LANDSCAPE ECOLOGICAL VEGETATION MAP OF THE ISLAND OF BONAIRE (SOUTHERN CARIBBEAN)

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ABSTRACT

A semi-detailed landscape-based vegetation map (scale 1:50,000) is presented for the southern Caribbean arid island of Bonaire (mean annual precipitation is 463mm). Color aerial photographs (1:8,000) taken in 1995 and 1996 were used to produce the map. A total of 302 vegetation sample plots were analyzed using a stratified random sampling design and TWINSPAN cluster analysis.

A total of 18 vegetation types, and 32 (sub-)landscape types were distinguished. The three principal vegetation types, *Casearia tremula-Prosopis juliflora* type (Type 17), *Croton flavens-Haematoxylon brasiletto* type (Type 14) and *Prosopis juliflora-Opuntia wentiana* type (Type 16), account for 40% of total vegetation cover. The four principal landscape types also cover 40% of the island and are: D3 (*Prosopis-Casearia* Landscape), TH1(*Haematoxylon-Croton* Higher Terrace), D2 (*Haematoxylon-Casearia* Landscape) and TM7 (*Acacia-Croton* Middle Terrace). The vegetation on the volcanic Washikemba Formation is more uniform than that on the limestone formations. Most of the vegetation types can be categorized as secondary. This is considered mainly to be the result of the impact of introduced grazing mammals (principally goats and donkeys) and woodcutting in the past. Six vegetation types are considered of relatively high natural value. Three of these (Types 1, 9, and 10) are comparable to Stoffers' less degraded communities. The other three have been selected based on criteria such as structural complexity, diversity and number and rarity of rare species. A comparison with a vegetation map from the 1950's shows that three types of areas can be distinguished: areas in which the vegetation has remained more or less the same, areas in which the vegetation shows improvement and areas that show broadscale deterioration of the vegetation. The largest area that shows deterioration is the southern part of Bonaire. The northern part of the Washington-Slagbaai National Park is the largest area with improvement. The findings are discussed in relation to the Nature Management Plan for Bonaire and conservation recommendations are made.

Keywords: Caribbean, Bonaire, arid island, aerial photo interpretation, vegetation, landscape, survey.

INTRODUCTION

Bonaire is an island that forms part of the so-called 'Caribbean dry region' (Sarmiento 1976) situated between the Araya Peninsula in Venezuela (64° W long., 11° N lat.) and Cartagena in Colombia (75° W long., 10.5 N lat.). This region is characterized by the presence of semi-arid areas with rainfall below 800mm/yr and arid areas with rainfall below 500mm/yr. With its 30yr. average of 463mm/yr (1971-2000; Meteorological Service of the Netherlands Antilles, pers. comm.) Bonaire belongs to the latter category. Rainfall on the island is seasonal, with the last three months of the year accounting for 51% of the long-term annual average. Only in November is the average monthly rainfall almost 100mm, the critical point below which evaporation exceeds precipitation in tropical areas (Beard 1949; Nix 1983).

In his description of the flora of the Dutch Leeward Islands, Boldingh (1914) only provided a general description of the vegetation of the islands. He distinguished two vegetation types (a littoral vegetation and a *Croton* vegetation) that were difficult to differentiate from each other. Stoffers (1956) made the first vegetation maps for each island of the Dutch Antilles. However, Stoffers' distinction between plant communities was based on qualitative descriptions of a limited number of sites dispersed over the islands. His map of Bonaire is on a scale of approximately 1:60,000.

Land-use planning in the Dutch Antilles began in the early 1980s and the need arose for up-to-date and (more) quantitative vegetation maps for the islands. Curaçao was the first island for which such a map became available (Beers *et al.* 1997). This map proved important to the elaboration of the Islandwide Development Plan ('Eilandelijk Ontwikkelingsplan'; Executive Council of Curaçao 1995) and the proposed Nature Management Plan for Curaçao (Executive Council of Curaçao 2001). Because of the similarity in purpose with the Curaçao study (land-use planning and nature management), the same methods were used in the present study (Küchler & Zonneveld 1988; Loth 1990; Groten *et al.* 1991). The resulting landscape ecological vegetation map is therefore on the semi-detailed scale of 1:50,000 (Küchler & Zonneveld 1988). Use of the same methods also facilitates comparison of results between the islands.

THE ISLAND OF BONAIRE

GEOGRAPHY

Bonaire is located in the Southern Caribbean Sea (between 68°11' and 68°25' W and 12°2' and 12°19' N) about 87 kilometers north of the coast of Venezuela and 40 kilometers east of Curaçao (Figure 1). The length of the island is 40km, its width varies between 5 and 12km and the total surface area is 288km^2 (De Palm 1985). Klein Bonaire is an islet of 6km^2 out of the leeward coast (west of the capital Kralendijk) and forms part of the island territory of Bonaire.

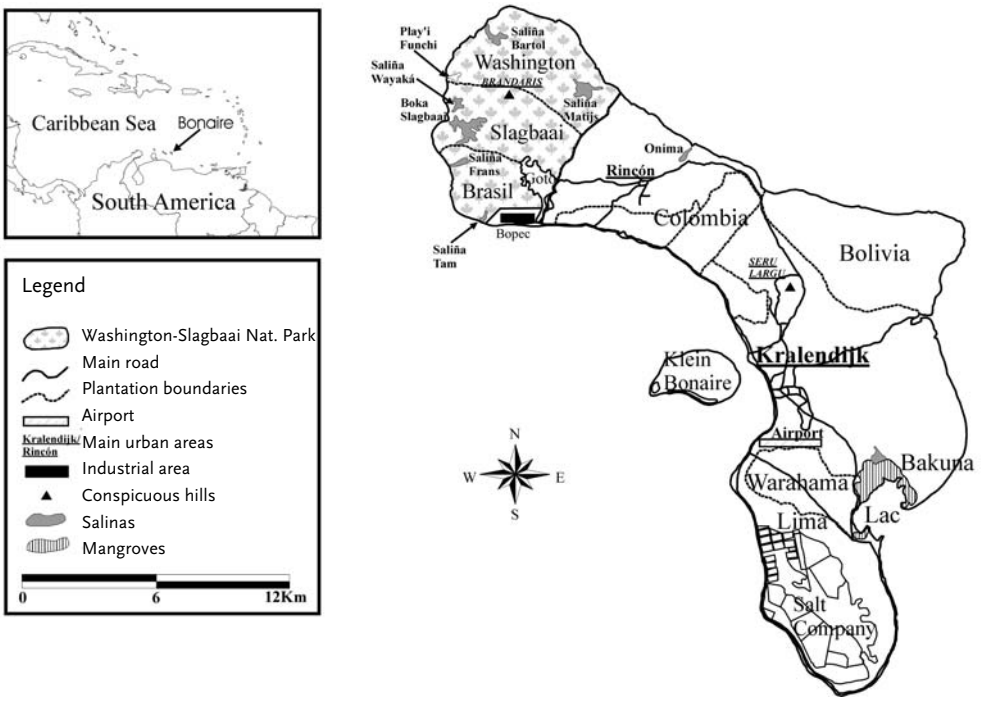

Fig 1. Maps showing the location of Bonaire in the Caribbean Sea and main topographical features of the island. Important former plantations are also indicated.

CLIMATIC DATA

Average annual temperature on Bonaire is 28.0°C (1971-2000; Meteorological Service of the Netherlands Antilles and Aruba, pers. comm.). September is the warmest month (29.1°C), while January and February are the coolest (26.7°C and 26.8°C respectively). The average daily evaporation is 8.4mm. Relative humidity is 75.9%. Wind speed (at 10m) averages 6.6m/s. The average direction of the trade wind is east (079 degrees). Figure 2 shows the Walter climate diagram for Bonaire depicting the wet season in the last three months of the year.

Not only can rainfall vary significantly between years but also between stations. In 1998, the rainfall was 217mm at the station with the lowest rainfall while 527mm was registered at the station with the highest rainfall (Meteorological Service of the Netherlands Antilles and Aruba, pers. comm.). At the other two stations 315mm and 382mm were measured. The 1998 average rainfall of the four stations for the months of October, November and December combined is 230mm, which approximates the 1971-2000 average for these three months very well (237mm).

GEOLOGY AND GEOMORPHOLOGY

Figure 3 provides a schematic geological map of Bonaire (De Palm 1985). Broadly speaking, on Bonaire the rocks at the surface can be divided in two different groups, namely the volcanic Washikemba Formation and limestone formations (De Buisonjé 1974). The Washikemba Formation is named after the Washikemba plantation in eastern Bonaire. It is a heterogeneous, submarine volcanic succession of mid-Cretaceous

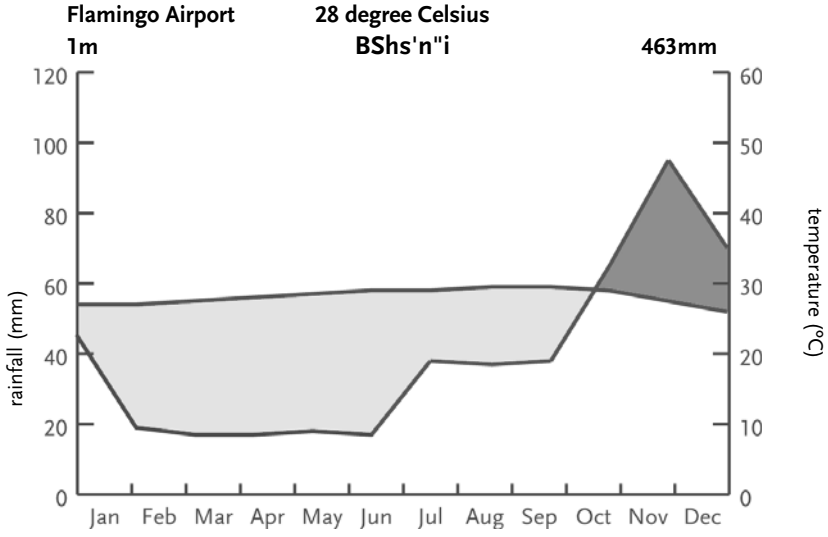

Fig. 2. Climate diagram for Bonaire showing the dry period from January to October and the short wet period between October and December. The data are for the period 1971-2000.

age (~90 – 100million years ago) and largely consists of basaltic, andesitic and dacitic lavas, sills and dikes, interbedded with, or intrusive into volcanic (tuffs) and biogenic (cherty limestones) sediments. The thickness of this succession is approximately five kilometers. The Cretaceous rocks of the Washikemba Formation are exposed in the northwest of Bonaire from Slagbaai to Rincón, and in the east of Bonaire from Bolivia to Seru Largu. In both regions the rocks dip 45 to 60 degrees to the northeast (Pijpers 1933). These two areas are separated and rimmed seaward by limestones of Eocene, Neogene and Quaternary age, which unconformably overlie the Cretaceous sequence. The dacitic lavas are the most resistant to weathering. They form the highest terrains of the island (e.g. Brandaris, Yuana, Seru Mangel, Seru Wekua). As they alternate with more easily weathered volcanic sediments, the terrain is rocky and can be strongly uneven. The basalts and basaltic andesites, on the other hand, are often deeply eroded and their outcrop areas give a more undulating terrain. A good example of this is the area in the west between Saliña Slagbaai and Goto Meer, and also a large part of the outcrop area of the Washikemba Formation in the south. The sharp hills in the latter area consist again of dacitic lavas and dikes. The limestone formations are a predominantly Neogene sequence of calcareous forereef deposits (the Seroe Domi Formation) partially overlain by Quaternary reefal limestones. Locally, isolated outcrops of Eocene limestone are found, almost always associated and overlain by the younger limestone units. The Quaternary reefal limestone forms terraces, due to the relatively rapid sea-level changes in the Quaternary, superimposed upon slow

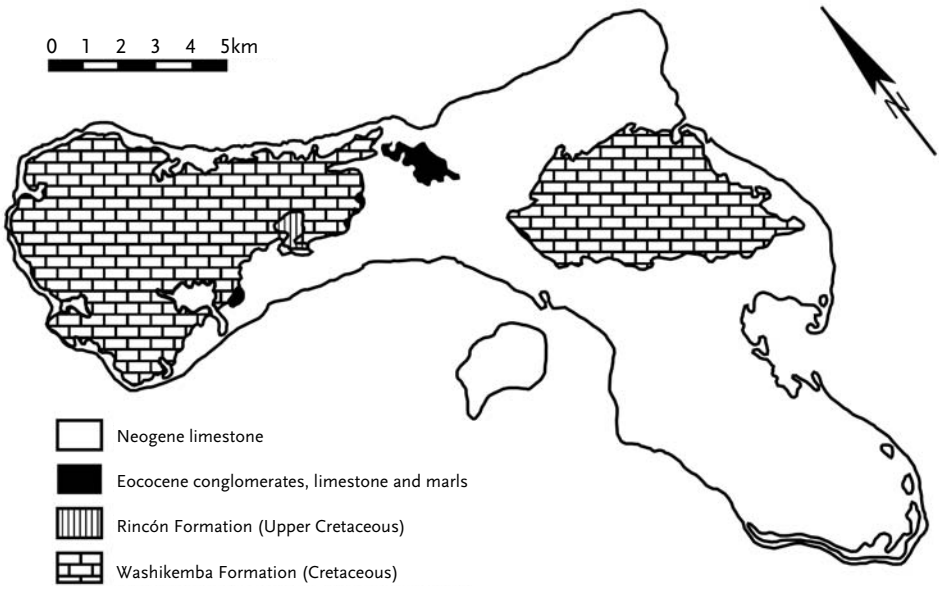

Fig. 3. Schematic geological map of Bonaire
(source: De Palm 1985, used with permission of De Walburg Pers)

emersion of the island. The Quaternary terraces consist of yellowish or white, horizontally bedded limestones. A distinction can be made between erosional and depositional terraces.

The Neogene forereef of the Seroe Domi Formation occurs along the leeward coast between Saliña Tam in the west and Nort'i Saliña in the east. In the central part of Bonaire the Seroe Domi Formation extends in northern direction towards Fontein. Smaller occurrences are found in the Washington-Slagbaai National Park on the windward coast (Seru Grandi) or on the leeward coast (near Saliña Wayaká). The Seroe Domi Formation consists of limestone and dolomitized limestone rich in algal, coral and other fossil remains and possesses a distinct bedding that dips seaward (De Buisonjé 1974). Landwards, the Seroe Domi Formation is bounded almost everywhere by a steep and in most cases nearly vertical escarpment. Quaternary limestone terraces cover large parts of central and southeast Bonaire. Broadly outlined, three terraces can be distinguished, and these are from old to young: Higher Terrace, Middle Terrace and Lower Terrace. In these, de Buisonjé (1974) distinguished depositional and erosional terraces. The former consist of reefs and reef debris, while the latter were formed in the limestone of the Seroe Domi Formation. The highest part of the limestone areas of Bonaire (situated in the central part of Bonaire) is formed by the Seroe Domi Formation. The highest point is 138m (Seru Largu). A huge eolianite deposit is found in the Seroe Domi Formation between Colombia and Montaña.

Landwards, the top of the Higher Terrace attains its greatest topographical height. From about 85m it slants down in seaward direction where the top level is situated at an altitude of about 50m. Because of the older age of the Higher Terrace (and thus the relatively longer exposure to the effects of erosion), a considerably less continuous section of this terrace remains compared to the other two terraces. The largest part of the Higher Terrace (viz. between Tolo and Hato) is erosional and only a very small depositional part has remained (to the west of Fontein).

Generally, the height of the Middle Terrace varies from 15 to 20m at the seaward side to 45m landwards. This terrace appears on Bonaire in a small or broad continuous belt or in a discontinuous series of small hills. Usually a cliff borders it on its seaward margin. The Middle Terrace mostly consists of depositional terraces (e.g. Bolivia, Lima, Klein Bonaire). Along the leeward coast (between Nort'i Saliña and Saliña Tam) the Middle Terrace consists of both erosional and depositional terraces. The erosional terraces form the landward part of the Middle Terrace in this part of Bonaire. The topography of the largest Eocene limestone outcrop near Porto Spaño is also classified as erosional Middle Terrace. Small sections of erosional Middle Terrace are found in the Washington-Slagbaai National Park along the leeward coast.

A Lower Terrace zone almost completely surrounds the island. The Lower Terrace has a very flat surface with an altitude varying from 4 to 15m. Only in the southeast of Bonaire is it found at less than 4m. On the windward side of the island, the surface shows a faint dip (mostly less than two degrees) directed landwards. The Lower Terrace consists almost entirely of depositional terraces. Only at Beneden Bolivia are two small sections of erosional Lower Terrace found, cut within the Seroe Domi Formation. The Lower Terrace is generally wider on the windward side of the island.

Towards the sea the Lower Terrace generally ends in a more or less vertical cliff. In south Bonaire the Lower Terrace terminates in recent to sub-recent beach ridges.

Klein Bonaire in turn consists entirely of limestone sedimentary deposits. The Lower Terrace is partly encircled by recent to sub-recent beach ridges consisting of both sandy and coral shingle areas. The Middle Terrace forms the central part of this small island.

SOIL- AND LANDTYPES OF THE GEOLOGICAL FORMATIONS

In 1998 between 7.5% and 10% of the total surface of Bonaire was urban area (including the Flamingo Airport; D.R.O.B., pers. comm., but excluding the industrial salt complex in the south of Bonaire that amounts to approximately 14% of the surface of the island). In 1968 about 2% was urban area (Grontmij & Sogreah 1968). The remaining land can be divided into five groups of soil- and landtypes. These types are mainly based on differences in geological formations:

- Soil- and landtypes of Washikemba Formation;
- Soil- and landtypes of Limestone Formation;
- Alluvial and colluvial soils;
- Miscellaneous landtypes: Salinas;
- Complex of soils on Washikemba Formation and Rooibottom soils.

The included soil map of Grontmij & Sogreah (1968) shows the distribution of these soil- and landtypes. All data on the soil- and landtypes in the present study comes from that report.

About 20% of the island is covered with soil profiles of at least 15 to 20cm and which are found in all the three groups. The landtypes (78% of the island) are considered as 'not-soils' in which the rock exposures cover the majority of the surface, or where this rock material is present at very shallow depth. This category is formed by the hills, the Stony plateau land of the Washikemba Formation, the rock land of the limestone terraces and the Salinas.

SOIL- AND LANDTYPES OF THE WASHIKEMBA FORMATION

This formation covers about 31% of Bonaire and appears in two large areas in northwest and east Bonaire. Four different landforms can be distinguished: 'Plains' (Wp2, Wu2), 'Hilly land' (Wr, Wi), 'Stony land' (Ws) and 'Stony plateau land' (Wx). The pertaining reddish soils are characterized by a cherty stony surface and a cherty profile with loamy texture, and are partly influenced by alluvial and colluvial deposits. The 'Soils of the plains' often have a profile depth of 15-50cm. Shallow drainage channels are present in the plains, and increase in number in the more undulating parts.

Two landtypes of the 'Hilly land' can be distinguished based on differences in alti-

tude and position within the landscape: The 'Very high and high hills' (Wr) and the 'Isolated medium-high and low hills' (Wi). Wr occupies the majority of the 'Hilly land' and is found in three locations: (1) The Washington-Slagbaai area with the Brandaris (241m); (2) Brasil with Seru Wekua as the highest top (161m); (3) The Seru Grandi complex of east Bonaire (117m). The 'Hilly land' is characterized by irregular ridges often with rounded rocky tops, many rock exposures along the slopes, and a hilly to steep relief with slopes of generally more than 20°. Between the ridges, rather wide valleys with an irregular relief and also deeply incised gullies ("Roois") are found. The soils are very shallow, cherty-stony with a loamy and sandy texture. Higher up the slopes, the profiles become more shallow and the stoniness and amount of rock exposures increases. Relatively deeper profiles are found in the footplains and along the gullies. Wi is formed by the 'Isolated medium-high and low hills' and is mainly found in eastern Bonaire. Ws is characterized by an undulating to rolling relief with slopes less than 20°. Wx has a (gently) undulating relief and is only found in the southern part of Bolivia. It borders and slightly dips towards the Middle Terrace. The soil cover is less than that of Ws and the chertiness and stoniness more outspoken. In Wx some (wide) valleys are found (e.g. Rooi Tuna).

SOIL- AND LANDTYPES OF THE LIMESTONE FORMATION

This group covers some 58% of Bonaire (including Klein Bonaire). Based on differences in landform and age or altitude, the landtypes are divided in: a) depositional and erosional terraces, b) 'Plateau land' and c) 'Miscellaneous landtypes'. Relatively large areas with soils are found only on the Lower Terrace and Middle Terrace. This formation consists in general of an irregular pattern of rock land, and relatively small areas of shallow to moderately deep-profiled reddish loamy soils, with fair to good internal drainage (lTl and lTm respectively) and yellowish brown clayey soils on Tm (cTm9). The latter category is only found in Bolivia and covers a relatively small area. The 'Erosional terraces' (Te) have a flat relief but distinctly dip towards the leeward coast. The rock land is relatively continuous and has a karst structure. In Te also a (Lower), Middle and Higher Terrace can be distinguished. The 'Plateau land' (Tx) consists of two parts: The most extensive part is characterized by the dominance of karst rock outcrops and partly undulating relief (corresponding with the Seroe Domi Formation); A smaller part of Tx has a smoother and flatter surface that mainly consists of eolianite fragments and calcareous sand (De Buisonjé 1974).

Three other small landtypes need also to be mentioned: a) Deeply incised rocky valleys with steep escarpments (gorges: Tg); b) Terrace remnants (Tr) forming severely eroded rocky outcrops that are partly denuded (Trd); and c) Ridges of coral shingle, beach rock, ramparts and sandy deposits (Tc) along the leeward coast and around "bokas" (= small inlets on the windward coast).

ALLUVIAL AND COLLUVIAL SOILS

The (recent) alluvial and colluvial deposits of Bonaire are found on the footplains of the hilly land (e.g. at Washington), as fan-shaped deposits at the foot of some of the depositional terraces, and along the shallow gullies on both the Washikemba plains and the lower terraces. They cover about 9% of Bonaire and are divided in three categories: 1) 'Rooibottom and plain soils' (Ab9), with clayey or loamy cherty profiles, generally deeper than 45cm (cAb9/lAb9 respectively). The 'Rooibottom and plain soils' are found in nearly level plains, footplains and long-stretched rooibottoms, and locally the influence of salt can be significant. Characteristic is the fact that the alluvial and colluvial deposits cannot be distinguished from each other; 2) 'Soils of the roois' (Ar2) with predominantly shallow (less than 45cm deep), clayey or loamy profiles (cAr2 and lAr2 respectively). The Ar2 soils are moderately well drained outside the saline parts; 3) 'Soils of the fans' (Af2), with also shallow (less than 45cm deep) clayey or loamy profiles (cAf2 and lAf2 respectively). As opposed to clayey soils, the loamy soils in the Af2 category have a good drainage. The relief of the 'Soils of the fans' is nearly level, but slightly elevated.

MISCELLANEOUS LANDTYPES: SALINAS

Salinas (Sa) are salt flats located in close proximity of the sea and comprise 3% of Bonaire's surface. They occur: (1) In depressional sites on Tl, partly as shallow saltwater lakes (remnants of former lagoons); (2) At the extreme end of the valleys, debouching into the sea; (3) On the lower banks and depressional sites around the inland bays and "bokas".

Most of the Salinas are permanently flooded. The profiles have a sandy, loamy or clayey texture, and a high and saline groundwater table. The former shallow lagoons in south Bonaire have been converted into large industrial salt pans.

COMPLEX OF SOILS ON WASHIKEMBA FORMATION AND ROOIBOTTOM SOILS

This complex (c/l Wp2:Ab9-ch) covers 1% of Bonaire's surface and can be found north of Rincón bordering Tl. The relief is undulating with small nearly level parts. Several gullies run through this area, which is slightly or moderately eroded. The soils consist of shallow residual 'Washikemba plain soils' (Wp2) intersected by a capricious system of small and long-stretched, moderately deep 'Rooibottom soils' (Ab9). All these soils are cherty and locally (strongly) affected by salt. The subsoil in the Rooibottom parts is clay with a poor internal drainage.

The flora of Bonaire consists of 387 vascular species (including 36 introduced and naturalized species) in 246 genera and 89 families (Stoffers 1981, 1984; De Freitas & Rojer 2000). The main families are: Gramineae (20 genera, 40 indigenous spp.), Cyperaceae (5 genera, 25 indigenous spp.), Euphorbiaceae (10 genera, 24 indigenous spp.), Fabaceae (13 genera, 17 indigenous spp.), Rubiaceae (10 genera, 11 indigenous spp.), Caesalpiniaceae (4 genera, 9 indigenous spp.). When comparing the data in our section 'Flora and Vegetation' with Sarmiento (1976) it can be concluded that the floristic richness of Bonaire is similar to that of other arid areas of the Caribbean and American continent. The dry Caribbean vegetation is highly heterogeneous in origin and affinities, with the most significant contribution coming from neighboring less-dry woody formations, particularly the 'tropical deciduous forest' and 'dry evergreen woodland' (Sarmiento 1976). An important contribution also comes from cosmopolitan or sub-cosmopolitan weeds, and a variety of floristic elements stemming from either more northern or more southern latitudes.

The following species are restricted to one or more islands of the Leeward Dutch Antilles, but none are endemic to Bonaire only (Stoffers 1981; De Freitas & Rojer 2000): *Paspalum bonairense, Maytenus versluysii, Myrcia curassavica* and *Cynanchum boldinghii* occur only on Bonaire and Curaçao; *Agave boldinghiana* is known only from Bonaire, Aruba and Curaçao.

In the 1950s, Stoffers (1956) studied the vegetation of the Netherlands Antilles quite extensively. For the Leeward Islands (Bonaire, Curaçao and Aruba) he described 18 different vegetation types. Following Beard (1949) he classified these in two categories: (a) primary climatic climax communities and (b) secondary and sub-climax communities. The climatic and edaphic climax communities belong to the first category. The climatic climax communities are divided into seasonal and dry evergreen formations. Secondary and degraded formations can be found in both of the latter groups. Stoffers (1956) considered this classification quite difficult due to the lack of knowledge of the extent as to which the vegetation had departed from the original state. He considered the degradation of the vegetation to be the result of anthropogenic influences (repeated clearance and grazing by introduced animals (goats)). The primary climatic climax communities have been sub-divided by him into seasonal formations and dry evergreen formations. On Bonaire the vegetation of the dry evergreen formation series occurs on limestone hills and terraces and also two of the highest hills of the Washikemba Formation (Brandaris and Juwa). The vegetation of the seasonal formation series is characteristic for the Washikemba Formation and also alluvial and colluvial soils.

A study on the water relations in plants, showed that water deficit in plants growing on non-calcareous soil appears to be much higher than those on limestone at the end of the rainy season (Stoffers & Mansour Elassaiss 1967). In the upper soil layers, the amount of water that can be taken up by plants is small, both in calcareous and non-calcareous soils. However, in deeper layers of the limestone soil more water is available than in non-calcareous soils at the same depth. Vegetation development on non-calcareous soil is dictated by water availability in the soil during the rainy season

and scarcity during the dry season. On limestone all the water disappears into the cracks and holes of the porous rocks, in which a soil with a high retention capacity is found. This means that there is a larger amount of water available in the soil for a longer period of time.

Since Stoffers' work in the 1950s few floristic studies have been carried out on Bonaire: Stoffers (1980) studied the coastal communities in more detail and Lo Fo Wong & de Jong (1994) described the vegetation (including the presence of rare plant species) in certain parts of the Washington-Slagbaai National Park; De Freitas (1996), Debrot (1997), Debrot *et al*. (1998), De Freitas & Rojer (2000) and van Proosdij (2001) provide more recent information on the presence of floristic elements, based on relatively short visits to the island.

HUMAN INFLUENCE ON THE VEGETATION OF BONAIRE

It may be assumed that human influence on Bonaire's vegetation was limited during prehistoric times based on the fact that the small groups of Amerindians that inhabited Bonaire only cultivated a few food crops for their own use. This situation changed dramatically with the colonization of the island by Europeans (e.g. Terpstra 1948; Van Meeteren 1949; Teenstra 1977). Felling of trees (in particular *Haematoxylon brasiletto, Zanthoxylum flavum* and *Guaiacum officinale*) was done everywhere on Bonaire and Klein Bonaire. Large grazers such as goats, sheep, donkeys, cattle and horses were introduced and left to roam. During the second British interim government (1807-1816) exploitation of wood was so devastating, that hardly any trees were left (de Hullu 1923). Euwens (1907) indicates the disappearance of areas with dense cover of trees. In the course of the 19th and 20th centuries several official acts and resolutions were emitted, with the purpose of controlling the felling of trees, charcoal burning, collection of *Caesalpinia coriaria* pods and grazing by introduced mammals (Van Grol 1942; Westermann & Zonneveld 1956). However, the impact of these measures was limited due to the fact that they were not enforced and did not apply to private lands. The latter aspect plays a role particularly in the period after the emancipation of the slaves when public lands were sold to private citizens.

Furthermore it must be mentioned that large amounts of charcoal continued to be exported to Curaçao until the first half of the 20th century (Gerharts 1982). Extensive deforestation also took place into the 1950's for the cultivation of *Aloe* (Miller *et al*. 2003). In the second half of the 20th century, tourism and industrial activities became important segments of the economy. As a consequence land was cleared to build houses, hotels and apartments (De Palm 1982). The large saline area in the southern part of the island was converted into a modern salt industry complex. Parallel to the development of tourism and industry, the importance of lime and charcoal burning and agriculture decreased in recent decades. However, at present free roaming animals (goats, donkeys, sheep) can still be seen in all areas of the island (including the Washington-Slagbaai National Park). The deleterious effects of these animals on (insular) ecosystems are well known. These effects include reduced vegetation cover, diminished recovery potential and dominance of weedy species (e.g. Hamann 1979;

Department of the Interior 1979; Noy-Meir 1989; Debrot & De Freitas 1993; Albaladejo *et al*. 1998; Steen 1998). Human influence has undoubtedly also strongly reduced the mangrove cover on the island (Teenstra 1977; Haviser 1991).

METHODS

PHOTO INTERPRETATION AND FIELDWORK

The ITC (International Institute for Aerospace Survey and Earth Sciences, Enschede, The Netherlands) method used for the survey of the (semi)-natural vegetation of Bonaire is a landscape-guided method (Küchler & Zonneveld 1988; Loth 1990; Groten *et al.* 1991). The principle of this method is to combine aerial photo interpretation and efficient stratified field sampling. Due to the lack of recent stereoscopic aerial photographs with 60% overlap for Bonaire, the present map is based on 1:8,000 true colour aerial photographs (with 30% or less overlap, taken in December 1995 and June 1996). Photo interpretation was based on analysis of different photo-features such as tone of vegetation and soil, texture and spatial pattern (density). The resulting units of the photo interpretation were indicated on a 1:25,000 topographic map. This map was used in choosing the location of the sample plots. At each site the plot was randomly selected in a representative area of the unit. A varying number of sample plots ('relevés') were taken in each of the preliminary mapping units. Plot size was chosen following the guidelines of the ITC method, but slightly modified for herbaceous vegetation types (a) and woodlands and heterogeneous higher vegetation (d and e respectively). These modifications were based on the diversity of the herbaceous vegetation and the relative homogeneity of woody species in the woodlands. The following plot sizes were used in the present study:

a. herb and grass vegetation:	3m x 3m
b. low shrub vegetation ($\leq$1m):	5m x 5m
c. high shrub vegetation (> 1m):	7m x 7m
d. woodland:	10m x 10m
e. very open heterogeneous higher vegetation:	15m x 15m

DATA COLLECTION

Field data were collected during and shortly after the 1998 rainy season (between December 13, 1998 and March 16, 1999). All data collected for each plot were recorded on standard ITC relevé sheets. The following data categories were used:

Terrain characteristics: geological formation; relief type; slope type (gradient and exposure); percentage surface stoniness (i.e. percentage rock outcrops at the surface as part of the sample plot). Data on soil- and landtypes (Grontmij & Sogreah 1968) were also noted.

Soil characteristics: pH of the top layer (using Hellige indicator solution) and relative calcium carbonate content (using HCl).

Vegetation structure and floristic composition: cover, average and maximum height of each stratum as well as total real cover of the vegetation are given; where there was considerable overlap in height between the tree layer and the shrub layer, these were considered as one layer. At some sites a distinction could be made between a high and a low shrub layer. The average height is the height of the layer that had the highest cover percentage in most of the sample plots of the corresponding vegetation type.

In each plot, all species were recorded for each stratum and their abundance or cover estimated. The decimal scale of Londo (1976) was used for recording species abundance or cover. Nomenclature of the plant species follows Stoffers (1981, 1984) and Howard (1979, 1988, 1989a,b). Species that could not be determined to the species level are indicated with the extension *spec.* after the genus name.

To provide an indication of the present level of disturbance affecting the vegetation, the presence of goat dung, donkey excrements and stumps (as a result of past felling of trees) were also recorded.

DATA PROCESSING

The clustering program TWINSPAN (Two Way Indicator Species Analysis; Hill 1979) was used to analyze the vegetation data collected in 302 sample plots. Field data on species cover and abundance were converted to the Londo (1976) scale for input into TWINSPAN (see Table 1). Our field observations helped us to identify misplaced samples and these were moved to the most appropriate group. These clusters and their corresponding samples were arranged in a synoptic table using CLUTAB (Wageningen Agricultural University 1994). Appendix 1 presents such a table. The presence or absence in the clusters is indicated for the 162 species found and a frequency scale of I-V is used for species present. An asterisk indicates a species with an average cover of 15% or more in a cluster. The synoptic table also lists the species according to four categories (from top to bottom): characteristic, common, other species and rare species. The numbers in bold indicate the differentiating species. In the present study a species was considered differentiating for a cluster when its frequency in that cluster was 30% higher compared to all other clusters and when it occurred in 50% or more of the sample plots.

Table 1. Decimal scale for abundance/coverage after Londo (1976) and the conversion values applied for the TWINSPAN clustering program.

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

Legend: [a] Overall cover < 5% : r = rare (1-4 individuals), p = present (5-12 individuals), a = abundant (13-40 individuals),m = many (>40 individuals); Cover categories: 1 = 5-15%; 2 = 16-25%, etc.; 9 = 86-95%; 10 = 96-100%.

The hierarchical order used for the names of the landtypes is as follows: (1) geology and landtype; (2) terrain form (high hills, low hills, terraces, gully, escarpment, beach, salina); (3) vegetation structure and floristic composition (vegetation types). The final map was prepared using ArcView (E.S.R.I. 1996) and shows the landscape units and their distribution over the island.

RESULTS

VEGETATION TYPES

Cluster analysis resulted in the distinction of 18 vegetation types. Most of the vegetation types are indicated by binary names are used to indicate most of the vegetation types. Although Weber *et al.* (2000) recommend using a dominant species in the second place of the name of an association or a syntaxon, we use it here in the first place in order to facilitate the comparison of our results with those of Beers *et al.* (1997). Our names for the vegetation types have been derived as follows: the most common and often dominant species is indicated by the first part of the name while the second part of the name indicates a differentiating or an accompanying species occurring in at least 61% of the sample plots of that type. In two cases (Types 3 and 5) there was an exclusive dominant species and no other differentiating species. In these cases only the name of the dominant species was used to denote the vegetation type.

Along with the name of each vegetation type, the percent total cover of each type as part of the total island surface (without the water areas) is recorded between brackets. The total island cover for each vegetation type was obtained as the sum of the estimated cover of each vegetation type across all (sub-)landscape units (see Appendix 2).

The vegetation types are described below and include quantitative data on other relevant characteristics. The values given are averages per sample plot, while the figures between brackets indicate range values. The height values indicate the values for the most important (= most covering) layer of the vegetation type. Appendix 1 shows all species encountered, their frequency of occurrence and average cover in all 18 vegetation types. The habit of each species as encountered in the field is also indicated in Appendix 1.

Table 2 (p. 36) shows how the vegetation types are distributed over the soil- and landtypes of Grontmij & Sogreah (1968). The figures are based on the number of sample plots on each soiltype or in each landtype as a percentage of all the sample plots of that vegetation type.

1. Rhizophora mangle-Batis maritima type (1.2%)

Relatively high values for cover and height are typical for this mangrove (tree) vegetation that is found on sandy and sheltered transition zones from land to sea. Trees of *Rhizophora mangle* occupy the zone in shallow water, while *Avicennia germinans* and *Laguncularia racemosa* are found on the (higher) parts that are only flooded at high tide. *Laguncularia* normally occurs more landward than *Avicennia*. Significant parts of the mangrove areas of the island consist only of *Rhizophora mangle*. The latter species and *Salicornia perennis* are differentiating species. Type 1 occurs at sites indicated by Grontmij & Sogreah (1968) as the Lower Terrace, coral shingle (Tc) and mangrove vegetation (see Table 2, p. 36). On Bonaire the main occurrence is at Lac, where small sandy areas occur between the mangrove stands. The succulent herb species *Sesuvium portulacastrum* and *Salicornia perennis* are dominant in these sandy areas. The transition zone between the mangroves and the sandy areas is usually dominated by *Batis maritima*.

pH	8
reaction to HCl	+
# of species	3 (1-7)
total real cover	50% (15-95%)
height	3.5m (1.4-5.0m)
surface stoniness	0.1% (0-1%)

2. Sesuvium portulacastrum-Lithophila muscoides type (4.1%)

This is a very low herb vegetation (coastal shrubs such as *Suriana maritima* and *Corchorus hirsutus* occur only sporadically). *Sesuvium portulacastrum* is often the only species present and also differentiating. *Lithophila muscoides* is the principal accompanying species. Type 2 is characteristic for coastal areas on the Lower Terrace (Tl, Tc; see Table 2, p. 36) and Salinas. At some places (e.g. the north coast of Klein Bonaire, near Oranje Pan and to the south of Trans World Radio) a *Suriana maritima* facies can be found on sandy areas. More inland on this terrace it can be found in clayey areas that are subjected to flooding by rainwater. Of minor importance are occurrences on coral shingle (Tc) and in mangrove areas. Type 2 is often associated with Type 4 (*Lithophila-Euphorbia* type) or surrounded by barren areas (Landscape of the Salinas).

pH	8.5
reaction to HCl	+
# of species	3 (1-9)
total real cover	15% (1-70%)
height	0.05m (0.01-0.3m)
surface stoniness	26% (0-60%)

3. Conocarpus erecta type (2.4%)

This generally open shrub vegetation consists almost exclusively of *Conocarpus erecta*, with an occasional herb species such as *Lithophila muscoides, Sporobolus pyramidatus, S. virginicus* and *Euphorbia spec.* It occurs on the Lower Terrace (Tl) in southern Bonaire as well as on the Middle Terrace (Tm) at Lima. On Tm it is found around puddles that are formed after significant rainfall. It is also occasionally present on the leeward coast on coral shingle (Tc; see Table 2, p. 36).

pH	8.5
reaction to HCl	+
# of species	3 (1-5)
total real cover	20% (10-50%)
height	0.9m (0.3-2.2m)
surface stoniness	39% (0-94%)

4. Lithophila muscoides-Euphorbia spec. type (3.7%)

This very low and generally open herb vegetation is dominated by *Lithophila muscoides* (differentiating species). *Euphorbia spec.* and *Sporobolus pyramidatus* occur frequently (accompanying species). Type 4 often forms a mosaic vegetation with the *Sesuvium-Lithophila* type (Type 2) indicating the direct influence of salt spray on the Lower Terrace. Further from shore Type 6 (*Euphorbia-Sporobolus* type) or Type 3 (*Conocarpus erecta* type) replaces Type 2. On the Middle Terrace (Tm) and coral shingle (Tc) the occurrence of Type 4 is very limited (see Table 2, p. 36).

pH	8.5
reaction to HCl	+
# of species	4 (1-6)
total real cover	11% (1-45%)
height	0.03m (0.01-0.08m)
surface stoniness	35% (0-95%)

5. Strumpfia maritima type (0.1%)

This wind-blown and low shrub vegetation is subjected to the influence of salt spray. *Strumpfia maritima* is dominant and restricted to this type. Of the herb species found in this vegetation type, *Euphorbia spec.* is the most frequent (III) companion. Type 5 is only found on the Lower Terrace (Tl; see Table 2, p. 36) along the northeastern coast (Bolivia) and covers a relatively small area.

pH	8.5
reaction to HCl	+
# of species	3 (1-10)
total real cover	29% (5-45%)
height	0.2m (0.15-0.3m)
surface stoniness	49% (0-90%)

6. Euphorbia spec.-Sporobolus pyramidatus type (4.4%)

In the large majority of cases the low shrub layer is the most important layer but its composition is very variable. Although the herb layer seldom is the most important layer it consists of quite a diverse array of species. The most common species are the herb *Euphorbia spec.* and the grasses *Sporobolus pyramidatus, Eragrostis urbaniana* and *Anthephora hermaphrodita*. *Prosopis juliflora* is the main woody species. No species is differentiating. Type 6 is mainly found more inland on the Lower Terrace (Tl). Occasionally it also forms part of relatively open shrub vegetations on the Middle Terrace (Tm) and Hilly land of the Washikemba Formation (Wr; see Table 2, p. 36).

pH	8
reaction to HCl	+
# of species	9 (3-18)
total real cover	23% (3-70%)
height	0.7m (0.1-1.7m)
surface stoniness	30% (0-90%)

7. Lantana involucrata-Capraria biflora type (1.5%)

This is a low, open and poor shrub vegetation. It is only present on Klein Bonaire. *Lantana involucrata, Capraria biflora* and *Corchorus hirsutus* are common and the first two are differentiating. *Opuntia wentiana* and *Croton flavens*, two (very) common species on Bonaire, are absent. *Cyperus fuligineus, Euphorbia spec.* and *Paspalum bakeri* are common in the herb layer. Type 7 covers most of the Lower Terrace (Tl) of Klein Bonaire and is occasionally found on coral shingle (Tc) and the Middle Terrace (Tm; see Table 2, p. 36, p. 36). *Condalia henriquezii* is common on more inland sites of the Lower Terrace.

pH	8
reaction to HCl	+
# of species	8 (2-16)
total real cover	15% (5-25%)
height	0.8m (0.5-2.4m)
surface stoniness	39% (0-95%)

8. Eragrostis urbaniana-Melocactus macracanthos type (2.9%)

The most important layer is most often the low shrub layer, although frequently a combined tree and shrub layer can take precedence. The only differentiating species is *Melocactus macracanthos* and its presence is related to the high percentage of surface stoniness. Other very common species are two grasses and a herb: *Eragrostis urbaniana, Aristida adscensionis* and *Euphorbia spec. Corchorus hirsutus, Croton flavens, Haematoxylon brasiletto* and *Jatropha gossypiifolia* are common in the shrub layer. Type 8 is mainly found on the Middle Terrace (Tm) but sporadically also on the Lower Terrace (Tl; see Table 2, p. 36). At Bolivia Type 8 is present along the northern edges of

the Middle Terrace. At its other localities (Hato, Warahama, Lima, Bakuna) it is found as the more open parts amidst other more dense vegetation types.

pH	7.5
reaction to HCl	+
# of species	12 (9-16)
total real cover	14% (5-27%)
height	0.8m (0.35-1.7m)
surface stoniness	65% (2-95%)

9. Coccoloba swartzii-Metopium brownei type (3.9%)

The low shrub layer is in the majority of cases the most important layer, but quite often this can also be the combined tree and shrub layer. The tree layer is rarely the most important layer. *Coccoloba swartzii*, *Haematoxylon brasiletto* and *Metopium brownei* are common in the shrub or tree layer. *C. swartzii* is differentiating while *Prosopis juliflora* is absent from Type 9. *Euphorbia spec.* and *Paspalum bakeri* are common species in the herb layer. *Waltheria americana* is often present (III). The presence of *Melocactus macracanthos* (III) here is related to the high percentage of surface stoniness. Type 9 is only found on limestone formations (Tm, Tl, Tx). The main occurrence of this vegetation is at Lima (both Tm and Tl; see Table 2, p. 36). A small area is found in the central part of Klein Bonaire where *Zanthoxylum flavum* replaces *M. brownei*.

pH	7.5
reaction to HCl	+
# of species	13 (7-23)
total real cover	20% (15-40%)
height	1.2m (0.5-2.2m)
surface stoniness	80% (0-98%)

10. Haematoxylon brasiletto-Antirhea acutata type (4.9%)

In Type 10 usually the combined tree and shrub layer is the most important layer, but occasionally the low shrub layer will take precedence. Often the vegetation of this Type 10 consists of quite a diverse array of species. The differentiating species is the evergreen shrub *Antirhea acutata*, which is often accompanied by *Erithalis fruticosa*, also an evergreen shrub. *Prosopis juliflora* is absent. Overall *H. brasiletto* is the most common species. *Caesalpinia coriaria* and *Coccoloba swartzii* are accompanying species in the highest layer. *Croton flavens, Cordia curassavica* and *Lantana involucrata* are common in the low shrub layer. The most common species in the herb layer are: *Euphorbia spec., Cyperus fuligineus* and *Melocactus macracanthos*. This cactus and *Phyllanthus pentaphyllus* have a relatively high presence in this vegetation type and grow in small soil pockets found in the preponderant rocky surface. Type 10 is only found on lime-

stone (mainly Tx and Tm; occasionally Te and Tl) (see Table 2, p. 36). This vegetation type occurs more often on deeply dissected karst surface than the other vegetation types.

pH	7.5
reaction to HCl	+
# of species	18 (12-27)
total real cover	21% (3-30%)
height	1.9m (1.2-3.5m)
surface stoniness	76% (0-97%)
slope	3° (0-12°)
exposure	variable

11. Aristida adscensionis-Jatropha gossypiifolia type (4.2%)

The most important layer of this type is usually the low shrub layer, but sometimes the combined tree and shrub layer takes precedence. Rarely is this the case with the tree layer. The grass *Aristida adscensionis* is the most common species (indicating a high level of disturbance) and the shrub *Jatropha gossypiifolia* is differentiating. *Prosopis juliflora* is absent. *Lantana camara*, *Croton flavens* and *Caesalpinia coriaria* are common in the shrub layer. Type 11 is mainly found on the Middle Terrace (Tm; see Table 2, p. 36) of Bolivia and Lima.

pH	7.5
reaction to HCl	+
# of species	11 (7-25)
total real cover	20% (6-34%)
height	0.9m (0.3-2.0m)
surface stoniness	32% (0-98%)

12. Acacia tortuosa-Caesalpinia coriaria type (5.6%)

This is a thorny vegetation type in which usually the shrub or a combined tree and shrub layer is the most important layer. The tree layer rarely takes precedence. *Acacia tortuosa* and *Caesalpinia coriaria* are differentiating. The former is the overall dominant species. Where a lower shrub layer is present, it often has a high cover with *Opuntia wentiana* and *Croton flavens* as the main species. The abundance of *A. tortuosa*, *O. wentiana*, the grass *Aristida adscensionis* and presence of *Aloe barbadensis* in some plots indicate a high level of disturbance. The main presence of Type 12 is on the Middle Terrace (Tm; see Table 2, p. 36) of Bolivia and Bakuna. It has a limited number of occurrences on the Lower Terrace (Tl) and even less on the Stony plateau land of the Washikemba Formation (Wx) and Soils of the roois (cAr2). On limestone Type 12 is mainly present where soil cover is high.

pH	7
reaction to HCl	±
# of species	11 (10-14)
total real cover	23% (10-37%)
height	1.4m (0.8-3.0m)
surface stoniness	10% (0-92%)

13. Cordia curassavica-Melochia tomentosa type (2.2%)

In this type the low shrub layer is the most important layer and only very rarely does the combined tree and shrub layer take precedence. This type has the highest average number of species and the largest number of differentiating species (7) of all the vegetation types described in this study. In the tree or combined tree and shrub layer, *Casearia tremula* and *Haematoxylon brasiletto* are common species. Four differentiating species occur in the low shrub layer: *Melochia tomentosa, Bastardia viscosa, Rhynchosia minima* and *Cordia curassavica*. The other differentiating species are: *Bursera bonairensis, Cereus repandus* and *Opuntia curassavica*. *Cordia curassavica* dominates in the shrub layer, while *Croton flavens* and *Melochia tomentosa* are other common subcanopy species. Frequent species in the herb layer are *Bulbostylis curassavica* and *Cyperus confertus*. This vegetation type is restricted to limestone areas (Tx, Tm, Tl; see Table 2, p. 36) that have an abundant presence of karst surface. Its main occurrence is on Tx (i.e. on the higher parts of the limestone areas) and Tm and Tl are only of marginal importance. Type 13 occurs at Colombia (Tx), Karpata (Tm) and Beneden Bolivia (Tl).

pH	7
reaction to HCl	+
# of species	22 (18-29)
total real cover	29% (17-53%)
height	1.3m (0.6-2.5m)
surface stoniness	60% (2-95%)
slope	4° (0-7°)
exposure	N-SE

14. Croton flavens-Haematoxylon brasiletto type (11.8%)

In this type, three layers can be the most important layer and these are in descending order of prevalence: the low shrub layer, the tree layer and the combined tree and shrub layer. Type 14 has no differentiating species. *Haematoxylon brasiletto* is dominant in the tree layer while *Croton flavens* is dominant in the low shrub layer and always present. *Caesalpinia coriaria, Opuntia wentiana* and *Cyperus confertus* are other common species. Type 14 is much more often found on limestone terraces (Tl, Tm, Tx, Te) than in areas of the Washikemba Formation (see Table 2, p. 36). Type 14 is the most common vegetation type on limestone. At some locations (e.g. south and

north of Playa Frans, to the east of Saliña Tam, Seru Largu, Beneden Bolivia and Lima) a *Haematoxylon* facies can be distinguished in which *Haematoxylon brasiletto* is clearly the dominant species.

pH	7
reaction to HCl	±
# of species	15 (6-29)
total real cover	27% (20-47%)
height	1.1m (0.4-2.0m)
surface stoniness	24% (0-97%)
slope	0-30°
exposure	variable

15. Eragrostis ciliaris-Cyperus amabilis type (2.0%)

This is a vegetation type in which the most important layer can vary from the tree layer to the herb layer, but it is the shrub layer that usually prevails. Differentiating are *Eragrostis ciliaris* and *Cyperus amabilis*. Four other herbs are also common: *Cyperus confertus, Aristida adscensionis, Euphorbia spec.* and *Cyperus nanus*. *Croton flavens, Phyllanthus botryanthus* and *Casearia tremula* are the scattered woody species most often found.

This vegetation type is only found on the Washikemba hills (Wr) in northwestern Bonaire, an area that is strongly influenced by the trade wind. The average surface stoniness (21%) is high compared to that of the Washikemba areas of Type 16 (2%) and Type 17 (6%).

pH	5.5
reaction to HCl	-
# of species	11 (6-20)
total real cover	15% (2-20%)
height	0.8m (0.3-1.8m)
surface stoniness	21% (0-70%)
slope	6-38°
exposure	variable

16. Prosopis juliflora-Opuntia wentiana type (11.7%)

This is a thorny and species-poor vegetation type. The low shrub layer occurs slightly more often as the most important layer than the combined tree and shrub layer or the tree layer. *Prosopis juliflora* is always present and usually dominant, but in some places *Capparis odoratissima* takes precedence (*Capparis* facies). No differentiating species was found. The columnar cacti *Lemaireocereus griseus* and *Cereus repandus* are abundant in the higher layer(s). *Opuntia wentiana* is the most common species in the lower layer(s).

This vegetation type occurs in a wide range of land- and soiltypes (see Table 2, p. 36). More often it is found on Washikemba soils, reddish soils and saline areas of the Lower Terrace (lTl2, Tl) and alluvial and colluvial areas (cAb9) where soil cover is high.

Type 16 is found e.g. in the Washington-Slagbaai National Park (Washikemba Formation) and the limestone areas of Bolivia.

pH	6
reaction to HCl	-
# of species	7 (1-14)
total real cover	26% (11-49%)
height	1.2m (0.2-3.5m)
surface stoniness	7% (0-80%)
slope	0-32°
exposure	variable

17. Casearia tremula-Prosopis juliflora type (15.7%)

This is a relatively diverse and dense vegetation type for which no differentiating species was found. The combined tree and shrub layer is by far the most important layer in this type. Only occasionally will the tree layer take precedence and only rarely will that be the case for the low shrub layer. *Casearia tremula, Prosopis julifora, Randia aculeata, Opuntia wentiana, Croton flavens, Phyllanthus botryanthus* and *Caesalpinia coriaria* are common in the higher layer(s). *Cyperus confertus* is very common in the herb layer. At a few places the vegetation is or tends towards a *Prosopis* facies (e.g. hills to the east of Goto Meer, to the east of Saliña Slagbaai, near Rooi Tuna and to the east of Saliña Matijs).

Type 17 is mainly present in areas of the Washikemba Formation (in particular the 'Very high and high hills', Wr and Stony Land, Ws; see Table 2, p. 36) and is the principal vegetation on that geological formation in southeastern Bonaire. Its presence in limestone areas is limited, and there it is at least 1m lower in height than in Washikemba areas. Another distinctive feature of this vegetation type on the Washikemba Formation is the presence of a significant herb layer, in which often a number of *Cyperaceae* abound.

pH	6
reaction to HCl	-
# of species	17 (8-27)
total real cover	30% (14-53%)
height	2.9m (0.7-7.0m)
surface stoniness	10% (0-60%)
slope	0-24°
exposure	variable

18. Casearia tremula-Bourreria succulenta type (0.5%)

The most important layer is usually the tree layer or the combined tree and shrub layer. The low shrub layer rarely takes precedence. Type 18's height is the highest of all vegetation types described on Bonaire. Relatively high soil humidity in gullies and on escarpments is responsible for the height of this vegetation type. The following species are common in this type: *Casearia tremula, Randia aculeata, Prosopis juliflora, Cordia dentata, Bourreria succulenta, Opuntia wentiana, Passiflora suberosa* and *Tournefortia volubilis*. The first five are trees and the latter two are vines. Four of these species are differentiating: *B. succulenta, C. dentata, P. suberosa* and *T. volubilis*. *Tillandsia recurvata, Nama jamaicensis* and *Heliotropium angiospermum* are additional differentiating species. The commonness of *P. juliflora* and *O. wentiana* indicate anthropogenic disturbance. The relatively high soil humidity on escarpments is caused by water runoff and percolation from the edges and the effect of shade from the edge cap and (large) limestone boulders. Gullies in deeply incised gorges (Tg) and escarpments of the Plateau land (Tx) are the two main land-types in which Type 18 is found (see Table 2, p. 36). A particular aspect of this vegetation type in Rooi Sangu (Tg) is the dominance of *Erithalis fruticosa* (an evergreen species) in the shrub layer. Type 18 has only a limited occurrence in gullies in the Washikemba Formation (Stony plateau land, Wx; Hilly land, Wr).

pH	7
reaction to HCl	+
# of species	18 (11-23)
total real cover	29% (19-45%)
height	3.2m (1.3-5.5m)
surface stoniness	7% (0-40%)
slope	3-26°
exposure	variable

Table 2. Vegetation types versus the soil- and landtypes on and in which they were found. Soil- and landtypes are according to Grontmij & Sogreah (1968).

SOIL- and LANDTYPE	1 Man-groves	2 Sa	3 ITl9	4 ITl2	5 Tl	6 Tm	7 Te	8 Tx	9 Tc	10 Tg	11 lWp2	12 Wr	13 Ws	14 Wx	15 cAb9	16 cAr2	17 cAf2	18 lAf2	19 c/ lWp2/ Ab9	20 Trd
VEGETATION TYPE																				
1. Rhizophora – Batis type	5	–	–	–	3	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–
2. Sesuvium – Lithophila type	+	+	–	–	8	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
3. Conocarpus type	–	–	–	–	5	4	–	–	1	–	–	–	–	–	–	–	–	–	–	–
4. Lithophila – Euphorbia type	–	–	–	–	9	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–
5. Strumpfia type	–	–	–	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6. Euphorbia – Sporobolus type	–	–	–	–	8	2	–	–	–	–	–	+	–	–	–	–	–	–	–	–
7. Lantana – Capraria type	–	–	–	–	7	1	–	–	2	–	–	–	–	–	–	–	–	–	–	–
8. Eragrostis – Melocactus type	–	–	–	–	1	9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9. Coccoloba – Metopium type	–	–	–	–	1	8	–	1	–	–	–	–	–	–	–	–	–	–	–	–
10. Haematoxylon – Antirhea type	–	–	–	–	1	4	2	4	–	–	–	–	–	–	–	–	–	–	–	–
11. Aristida – Jatropha type	–	–	–	–	1	9	–	1	–	–	–	–	–	–	–	–	–	–	–	–
12. Acacia – Caesalpinia type	–	–	–	–	2	6	–	–	–	–	–	–	–	1	–	1	–	–	–	–
13. Cordia – Melochia type	–	–	–	–	1	1	–	7	–	–	–	–	–	–	–	–	–	–	–	–
14. Croton – Haematoxylon type	–	–	–	–	2	2	1	2	–	–	–	1	+	1	–	–	–	–	–	–
15. Eragrostis – Cyperus type	–	–	–	–	–	–	–	–	–	–	–	10	–	–	–	–	–	–	–	–
16. Prosopis – Opuntia type	–	–	–	2	1	1	–	1	–	–	–	1	2	+	2	–	–	+	+	+
17. Casearia – Prosopis type	–	–	1	–	1	–	1	–	–	–	+	4	2	+	–	–	+	–	–	–
18. Casearia – Bourreria type	–	–	–	–	–	–	–	3	–	4	–	1	–	1	–	–	–	–	–	–

Legend: + = cover less than 5%; 1 = cover 5-14%; 2 = 15-24%; etc.; 10 = 95-100%
Columns: 1 = Mangroves; 2 = Salina; 3-10 and 20 = Soil- and landtypes of Limestone Formation;
11-14 = Soil- and landtypes of Washikemba Formation; 15-18 = Alluvial and colluvial soils;
19 = Complex of soils of Washikemba Formation and Rooibottom soils.

DESCRIPTION OF THE FINAL LEGEND UNITS

The main legend of the landscape ecological vegetation map is divided into seven different landscape types: Beaches (B), Salinas (S), Landscape of the Lower Terraces (TL), Landscape of the Middle Terraces (TM), Landscape of the Higher Terrace and Plateau land (TH), Landscape of the Escarpments (E) and Undulating Landscapes (D). These landscapes in turn are subdivided on the basis of vegetational differences. The name of each legend unit reflects principal terrain features and the vegetation types with the highest cover in that landscape. The relative occurrence of each vegetation type in each (sub-)landscape unit is provided in Table 3 (p. 46). The total surface area of each (sub-)landscape as a percentage of the total island surface (without the water areas) added up is given in brackets after the name of that unit. The following landscape units are distinguished:

LANDSCAPE OF THE BEACHES (B)

This landscape was mainly found on coral shingle and to a lesser extent on sandy areas of Tl. Coral shingle beaches are found mainly along the leeward coast and southern tip of Bonaire as well as covering the biggest part of the coastal areas of Klein Bonaire. Sandy beaches are mainly found north(east) of Brua Wesu and on the north side of Klein Bonaire. Most part of B is not vegetated. Description of the beach vegetation types is based on sample plots taken in the vegetated parts of this landscape. Typical for beach vegetation types is the presence of few low growing wind- and salt-resistant species and the large variations in vegetation coverage. Three sub-landscapes can be distinguished.

B1 Sesuvium-Lithophila beach (1.0%)

Although the *Sesuvium-Lithophila* beach was predominantly found in places where Salinas are in direct contact with the sea, it was also found in other areas of Tl. In southern Bonaire (Manparía Kutu), B1 is part of a disturbed area. A low wall of coral shingle that runs parallel to the coastline is generally characteristic for B1. Type 2 (*Sesuvium-Lithophila* type) and Type 4 (*Lithophila-Euphorbia* type) co-dominate this sub-landscape. The shrubs *Suriana maritima* and *Argusia gnaphalodes* also form part of this landscape. Saliña Tam is the only place where *Coccoloba uvifera* has been seen to occur naturally along beaches.

B2 Conocarpus beach (0.3%)

The *Conocarpus* beach is characterized by a flat layer of coral debris and type 3 vegetation (*Conocarpus erecta* type). It is mostly found inland of B1. Not only is its distribution limited to southern Bonaire and a small area north of Lac, but also its total surface area is small. *Suriana maritima* and *Argusia gnaphalodes* may also occur, but to a much lesser extent than in B1. A relatively large (periodically) inundated area near Supladó has also been included in this unit.

B3 Lantana beach (0.3%)

This beach type is limited to Klein Bonaire. Its surface is coral shingle with the exception of the northern part of the island where a sandy beach is present. The main vegetation belongs to Type 7 (*Lantana-Capraria* type). *Euphorbia-Sporobolus* type (Type 6) and *Sesuvium-Lithophila* type (Type 2) occur to a lesser extent.

LANDSCAPE OF THE SALINAS (S)

Contrary to Stoffers (1956) the saline areas included here do not include areas that are periodically inundated due to abundant rainfall (areas of the Lower Terrace and Middle Terrace in southern Bonaire). *Conocarpus erecta* is generally the dominant species around these areas and therefore we have included these areas in TL3, TM3 and B2.

The Landscape of the Salinas surrounds the permanently inundated 'w' areas and is therefore strongly influenced by these salty waters. A large part of especially S2 is not vegetated. The vegetation types described represent thus the vegetated parts of the landscape units.

S1 Rhizophora salina (1.4%)

Relatively undisturbed areas of this sub-landscape are mainly found in the sheltered Lac bay. There the dense mangrove vegetation (Type 1: *Rhizophora-Batis* type) is alternated with mounds of sand of various sizes and on which vegetation type 2 (*Sesuvium-Lithophila* type) is found. These sand patches occupy approximately 10% of the whole mangrove area. The sand patches of the S1 areas in southwestern Bonaire occupy about half of the total mangrove area. S1 is found in shallow coastal waters, areas of coral shingle, and on calcareous or dune sand.

S2 Sesuvium salina (1.4%)

S2 is found on the Lower Terrace, calcareous or dune sand and strongly saline areas prone to inundation by the sea. Only vegetation type 2 (*Sesuvium-Lithophila* type) is found here. Although mapped as *Sesuvium* salina, the southeast part of Saliña Playa Grandi, and the southern part of the Saliña of Onima, are different due to the dominance of the herb *Stemodia maritima*. The Salinas of Bartol, Playa Funchi, Saliña Wayaká and Slagbaai are deprived of almost any vegetation, but have still been classified as S2. The reason for this is the fact that in the real *Sesuvium* salina also parts without any vegetation are found.

LANDSCAPE OF THE LOWER TERRACES (TL)

TL is found along the entire coast of Bonaire and Klein Bonaire and locally borders the Landscape of Beaches (B). The width of TL is very variable along the coasts. Salt (spray) and wind strongly influence the vegetation. Vegetation is mainly present in cracks on solid limestone rock and in small erosional pits or otherwise shallow soils. The TL-units abutting the Middle Terrace receive a significant amount of soil material washed down from nearby Washikemba Formation areas via rainwater through gullies. On the windward side of the island a zonation can be seen of the sub-landscapes: TL1 and TL2 are found in the seaward zone, while TL7-TL9 have the most inward location of all the units. There is little difference in coverage between the units, but TL5 and TL6 are the least important. TL9 has the highest vegetation (average of 2.2m) of all TL units.

TL1 Lithophila-Sesuvium lower terrace (3.0%)

TL1 is prominently present on the northern and eastern coasts of Bonaire. Probably a large part of this unit has been altered due to the collection of coral rubble for industrial purposes. The sparse vegetation of TL1 consists of Type 2 (*Sesuvium-Lithophila* type) and Type 4 (*Lithophila-Euphorbia* type) vegetations. Type 2 is slightly more prominent than Type 4.

TL2 Conocarpus lower terrace (1.4%)

This sub-landscape is exclusively found in southern Bonaire. Only Type 3 (*Conocarpus erecta* type) is present. The cover of the low, wind-blown shrub vegetation can vary significantly between sites.

TL3 Lithophila-Euphorbia lower terrace (2.7%)

This barren sub-landscape is mainly found along the eastern coast between Beneden Bolivia and Brua Wesu. The vegetation is a complex of mainly Type 4 (*Lithophila-Euphorbia* type), together with Type 6 (*Euphorbia-Sporobolus* type), Type 3 (*Conocarpus erecta* type) and Type 5 (*Strumpfia* type). Type 5 is only present in the southern part of the eastern tip of Bolivia. Periodically inundated areas near Bakuna have been included in this unit.

TL4 Lantana-Corchorus lower terrace (1.2%)

This sub-landscape is restricted to the Lower Terrace of Klein Bonaire, where it is found inland of B3. A rather open variant of the shrubby *Lantana-Capraria* vegetation type (Type 7) is present in TL4.

TL5 Euphorbia-Corchorus lower terrace (0.7%)

TL5 is only found at the northern and eastern sections of Bolivia. Type 6 (*Euphorbia-Sporobolus* type) is the main vegetation type, while three other vegetation types (2, 4, and 11) occur to a lesser extent.

TL6 Caesalpinia-Metopium lower terrace (0.8%)

TL6 occurs on the leeward coast (between Saliña Wayaká and Play'i Lechi) and in one area on Klein Bonaire. Type 6 (*Euphorbia-Sporobolus* type), Type 9 (*Coccoloba-Metopium* type) and Type 14 (*Croton-Haematoxylon* type) are the main vegetation types. Two other vegetation types (10 and 12) occur to a lesser extent. On Klein Bonaire *Metopium brownei* is replaced by *Zanthoxylum flavum*.

Fields of *Aloe barbadensis* are found at Karpata and Sta. Barbara and indicate that these areas were formerly used for *Aloe* cultivation.

TL7 Croton-Prosopis lower terrace (2.0%)

TL7 occurs on both the leeward and windward coasts of the island. The areas of occurrence are quite separated from each other. The vegetation of TL7 consists of a mix of vegetation types in which Type 14 (*Croton-Haematoxylon* type) occurs somewhat more often than Type 6 (*Euphorbia-Sporobolus* type), Type 12 (*Acacia-Caesalpinia* type), Type 13 *(Cordia-Melochia* type) and Type 16 (*Prosopis-Opuntia* type).

TL8 Prosopis-Capparis lower terrace (1.3%)

TL8 has a more limited distribution and more developed vegetation compared to TL7 and TL9. Type 17 (*Casearia tremula-Prosopis juliflora* type), Type 14 (*Croton-Haematoxylon* type) and Type 16 (*Prosopis-Opuntia* type) are the main vegetation types, whereby Type 17 is the most important one. Three other vegetation types (8, 9, and 10) occur occasionally.

TL9 Prosopis-Subpilocereus lower terrace (1.9%)

TL9 is present on the windward coast of Bonaire and is found inland of TL1 and TL3. The vegeatation is a complex of Type 16 (*Prosopis-Opuntia* type) and Type 6 (*Euphorbia-Sporobolus* type). The latter characterizes the more barren areas. The relatively broad crowns of *Prosopis* and big specimens of columnar cacti are characteristic elements of TL9. Sporadically signs of past or present agrarian use and/or anthropogenic structures are seen in this sub-landscape.

LANDSCAPE OF THE MIDDLE TERRACES (TM)

TM is present in most of Bonaire and consists of both depositional and erosional terraces. It is less continuous than the Lower Terrace. The transition between the Middle

Terrace and the other terraces and the undulating landscape is not always clear. The most extensive areas of the Middle Terrace landscape are found at Bolivia. Nine sub-landscapes can be distinguished, of which TM7, TM4 and TM9 are the most important in coverage. TM8 has the highest vegetation (average of 2.6m) of all TM units.

TM1 Lithophila middle terrace (0.1%)

This sub-landscape is limited to a very small (remnant) area of the Middle Terrace in the northern part of the Washington-Slagbaai National Park (Seru Grandi). The very low and open herbaceous vegetation belongs to Type 4 (*Lithophila-Euphorbia* type).

TM2 Aristida-Melocactus middle terrace (2.1%)

This sub-landscape is found on the northern edges of the Middle Terrace between Beneden Bolivia and Lac and also to the southeast of the airport. Especially the first two areas are under the influence of the (strong) trade wind. The low and more or less open shrub vegetation is a mixture of the *Aristida-Jatropha* and *Eragrostis-Melocactus* vegetation types (Type 11 and Type 8 respectively). The *Euphorbia-Sporobolus* type (Type 6) may occur. Signs of past or present agrarian use and/or anthropogenic structures are sporadically seen in this sub-landscape.

TM3 Conocarpus middle terrace (0.9%)

This sub-landscape exclusively occurs on the lower parts of the Middle Terrace of Lima which are subjected to flooding. For the greater part the surface consists of a layer of silty soil, but in some parts the rocky limestone substratum is visible. The *Conocarpus* type (Type 3) is dominant in the very poor and open shrub vegetation. Type 6 (*Euphorbia-Sporobolus* type) occurs sometimes. Periodically inundated areas at Lima have been included in this unit.

TM4 Coccoloba-Melocactus middle terrace (4.1%)

This sub-landscape covers an extensive area between the windward and leeward side of the island at Lima. It is also present on Klein Bonaire. The main vegetation type is the *Coccoloba-Metopium* type (Type 9). Vegetation types 8, 7, and 14may be found. Signs of past or present agrarian use and/or anthropogenic structures are sporadically seen in this sub-landscape.

TM5 Aristida-Jatropha middle terrace (1.7%)

Only small patches of this unit are found outside Bolivia, where it has its main occurrences. Only the low and shrubby *Aristida-Jatropha* vegetation type (Type 11) is present. Signs of past or present agrarian use and/or anthropogenic structures are sporadically found in this sub-landscape.

TM6 Haematoxylon-Croton middle terrace (2.8%)

Although occurring on both the leeward and windward sides of Bonaire, its presence on the leeward side is much more significant. On the windward side it is limited to Porto Spaño and Beneden Bolivia. TM6 is also present on Klein Bonaire. The vegetation is principally a complex of the *Haematoxylon-Antirhea* type (Type 10) and the *Croton-Haematoxylon* type (Type 14). Two other vegetation types (9 and13) occur occasionally. Signs of past or present agrarian use and/or anthropogenic structures are sporadically present in this sub-landscape.

TM7 Acacia-Croton Middle terrace (5.6%)

This sub-landscape forms a large part of the Middle Terrace of Bolivia. Patches are also found at Bakuna, Warahama and Lima. The *Acacia-Caesalpinia* type (Type 12) is the dominant vegetation type. Three other vegetation types occur sometimes: *Eragrostis-Melocactus* type (Type 8), *Aristida-Jatropha* type (Type 11) and *Croton-Haematoxylon* type (Type 14). Sporadically groups of *Aloe barbadensis* plants form part of this unit and indicate that those areas were formerly used for *Aloe* cultivation. Other signs of past or present agrarian use and/or anthropogenic structures are also sporadically present in this sub-landscape.

TM8 Haematoxylon-Caesalpinia middle terrace (3.2%)

The sub-landscape is mainly present in Bolivia and Warahama. The vegetation is more or less a complex of five vegetation types: *Croton-Haematoxylon* type (Type 14), *Acacia-Caesalpinia* type (Type 12), *Prosopis-Opuntia* type (Type 16), *Casearia-Prosopis* type (Type 17) and *Aristida-Jatropha* type (Type 11). Type 14 is slightly more often found than the other ones, while Type 11 occurs the least. Every now and then groups of *Aloe* plants (signs of remnants of former *Aloe* cultivation areas) also form part of this unit. Other signs of past or present agrarian use and/or anthropogenic structures are also occasionally found in this sub-landscape

TM9 Prosopis-Euphorbia middle terrace (4.1%)

Large areas of this sub-landscape are found between Kralendijk and Bakuna and include mainly former agricultural areas. The main vegetation types are the *Euphorbia-Sporobolus* type (Type 6) and *Casearia-Prosopis* type (Type 17). Three other vegetation types have a significantly lower presence: *Eragrostis-Melocactus* type (Type 8), *Acacia-Caesalpinia* type (Type 12) and *Prosopis-Opuntia* type (Type 16). Sporadically groups of *Aloe* plants (remnants of former *Aloe* cultivation areas) also form part of this sub-landscape. The dominance of *Hippomane mancinella* between Warahama and Lac makes this area somewhat different from the other TM9 areas. Other signs of past or signs of present agrarian use and/or anthropogenic structures are also occasionally present in this sub-landscape.

LANDSCAPE OF THE HIGHER TERRACE AND PLATEAU LAND (TH)

This landscape is only found in the central part of Bonaire, and includes some of the less disturbed vegetation types of the island. The Plateau land (Tx), the Higher Terrace consisting of a very small depositional part (Th) and a much bigger erosional part (Te), and a deeply incised gorge (Tg) form this landscape. Two sub-landscapes can be distinguished. The principal sub-landscape in this category is: TH1. TH2 has the highest vegetation of all landscape units on limestone (average of 2.8m).

TH1 Haematoxylon-Croton higher terrace (7.1%)

The *Haematoxylon-Antirhea* type (Type 10) is the main vegetation type. Sometimes the *Cordia-Melochia* type (Type 13) and *Croton-Haematoxylon* type (Type 14) occur. Sporadically Type 9 (*Coccoloba-Metopium* type) and Type 11 (*Aristida-Jatropha* type) are present. Signs of past or present agrarian use and/or anthropogenic structures are sporadically present in this sub-landscape.

TH2 Erithalis-Bourreria rooi (0.1%)

This sub-landscape is found in the only gorge (Rooi Sangu) on the island and is exclusively composed of Type 18 (*Casearia-Bourreria* type). The average height of the trees in the gorge (5.6m) is above average for the type (4.4m), as well as for the island in general.

LANDSCAPE OF THE ESCARPMENTS (E)

This landscape is limited to the escarpments of the 'Plateau land' surrounding the village of Rincón and the limestone hill Seru Largu (also a 'Plateau land'). Escarpments are the result of the exposure of the volcanic material underlying the harder limestone caps as a result of the weathering of these caps. The presence of limestone rocks and boulders on the slopes gives evidence of this process. Near the top the escarpment is almost perpendicular, whereas lower on the slope it becomes less steep (about 10-30° on Bonaire). Two sub-landscapes can be distinguished and of these E1 covers the largest area. Both E1 and E2 have among the highest vegetations, of all landscape units in this study (on average respectively 3.5m and 3.1m).

E1 Prosopis-Casearia escarpment (0.7%)

This sub-landscape is the landscape of the escarpments around the village of Rincón. The (north)eastern escarpment of Seru Largu and the escarpment at Fontein also belong to this sub-landscape. The vegetation is a complex of the *Casearia-Prosopis* type (Type 17) and *Casearia-Bourreria* type (Type 18).

E2 Prosopis-Subpilocereus escarpment (0.1%)

This sub-landscape only occurs on the southern escarpment of Seru Largu. Higher up the escarpment consists partly of narrow rocky limestone terraces. At several places (erosional) gullies (running in the direction of the slope) can be seen. The main vegetation type is Type 16 (*Prosopis-Opuntia* type), but is represented here by a very open and poor variant. Type 14 (*Croton-Haematoxylon* type) is found sporadically.

UNDULATING LANDSCAPE (D)

This landscape consists of the Washikemba Formation areas in the western and central sections of the island. Five sub-landscapes can be distinguished. Outside the Washington-Slagbaai National Park, D3 and D2 form the largest continuous areas of this landscape. D5 and D3 have the highest vegetation of all D-units (3.6m and 3.1m respectively) and thus belong to the units with the highest vegetations in the present study.

D1 Eragrostis-Cyperus landscape (1.7%)

The more degraded tops of the higher hills of the Washikemba Formation form D1. This sub-landscape is mainly found in western Bonaire with only a small occurrence on the Seru Grandi in the central part of the island. Those tops generally have a rocky surface. The vegetation found is an open herbaceous vegetation with very scattered groups of wind-blown, low trees and shrubs. The main vegetation type is the *Eragrostis-Cyperus* type (Type 15). Occasionally patches of Type 17 (*Casearia-Prosopis* type) and Type 16 (*Prosopis-Opuntia* type) are found, while Type 6 (*Euphorbia-Sporobolus* type) is sporadically present.

D2 Haematoxylon-Casearia landscape (6.3%)

This sub-landscape has its largest occurrence in the southern part of the Washington-Slagbaai National Park and is often found in former agricultural fields. The vegetation mainly consists of the *Croton-Haematoxylon* type (Type 14). The *Casearia-Prosopis* type (Type 17) occurs quite often while the *Eragrostis-Cyperus* type (Type 15) is only sporadically found. Signs of past or present agrarian use and/or anthropogenic structures are sporadically found in this sub-landscape.

D3 Prosopis-Casearia landscape (20.1%)

This sub-landscape is the most common of the D-units. Large areas of the Washington-Slagbaai National Park are formed by D3. It is also prevalent in Washikemba Formation areas outside the Park that formerly were often used as agricultural fields. Two vegetation types dominate this sub-landscape: Type 17 (*Casearia-Prosopis* type) and Type 16 (*Prosopis-Opuntia* type). Type 17 is more often found than Type 16. Type 14

(*Croton-Haematoxylon* type) and Type 12 (*Acacia-Caesalpinia* type) can also be found. Signs of past or present agrarian use and/or anthropogenic structures are sporadically present in this sub-landscape.

D4 Prosopis-Subpilocereus landscape (2.6%)

The distribution of this sub-landscape is limited to the windward coast of the island and is often found in former agricultural areas. Only the shrubby *Prosopis-Opuntia* type (Type 16) occurs. Signs of past or present agrarian use and/or anthropogenic structures are sporadically found in this sub-landscape.

D5 Prosopis-Opuntia rooi (0.2%)

This sub-landscape is formed by gullies found in the areas of the Washikemba Formation (Rooi Tuna in Boven Bolivia and in the Washington-Slagbaai National Park near Saliña Matijs and near Pos di Mangel). Type 18 (*Casearia-Bourreria* type) is the main vegetation type, but Types 12 (*Acacia-Caesalpinia* type) and 16 (*Prosopis-Opuntia* type) also have a significant presence.

Table 3. Estimated cover of plant communities in the different (sub-)landscape units. Calculation is based on plot data, field observation and photo interpretation.

		VEGETATION TYPE																		
		Rhizophora – Batis type	Sesuvium – Lithophila type	Conocarpus type	Lithophila – Euphorbia type	Strumpfia type	Euphorbia – Sporobolus type	Lantana – Capraria type	Eragrostis – Melocactus type	Coccoloba – Metopium type	Haematoxylon – Antirhea type	Aristida – Jatropha type	Acacia – Caesalpinia type	Cordia – Melochia type	Croton – Haematoxylon type	Eragrostis – Cyperus type	Prosopis – Opuntia type	Casearia – Prosopis type	Casearia – Bourreria type	agrarian use and/or anthropogenic structures
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
LANDSCAPE UNIT	SYMBOL																			
Sesuvium – Lithophila Beach	B1	–	5	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Conocarpus Beach	B2	–	–	10		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lantana Beach	B3	–	3	–	–	–	3	5	–	–	–	–	–	–	–	–	–	–	–	–
Rhizophora Salina	S1	9	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sesuvium Salina	S2	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lithophila – Sesuvium Lower Terrace	TL1	–	6	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Conocarpus Lower Terrace	TL2	–	–	10		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lithophila – Euphorbia Lower Terrace	TL3	–	–	1	7	+	2	–	–	–	–	–	–	–	–	–	–	–	–	–
Lantana – Corchorus Lower Terrace	TL4	–	–	–	–	–	–	10	–	–	–	–	–	–	–	–	–	–	–	–
Sporobolus – Corchorus Lower Terrace	TL5	–	2	–	2	–	5	–	–	–	–	2	–	–	–	–	–	–	–	–
Caesalpinia – Metopium Lower Terrace	TL6	–	–	–	–	–	3	–	–	3	1	–	1	–	3	–	–	–	–	–
Croton – Prosopis Lower Terrace	TL7	–	–	–	–	–	2	–	–	–	–	–	2	2	3	–	2	–	–	–
Prosopis – Capparis Lower Terrace	TL8	–	–	–	–	–	–	–	1	1	1	–	–	–	3	–	3	2	–	–
Prosopis – Subpilocereus Lower Terrace	TL9	–	–	–	–	–	4	–	–	–	–	–	–	–	–	–	6	–	–	+
Lithophila Middle Terrace	TM1	–	–	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Aristida – Melocactus Terrace	TM2	–	–	–	–	–	1	–	4	–	–	4	–	–	–	–	–	–	–	+
Conocarpus Middle Terrace	TM3	–	–	8	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–
Coccoloba – Melocactus Middle Terrace	TM4	–	–	–	–	–	–	1	2	7	–	–	–	–	1	–	–	–	–	+
Aristida – Jatropha Middle Terrace	TM5	–	–	–	–	–	–	–	–	–	–	10	–	–	–	–	–	–	–	+
Haematoxylon – Croton Middle Terrace	TM6	–	–	–	–	–	–	–	–	1	5	–	–	1	4	–	–	–	–	+
Acacia – Croton Middle Terrace	TM7	–	–	–	–	–	–	–	1	–	–	1	6	–	1	–	–	–	–	+
Haematotylon – Caesalpinia Middle Terrace	TM8	–	–	–	–	–	–	–	–	–	–	1	2	–	3	–	2	2	–	+
Prosopis – Euphorbia Middle Terrace	TM9	–	–	–	–	–	3	–	1	–	–	–	1	–	–	–	1	3	–	+
Haematoxylon – Croton Higher Terrace	TH1	–	–	–	–	–	–	–	–	1	5	1	–	2	2	–	–	–	–	+
Erithalis – Bourreria Rooi	TH2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10	–
Prosopis – Casearia Escarpment	E1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	5	–
Prosopis – Subpilocereus Escarpment	E2	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	10	–	–	–
Eragrostis – Cyperus Landscape	D1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	7	1	2	–	–
Haematoxylon – Casearia Landscape	D2	–	–	–	–	–	–	–	–	–	–	–	–	–	6	1	–	3	–	+
Prosopis – Casearia Landscape	D3	–	–	–	–	–	–	–	–	–	–	–	+	–	1	–	3	6	–	+
Prosopis – Subpilocereus Landscape	D4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10	–	–	+
Prosopis – Opuntia Rooi	D5	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	3	–	5	–

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

DISCUSSION AND CONCLUSIONS

ANTHROPOGENIC EFFECTS

Our results indicate that Bonaire is predominantly covered by secondary scrub growth (Tables 3 and 4). It is also evident that the aspect of the vegetation on Bonaire is dominated by a relatively small number of species. This is due to the combined effects of grazing by introduced mammals and the felling of trees in the past, and is in agreement with Stoffers' (1956) results for the Dutch Leeward Islands. At present the felling of trees is low (in only 2% of the sample plots stumps were seen). In contrast, grazing goats and donkeys or their excrements, were seen almost all over the island (including the Washington-Slagbaai National Park). Goat dung and donkey excrement were found in 52% and 36% of the sample plots, respectively. Grazing is known to slow succession to mature forest, and to result in the decline or elimination of grazing-sensitive species and the competitive release of grazing-resistant species (Debrot & De Freitas 1993). In accordance with this we found the frequent presence (and dominance) of e.g. thorny and grazing-resistant species. Grazing-resistant species include: e.g. *Aristida adscensionis, Caesalpinia coriaria, Casearia tremula, Croton flavens, Euphorbia spec., Lantana spp., Opuntia spp.* and *Prosopis juliflora* (Ramia 1960; Anoldo 1967; Morton 1981; Oakes & Butcher 1981; Allen *et al.* 1991; Cheeke 1998). While the same negative impacts of grazing have also been found on Curaçao (Beers *et al.* 1996), the effects are decidedly more severe on Bonaire.

While on Bonaire *Prosopis juliflora* is present in almost all thorny vegetation types and dominant in some of them, this is the case with *Acacia tortuosa* on Curaçao. Outside limestone areas, a *Prosopis* facies of thorny woodland generally takes over after abandonment of cultivated plots (Stoffers 1956). *P. juliflora* is considered an indigenous species of Bonaire (Stoffers 1981) but an introduced species and aggressive invader in many parts of the world. Goats do eat its mature pods but hardly take the leaves (National Academy of Sciences 1980; Morton 1981).

COMPARISON WITH STOFFERS (1956)

Stoffers (1956) distinguished in the category of 'Climatic climax communities' three communities for the islands of Bonaire, Curaçao and Aruba viz.: 'Deciduous seasonal forest', 'Dry evergreen bushland' and 'Littoral woodland'. On Bonaire he only found the 'Dry evergreen bushland' that in our study best corresponds with Type 9 (*Coccoloba-Metopium* type; see Table 4). One community in the category of 'Edaphic climax communities' category is well matched in the present study: Stoffers' 'Mangrove woodland' corresponds with Type 1 (*Rhizophora-Batis* type). All plant commu-

nities that did not fit one of the climax communities were considered by Stoffers to be secondary or sub-climax communities. The comparison of Stoffers'communities with the vegetation types in the present study is found in Table 4.

Table 2 shows that only one vegetation type is restricted in occurrence to the soils of the Washikemba Formation (viz. Type 15, the *Eragrostis ciliaris-Cyperus amabilis* type) while a number of vegetation types (Types 2, 3, 4, 5, 7, 8, 9, 10, 11 and 13) are restricted to soil- and landtypes of the Limestone Formation. This is related to the fact that the differentiating and dominant species in these vegetation types are virtually restricted to limestone formations and the corresponding soiltypes (e.g. *Antirhea acutata, Conocarpus erecta, Corchorus hirsutus, Lantana involucrata, Lithophila muscoides* and *Strumpfia maritima*). From Table 2 it can also be seen that a significant number of vegetation types can be found on a variety of soiltypes. The table shows that most of the thorny vegetation types occur on both limestone and Washikemba formations. Stoffers (1956) already indicated this convergence of vegetation types towards the same types, independent of soiltype or original climax vegetation. He found such convergence of secondary communities not only among thorny vegetation types, but also among low scrub communities (Table 4). In the present study we found such convergence only for two vegetation types that match Stoffers' thorny woodland types (Types 17 and 18).

For the purpose of the present project, and with the data obtained, a brief evaluation will be made subsequently of our vegetation types and landscape units. Taking into consideration that all vegetation types on Bonaire have been more or less degraded, it is necessary to rank these types based on their relative value to nature conservation. Ranks are based on the structural complexity and the development of the highest layer, diversity of plant species, relative scarcity and number of rare species found, and presence of species that can be considered characteristic for climax communities (valuation of the latter aspect is based on Stoffers (1956) and knowledge of the local flora). Rare and characteristic species of climax communities that played a role in the present valuation include *Bursera simaruba, Convolvulus nodiflorus, Guaiacum sanctum, Guapira pacurero, Manihot carthaginensis, Maytenus tetragona, Pisonia fragrans, Serjania curassavica, Tabebuia billbergii, Tillandsia flexuosa* and *Zanthoxylum monophyllum*. Based on the above criteria, the following vegetation types emerge as having relatively high conservation value: 1, 9, 10, 13, 17 and 18. The correspondence between Types 1 and 9 with Stoffers' climax communities has already been mentioned. Type 10 (*Haematoxylon-Antirhea* type) is the only vegetation type dominated by high shrubs and trees that lacks *P. juliflora*. This and other characteristics (e.g. the presence of *Metopium brownei, Coccoloba swartzii, Erithalis fruticosa* and *Antirhea acutata*) indicate that Type 10 is one of the least disturbed vegetation types of the island. Type 13 corresponds with the '*Croton-Lantana-Cordia* thicket' on limestone (Table 4) and is the most diverse vegetation of our study. Also the relatively high incidence of rare species, the presence of species that are characteristic for climax communities (*Guaiacum sanctum, Bursera simaruba, Tabebuia billbergii* and *Tillandsia flexuosa*; see Stoffers 1956; Debrot & De Freitas 1993), the lack of *Acacia tortuosa*, and the very low presence of *Prosopis Juliflora* show that this vegetation type also has significant conservation value. While Types 17 and 18 do not fit the description of any of Stoffers' climatic climax communities, they should be considered valuable because of their

structural complexity, height of the vegetation, diversity of plant species and the presence of rare plant species.

Based on the presence of a significant percentage of vegetation types 1, 9, 10, 13, 17 and 18 in S1, TM4, TM6, TH1, TH2, E1, D3 and D5 (see Table 3), these units should receive special consideration (=weighted heavier) in spatial planning projects and conservation programs. Of these landscape units only D3 is adequately represented in the Washington-Slagbaai National Park.

Table 4. Correspondence between the vegetation types of the present study and those of Stoffers (1956).

STOFFERS	PRESENT STUDY
Climatic climax communities	
SEASONAL FORMATIONS	
Thorny woodland* [II]	*Casearia-Prosopis* type (Type 17)
	Croton-Haematoxylon type (Type 14)
Prosopis facies [II A]	*Prosopis* facies of Type 17
Cactus-thorn scrub [III]	
Cactus scrub [IV]	*Prosopis-Opuntia* type (Type 16)
Croton-Lantana-Cordia thicket* [V]	
Croton facies [V A]	
'Desert' [VI]	*Eragrostis-Cyperus* type (Type 15)
DRY EVERGREEN FORMATIONS	
Dry evergreen woodland [VII]	*Haematoxylon-Antirhea* type (Type 10)
Thorny woodland** [VIII]	*Acacia-Caesalpinia* type (Type 12)
	Croton-Haematoxylon type (Type 14)
	Casearia-Bourreria type (Type 18)
Haematoxylon facies [VIII A]	*Haematoxylon* facies of Type 14
Dry evergreen bushland [IX]	***Coccoloba-Metopium type*** (Type 9)
Coccoloba diversifolia facies [IX A]	
Croton-Lantana-Cordia thicket** [X]	*Eragrostis-Melocactus* type (Type 8)
	Aristida-Jatropha type (Type 11)
	Cordia-Melochia type (Type 13)
	Lantana-Capraria type (Type 7)
Phyllanthus facies [X B]	
Littoral woodland [XI]	
Coccoloba uvifera type [XI A]	Related to Type 7
Vegetation of the rock pavement [XII]	*Lithophila-Euphorbia* type (Type 4)
	Strumpfia type (Type 5)
	Euphorbia-Sporobolus type (Type 6)
Conocarpus community [XII A]	***Conocarpus* type** (Type 3)
Edaphic climax communities	
Mangrove woodland [XIII]	***Rhizophora-Batis* type** (Type 1)
Strand scrub community [XV]	
Tournefortia facies [XV A]	
Suriana facies [XV B]	*Suriana* facies of Type 2
Euphorbia buxifolia facies [XV C]	
Vegetation of the salt flats and Salinas [XVII]	*Sesuvium-Lithophila* type (Type 2)
Fresh and brackish water communities [XVIII]	Not studied

The vegetation types indicated in bold (right column) match Stoffers' communities very well.
* derived from deciduous seasonal forest; ** derived from dry evergreen forest

Comparison of the present study's map with that of Stoffers (1956) is significantly limited due to the more general scope of Stoffers' study. The comparison will start with areas in the west of the island and move subsequently in eastward and southward direction over the island: Stoffers indicated a large 'Cactus-thorn scrub' area in the northern part of the Washikemba Formation area in the Washington-Slagbaai National Park. This area at present corresponds with the D3 (dominated by Type 17, a vegetation type that corresponds with Stoffers' 'Thorny woodland derived from seasonal formations'). This improvement of the vegetation thus shows an increase in the presence of *P. juliflora* to the detriment of columnar cacti species. This probably has to do with the cessation of the felling of trees for commercial purposes in the second half of the last century. At that time, this commercial activity was mainly concentrated in the Washington estate area (Westermann & Zonneveld 1956; Gerharts 1982). Very few dead stumps were seen in the sample plots that were taken in this area in the present study. It is necessary to take into account, however, that *P. juliflora* is very resilient to cutting. It easily grows back after cutting, whereas many other species would not survive.

Stoffers indicated the terrace vegetation to the west and east of Rooi Sangu as 'Dry evergreen woodland'. In the present study these areas are part of the TH1 unit in which only Type 10 is found. It can thus be concluded that these areas have maintained their value.

The northern border area of the Middle Terrace of Bolivia has been categorized as TM2. Types 8 and 11 are dominant in this unit and both are comparable to the '*Croton-Lantana-Cordia* thicket' Stoffers found there. The vegetation in this area has thus apparently not changed. Stoffers categorized the largest part of the Middle Terrace of Bolivia as 'Dry evergreen woodland'. This area corresponds with our TM7, TM8 and TM5 units. Stoffers' 'Dry evergreen woodland' has been considered similar to Type 10 in the present study. Type 10 is one of two dominant vegetation types in TM6. TM6 covers only a small part of Middle Terrace. It can thus be concluded that the area covered by the valuable Type 10 has been significantly reduced since Stoffers' study.

To the south of Bolivia, Stoffers marked a large area as 'Cultivated and semi-cultivated areas'. Although in the present study we also found the landscape units of the area to have a high presence of disturbed vegetation types, we cannot provide a detailed comparison due to a lack of description in Stoffers' study of the vegetation of those areas. Southwards of this zone Soffers' map shows a quite large 'Dry evergreen bushland' area. This area of Bonaire is called 'Lima', an area in which TM4 prevails. Although several disturbed vegetation types (7, 8, and 14) also form part of this landscape unit, it can be concluded that based on the dominance of Type 9 in TM4 there is sufficient similarity with what Stoffers found. The mangrove area found along the borders of the Lac bay is very similar to Stoffers' findings for this community.

The 1956 map shows that the remaining part of Bonaire consists of two large adjoining areas: a '*Conocarpus* community' area and a 'Vegetation of the salt flats and Salinas' area. In the present study, a large part of this whole area has been found to consist of water. In the coastal areas we have indicated the presence of TL2, TL3, B1,

B2 and S1. These coastal areas correspond for a very large part with Stoffers' '*Conocarpus* community'. Only two (TL2 and B2) of the just-mentioned five landscape units are dominated by Type 3, which is comparable to Stoffers' '*Conocarpus* community'. TL3 and B1 on the other hand are characterized by the presence of herbaceous vegetation types. The presence of Type 3 is very small compared to its homologue in Stoffers' study. Herbaceous vegetation types thus have mainly replaced this woody vegetation. All of this, together with the presence of mangrove areas in S1, shows that activities of the salt industry in this part of Bonaire have completely changed the area. The construction of the industrial salt complex has inundated most of the southern part of Bonaire. Almost all of the vegetation that according to Stoffers surrounded the brackish and salt pools has been eliminated. Massive expansion in the 1990s of the salt works inland in Lima accompanied by extensive flooding with brine can be expected to raise groundwater salinity in large areas including the last remaining habitat of the rare *Sabal* palm, and is reason for concern.

Our TL1 and TL3 areas along the windward coast of the island correspond with Stoffers' 'Vegetation of the rock pavement' with respect to both location and vegetation characteristics.

According to Stoffers Klein Bonaire consists for a very large part of the '*Croton-Lantana-Cordia thicket*'. At present this area corresponds with the following landscape units and their dominant vegetation types: TL4 (Type 7), TL6 (Types (6, 9, and 14), TM4 (Types 9, and 8) and TM6 (Types 10, and 14). Types 7 and 8 correspond with Stoffers' '*Croton-Lantana-Cordia* thicket'. The presence of Types 9, 10, and 14 indicate a significant recovery of the vegetation especially in the central part of Klein Bonaire. This certainly is the result of the eradication of goats over 30 years ago on this small island.

COMPARISON WITH SISTER ISLAND CURAÇAO

On Curaçao 21 vegetation types and 25 landscape units have been described, while for Bonaire we found 18 vegetation types and 32 landscape units. While on Curaçao a number of vegetation types only occur in one landscape unit, on Bonaire this is only the case for S1 (Type 1). The most remarkable difference between the vegetation of the two islands is the large difference in average cover of the woody vegetation types (54% in Curaçao and 21% in Bonaire). A number of other important differences between the two islands follow next: The relatively undisturbed T3 (*Haematoxylon-Bourreria* terrace) on Curaçao (Beers *et al.* 1997) has its parallel on Bonaire in TM6 (*Haematoxylon-Croton* Middle Terrace) and TH1 (*Haematoxylon-Croton* Higher Terrace) that are both dominated by Type 10 (*Haematoxylon-Antirhea* type). Type 10 is similar to Type 18 (*Haematoxylon-Randia* type) on Curaçao. It is interesting to note that also on Bonaire these terraces tend to occur more on the leeward side than on the windward side of the island. Although these terraces are more present on Bonaire than on Curaçao (12% respectively 4% of all landscape units), the relatively least disturbed TM4 (*Coccoloba-Melocactus* Middle Terrace) on Bonaire occupies a significantly small-

er area than its homologue T4 (*Coccoloba-Erithalis* Terrace) on Curaçao (5% respectively 11% of all landscape units).

None of the landscape units of the Washikemba Formation can compare with the best Curaçao Lava Formation sub-landscape (D5, the *Bourreria-Haematoxylon* unit that forms 12% of all landscape units). The dominant vegetation type in D5 is similar to Stoffers' 'Dry evergreen woodland' (see Beers *et al*. 1997). This woodland on Bonaire is only found on limestone formations.

Compared to Curaçao, the 'Landscape of the Rooi' on Bonaire has a very limited occurrence. On Curaçao it forms 3% of all landscape units while on Bonaire it amounts to only 0.3% of all landscape units. The 'Landscape of the Rooi' plays an important role in the survival of land and freshwater crustaceans (see e.g. de Wilde 1973; Debrot 2003a) and freshwater fishes (Debrot 2003b).

Hippomane mancinella occurs much less on Bonaire than on Curaçao. While on Curaçao the vegetation type in which it is dominant occurs in gullies ("Roois"), on escarpments and the Lower Terrace (and covers approximately 5% of the island surface:), on Bonaire this species is only sporadically found on the Lower Terrace in vegetation types 6 and 9.

On Curaçao *Acacia tortuosa* determines the aspect of a number of vegetation types (including the thorny vegetation types). On Bonaire it is only of significance in two vegetation types. In the vegetation types corresponding with the 'Thorny woodland communities' on Bonaire the role of *A. tortuosa* is played by *Prosopis juliflora*.

On Bonaire the mangrove system covers a relatively larger fraction of the island than on Curaçao (1.6% vs. 0.3%). On both islands *Rhizophora mangle* is the dominant species. However, on Bonaire *Laguncularia racemosa* is more important than *Avicennia germinans*, while on Curaçao the opposite is the case.

Finally, it must be mentioned that Bonaire lacks two vegetation types that are characterized by the presence of orchids (*Brassavola nodosa* and *Schomburgkia humboldtii*) and bromeliads (*Bromelia humilis* and *Tillandsia flexuosa*) present in Curaçao's least disturbed landscape unit (viz. *Bromelia-Schomburgkia* hills; Beers *et al*. 1997). These vegetation types correspond to two of Stoffers' climatic climax communities: 'Deciduous seasonal forest' and 'Dry evergreen bushland'. Only the latter was found on the Washikemba Formation during Stoffers' study in two relatively small areas (Brandaris and Juwa). On the highest part of the Brandaris a relatively small (and more or less united) area of this bushland is still present.

NATURE CONSERVATION

The Bonaire Nature Management Plan 1999-2004 (BNMP; Executive Council Bonaire 1999) has categorized and mapped a number of areas of the island according to the (varying) degree of protection they should receive (see Appendix 3). In the present publication a number of areas are presented that are not yet afforded adequate protection in the BNMP or that should be upgraded to a category that gives more protection. No part of the Middle Terrace of Bolivia has been designated as a conservation area in the BNMP. Considering the presence of important cave areas (Rojer, in prep.;

Wagenaar Hummelinck 1992), the very rare Bonaire barn owl (Prins *et al.*, 2003) and the potential of the vegetation to develop into a more valuable vegetation type (e.g. 'Dry evergreen woodland' in Stoffers 1956), a broad area of the Middle Terrace of Bolivia should be added. This should include a substantial part of its TM6 and TM8 areas. This will help ensure the protection of a broader zone of the (north-south) combination of (depositional) Middle Terrace and the important Higher Terrace and Plateau land areas. This expansion area should minimally receive the status of 'Island park', the same status of the limestone terraces of the nearby 'Terrace landscape of central Bonaire'. This category would permit limited sustainable use of the natural resources.

Based on the fact that vegetation Type 9 is considered a climax vegetation type and is dominant in TM4, found only at Lima, this TM4 should be incorporated into the Lac National Park (see the BNMP). Lima is also the most important area on Bonaire with respect to shallow ground water localities (Wagenaar Hummelinck 1933; Haviser 1991). In the BNMP the southern part of Lima has been given the status of 'Island park'.

As discussed earlier "Rooi" systems have important functions but are very scarce on Bonaire. Occurrences of these systems that are located outside the Washington-Slagbaai National Park (e.g. Rooi Sangu, Rooi Tuna, Rooi Promèntè) should therefore receive protected status.

To achieve adequate nature protection, not only the designation of conservation areas and the eradication of goats and donkeys from these areas are needed, but also a system of corridors and buffer zones (see e.g. Forman & Godron 1986; Baerselman & Vera 1989; Gutzwiller & Barrow Jr. 2003). It is recommended to include these in a follow-up to the BNMP. To better understand the ecological potential of the vegetation of Bonaire it is advisable to compare its vegetation with that of Curaçao, not only in historical perspective but also by establishing exclosure zones in similar or comparable vegetation types on both islands.

CONCLUSIONS

The present study has resulted in the distinction of 18 vegetation types and 32 landscape units on Bonaire. The vegetation of the island continues to be dominated by secondary scrub growth and its woody vegetation types have a significantly lower average cover compared to those of sister island Curaçao. The major causal factor is considered to be the impact of grazing by goats and donkeys, which are ubiquitous on the island. Aside from areas that have not undergone significant change compared to Stoffers' findings, we have also found areas that show recovery and others that have undergone deterioration in the last 50 years. The largest area that has been impacted negatively is the area of South Bonaire and this is due to the effects of the construction and expansion of the salt industry there. The eradication of goats on Klein Bonaire is allowing recovery of the vegetation.

Based on a comparison with Stoffers' study, and using criteria such as structural complexity, (average) vegetation height, (average) diversity of plant species and the presence and rarity of rare species, a number of vegetation types possess relative high

conservation value. The landscape units in which these vegetation types dominate should receive special consideration in conservation programs and spatial planning projects (TM4, TM6, TH1, TH2, E1, D3 and D5). Of these units only D3 is appropriately represented in the Washington-Slagbaai National Park. The results of the present study are evaluated in light of the (proposed) conservation areas designated in the BNMP and highlight both problems and possible solutions. However, true protection and restoration can only be ensured by solving the problem of free roaming goats and donkeys in key natural areas of Bonaire. It is also necessary to establish a monitoring program of the vegetation around the industrial salt complex in order to assess the long-term effects of the recent industrial expansions into important vegetation areas.

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APPENDIX 1 SYNOPTIC TABLE OF THE VEGETATION TYPES OF THE ISLAND BONAIRE

The first column denotes the growth form of the more relevant species (b= bromeliad; c=cactus; cyp=*cyperaceae*; g=grass; h=herb; s=shrub; t=tree). Roman figures indicate the presence of species in each cluster and figures between brackets denote the maximum cover of each species. A detailed explanation of these codes is found at the bottom of the table.

VEGETATION TYPE		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NUMBER OF SAMPLE PLOTS		12	21	15	20	4	21	13	10	19	19	14	10	7	29	14	33	32	9
AVERAGE NUMBER OF SPECIES		3	3.4	3.4	3.8	3.8	9.9	8.5	12.8	13.2	18.4	12.4	11.7	22.3	15.4	10.6	7.6	17.3	18.3
STANDARD DEVIATION		1.5	2.1	1.1	1.6	3.7	4.1	3.5	2.1	4.7	3.9	4.6	1.5	3.1	5.4	3.5	2.8	4.1	3.7
Differentiating species	*Growth form*																		
Avicennia germinans	t	**II(7)**	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Batis maritima	h	**III(5)**	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Laguncularia racemosa	t	**III(4)**	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Rhizophora mangle	t	**III(5)**	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Salicornia perennis	h	**III(4)**	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sesuvium portulacastrum	h	III(4)	**V(3)**	I(1)	I(2)	II(1)	I(3)	–	–	–	–	–	–	–	–	–	+	–	–
Conocarpus erecta	t	I(6)	I(1)	**V(5)**	–	–	+	–	–	–	–	–	–	–	–	–	+	–	–
Lithophyla muscoides	h	–	III(2)	II(2)	**V(3)**	II(1)	III(3)	II(2)	I(1)	–	I(2)	I(1)	I(1)	–	–	I(3)	–	–	–
Strumpfia maritima	s	–	–	–	–	**V(6)**	–	–	–	–	–	–	–	–	–	–	–	–	–
Capraria biflora	h	–	+	–	–	–	+	**V(2)**	–	I(2)	–	–	I(1)	–	–	–	–	+	–
Lantana involucrata	s	–	I(1)	–	–	–	I(1)	**V(2)**	II(1)	III(2)	IV(1)	II(1)	I(1)	I(1)	I(1)	–	–	I(1)	III(1)
Melocactus macracanthos	c	–	–	–	I(1)	–	II(2)	–	**V(1)**	III(1)	IV(2)	II(1)	I(1)	II(1)	I(2)	I(1)	II(1)	I(1)	I(1)
Coccoloba swartzii	s or t	–	–	–	–	–	+	–	I(1)	**V(3)**	IV(1)	I(1)	–	I(1)	+	I(1)	+	+	–
Metopium brownei	t or s	–	–	I(1)	–	–	I(1)	–	–	IV(3)	III(2)	–	–	–	–	–	–	–	–
Antirhea acutata	s	–	–	–	–	–	–	–	I(3)	II(1)	**IV(2)**	–	–	I(1)	I(1)	–	–	–	–
Pappophorum pappiferum	g	–	–	–	–	–	–	–	–	–	**II(3)**	–	–	–	–	–	–	–	–
Jatropha gossypiifolia	h	–	–	I(2)	–	II(4)	I(4)	II(2)	III(3)	I(1)	II(1)	**IV(2)**	II(2)	II(1)	II(1)	–	I(2)	I(1)	–
Acacia tortuosa	s or t	–	–	–	–	–	–	–	I(1)	–	I(1)	III(2)	**V(4)**	–	I(1)	–	I(2)	I(1)	–
Bastardia viscosa	s	–	–	–	–	–	–	–	–	–	–	I(1)	I(2)	**IV(1)**	I(2)	–	I(1)	II(1)	–
Cephalocereus lanuginosus	c	–	–	–	–	–	–	–	–	–	I(1)	–	–	**III(1)**	–	–	–	I(1)	–
Cyperus filiformis	cyp	–	–	–	–	–	+	–	–	–	I(2)	–	–	**III(2)**	I(2)	–	–	–	–
Guaiacum sanctum	t	–	–	–	–	–	–	–	–	–	–	–	–	**III(1)**	I(1)	–	–	–	–
Rhynchosia minima	s	–	–	–	–	–	I(2)	II(2)	II(1)	I(1)	I(1)	II(1)	I(1)	**IV(1)**	I(1)	–	+	I(1)	–
Cordia curassavica	s	–	–	–	–	–	+	I(4)	–	II(1)	IV(1)	I(1)	–	**V(4)**	II(2)	–	–	I(1)	II(1)
Bursera bonairensis	t	–	–	–	–	–	+	–	–	I(1)	II(1)	I(1)	I(1)	**IV(1)**	II(1)	–	I(1)	I(1)	I(1)
Cyperus amabilis	cyp	–	–	–	–	–	–	–	–	–	–	–	–	–	I(2)	**IV(2)**	+	II(3)	–
Bourreria succulenta	t	–	–	–	–	–	–	–	I(1)	II(2)	II(2)	II(3)	–	–	+	I(4)	–	II(2)	**IV(1)**
Cordia dentata	t or s	–	–	–	–	–	–	–	–	–	I(1)	I(1)	–	–	+	I(1)	+	II(1)	**IV(2)**
Heliotropium angiospermum	h	–	–	–	–	–	–	I(1)	–	–	–	I(1)	I(1)	–	I(2)	–	–	II(1)	**III(1)**
Nama jamaicensis	h	–	–	–	–	–	–	–	–	–	–	–	–	I(1)	I(3)	–	–	I(2)	**III(2)**
Pilea tenerrima	h	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**II(3)**
Tillandsia recurvata	b	–	–	–	–	–	–	–	–	–	I(2)	–	–	I(2)	I(2)	–	+	I(3)	**III(3)**
Tournefortia volubilis	s	–	–	–	–	–	–	–	–	I(1)	–	–	–	–	+	–	+	II(2)	**IV(1)**

Explanation:
– = species not present in the relevés of that cluster
\+ = species present in 1 - 5% of the relevés of that cluster
I = species present in 6 - 20% of the relevés of that cluster
II = species present in 21 - 40% of the relevés of that cluster
III = species present in 41 - 60% of the relevés of that cluster
IV = species present in 61 - 80% of the relevés of that cluster
V = species present in 81 - 100% of the relevés of that cluster
* = average cover of species within cluster = > 15%.

The figures between brackets represent the following cover ranges: 1=5-14%; 2=15-24%, etc.; 7=65-74%.

VEGETATION TYPE		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NUMBER OF SAMPLE PLOTS		12	21	15	20	4	21	13	10	19	19	14	10	7	29	14	33	32	9
AVERAGE NUMBER OF SPECIES		3	3,4	3,4	3,8	3,8	9,9	8,5	12,8	13,2	18,4	12,4	11,7	22,3	15,4	10,6	7,6	17,3	18,3
STANDARD DEVIATION		1,5	2,1	1,1	1,6	3,7	4,1	3,5	2,1	4,7	3,9	4,6	1,5	3,1	5,4	3,5	2,8	4,1	3,7
Common species including some differentiating species	*Growth form*																		
Sporobolus pyramidatus	g	–	II(2)	II(2)	IV(2)	II(2)	IV(2)	III(3)	–	I(2)	I(2)	II(2)	II(1)	II(2)	+	–	I(2)	I(2)	–
Corchorus hirsutus	s	–	I(2)	–	I(1)	II(2)	II(2)	IV(3)	IV(2)	III(2)	II(1)	III(2)	II(1)	II(2)	I(1)	–	–	–	–
Eragrostis urbaniana	g	–	I(2)	I(3)	I(2)	II(3)	IV(2)	II(3)	V(3)	III(2)	II(2)	I(3)	I(2)	III(2)	II(3)	III(2)	I(2)	I(3)	III(2)
Anthephora hermaphrodita	g	–	+	–	I(1)	II(1)	III(2)	I(1)	II(2)	II(2)	I(2)	III(3)	II(2)	II(4)	III(2)	II(2)	+	I(3)	II(2)
Euphorbia spec.	h	–	I(2)	I(1)	V(2)	III(3)	IV(3)	IV(3)	V(2)	IV(2)	V(2)	II(2)	II(1)	I(3)	II(1)	V(2)	I(2)	I(2)	–
Haematoxylon brasiletto	t	–	–	I(1)	–	–	I(1)	–	IV(2)	IV(3)	V(3)	III(1)	II(1)	IV(2)	IV(3)	I(1)	I(2)	I(3)	II(1)
Croton flavens	s	–	–	–	–	–	II(2)	–	IV(2)	II(2)	IV(2)	IV(2)	IV(3)	V(3)	V(4)	III(3)	II(1)	IV(3)	III(2)
Opuntia wentiana	c	–	–	–	–	II(1)	II(1)	–	II(1)	II(1)	III(1)	III(1)	V(2)	II(2)	IV(1)	II(2)	IV(2)	V(2)	IV(1)
Aristida adscensionis	g	–	–	–	–	–	II(2)	I(2)	V(3)	III(2)	I(1)	V(3)	IV(2)	IV(2)	III(3)	V(2)	I(1)	II(2)	II(2)
Eragrostis ciliaris	g	–	–	–	–	–	II(2)	I(2)	I(3)	II(2)	I(2)	II(2)	–	III(3)	III(2)	**V(2)**	I(2)	III(2)	II(2)
Passiflora suberosa	s	–	–	–	–	–	I(1)	II(3)	I(1)	III(1)	I(1)	–	I(1)	I(2)	I(1)	I(1)	+	III(1)	**IV(1)**
Cyperus confertus	cyp	–	–	–	+	–	I(3)	I(3)	I(1)	I(1)	II(1)	–	I(3)	IV(3)	IV(2)	V(3)	II(3)	V(3)	III(2)
Melochia tomentosa	s	–	–	–	–	–	–	–	III(2)	II(1)	I(2)	III(3)	III(2)	**V(3)**	III(3)	I(1)	–	III(1)	III(1)
Opuntia curassavica	c	–	–	–	–	–	+	I(1)	–	I(1)	III(1)	I(1)	I(1)	**V(2)**	II(2)	II(2)	II(2)	III(2)	III(1)
Cereus repandus	c	–	–	–	–	–	I(1)	–	I(1)	I(1)	III(1)	–	I(1)	**V(2)**	III(1)	I(1)	III(1)	III(1)	–
Casearia tremula	t	–	–	–	–	–	I(1)	I(1)	II(1)	I(1)	III(1)	I(1)	–	V(1)	III(1)	III(2)	II(2)	V(3)	V(2)
Condalia henriquezii	s or t	–	–	–	–	–	+	III(3)	–	II(2)	I(1)	II(2)	–	II(1)	II(2)	–	–	I(2)	II(1)
Crescentia cujete	t or s	–	–	–	–	–	I(1)	I(1)	–	I(1)	I(1)	–	I(1)	I(1)	+	–	+	I(1)	II(4)
Caesalpinia coriaria	t	–	–	–	–	–	I(2)	–	II(1)	–	IV(2)	IV(1)	V(1)	I(1)	IV(1)	II(2)	I(2)	IV(2)	III(2)
Bulbostylis curassavica	cyp	–	–	–	I(1)	–	II(3)	I(3)	III(2)	II(2)	II(2)	I(2)	I(1)	IV(2)	II(3)	–	+	I(2)	–
Jacquinia armillaris	t or s	–	–	–	–	II(1)	I(1)	I(1)	I(1)	I(4)	I(1)	–	I(4)	–	I(1)	–	+	–	–
Paspalum laxum	g	–	–	–	I(3)	–	I(3)	I(2)	–	I(1)	–	–	I(2)	I(1)	+	–	–	–	–
Waltheria indica	s	–	–	–	–	–	–	I(1)	I(1)	III(2)	–	II(1)	I(2)	–	–	–	–	–	–
Erithalis fruticosa	s	–	–	–	–	–	+	–	–	I(2)	III(2)	I(1)	–	–	+	–	–	–	III(4)
Paspalum bakeri	g	–	–	–	–	–	I(2)	IV(3)	II(2)	IV(2)	III(2)	I(3)	I(1)	II(2)	I(3)	–	+	–	–
Setaria distantiflora	g	–	–	–	–	–	–	I(1)	–	I(3)	I(1)	–	–	I(2)	I	–	–	+	–
Phyllanthus pentaphyllus	s	–	–	–	–	–	+	I(1)	I(1)	II(2)	III(1)	I(2)	–	I(1)	+	–	–	–	–
Cyperus fuligineus	cyp	–	+	I(2)	–	–	I(3)	IV(3)	I(1)	III(2)	IV(2)	I(1)	–	II(2)	I(2)	–	–	–	–
Lantana camara	s	–	–	–	–	–	+	–	I(1)	I(1)	III(2)	IV(3)	II(2)	III(2)	II(1)	–	I(1)	III(1)	II(1)
Lemaireocereus griseus	c	–	–	–	–	–	+	–	–	–	II(1)	–	I(2)	I(1)	I(1)	I(2)	III(2)	IV(1)	II(2)
Pithecellobium unguis-cati	s or t	–	–	–	–	–	+	–	–	I(1)	II(1)	I(1)	II(2)	III(1)	II(2)	I(1)	I(1)	I(1)	II(3)
Randia aculeata	t	–	–	–	–	–	–	–	I(1)	–	III(1)	II(2)	–	IV(1)	III(1)	I(13)	II(1)	V(2)	V(2)
Prosopis juliflora	t	–	–	–	–	–	III(4)	–	I(1)	–	–	–	III(1)	I(1)	II(1)	II(3)	V(4)	V(3)	IV(3)
Phyllanthus botryanthus	s	–	–	–	–	–	–	–	I(1)	–	II(2)	I(3)	–	II(1)	II(2)	III(2)	+	IV(2)	III(2)
Cyperus nanus	cyp	–	–	–	–	–	–	–	–	–	I(1)	–	–	II(2)	I(2)	IV(3)	I(3)	III(3)	III(3)
Hemicarpha micrantha	cyp	–	–	–	–	–	I(3)	–	–	–	–	–	–	I(1)	+	II(3)	+	I(2)	–
Doyerea emetocathartica	h	–	–	–	–	–	I(3)	–	I(1)	–	I(1)	–	–	II(1)	–	–	I(2)	I(1)	–
Aloe barbadensis	h	–	–	–	–	–	+	–	–	–	–	I(4)	II(4)	I(1)	+	–	–	I(3)	–

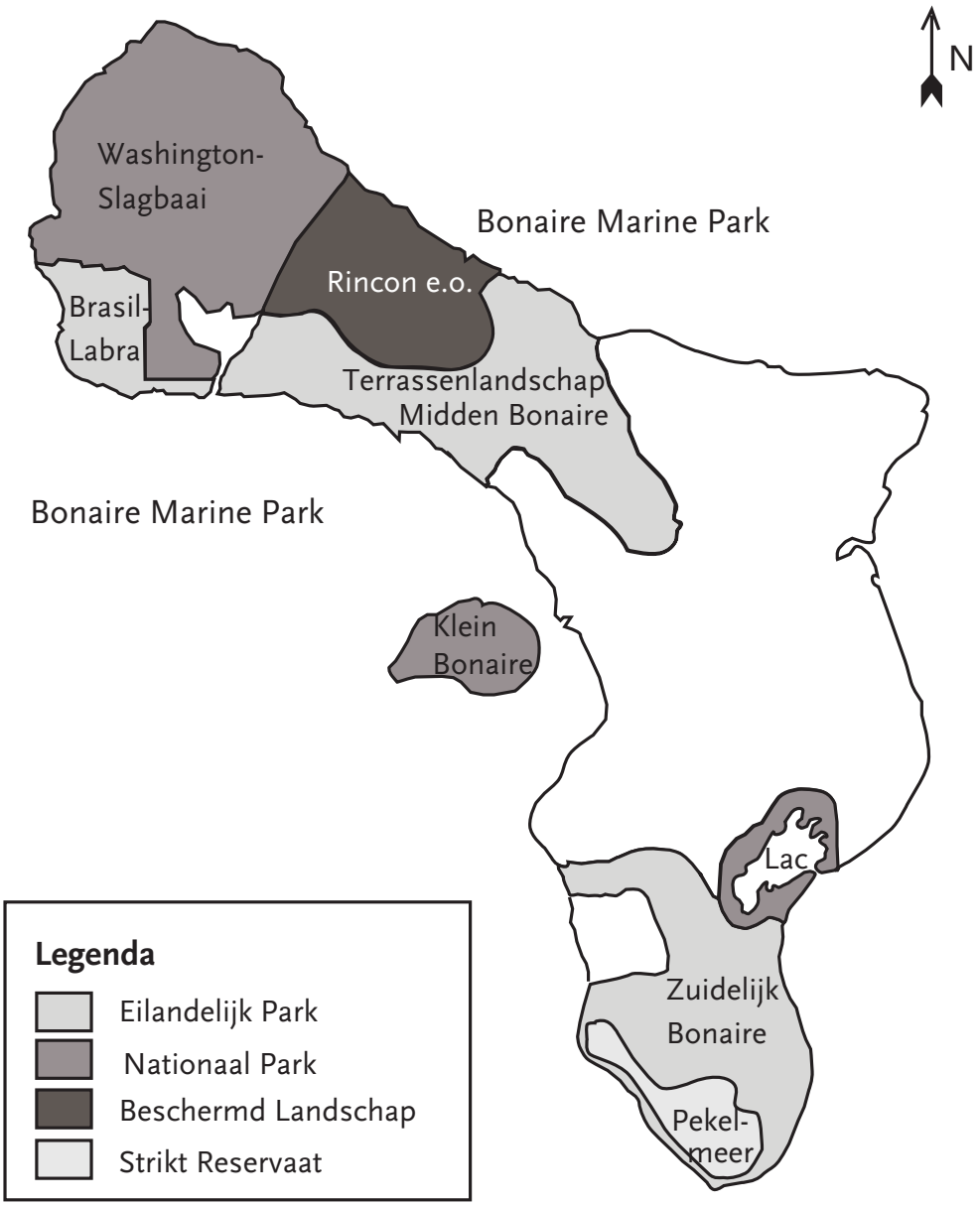
VEGETATION TYPE		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NUMBER OF SAMPLE PLOTS		12	21	15	20	4	21	13	10	19	19	14	10	7	29	14	33	32	9
AVERAGE NUMBER OF SPECIES		3	3,4	3,4	3,8	3,8	9,9	8,5	12,8	13,2	18,4	12,4	11,7	22,3	15,4	10,6	7,6	17,3	18,3
STANDARD DEVIATION		1,5	2,1	1,1	1,6	3,7	4,1	3,5	2,1	4,7	3,9	4,6	1,5	3,1	5,4	3,5	2,8	4,1	3,7
Other species (occurring in max. 5 clusters)	*Growth form*																		
Sporobolus virginicus	g	II(2)	I(4)	II(2)	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Fimbristylis cymosa	g	–	I(3)	I(1)	+	–	I(3)	–	–	I(1)	–	–	–	–	–	–	–	–	–
Suriana maritima	s	–	II(3)	I(5)	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Tabebuia billbergii	t	–	–	–	–	–	–	–	–	–	I(1)	–	–	II(1)	–	–	–	+*	–
Maytenus tetragona	t	–	–	I(1)	–	–	–	–	–	–	–	–	–	I(1)	–	–	–	–	–
Dactyloctenium aegyptium	g	–	+	–	+	–	I(2)	–	–	–	–	I(1)	–	–	–	–	–	–	–
Heliotropium curassavicum	h	–	I(1)	–	–	–	–	–	–	–	I(3)	–	–	–	–	–	–	–	–
Paspalum caespitosum	g	–	–	–	+	–	+	–	–	I(3)	–	–	–	I(1)	+	–	–	–	–
Hippomane mancinella	t	–	–	–	–	–	I(4)	–	–	I(1)	–	–	–	–	–	–	–	–	–
Ernodea littoralis	s	–	–	–	–	–	+	–	–	I(1)	I(1)	–	–	–	–	–	–	–	–
Desmanthus virgatus	s	–	–	–	–	–	+	–	I(1)	–	–	I(1)	–	–	–	–	–	–	–
Krameria ixine	s	–	–	–	–	–	–	–	II(1)	II(2)	I(1)	–	–	–	–	–	–	–	–
Sideroxylon obovatum	t	–	–	–	–	–	+	–	–	I(1)	–	I(4)	I(4)	–	+*	–	–	–	–
Alternanthera flavescens	s	–	–	–	–	–	–	–	–	–	I(1)	–	–	–	–	–	–	I(1)	–
Guaiacum officinale	t	–	–	–	–	–	–	–	–	–	I(1)	–	–	I(1)	I(3)	–	+	I(3)	–
Crossopetalum rhacoma	t or s	–	–	–	–	–	–	–	–	I(1)	I(1)	–	–	I(1)	I(3)	–	–	–	I(1)
Sida abutifolia	h	–	–	–	–	–	–	–	–	–	–	I(3)	–	I(1)	I(1)	–	–	–	–
Malphigia emarginata	t or s	–	–	–	–	–	–	–	–	–	–	–	I(2)	–	I(1)	–	+	I(1)	I(4)
Capparis indica	t	–	–	–	–	–	–	–	–	–	–	–	–	I(1)	–	–	+	I(1)	–
Zanthoxylum monophyllum	t	–	–	–	–	–	–	–	–	–	I(1)	–	–	–	–	–	–	–	I(5)
Passiflora foetida	s	–	–	–	–	–	–	–	–	–	–	–	I(1)	I(1)	–	–	+	–	I(1)
Ipomoea incarnata	s	–	–	–	–	–	–	–	–	I(1)	–	–	–	I(1)	–	–	–	–	–
Tephrosia cinerea	s	–	–	–	–	–	–	–	–	–	–	II(3)	–	–	I(1)	–	–	I(1)	–
Bursera tomentosa	t	–	–	–	–	–	–	–	–	I(1)	–	–	–	–	I(2)	–	I(1)	I(3)	–
Tillandsia flexuosa	b	–	–	–	–	–	–	–	–	–	–	–	–	I(2)	+	–	–	+	–
Senna bicapsularis	s	–	–	–	–	–	+	–	–	–	–	–	–	–	+	I(1)	–	I(1)	–
Spermacoce confusa	h	–	–	–	–	–	+	–	–	–	–	–	–	–	I(1)	I(1)	–	–	–
Serjania curassavica	s	–	–	–	–	–	–	–	–	–	II(1)	–	–	–	I(1)	–	–	I(1)	–
Croton ovalifolius	s	–	–	–	–	–	–	–	–	–	–	–	–	–	I(4)	–	–	–	I(1)
Physalis pubescens	h	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I(1)	–	I(1)	II(1)
Capparis odoratissima	t	–	–	–	–	–	–	–	–	–	–	–	–	–	I(2)	I(4)	II(3)	II(2)	I(1)
Paspalum curassavicum	g	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I(3)	+	–
Chloris mollis	g	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	+	I(1)
Rivina humilis	h	–	–	–	–	–	–	–	–	–	–	–	–	–	I(1)	–	–	I(1)	–
Machaonia ottonis	s or t	–	–	–	–	–	–	–	–	–	I(2)	–	–	–	–	–	–	I(1)	I(1)
Elytraria imbricata	h	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	II(1)	II(1)
Cynanchum boldinghii	h	–	–	–	–	–	–	–	–	I(1)	–	–	–	–	+	–	–	I(1)	I(1)
Isocarpha oppositifolia	h	–	–	–	–	–	–	–	–	–	I(1)	–	–	–	I(2)	–	–	I(2)	II(1)
Bursera simaruba	t	–	–	–	–	–	–	–	–	–	I(1)	–	–	II(1)	–	–	–	–	II(4)

Rare species
Acalypha cuspidata 17:+;
Agave spec. 17:+
Argusia gnaphalodes 6:I
Ayenia magna 14:+
Boerhavia scandens 17:+,18:I
Bontia daphnoides 6:+,7:I;
Borreria laevis 14,17:+
Botriochloa ischaemum 16:I
Capparis flexuosa 9:I,14:+
Celtis iguanaea 14,17:+
Cenchrus ciliaris 6:+,14:I
Cenchrus echinatus 2,14:+
Chamaecrista nictitans 11:I
Chloris inflata 13:I,14:+
Chloris spec. 6:+
Chloris suringari 14:+
Convolvulus nodiflorus 14:I,17:+
Corchorus aestuans 14,17:+
Corchorus hirtus 14:+
Cordia sebestena 3:I
Croton niveus 9:I,14:+
Cuscuta spec. 2:I
Cyperus elegans 6:+
Cyperus esculentus 17:+
Cyperus planifolius 9:I
Cyperus spec. 10:I
Cyperus squarrosus 14:I
Datura inoxia 18:I
Diodia apiculata 11:I
Eragrostis spec. 14:+
Euphorbia mesembrianthemifolia 2:+
Evolvulus convolvuloides 2:+;
Fimbristylis spadicea 3:I
Fimbristylis ovata 12:I,17:+
Fimbristylis spec. 10:I
Geoffroea spinosa 12:I,17:+
Gossypium hirsutum 9:I
Guapira pacurero 17:+
Heliotropium ternatum 14:+
Indigofera suffruticosa 14:I
Lantana canescens 17:+
Leptochloa mucronata 17:+
Malvastrum americanum 6,17:+
Manihot carthaginensis 10:I
Pectis linearis 11:I
Pectis linifolia 14,17:+
Piriqueta ovata 11:I
Pisonia fragrans 13:I;
Porophyllum ruderale 7:I,14:+
Portulaca halimoides 15:I
Schoepfia schreberi: 15:I
Senna italica 6:+
Sida spinosa 14:+
Solanum agrarium 16:+
Solanum americanum 17:+
Sporobolus spec. 6:+
Thespesia populnea 2:+
Tragus berteronianus 11:I
Zanthoxylum flavum 9:I.

APPENDIX 2 COVER PARAMETERS OF LANDSCAPE UNITS ON THE ISLAND OF BONAIRE

MAP LEGEND UNIT	CODE	AREA (M^2)	% of total surface	% of total surface less W (%)
Agrarian use and/or anthropogenic structures	A	42.314.771	15.1	17.1
Sesuvium – Lithophila Beach	B1	2.371.105	0.9	1.0
Conocarpus Beach	B2	700.189	0.2	0.3
Lantana Beach	B3	604.366	0.2	0.3
Eragrostis – Cyperus Landscape	D1	4.290.946	1.5	1.7
Haematoxylon – Casearia Landscape	D2	15.631.534	5.6	6.3
Prosopis – Casearia Landscape	D3	49.826.155	17.8	20.1
Prosopis – Subpilocereus Landscape	D4	6.542.079	2.3	2.6
Prosopis – Opuntia Rooi	D5	418.033	0.2	0.2
Prosopis – Casearia Escarpment	E1	1.728.941	0.6	0.7
Prosopis – Subpilocereus Escarpment	E2	265.397	0.1	0.1
Rhizophora Salina	S1	3.403.121	1.2	1.4
Sesuvium Salina	S2	3.496.894	1.3	1.4
Haematoxylon – Croton Higher Terrace	TH1	17.635.464	6.3	7.1
Erithalis – Bourreria Rooi	TH2	263.530	0.1	0.1
Lithophila – Sesuvium Lower Terrace	TL1	7.555.456	2.7	3.0
Conocarpus Lower Terrace	TL2	3.474.111	1.2	1.4
Lithophila – Euphorbia Lower Terrace	TL3	6.720.715	2.4	2.7
Lantana – Corchorus Lower Terrace	TL4	3.064.016	1.0	1.2
Euphorbia – Corchorus Lower Terrace	TL5	1.641.351	0.6	0.7
Caesalpinia – Metopium Lower Terrace	TL6	1.986.628	0.7	0.8
Croton – Prosopis Lower Terrace	TL7	4.883.536	1.7	2.0
Prosopis – Capparis Lower Terrace	TL8	3.341.959	1.2	1.3
Prosopis – Subpilocereus Lower Terrace	TL9	4.739.543	1.7	1.9
Lithophila Middle Terrace	TM1	234.519	0.1	0.1
Aristida – Melocactus Middle Terrace	TM2	5.311.835	1.9	2.1
Conocarpus Middle Terrace	TM3	2.235.516	0.8	0.9
Coccoloba – Melocactus Middle Terrace	TM4	10.260.669	3.6	4.1
Aristida – Jatropha Middle Terrace	TM5	4.229.161	1.5	1.7
Haematoxylon – Croton Middle Terrace	TM6	6.866.622	2.4	2.8
Acacia – Croton Middle Terrace	TM7	13.840.325	5.0	5.6
Haematoxylon – Caesalpinia Middle Terrace	TM8	8.043.067	2.9	3.2
Prosopis – Euphorbia Middle Terrace	TM9	10.233.994	3.7	4.1
Water	W	32.088.015	11.5	n.a.
Total		**280.243.563**	**100**	**100**

n.a.= not applicable
The figures have been calculated from the landscape ecological vegetation map


N
Washington-
Slagbaai
Bonaire Marine Park
Rincon e.o.
Brasil-
Labra
Terrassenlandschap
Midden Bonaire
Bonaire Marine Park
Klein
Bonaire
Lac
Zuidelijk
Bonaire
Pekel-
meer
Legenda
Eilandelijk Park
Nationaal Park
Beschermd Landschap
Strikt Reservaat