest, making this type correspond more to "Pioneer forest" as described by BEARD (1949) and STOFFERS (1956) than with the "Tree fern brake" of STOFFERS (1956). Hence, the "Tree fern brake" seems to have entered its next stage in succession. This is in accordance with BEARD's (1949) suggestion that the 'Tree fern brake' represents a second-growth community on poor soils that in time is succeeded by "Pioneer forest" after soil improvement has taken place. The suggestion of STOFFERS (1956) that tree ferns only grow in places usually hidden in clouds was also confirmed by the results of this study. Elfin woodland and "Tree fern brake" were two prominent communities at the time of STOFFERS. Hurricane Georges wiped away key structural differences, and as a consequence these appear to have been replaced by two largely converging vegetation types (types 1 and 2).

Comparing the floristic composition of our vegetation types with the descriptions of STOFFERS' communities, the actual scarcity of formerly abundant *Opuntia* species, is striking. Three species of *Opuntia* formed part of the Croton thickets STOFFERS found on Saba (STOFFERS 1956) but only one very rare species of *Opuntia* appeared still present in the corresponding vegetation types of our assessment (types 8 and 9). A similar large loss of *Opuntia* from vegetation types has been documented for St. Eustatius (FREITAS ET AL. 2014). This scarcity of *Opuntia* species must be explained by the presence of the moth *Cactoblastis cactorum* on Saba (VAN HALTEREN 1994). In 1994 *Opuntia* cacti already had all but disappeared from Saba. It is likely that *Cactoblastis cactorum* arrived on Saba from neighbouring islands. This insect has spread throughout the Caribbean since its introduction in Nevis, Montserrat, Antigua and Grand Cayman between 1957 and 1970 (FRANK & MCCOY 1995).

Another species that suffered from the attack of a different moth is *Tabebuia heterophylla* (VAN HALTEREN 1994). This species was one of the main components of the 'Woodland derived from dry evergreen forest' at the time of STOFFERS' (1956) survey. This woodland occurred then mainly in four areas: 1) the area from north to south between Mary's Point and Cow Pasture; 2) on Paris Hill; 3) hilly areas directly to the west, north and south of St. John; 4) areas to the north and east of English Quarter. In 1994 most *Tabebuia* trees were infested by the moth resulting in major mortalities (VAN HALTEREN 1994). Nevertheless, at present this *Tabebuia* species still has a rather high occurrence in Type 6 and a low occurrence in type 7. Type 6 is only found in M4 and is the only vegetation type

occurring there. M4 corresponds with the area of this woodland between Mary's Point and Cow Pasture in STOFFERS (1956). Remarkable is also the dominance of the invasive *Bothriochloa pertusa* (HOWARD 1979) in our type 8 that corresponds with STOFFERS' Croton thickets. As was the case with St. Eustatius (FREITAS ET AL. 2014) this grass species was not yet present during STOFFERS' study.
Some of the vegetation types show an apparent preference to certain soil types (Table 4). For example *Heliconia-Charianthus* type (type 1) was found only on 'Scenery clay loam'. Two vegetation types *Wedelia-Plumbago* (type 7) and *Bothriochloa* (type 8) were only found on 'Gile's cherty sandy loam'. Nevertheless, for all vegetation types climatic factors are likely of equal or greater importance to their occurrence in different altitudinal zones of the island.

Both maps show a clear altitudinal zonation of legend units along the slopes of Mount Scenery from top to sea level. On the lowest southern and eastern slopes the *Aristida-Botriochloa* sub-landscape (M7) was dominated by two corresponding vegetation types of Croton thickets (types 9 and 8), and practically cover the whole area of 'Croton thickets' on the map of STOFFERS (1956). The poor and dry character of this vegetation is due to soil factors in combination with the long-time use as pasture land. Soil formation is very poor on these steep, sun-exposed slopes.

Better-developed dry evergreen vegetation is found both formerly and presently on the lowest western slopes. It is present in the *Swietenia* sub-landscape of our map (M4). Better soil conditions and rooting potential of the 'Middle island very stony loam' on which this sub-landscape occurs may explain the difference in vegetation between the sun-exposed and shady side of Mount Scenery. The northern lower slopes were not surveyed by STOFFERS. On the present map a *Coccoloba-Wedelia* sub-landscape was present there and was dominated by a 'Dry evergreen woodland' (type 5: *Coccoloba-Myrcianthus* type). The occurrence of a better-developed vegetation here is not completely explained by the presence of a better soil (largely 'Gile's cherty sandy loam'). Higher precipitation values are not probable either at this windward, exposed side of Mount Scenery. The lower inclination of the slopes and less intensive use as grazing land remains a possible explanation for the occurrence of a 'Dry evergreen woodland' in these areas.

At a higher elevation the *Philodendron-Inga* sub-landscape (M3) coincide rather well with the area indicated by STOFFERS (1956) as 'Secondary rainforest' together with a part of the 'Woodland derived from Dry evergreen forest' on the western slope of Mount Scenery. In addition to higher precipitation at these higher elevations, this sub-landscape is mainly present on 'Middle island very stony loam' which allows deeper rooting for tree growth.

Until now, large areas with (semi-)natural vegetation are present on Saba. Especially the northern and north-western parts of the island have suffered less disturbance by man even though feral goats can be found in these areas in notable numbers. The vegetation of the top of Mount Scenery suffered substantial loss from hurricane damage, the construction of antennas and the ongoing disturbance by man and livestock. Residential areas have expanded around the villages but most of the former agricultural lands have been abandoned. Only remnants of the secondary shrub communities like *Miconia* thickets, *Piper dilatatum* thickets and *Leucaena* thickets were still found in this study, which we interpret as evidence of expected succession having taken place. The different villages of Saba are all located in the belt of *Coccoloba-Inga* Mountains (M6). At present the heterogeneity of the vegetation in this belt (Table 5) reflects on the one hand the fact that this is an altitudinal climatic transition zone and on the other hand the effects of former human activities (such as cultivation and woodcutting).

In conclusion, when taking into account the difference in scale and legend, a comparison between the vegetation map of STOFFERS (1956) and our landscape ecological map, reveals some striking similarities but also many important differences. The changes that have taken place in the vegetation since the survey of STOFFERS (1956) largely appear to be due to three major forces: hurricanes, the process of succession and invasive plant species. More information on the naturalised and invasive alien plant species of the Dutch Caribbean is provided by BURG ET AL. (2012) who concluded that alien invasive plants constitute a major disruption and threat to the integrity of the flora and vegetation of all of the Dutch Caribbean islands, including Saba. Hurricane Georges clearly caused much damage to the vegetation especially high on Mount Scenery, throwing back the vegetation into

an earlier stage of succession. This corresponds to the findings of other studies which document major and long-lasting deterioration of vegetation as a result of hurricanes (LUGO ET AL. 1983; BROKAW & WALKER 1991; WEAVER 1999; ROJER & FREITAS 2002). The development of the 'Tree fern brake' into 'Pioneer forest' must be seen as a positive change in which a secondary community has entered a higher stage in the sequence of succession. Finally, the new presence of the invasive *Colocasia esculenta* (a perennial herb) in type 2 is worrisome because of the importance of this relatively undisturbed vegetation type and the invasive capability of this plant (LANGELAND ET AL. 2008).

6. Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 September 2018. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Justification

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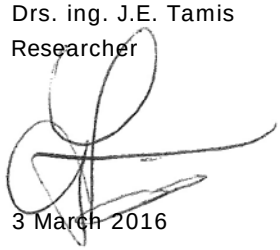
The scientific quality of this report has been peer reviewed by the a colleague scientist and the Business Unit Manager of IMARES.

Approved:	Drs. ing. J.E. Tamis Researcher
Signature:	
Date:	3 March 2016

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Appendix 1. Monthly and annual meteorological parameters for Saba (1971-2000).

Source: METEOROLOGICAL SERVICE NETHERLANDS ANTILLES & ARUBA. 2010

METEOROLOGICAL SERVICE NETHERLANDS ANTILLES & ARUBA

THE BOTTOM, SABA (17° 38'N, 63° 15' W) SUMMARY OF CLIMATOLOGICAL DATA, PERIOD 1971 -

ELEMENT		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Av. Air temperature	°C	25.7	25.3	25.7	26.6	27.4	28.1	28.1	28.5	28.5	28.2	27.4	26.3	27.2
Av. Maximum temperature	°C	28.1	27.7	28.3	29.2	30.0	30.4	30.5	30.9	30.8	30.4	29.8	28.6	29.6
Abs. Maximum temperature	°C	30.4	30.8	30.7	31.7	31.9	32.5	32.8	33.2	33.2	32.1	32.0	31.1	33.2
Av. Minimum temperature	°C	24.1	23.6	23.9	24.7	25.6	26.2	26.0	26.4	26.5	26.3	25.4	24.7	25.3
Abs. Minimum temperature	°C	20.8	20.0	21.4	22.1	22.6	23.1	21.8	22.0	22.4	22.4	22.6	21.3	20.0
Av. Air pressure (-1000)	hpa	16.9	17.3	16.6	16.0	16.4	17.2	17.1	15.2	14.0	14.3	14.4	16.0	15.9
Av. Vapour pressure	hpa	27.3	26.9	26.0	27.3	28.6	31.0	34.5	35.3	34.4	30.9	26.0	24.5	29.4
Av. Relative humidity	%	82.0	82.3	78.2	78.8	78.0	81.9	84.5	88.8	87.4	81.2	71.1	74.5	80.7
Av. Dewpoint temperature	°C	22.3	22.0	21.6	22.5	23.3	24.6	26.4	26.8	26.3	24.5	21.7	20.7	23.6
Av. Montly rainfall	mm	36.8	75.3	35.4	28.1	95.9	44.4	60.8	77.0	60.5	35.5	134.5	76.5	760.5
Av. Days with rain	≥ 1,0	10.3	10.3	6.3	4.0	6.7	5.8	5.8	6.3	7.3	3.5	10.0	9.7	7.2
Highest rainfall in 24 hours		12.6	116.8	14.8	30.6	124.8	28.4	37.4	96.8	62.2	33.4	71.2	41.6	124.8
Av. Wind speed (10m)	m/s	5.7	5.8	5.5	4.7	5.1	5.8	5.6	5.1	4.8	4.6	4.5	5.2	5.2
Av. Maximum wind speed	m/s	12.5	13.0	11.7	10.5	11.2	12.4	12.7	12.0	12.4	11.3	11.6	11.7	11.9
Strongest gust	m/s	19.6	27.3	18.0	18.0	18.0	23.2	26.8	27.3	24.2	24.7	22.2	21.6	27.3

Appendix 2. Hurricanes passing within 222 km from Saba in the period 1956-1999.

Only hurricanes or tropical storms with maximum sustained surface wind speed (1 minute mean; msswp) of minimally 50 mph near the Dutch Windward Islands (St. Eustatius, Saba and St. Maarten) are listed. Hurricanes that caused considerable damage to one or more of the Dutch Windward Islands are marked with an *.

Year	**Month / day**	**Name hurricane**	**Msswp** (mph)
1956	11-Aug	Betsy	90
1959	18-Jul	Edith	50
1960	4-Sep	Donna	145*
1963	27-Oct	Helena	50
1964	22-Aug	Cleo	100
1965	28-Aug	Betsy	55
1966	26-Aug	Faith	90
1966	27-Sep	Inez	130
1975	14-Sep	Eloise	35[1]
1979	29-Aug	David	150
1979	3-Sep	Frederic	75[1]
1984	8-Nov	Klaus	75
1989	3-Aug	Dean	85
1989	17-Sep	Hugo	140*
1990	6-Oct	Klaus	70
1995	27-Aug	Iris	65
1995	5-Sep	Luis	145*
1995	15-Sep	Marilyn	95*
1996	8-Jul	Bertha	80
1998	21-Aug	Bonnie	50
1998	21-Sep	Georges	110*
1999	20-Oct	José	75*
1999	18-Nov	Lenny	115*

[1] These two events caused prolonged extensive flooding because of their associated torrential rainfall of more than 250 mm.

Source: www.meteo.cw (2014).

Appendix 3. Synoptic table of the vegetation types of Saba.

VEGETATION TYPE:	1	2	3	4	5	6	7	8	9
NUMBER OF SAMPLE PLOTS	4	6	9	4	6	4	3	5	8
AVERAGE NO. OF SPECIES	43.5	38.3	41.1	46.5	31.5	31.5	29.7	12.8	9.5
STANDARD DEVIATION	5.1	5.7	4.8	7.1	5.3	12.8	9.0	7.7	7.7
Differentiating species*									
Charianthus purpureus	**V (2)**	-	-	-	-	-	-	-	-
Hymenophyllum hirtellum	**IV (3)**	-	-	-	-	-	-	-	-
Pilea obtusata	**IV (5)**	-	-	-	-	-	-	-	-
Besleria lutea	**IV (3)**	-	-	-	-	-	-	-	-
Laportea aestuans	III (5)	-	-	-	-	-	-	-	-
Erechtites valerianifolia	III (3)	-	-	-	-	-	-	-	-
Peperomia hernandiifolia	III (3)	-	-	-	-	-	-	-	-
Diplazium striatum	III (4)	-	-	-	-	-	-	-	-
Sauvagesia erecta	III (3)	-	-	-	-	-	-	-	-
Philodendron lingulatum	III (3)	-	-	-	-	-	-	-	-
Rhynchospora polyphylla	III (3)	-	-	-	-	-	-	-	-
Marila racemosa	III (1)	-	-	-	-	-	-	-	-
Rubus rosifolius	**V (3)**	II (2)	-	-	-	-	-	-	-
Peperomia emarginella	**V (3)**	II (2)	-	-	-	-	-	-	-
Clibadium erosum	IV (3)	I (1)	-	-	-	-	-	-	-
Nephrolepis rivularis	V (3)	III (2)	-	-	I (2)	-	-	-	-
Thelypteris reticulata	IV (4)	I (1)	I (2)	-	-	-	-	-	-
Paspalum conjugatum	IV (2)	I (3)	I (2)	II (2)	-	-	-	-	
Myrsine coriacea	IV (3)	II (2)	-	-	-	-	-	-	-
Marcgravia umbellata	II (3)	IV (2)	I (1)	-	-	-	-	-	-
Nectandra krugii	-	III (1)	-	-	-	-	-	-	-
Cordia sulcata	-	I (1)	**V (3)**	II (1)	I (1)	-	-	-	-
Melothria pendula	-	-	IV (1)	II (3)	I (1)	II (1)	-	-	-
Tetrazygia discolor	-	-	III (2)	-	-	-	-	-	-
Pharus glaber	-	-	II (3)	V (2)	-	-	-	-	-
Oeceoclades maculata	-	-	II (2)	IV (2)	-	-	-	-	-
Picrasma excelsa	-	-	II (2)	IV (1)	I (1)	-	-	-	-
Guapira fragrans	-	-	III (1)	V (2)	II (1)	III (2)	II (1)	-	-
Adiantum tenerum	-	-	-	**IV (2)**	-	-	-	-	-
Smilax guianensis	-	-	-	**IV (2)**	-	-	-	-	-
Thelypteris tetragona	-	-	-	III (2)	-	-	-	-	-
Passiflora laurifolia	-	-	-	III (1)	-	-	-	-	-
Cassipourea guianensis	-	-	-	III (1)	-	-	-	-	-
Tragia volubilis	-	-	-	IV (2)	I (3)	-	-	I (1)	-
Maytenus laevigata	-	-	I (1)	II (4)	V (2)	II (1)	II (1)	-	-
Annona muricata	-	-	-	II (1)	**V (2)**	II (1)	-	-	-
Ardisia obovata	II (3)	-	-	-	**V (2)**	-	-	-	-
Myrcianthes fragrans	-	-	-	-	V (2)	-	II (1)	-	-
Commelina elegans	-	I (2)	I (2)	II (1)	I (3)	IV (2)	II (3)	I (4)	-
Leucaena leucocephala	-	-	I (2)	II (3)	I (1)	**V (2)**	-	-	-
Passiflora suberosa	-	-	-	II (2)	I (1)	IV (1)	II (3)	-	-
Capparis baducca	-	-	-	-	-	**IV (1)**	-	-	-
Rhynchosia reticulata	-	-	-	-	II (2)	IV (2)	II (3)	-	-
Guettarda odorata	-	-	-	-	I (1)	III (1)	-	-	-
Melicoccus bijugatus	-	-	-	-	-	III (1)	-	-	-
Swietenia mahagoni	-	-	-	-	I (1)	**V (7)**	-	-	-
Plumbago scandens	-	-	-	-	-	II (2)	**V (2)**	II (3)	I (1)
Justicia sessilis	-	-	-	-	I (2)	II (3)	IV (2)	I (2)	I (2)
Hyptis pectinata	-	-	I (1)	-	I (1)	-	VI (2)	-	-
Wedelia calycina	-	-	-	-	III (2)	-	V (4)	-	I (2)

VEGETATION TYPE:	1	2	3	4	5	6	7	8	9
Iresine diffusa	-	-	-	-	-	-	**IV (2)**	-	-
Setaria setosa	-	-	-	-	-	-	IV (2)	-	I (4)
Bryophyllum pinnatum	-	-	I (2)	-	-	-	IV (3)	-	I (4)
Bothriochloa pertusa	-	-	-	-	-	-	-	**V (7)**	I (2)

VEGETATION TYPE:	1	2	3	4	5	6	7	8	9
NUMBER OF SAMPLE PLOTS	4	6	9	4	6	4	3	5	8
AVERAGE NO. OF SPECIES	43.5	38.3	41.1	46.5	31.5	31.5	29.7	12.8	9.5
STANDARD DEVIATION	5.1	5.7	4.8	7.1	5.3	12.8	9.0	7.7	7.7
Common species									
Clusia major	IV (1)	III (1)	V (3)	II (1)	-	-	-	-	-
Heliconia bihai	V (4)	V (4)	IV (1)	II (1)	-	-	-	-	-
Piper dilatatum	IV (4)	III (2)	IV (3)	II (2)	-	-	-	-	-
Gonzalagunia hirsuta	V (3)	V (3)	III (2)	II (1)	-	-	-	-	-
Polypodium phyllitidis	IV (2)	I (1)	III (1)	V (2)	-	-	-	-	-
Pisonia aculeata	II (2)	I (2)	I (1)	III (2)	-	-	-	-	-
Vriesia ringens	IV (2)	V (2)	III (3)	-	I (1)	-	-	-	-
Blechnum occidentale	III (3)	V (5)	V (3)	IV (2)	I (1)	-	-	-	-
Miconia laevigata	VI (3)	V (2)	IV (2)	IV (2)	IV (2)	III (2)	-	-	-
Philodendron giganteum	V (5)	V (6)	V (6)	V (4)	IV (4)	-	II (1)	-	-
Panicum trichoides	IV (3)	V (3)	IV (3)	IV (3)	II (3)	II (3)	II (1)	-	-
Citharexylum spinosum	II (2)	V (3)	IV (2)	V (2)	IV (2)	IV (3)	II (2)	-	-
Peperomia magnoliifolia	II (2)	-	III (3)	IV (3)	II (3)	III (2)	-	-	-
Myrcia splendens	-	II (2)	V (4)	V (4)	II (1)	-	-	-	-
Polypodium piloselloides	-	III (3)	II (2)	III (3)	I (1)	-	-	-	-
Ipomoea tiliacea	-	V (2)	IV (3)	II (2)	II (2)	-	-	-	-
Ocotea leucoxylon	-	III (2)	IV (3)	III (2)	I (1)	-	-	-	-
Guettarda scabra	-	I (1)	IV (2)	IV (4)	V (4)	IV (3)	-	-	-
Coccoloba swartzii	-	I (1)	IV (2)	V (4)	V (5)	III (3)	-	-	-
Cissus verticillata	-	IV (2)	IV (2)	V (2)	V (2)	III (2)	IV (2)	I (1)	-
Nectandra coriacea	-	-	II (1)	IV (3)	I (4)	IV (1)	-	-	-
Peperomia myrtifolia	-	-	III (2)	V (2)	V (3)	IV (3)	V (2)	-	-
Daphnopsis americana	-	-	I (1)	II (1)	V (2)	IV (1)	IV (3)	-	-
Capparis flexuosa	-	-	I (2)	III (1)	I (2)	II (2)	IV (2)	-	-
Abrus precatorius	-	-	I (2)	IV (2)	I (3)	III (3)	II (3)	-	-
Casearia decandra	-	-	IV (2)	V (2)	V (2)	III (3)	II (4)	-	-
Rauvolfia viridis	-	-	I (1)	II (2)	I (1)	III (2)	-	I (1)	-
Momordica charantia	-	-	IV (2)	II (1)	I (2)	II (3)	II (1)	I (1)	-
Randia aculeata	-	-	I (1)	III (1)	V (2)	V (2)	V (1)	II (1)	-
Tabernaemontana citrifolia	-	-	IV (1)	III (2)	II (4)	-	II (1)	-	-
Eugenia axillaris	-	-	-	II (1)	V (2)	V (4)	IV (4)	-	-
Pisonia subcordata	-	-	-	III (2)	IV (1)	III (3)	IV (5)	-	-
Bursera simaruba	-	-	-	III (1)	IV (2)	IV (1)	II (4)	-	-
Solanum racemosum	-	-	-	II (2)	I (2)	III (3)	IV (1)	I (1)	-
Lantana camara	-	-	-	II (1)	II (2)	II (2)	IV (3)	IV (2)	-
Triumfetta semitriloba	-	-	-	II (1)	II (1)	II (2)	II (2)	II (2)	I (2)
Croton astroites	-	-	-	-	I (3)	II (1)	V (2)	IV (3)	II (3)
Urechites lutea	-	-	-	-	I (1)	II (1)	-	IV (1)	III (2)
Coccoloba uvifera	-	-	-	-	II (3)	II (4)	II (5)	-	II (5)

VEGETATION TYPE:	1	2	3	4	5	6	7	8	9
NUMBER OF SAMPLE PLOTS	4	6	9	4	6	4	3	5	8
AVERAGE NO. OF SPECIES	43.5	38.3	41.1	46.5	31.5	31.5	29.7	12.8	9.5
STANDARD DEVIATION	5.1	5.7	4.8	7.1	5.3	12.8	9.0	7.7	7.7
Other species *(occurring in max. 3 clusters or 5 with low presence)*									
Cecropia schreberiana	V (3)	VI (2)	-	-	-	-	-	-	-
Cyatheaceae spp.**	V (5)	V (3)	-	-	-	-	-	-	-
Cyperus oxylepis	III (3)	II (3)	-	-	-	-	-	-	-
Thelypteris balbisii	II (2)	II (2)	-	-	-	-	-	-	-
Clidemia umbrosa	II (2)	III (3)	-	-	-	-	-	-	-
Selaginella flabellata	IV (3)	II (5)	-	-	-	-	-	-	-
Peperomia serpens	II (3)	II (3)	-	-	-	-	-	-	-
Selaginella substipitata	III (4)	I (1)	-	-	-	-	-	-	-
Chenopodium ambrosioides	III (1)	I (1)	-	-	-	-	-	-	-
Epidendrum secundum	III (1)	I (1)	-	-	I (3)	-	-	-	-
Polybotrya cervina	IV (3)	IV (2)	I (1)	-	-	-	-	-	-
Diodia ocymifolia	III (3)	II (1)	III (2)	-	-	-	-	-	-
Tectaria incisa	II (1)	I (1)	II (1)	-	-	-	-	-	-
Acnistus arborescens	III (3)	II (3)	III (2)	-	-	-	-	-	-
Prestoea montana	V (4)	V (3)	V (2)	-	-	-	-	-	-
Passiflora rubra	V (3)	V (2)	III (2)	-	-	-	-	-	-
Neurolaena lobata	III (3)	IV (2)	I (2)	-	-	-	-	-	-
Boehmeria ramiflora	II (2)	III (2)	I (1)	-	-	-	-	-	-
Solanum torvum	II (2)	I (1)	I (2)	-	-	-	-	-	-
Monstera adansoni	V (3)	V (2)	I (2)	-	I (2)	-	-	-	-
Eupatorium macranthum	II (3)	III (2)	I (2)	-	-	-	-	-	-
Begonia retusa	V (3)	IV (2)	I (1)	-	-	-	-	-	-
Catopsis floribunda	II (3)	-	I (1)	-	-	-	II (1)	-	-
Tournefortia filiflora	-	II (1)	III (3)	-	-	-	-	-	-
Potomorphe peltata	-	III (2)	II (2)	-	-	-	-	-	-
Hirtella triandra	-	II (2)	III (3)	-	-	-	-	-	-
Nephrolepis multiflora	-	III (2)	II (2)	-	-	-	-	-	-
Piper hispidum	-	III (3)	II (2)	-	-	-	-	-	-
Thunbergia alata	-	III (2)	I (2)	-	-	-	-	-	-
Symplocos martinicensis	-	III (1)	I (1)	-	-	-	-	-	-
Trichostigma octandrum	-	I (1)	II (2)	-	-	II (1)	-	-	-
Byrsonima spicata	-	I (1)	IV (2)	III (3)	-	-	-	-	-
Anthurium grandifolium	-	I (3)	-	II (1)	I (1)	-	-	-	-
Kyllinga brevifolius	-	III (3)	I (3)	-	-	II (2)	-	-	-
Stachytarpheta jamaicensis	-	II (2)	-	-	I (2)	-	II (1)	II (2)	-
Tournefortia bicolor	-	-	III (3)	III (2)	-	-	-	-	-
Anthurium cordatum	-	-	III (1)	IV (1)	-	-	-	-	-
Solanum lanceifolium	-	-	II (1)	III (2)	-	-	-	-	-
Mangifera indica	-	-	II (4)	II (5)	-	-	-	-	-
Aegiphila martinicensis	-	-	II (3)	III (2)	-	-	-	-	-
Asplenium cristatum	-	-	II (1)	II (2)	-	-	-	-	-
Ficus nymphaeifolia	-	-	II (1)	-	I (1)	-	-	-	-
Tillandsia utriculata	-	-	I (1)	II (1)	I (1)	-	-	-	-
Chionanthus compacta	-	-	II (2)	III (3)	I (1)	-	-	-	-
Myrcia citrifolia	-	-	III (1)	III (3)	I (1)	-	-	-	-
Inga laurina	-	-	V (2)	V (4)	II (3)	-	-	-	-
Psychotria nervosa	-	-	II (1)	V (2)	IV (2)	-	-	-	-
Polypodium heterophyllum	-	-	III (3)	III (3)	III (3)	-	-	-	-
Pitcairnia angustifolia	-	-	I (1)	III (2)	II (3)	-	II (2)	-	I (3)
Allophyllus racemosus	-	-	IV (2)	V (3)	-	III (2)	-	-	-
Tournefortia hirsutissima	-	-	II (2)	II (2)	-	II (1)	-	-	-
Jasminum fluminense	-	-	I (3)	III (2)	-	III (2)	-	-	-
Pilea semidentata	-	-	II (1)	-	I (1)	-	II (3)	-	-
Cestrum laurifolium	-	-	I (1)	-	II (2)	-	II (1)	-	-
Pimenta racemosa	-	-	-	III (1)	IV (3)	V (4)	-	-	-
Tecoma stans	-	-	-	II (2)	I (1)	II (1)	-	-	-

VEGETATION TYPE:	1	2	3	4	5	6	7	8	9
Triphasia trifolia	-	-	-	II (1)	-	II (1)	-	-	-
Eugenia procera	-	-	-	II (2)	-	-	II (1)	-	-
Krugiodendron ferreum	-	-	-	II (2)	I (1)	-	II (1)	-	-
Polypodium polypodioides	-	-	-	II (3)	III (2)	-	IV (2)	-	-
Vernonia albicaulis	-	-	-	II (1)	-	II (1)	II (1)	-	-
Cyperus distans	-	-	-	III (3)	II (3)	-	-	-	I (2)
Chiococca parvifolia	-	-	-	-	III (2)	IV (2)	-	-	-
Tabebuia heterophylla	-	-	-	-	III (2)	II (1)	-	-	-
Bourreria succulenta	-	-	-	-	I (1)	III (1)	-	-	-
Senna bicapsularis	-	-	-	-	I (1)	III (1)	II (2)	-	-
Erythroxylum havanense	-	-	-	-	-	III (1)	II (2)	-	-
Asplenium pumilum	-	-	-	-	-	II (2)	II (2)	-	-
Eugenia rhombea	-	-	-	-	-	II (1)	II (1)	-	-
Phyllanthus amarus	-	-	-	-	-	II (1)	-	-	II (2)
Desmodium incanum	-	-	-	-	-	II (3)	-	II (2)	I (3)
Jatropha gossypiifolia	-	-	-	-	-	II (1)	-	II (1)	I (1)
Centrosema virginianum	-	-	-	-	-	-	II (2)	I (1)	I (2)
Lantana involucrata	-	-	-	-	-	-	-	II (3)	II (5)
Pityrogramma calomelanos	-	-	-	-	-	-	II (3)	-	II (2)
Mitracarpus polyclades	-	-	-	-	-	-	II (3)	I (2)	III (2)
Digitaria ciliaris	-	-	-	-	-	-	-	I (3)	II (3)
Aristida adscensionis	-	-	-	-	-	-	-	II (3)	IV (4)

VEGETATION TYPE:	1	2	3	4	5	6	7	8	9
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AVERAGE NO. OF SPECIES	43.5	38.3	41.1	46.5	31.5	31.5	29.7	12.8	9.5
STANDARD DEVIATION	5.1	5.7	4.8	7.1	5.3	12.8	9.0	7.7	7.7
Rare species									
Hillia parasitica	II (2)	-	-	-	-	-	-	-	-
Vriesia antillana	II (3)	-	-	-	-	-	-	-	-
Ctenitis subincisa	II (3)	-	-	-	-	-	-	-	-
Xiphidium caeruleum	II (2)	-	-	-	-	-	-	-	-
Elephantopus mollis	II (2)	-	-	-	-	-	-	-	-
Thelypteris opposita	II (3)	-	-	-	-	-	-	-	-
Pilea parietaria	II (1)	-	-	-	-	-	-	-	-
Epidendrum difforme	II (2)	-	-	-	-	-	-	-	-
Solanum americanum	II (2)	-	-	-	-	-	-	-	-
Peperomia glabella	II (3)	-	-	-	-	-	-	-	-
Blechum pyramidatum	II (1)	-	-	-	-	-	-	-	-
Bidens cynapiifolia	II (1)	-	-	-	-	-	-	-	-
Psychotria guadalupensis	II (3)	-	-	-	-	-	-	-	-
Freziera undulata	II (1)	-	-	-	-	-	-	-	-
Pilea rivoirae	II (4)	-	-	-	-	-	-	-	-
Sloanea dentata	II (1)	-	-	-	-	-	-	-	-
Elaphoglossum martinicensis	II (3)	-	-	-	-	-	-	-	-
Ageratum conyzoides	II (3)	-	-	-	-	-	-	-	-
Phytolacca rivinoides	II (3)	-	-	-	-	-	-	-	-
Elaphoglossum latifolium	II (2)								
Cyperus elegans	II (1)	-	-	-	-	-	-	-	-
Sloanea massoni	II (1)	I (1)	-	-	-	-	-	-	-
Serpocaulon triseriale	-	II (2)	-	-	-	-	-	-	-
Colocasia esculenta	-	II (2)	-	-	-	-	-	-	-
Stachytarpheta jamaicensis	-	II (2)	-	-	-	-	-	-	-
Thelypteris nephrodioides	-	II (2)	-	-	-	-	-	-	-
Hyperbaena domingensis	-	I (1)	-	II (1)	-	-	-	-	-
Desmodium axillare	-	I (3)							
Ipomoea triloba	-	I (2)	-	-	-	-	-	-	-
Psychotria berteriana	-	I (2)	-	-	-	-	-	-	-
Dioscorea trifida	-	I (1)	-	-	-	-	-	-	-

VEGETATION TYPE:	1	2	3	4	5	6	7	8	9
Hymenophyllaceae species	-	I (1)	-	-	-	-	-	-	-
Tradescentia pallens	-	I (2)	-	-	-	-	-	-	-
Pteris laciniata	-	I (1)	-	-	-	-	-	-	-
Tibouchina longifolia	-	I (3)	-	-	-	-	-	-	-
Musa paradisiaca	-	I (4)	-	-	-	-	-	-	-
Oxalis corniculata	-	I (3)	-	-	-	-	-	-	-
Niphidium crassifolium	-	I (2)	-	-	-	-	-	-	-
Abelmoschus moschatus	-	I (1)	-	-	-	-	-	-	-
Drypetes glauca	-	I (1)	-	-	-	-	-	-	-
Vitis tiliifolia	-	I (1)	I (4)	-	-	-	-	-	-
Cucurbitaceae species	-	I (1)	I (3)	-	-	-	-	-	-
Syzygium jambos	-	I (3)	I (2)	-	-	-	-	-	-
Bunchosia glandulosa	-	I (1)	I (1)	-	-	-	-	-	-
Guzmania lingulata	-	II (3)	I (2)	-	-	-	-	-	-
Symphysia racemosa	-	II (1)	I (3)	-	-	-	-	-	-
Dioscorea alata	-	-	II (1)	-	-	-	-	-	-
Citrus limon	-	-	II (2)	-	-	-	-	-	-
Thunbergia fragrans	-	-	II (2)	-	-	-	-	-	-
Trema micrantha	-	-	II (1)	-	-	-	-	-	-
Pilea nummelariifolia	-	-	II (3)	-	-	-	-	-	-
Polypodium aureum	-	-	I (1)	-	-	-	-	-	-
Schoepfia schreberi	-	-	I (1)	-	-	-	-	-	-
Sida spinosa	-	-	I (1)	-	-	-	-	-	-
Coccoloba venosa	-	-	I (1)	-	-	-	-	-	-
Triumfetta lappula	-	-	I (2)	-	-	-	-	-	-
Petiveria alliacea	-	-	II (1)	-	-	-	-	-	-
Simaroubaceae species	-	-	II (1)	-	-	-	-	-	-
Psidium guajava	-	-	I (1)	-	-	-	-	-	-
Hamelia axillaris	-	-	II (2)	-	-	-	-	-	-
Chaptalia nutans	-	-	I (1)	-	-	-	-	-	-
Carica papaya	-	-	I (1)	-	-	-	-	-	-
Psychotria domingensis	-	-	I (2)	-	-	-	-	-	-
Scleria pterota	-	-	I (2)	-	II (2)	-	-	-	-
Philodendron hederaceum	-	-	I (1)	II (3)	-	-	-	-	-
Pteris biaurita	-	-	I (1)	II (1)	-	-	-	-	-
Cheilanthes microphylla	-	-	-	II (4)	-	-	-	I (2)	-
Panicum maximum	-	-	-	II (3)	-	-	-	-	-
Ipomoea tricolor	-	-	-	II (3)	-	-	-	-	-
Asparagus species	-	-	-	II (1)	-	-	-	-	-
Zanthoxylum martinicense	-	-	-	II (1)	-	-	-	-	-
Pluchea carolinensis	-	-	-	II (1)	-	-	-	-	-
Palicourea crocea	-	-	-	II (2)	-	-	-	-	-
Eupatorium microstemon	-	-	-	II (1)	-	-	-	-	-
Rhynchospora radicans	-	I (1)	-	-	I (1)	-	-	-	-
Spermacoce verticillta	-	-	-	-	I (1)	-	-	-	-
Vernonia cinerea	-	-	-	-	I (1)	-	-	-	-
Comocladia dodonaea	-	-	-	-	I (1)	-	-	-	-
Epidendrum ciliare	-	-	-	-	I (3)	-	-	-	-
Polypodium plumula	-	-	-	-	I (1)	-	-	-	-
Agavaceae species	-	-	-	-	I (2)	-	-	-	-
Schaefferia frutescens	-	-	-	-	I (1)	-	-	-	-
Ternstroemia peduncularis	-	-	-	-	I (1)	-	-	-	-
Desmodium scorpiurus	-	-	-	-	I (2)	-	-	-	-
Digitaria insularis	-	-	-	-	I (3)	-	-	-	-
Agave sisilana	-	-	-	-	-	II (1)	-	-	-
Callisia repens	-	-	I (1)	-	-	II (2)	-	-	-
Aristolochia littoralis	-	-	-	-	-	II (1)	-	-	-
Convolvulaceae species	-	-	-	-	-	II (2)	-	-	-
Poaceae species I	-	-	-	-	-	II (1)	-	-	-
Citrus aurantium	-	-	-	-	-	II (1)	-	-	-
Bunchosia polystachia	-	-	I (3)	-	-	II (2)	-	-	-
Myrtaceae species	-	-	-	-	-	II (1)	-	-	-

VEGETATION TYPE:	1	2	3	4	5	6	7	8	9
Croton humilis	-	-	-	-	-	II (2)	-	-	-
Cyperaceae species	-	-	-	-	-	II (3)	-	-	-
Achyranthes aspera	-	-	-	-	-	II (3)	-	I (1)	-
Sida glabra	-	-	-	-	-	II (1)	-	I (2)	-
Fimbristylis dichotoma	-	-	-	-	-	II (1)	-	-	I (1)
Pavonia spinifex	-	-	I (2)	-	-	II (2)	-	-	-
Capparis indica	-	-	I (1)	-	-	-	II (1)	-	-
Ficus citrifolia	-	-	I (1)	-	-	-	II (1)	-	-
Antigonon leptopus	-	-	-	-	-	-	II (1)	-	-
Rhynchosia minima	-	-	-	-	-	-	II (2)	-	-
Rivina humilis	-	I (1)	-	-	-	-	II (1)	-	-
Hylocereus trigoneus	-	-	-	-	-	-	II (1)	-	-
Chiococca alba	-	-	-	-	-	-	II (1)	-	-
Cordia nesophila	-	-	-	-	-	-	II (1)	-	-
Clerodendrum aculeatum	-	-	-	-	-	-	II (3)	-	-
Galactia dubia	-	-	-	-	-	-	II (3)	-	-
Coccothrinax barbadensis	-	-	-	-	-	-	II (1)	-	-
Solenostemon scutellaroides	-	-	-	-	-	-	II (1)	-	-
Pilea microphylla	-	-	-	-	-	-	II (3)	-	I (3)
Portulaca oleracea	-	-	-	-	-	-	-	II (2)	I (3)
Mariscus capilaris	-	-	-	-	-	-	-	I (3)	-
Gundlachia corymbosa	-	-	-	-	-	-	-	I (1)	-
Sporobolus pyramidatus	-	-	-	-	-	-	-	I (3)	-
Opuntia triacantha	-	-	-	-	-	-	-	I (2)	-
Lantana urticifolia	-	-	-	-	-	-	-	I (2)	-
Tridax procumbens	-	-	-	-	-	-	-	I (3)	-
Eupatorium odoratum	-	-	-	-	-	-	-	I (2)	-
Salvia micrantha	-	-	-	-	-	-	-	I (3)	-
Emilia fosbergii	-	-	-	-	-	-	-	I (1)	-
Boerhavia coccinea	-	I (1)	-	-	-	-	-	II (1)	I (1)
Chloris inflata	-	-	-	-	-	-	-	I (2)	II (3)
Desmodium triflorum	-	-	-	-	-	-	-	I (1)	I (3)
Indigofera suffruticosa	-	-	-	-	-	-	-	I (1)	I (1)
Sidastrum multiflorum	-	-	-	-	-	-	-	I (2)	I (2)
Sida glomerata	-	-	-	-	-	-	-	I (1)	I (2)
Dactyloctenium aegyptium	-	-	-	-	-	-	-	-	II (3)
Lithophila muscoides	-	-	-	-	-	-	-	-	II (3)
Pectis linearis	-	-	-	-	-	-	-	-	II (3)
Portulaca rubricaulis	-	-	-	-	-	-	-	-	II (2)
Stylosanthes hamata	-	-	-	-	-	-	-	-	II (2)
Poaceae species II	-	-	-	-	-	-	-	-	II (4)
Catharanthus roseus	-	-	-	-	-	-	-	-	I (2)
Chamaesyce hirta	-	-	-	-	-	-	-	-	I (1)
Malvastrum americanum	-	-	-	-	-	-	-	-	I (2)
Ruellia tuberosa	-	-	-	-	-	-	-	-	I (3)
Poaceae species III									I (3)
Sida abutifolia	-	-	-	-	-	-	-	-	I (1)
Teramnus labialis	-	-	-	-	-	-	-	-	I (3)
Tragus berteronianus	-	-	-	-	-	-	-	-	I (4)
Sida cordifolia	-	-	-	-	-	-	-	-	I (2)
Cleome viscosa	-	-	-	-	-	-	-	-	I (1)
Euphorbia serpens	-	-	-	-	-	-	-	-	II (3)
Turnera ulmifolia	-	-	-	-	-	-	-	-	I (2)
Sida jamaicensis	-	-	-	-	-	-	-	-	I (2)

Explanation

* Differentiating species are indicated in bold in the table
\- = species not present in that vegetation type
\+ = species present in 1-5% of the sample plots of that vegetation type
I = species present in 6-20% of the sample plots of that vegetation type
II = species present in 21-40% of the sample plots of that vegetation type
III = species present in 41-60% of the sample plots of that vegetation type
IV = species present in 61-80% of the sample plots of that vegetation type
V = species present in 81-100% of the sample plots of that vegetation type
Numbers between brackets indicate cover categories explained in Table 3.

** Cyatheaceae spp. takes together Cyathea arborea, Cnemidaria grandifolia and Hemitelia muricata.

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'To explore the potential of marine nature to improve the quality of life'

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- To conduct research with the aim of acquiring knowledge and offering advice on the sustainable management and use of marine and coastal areas.
- IMARES is an independent, leading scientific research institute

IMARES Wageningen UR is part of the international knowledge organisation Wageningen UR (University & Research centre). Within Wageningen UR, nine specialised research institutes of the DLO Foundation have joined forces with Wageningen University to help answer the most important questions in the domain of healthy food and living environment.

To explore the potential of nature to improve the quality of life

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IMARES (Institute for Marine Resources and Ecosystem Studies) is the Netherlands research institute established to provide the scientific support that is essential for developing policies and innovation in respect of the marine environment, fishery activities, aquaculture and the maritime sector.

The IMARES vision

'To explore the potential of marine nature to improve the quality of life'

The IMARES mission

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