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Naturalised and invasive alien plant species in the Caribbean Netherlands: status, distribution, threats, priorities and recommendations

Report of a joint Imares/Carmabi/PRI project financed by the Dutch Ministry of Economic Affairs, Agriculture & Innovation

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Frontispiece: Lot for sale in Saba
Photography by W.J. van der Burg unless stated otherwise

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Executive summary

The Netherlands are signatories of the international Convention on Biological Diversity (CBD). This implies that the nation will protect biodiversity on its territory. This includes the protection of natural fauna and vegetation from negative impact caused by invasive alien species (see 2.1. for a definition). By 10-10-2010 the BES islands (Bonaire, St Eustatius and Saba) became 'special municipalities' of the Netherlands. They together form "Caribisch Nederland" (Caribbean Netherlands, Hulanda Karibe). Due to this stronger link to the Netherlands many responsibilities have moved from the Antillean government to the Netherlands. This includes important responsibilities with respect to the protection of nature.

The present study was financed by the Dutch Ministry of Economic Affairs, Agriculture and Innovation and included a literature study, a field trip and writing of the present document with main observations, conclusions and recommendations. A major part of the report consists of an alphabetical list of (known) invasives with their current status (4.1.1.).
Apart from the three islands belonging to Caribisch Nederland, for completeness, some attention is given to Aruba, Curacao and St. Maarten as well (esp. in 4.1.1. and Appendix II).

Stages of invasion
In order to define the problem of invasive alien (non-native) species of plants more accurately it is relevant to recognise the following categories:

Exotic
Species that are not part of the natural indigenous vegetation are called exotics. Examples are introductions as ornamental or agricultural species. If contained within the confines of gardens and farms, these species are not considered problematic.

Established
Species that occur 'in the wild', *i.e.* outside the control of cultivation or husbandry and are able to reproduce themselves resulting in new individuals, we call established (present). Species can stay in this phase, the 'lag phase' (see 2.1), for quite some time. It is the stage in which the species adapts to its new environment using its genetic flexibility.
At this stage complete eradication is still an option, because the number of individuals and locations is limited. This means that the costs can be relatively low, compared to eradication at a later stage.

Naturalised
If given enough time, species may start to adapt genetically to the new environment, by optimising its physiology and/or growth habit. As a result the species will start spreading more rapidly and effectively and becoming part of the natural flora. In most cases this is not considered a major problem; the plants will get their own function within the ecology of the island and will not replace indigenous species entirely. Moreover, the costs of complete eradication have become prohibitive at this stage, so only containment is an option.

Invasive
It is generally believed that about one in one thousand exotics becomes really problematic, e.g. with respect to environmental, ecological or economical impact (Williamson 1995). They start to grow out of control, massively invade natural habitats and reduce or eliminate native species. They have broken down the dispersal barrier and have become invasive.
At this stage one can only try to achieve a stage of equilibrium, of mitigation, by intensive control measures. These are usually limited by financial resources, and can normally only be

successful with commitment of the local society, e.g. shown by the enthusiastic support and hand labour of many volunteers.

Invasives of the Caribbean Netherlands

In this report 65 species of invasives are enumerated (4.1.1.) with their history and properties, based on a literature survey and completed with experience and findings of the authors. Four of the main problematic species are treated more extensively in 4.1.2. These are the Coral vine (*Antigonon leptopus*) which poses a great threat to nature, especially in St. Eustatius; the Rubber vine (*Cryptostegia grandiflora*) which is able to overgrow and smother shrubs and trees and is especially spreading on the Leeward Islands; the neem tree (*Azadirachta indica*) which is planted for shade and medicinal purposes, but is escaping on Bonaire; and 'Donna grass' (*Bothriochloa pertusa*) which is a very problematic species replacing the more palatable local grasses on the Windward Islands, most notably on St. Eustatius.

In a complementary list a further 80 species that need more investigation are mentioned (4.1.3.). This list is not complete but it enumerates species that are present on at least one of the islands. They need special attention because it is best to prevent them from entering at all or to eliminate the few plants or populations that have established themselves. Some species in this list are already present at some scale, like some of the arable weeds, but need careful monitoring to prevent them from entering nature.

A general problem are the free-roaming animals, cows, donkeys and especially goats (all non-native species) that are destroying nature in an uncontrolled way. Their presence has a detrimental effect on biodiversity, eating young seedlings and trees, and thereby preventing the natural regeneration and succession. Moreover, the bare soils that result are susceptible to water and wind erosion; material that is deposited in the surrounding seas.

Management options

Before an exotic has been introduced *prevention* is the most important action, i.e. keep the chance that exotic species may be introduced as low as possible. As soon as a first introduction has been realised and the exotic still occurs at low densities at few sites, *eradication* after first observation will be the most important action. Finally, if an exotic has already spread over different sites or even different habitats and has increased in densities, eradication might not be an achievable option anymore. Then *containment* and *population management* will be the most relevant actions to minimise the negative impact *(mitigation)*. In general, prevention will generate the most cost-effective options to avoid problems due to invasive exotic plants (Davis 2009).

The main observations are:

Prevention

Prevention plans need to be developed with regulations restricting the import of exotic species. This includes the development of 'Black lists' for the Leeward and Windward Islands respectively.

Public awareness (customs and other officials, general public, landscapers, new inhabitants) must be raised and alternatives for imported exotics must be offered.

Agricultural departments and customs offices on all islands are understaffed and not able to control the many routes through which exotics enter.

Eradication after first observation

Rapid first observation of an exotic plant after introduction into the wild is essential for the success of an eradication action. Therefore a 'Watch list' or 'Grey List' needs to be developed. Since the difference in climates, these watch lists will partly differ between islands and differ even more between the Leeward and Windward islands.

Also knowledge about the natural flora and invasives must be increased through education, at schools as well as for professionals (rangers, customs personnel, agricultural department, etc.). Floras for the Windward Islands are outdated and not accessible.

Containment/population management
Management plans need to be developed for the control *Antigonon*, *Cryptostegia* and neem to be able to stop further spreading and to mitigate the impact on nature.
Research on the life cycle of invasives and experiments for their control have to be carried out.
The problem of roaming animals must be tackled. Small island communities are not able to do this without outside assistance.
If chemical control is considered, special Dutch Caribbean regulations apply based on restricted import permissions for crop protection agents.

1. Introduction, why this study

1.1. The Caribbean Netherlands and biodiversity

The Netherlands are signatories of the international Convention on Biological Diversity (CBD). This implies that the nation will protect biodiversity on its territory. This includes the protection of natural fauna and vegetation from negative impact caused by invasive alien species (see 2.1. for a definition). By 10-10-2010 the BES islands (Bonaire, St Eustatius and Saba) became 'special municipalities' of the Netherlands. They together form "Caribisch Nederland" (Caribbean Netherlands, Hulanda Karibe). Due to this stronger link to the Netherlands many responsibilities have moved from the Antillean government to the Netherlands. This includes important responsibilities with respect to the protection of nature.

1.2. Aim of this study

This study aims at establishing the status of invasive plant species and their effect on the vegetative terrestrial ecosystem, as well as an analysis of the major bottlenecks and possibilities for management or mitigation.

2. Research approach

2.1 Definitions of exotic species, alien species, invasive species, invasive exotic species.

Much literature is available on exotic species and many different terms are used to refer to the same, or almost the same. After a short description of the invasion process we will discuss the definitions briefly which are the basis for the classification in this report.

2.1.1. The invasion process

A number of invasive plant species are present in the Caribbean Netherlands. Some are aggressively invading areas, others are perhaps in the 'lag phase' of establishment, and still others will never pose a problem. The behaviour, now or in the future, depends largely on two factors: the invasivity of a species and the invasibility of the environment. It is the interaction between these two that determines whether a plant becomes invasive (Davis 2009).
The invasivity, or the invasive strength, of a plant depends on its various characters. In time, these may vary or change in a population, rendering the plant more invasive after some time. This phenomenon is called the 'lag phase' of invasiveness (Figure 1). This may be caused by a genetic shift to adapt to the local conditions. Low genetic diversity at the start may cause a delay in the adaptation process, while plants coming in at larger numbers being able to adapt more quickly because of a greater chance of having the right genes in the population. But there can be other reasons why a plant may not be observed to be invasive, while after some time it does: plants may propagate exponentially if given the space, so in the beginning they may be rarely observed and after some time seem to be all over the place; it may also be that a certain vector was absent before, like in the case of plants that grow along railways and highways; climate change may play a role as well (Crooks 2005).

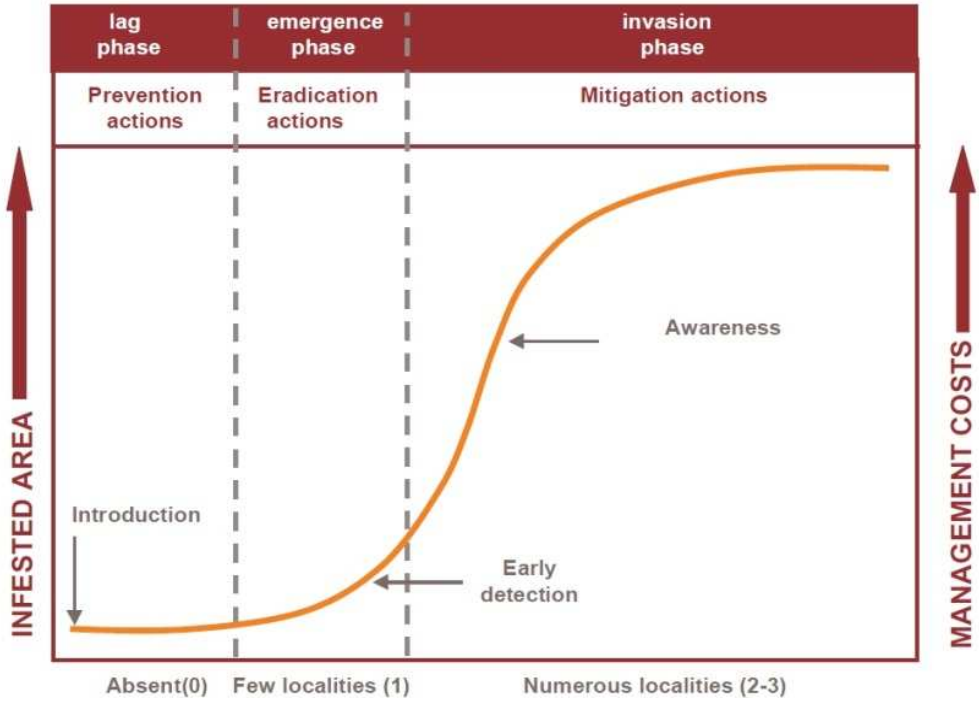

Figure 1. Population development of an invasive species (Branquart *et al.* 2010)

Invasibility is the property of an ecosystem to be liable to invasion. It seems, though there is some scientific debate about this, that a diverse ecosystem is in the best position to withstand invasion. Although it may have many ecological niches, which the newcomer may choose from, it are the more uniform pioneer vegetations that are really more open, also in the physical sense, that these are more suitable for invasion. This is corroborated by our observation (see *Antigonon* below) that some plants invade disturbed areas and not the natural vegetation. This may also in part be caused by the fact that these wastelands are more fertile than the natural parks. They have originally been selected by farmers for that reason too and some plants benefit from higher nutrition levels (and soil structure) more than others.

2.1.2. Phases of invasion: the basis for a classification of invasive species.

In the invasion process of exotic species various stages can be distinguished (Davis 2009). Table 1 shows the categories that are distinguished in this report. These are based on the stage in the process, which is a result of different types of barrier (Branquart 2007). The possible management actions follow from the type of barrier and the stage of invasion.

Table 1. Stages of invasion

Category	Stage	Barrier	Action
Exotic	Introduction	Geographic	Prevention
Established	Acclimatisation	Environmental	Eradication
Naturalised	Naturalisation	Reproductive	Containment
Invasive	Expansion/spread	Dispersive	Mitigation

Adapted after Branquart 2007.

Exotic
Species that are not part of the natural indigenous vegetation are called exotics. Examples are introductions as ornamental or agricultural species. If contained within the confines of gardens and farms, these species are not considered problematic. Even if they 'escape' into nature, meaning that they live outside the immediate control of man, but do not reproduce effectively, these species are not considered here. Typical example is banana.
However, if species are known to be invasive in other comparable environments, for instance in the case of the Dutch Caribbean if they are known from neighbouring islands, then it is important to keep the species away from the territory. The chances are big that people will help the species transgress the natural geographic barrier, on purpose or by accident. Therefore, strict prevention measures at borders and coasts are needed to prevent this to happen.

Established
Species that occur 'in the wild', *i.e.* outside the control of cultivation or husbandry and are able to reproduce themselves resulting in new individuals, we call established (present). Species can stay in this phase, the 'lag phase' (see 2.1), for quite some time. It is the stage in which the species adapts to its new environment using its genetic flexibility.
At this stage complete eradication is still an option, because the number of individuals and locations is limited. This means that the costs can be relatively low, compared to eradication at a later stage. A typical example is *Azadirachta*, the neem.

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If given enough time, species may start to adapt genetically to the new environment, by optimising its physiology and/or growth habit. As a result the species will start spreading more rapidly and effectively and becoming part of the natural flora. In most cases this is not considered a major problem; the plants will get their own function within the ecology of the

island and will not replace indigenous species entirely. Moreover, the costs of complete eradication have become prohibitive at this stage, so only containment is an option.
This means that one can no longer control the species at all sites, but may still be able to do so in vulnerable habitats. With some effort a sort of status quo can be achieved. A typical example is *Cryptostegia* on Saba.

Invasive
It is generally believed that about one in one thousand exotics becomes really problematic, e.g. with respect to environmental, ecological or economical impact (Williamson 1995). They start to grow out of control, massively invade natural habitats and reduce or eliminate native species. They have broken down the dispersal barrier and have become invasive.
At this stage one can only try to achieve a stage of equilibrium, of mitigation, by intensive control measures. These are usually limited by financial resources, and can normally only be successful with commitment of the local society, e.g. shown by the enthusiastic support and hand labour of many volunteers. A typical example is *Antigonon* on St. Eustatius.
Interestingly, the statistics of exotics becoming invasives seem to be very different for the Caribbean region. Kairo *et al.* (2003) report that 446 out of 552 known exotics become naturalised or invasive. This can in part be explained by differences in definition for these categories, but cannot explain the discrepancy entirely. It must therefore be assumed that exotic species in this region have a stronger tendency to behave more aggressively, or in complement, the islands are more vulnerable for invasions; their invasibility is larger. A similar phenomena has been observed by Vitousek *et al.* (1996) who noted that the percentage of non-native species tends to be greater on island habitats. The size of the island as well as the proximity to other islands or main land seem to play a role. While Cuba and the Solomon Islands have relatively low percentages of non-native species (around 6%), these figures are 65% for the Bermudas, and between 40 and 50% for the majority of the islands in the Pacific and about 20% for the Bahamas (no further data on Caribbean islands).

Table 2. Exotic (alien) species in the Caribbean by type or organism. (Kairo *et al.* 2003)

Organism type		Exotic	Naturalised and / or invasive
Plants	**Total**	**327**	**281**
	Aquatic	4	3
	Cattail	1	0
	Climber	17	17
	Fern	5	5
	Grass	28	26
	Herb	35	34
	Sedge	1	1
	Shrub	16	16
	Tree	220	179
Invertebrates	**Total**	**121**	**66**
	Crustacean	2	2
	Earthworm	1	0
	Insect	90	45
	Jellyfish	1	1
	Mite	8	8
	Mollusc	17	10
	Solifugud	1	0
	Tunicate	1	0
Vertebrates	**Total**	**100**	**95**
	Amphibian	8	8
	Bird	20	19
	Fish	37	35
	Mammal	20	18
	Reptile	15	15
Others	**Total**	**4**	**4**
	Fungi	2	2
	Diseases	2	2
All species	**Total**	**552**	**446**

Whether a true effect or not, there seems to be all reason to be vigilant regarding introduction of new species.

2.2. Field visits and information sources

A study visit was made from 2-22 April 2011, during which the three islands of Caribbean Netherlands have each been visited for 5-6 days. The trip ended with a 2 day visit to St. Marten. The team consisted of Drs. John de Freitas MBA (Carmabi) and Dr Bert Lotz and Ir. W. Joost van der Burg (both Plant Research International). Extensive trips were made to visit all representative vegetation types and sites known to have problems with invasive plants.

2.3. Stakeholders consultation

Discussions were held with the most relevant stakeholders present at the time. For a list of consulted persons, see Appendix I. Focus of the discussions were the problems with invasives as perceived by local organisations, officials and individuals. Local experts were consulted wherever possible.

2.4. Literature search

A preparatory desk study of available literature was performed during early 2011. The provisional list of invasive species as was available at the time was used as a guideline for more specific literature searches. An important source of background information was also provided by the book of Mark Davis (2009) which gives an overview of the current status of the research on invasive species. Where relevant for this report, literature is being cited and references are provided in Chapter 8. Literature.

2.5. How we report the results

After a general chapter on the islands with their specific geographic and social properties which is given in chapter 3, the findings of the study visits related to plants are presented in chapter 4. The species are presented alphabetically with a short resume of the state of knowledge (4.1.1.). After that, the most important invasive species are discussed (4.1.2.). These are the species having a strong impact on more than one island. In 4.1.3 a list is provided with plant species of which the status is not clear yet. Finally a list is provided in Appendix II summarising the status of the species mentioned in 4.1.1.
This classification is in line with that which is frequently being used for invasives (see also chapter 2.1):

1. Species that are known to have a negative impact and are already widespread. For these species eradication is no option and a form of management shall be applied to control the situation; to prevent it from becoming worse.
2. Species with the same negative impact on environment, nature, economy, or plant, animal or human health, but that are present in restricted locations. Species belonging to this group may possibly be eradicated, though usually at considerable effort and costs.
3. Species that have not yet arrived on a particular island, but are a potential danger and shall be controlled at ports and airports and eradicated as soon as they are spotted in cultivation or the wild. These are usually put on a 'Black List'.

Chapter 4 ends with an enumeration of recommendations and/or policy priorities per island.
Chapter 5 gives general discussion and conclusions.
Chapter 6 enumerates all recommendations given in the previous chapters.

Chapter 7 acknowledges the main informants.
Chapter 8 contains the most relevant literature.
Finally, the appendices present the itinerary and the people consulted and a checklist with an indication per island of the status of invasiveness.

3. The islands: general

3.1. Bonaire

LAND AREA 288 km2 HIGHEST MOUNTAIN Brandaris, 240 m
HUMAN POPULATION 14,000 CAPITAL Kralendijk

Bonaire is located in the Southern Caribbean Sea (between 68º11' and 68º25' W and12º2' and 12º19' N) about 87 km north of the coast of Venezuela and 40 km east of Curaçao.

CLIMATE
Bonaire is an island that forms part of the so-called 'Caribbean dry region' (Sarmiento1976) 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 30 yr. average of 463 mm/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).

TOPOGRAPHY
Bonaire is 35 km long, 8–15 km wide, and consists of a volcanic core, surrounded by limestone formations. The northern end of the island, within Washington-Slagbaai National Park, is dominated by hills including Mount Brandaris, the island's highest point. The flat, low elevation southern end of the island contains the Pekelmeer , once a series of natural shallow lagoons that have been modified over hundreds of years for salt production. Bonaire has jurisdiction over an offshore island—Klein Bonaire —situated c.1 km from the central west coast. Klein Bonaire is a low coral-limestone island fringed with sandy beaches.

Figure 2. Washington Slagbaai National Park

GEOLOGY
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 age (~90 – 100million years ago) and largely consists of basaltic, andesitic and daciticlavas, sills and dikes, interbedded with, or intrusive into volcanic (tuffs) and biogenic (cherty limestones) sediments. The thickness of this succession is approximately 5 km. 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.

VEGETATION
The island's vegetation is generally xerophytic with many areas dominated by columnar cactus intermixed with low scrub and large expanses of land largely devoid of vegetation, especially along the eastern shoreline which receives slightly less rainfall on average than the western side of the island. Virtually all trees on the island were removed by the early nineteenth century and woody vegetation continued to be cut for charcoal production into the twentieth century. Grazing animals were introduced by 1700 and have significantly altered the vegetation. Free roaming goats and donkeys have continued to have an impact in many areas even to the present day. In some regions, notably within Washington-Slagbaai National Park, there are patches of thicker and taller (3–4 m) thorn scrub forest supporting some epiphytic growth. Lac Bay on the south-eastern side of the island supports Bonaire's only significant mangrove woodland (Wells & Debrot 2011)

3.2. Saba

LAND AREA 13 $km^{2;}$ HIGHEST MOUNTAIN The Mountain, Mount Scenery, 877 m.
HUMAN POPULATION 2,000; CAPITAL The Bottom

Saba is located at 17º38' N latitude and 63º14' W longitude (De Palm 1985). The island, like St. Maarten and St. Eustatius, is part of the island arc of the Lesser Antilles, extending from the Virgin Islands to Venezuela. The distance from Saba to St. Maarten is 48.1 km. (in a straight line), Saba and St. Eustatius are 33.6 km from each other (Land Register, 1997).

CLIMATE
The climate of Saba is tropical (the average temperature in the coldest month lies above 18º C) and according to the system of Köppen (1931) falls between a savannah- and monsoon-climate (Stoffers 1956). The average rainfall is 1101.3 mm per year (1891-1980, rain station in The Bottom), but the variation in yearly rainfall is large (De Palm 1985). The monthly rainfall is very irregular too. No clear wet or dry season can be distinguished. Every 'wet' month may be dry and every 'dry' month may be wet. The average values over a large number of years do indicate however, that the least rain falls in February, March and April while the most rain falls in August, September, October and November. In those wet months the average rainfall is almost two and a half times as much as in the dry months. Lazell (1972) calls Saba and St. Eustatius "Snag-

islands". This type of island has one high peak (more than 600 m high) that arrests a few clouds and is able to hold on to them mainly because of evaporation from the island itself. The lowland of Saba is very dry. According to Veenenbos (1955) The Mountain on Saba has an estimated annual rainfall of 1500-2000 mm. The type of vegetation does in fact indicate this, exact data are lacking however. Augustinus' report (1985) indicates that differences in rainfall on Saba appear to occur above the critical height of 450 m. Rainfall there increases with height till it reaches a maximum on the top of The Mountain. The average yearly temperature on Saba is probably the same as on St. Eustatius: 25.7º C (De Palm 1985). The temperature drops however, with increasing height. In August 1980 the average day temperature at 600 m was 23º and at 800 meters 22º (Augustinus *et al.* 1985).

Figure 3. Saba from a distance

The top of The Mountain is almost constantly veiled in clouds (Van 't Hof 2010). The relative humidity in August 1980 varied between 90-98% at a height of 600 meters and between 90-100% at 800 meters (Augustinus *et al.* 1985).The dominant wind direction is east. Saba is situated in the Atlantic hurricane zone. On average one tropical storm or hurricane passes at a distance of less than 200 km each year. Once every 4 or 5 years hurricane conditions occur (De Palm, 1985).

TOPOGRAPHY

The island of Saba has an area of roughly 13 km² (De Palm, 1985). The island actually consists of the upper part of a volcano steeply rising from the sea. The lowest part is situated beneath the sea, which is more than 600 meters deep around the island. The highest point of the island is the top of the volcano, called The Mountain or Mount Scenery, which is 877 meters high. Around the top there are several lower elevations, like Troy (586 m.), Mary's Point Mountain (566 m), Peter Simmons Hill (223 m), Great Hill (423 m), Peak Hill (401 m) and Old Booby Hill (223 m). Weathering and erosion formed numerous deep, radially running ravines (so-called 'guts'). There are only a few flat areas. The largest is the valley where the little town The Bottom is situated. Another flat area is called Flat Point. Here the runway of the airport was built. The sea has steadily undermined the sides of the island, causing them to be very steep or even vertical. There are no permanent sand-beaches on Saba, only small rubble-beaches.

GEOLOGY
It may be assumed that the first eruptions with which the Saba volcano's sub-marine phase started, date from the Middle or Upper-Pleistocene era (± 500.000-10.000 years ago), while the latest volcanic processes possibly continued till the middle of the Holocene (± 5.000 years ago) (Westermann & Kiel 1961). The volcano has been dormant for a considerable time. Roobol & Smith (2004) estimate the time of the last eruption between 1610 and 1675. The typical cone shape of so many volcanoes has not been preserved above sea level, below sea level however, this form still exists (Westermann 1957). The lower parts of Saba consist mainly of agglomerates and tuffs (Westermann & Kiel 1961). In essence it is a strata-volcano, in which pyroclastic material dominates andesitic lava-streams. In the higher parts andesitic lava-layers become more numerous. Two lava-streams that erupted during the younger phase of the volcano now form the striking formations in the northwest of the island: Behind the Ridge and Flat Point. There are no craters on Saba. A viscous lava plug formed in the original main crater of the stratovolcano in the last active period, closing the entrance. Mount Scenery is the top of the volcano with the cooled lava plug. Before complete dormancy the volcano had a stage in which there were no real eruptions anymore but there was some activity such as the outpouring of sulphurous gases, coming from not quite hardened magma in the deep (Westermann 1957). This caused the sulphur and gypsum layer of Behind the Ridge, part of which was exploited in the 19th century. The old mine tunnels still exist. The only recent and notable manifestations of post-volcanic activity are the hot springs on the beach between Ladder Point and Tent Point (Westermann & Kiel 1961) and near Green Island along the north coast (Van 't Hof, pers.com.).

3.3. St. Eustatius

LAND AREA 21 km^2; HIGHEST MOUNTAIN The Quill, 602 m.
HUMAN POPULATION 2500; CAPITAL Oranjestad

St. Eustatius ('Statia') is located at 17.30º N and 73º W (De Palm 1985). The island, like Saba and St. Marten is part of the island arc of the Lesser Antilles, extending from the Virgin Islands to Venezuela.

CLIMATE
The climate of St. Eustatius is tropical (the average temperature in the coldest month lies above 18 ºC) and according to the system of Köppen falls between a savanna- and monsoon-climate (Stoffers 1956). The average rainfall is 1072.7 mm per year (1881-1980, Oranjestad) (De Palm 1985), but the deviation of yearly rainfall is large. The monthly rainfall is very irregular too. No clear wet or dry season can be distinguished. The average values over a large number of years do indicate however, that in February, March and April the least rain falls while in the most rain falls in August, September, October and November. In those wet months the average rainfall is twice as much as in the dry months. Lazell (1972) calls St. Eustatius and Saba "Snag-islands". This type of island has one high peak (more than 600 m high) that arrests a few clouds and is able to hold on to them mainly because of evaporation from the island itself. The lowland of St Eustatius is very dry. Indeed the low-lying rain-stations (at 25 and 40 m) collect on average a little less rain than a higher-lying station (at 300 m). According to Veenenbos (1955) The Quill (above 400 m) has an average rainfall of 1500-2000 mm, however, there are no rain-stations above 400 m, so numbers cannot confirm this. The average yearly temperature is 25.7º C (1959-1980; De Palm, 1985). The change in temperature all through the year is small. January is on an average the coldest month with 25.2º C and August is on an average the hottest month with 28.0º C. The temperature drops however, with increasing height. It is to be expected that on average on top of The Quill the temperature is a little lower. The dominant wind direction is east. St Eustatius is situated in the Atlantic hurricane zone. On average one tropical storm or hurricane passes at a distance of less than 200 km each year. Once every 4 or 5 years hurricane conditions occur (De Palm, 1985).

TOPOGRAPHY

The island of St. Eustatius has an area of roughly 21 km² (Westermann & Kiel 1961). It is more or less egg-shaped with the broadest part in the southeast. The northwest and the southeastern part are hilly and the area in between is almost flat. The hills in the northwestern part are called The Mountains or The Little Mountains. They are rather low, but they have steep slopes. The highest top is "Boven" (294 m). "Bergje", also called Little Mountain, is 223 m high and Signal Hill reaches up to 134 m. There are two well developed valley systems in The Mountains (Westermann & Kiel 1961), that run into Venus Bay at the east side and Tumble Down Dick Bay at the west side. Along the west coast of The Mountains there is a very steep cliff. The southeastern part of the island only consists of one hill, a sleeping volcano with a wide and deep crater, The Quill. This name is a corruption of the old Dutch name "De Kuil". Westermann & Kiel (1961) call this volcano perhaps the most beautiful example of this type in the Antilles. The edge of the crater is highest at the eastern side (601 m) and lowest at the Westside (378 m). The bottom of the crater lies at 273 m. above sea level. The craters shape is almost round. The slopes on the inside are extremely steep. The outer slopes are more gradual, however several steep ravines cut into them. The northwestern slope of The Quill changes into an almost flat area that extends to The Mountains. This low-lying, slightly sloping plain between both hill areas is called "De Kultuurvlakte". All along the southeastern and center part of the island the coast consists of a sheer cliff, on average about 30 meters high (Westermann 1957), except at Billy Gut and Concordia Bay where you can find sand beaches. At the base of the cliff on the west side of The Kultuurvlakte below Oranjestad there is also a sandy beach.

Figure 4. Heavy clouds over St. Eustatius

GEOLOGY The whole southeastern part of the island is taken up by one big volcano, The Quill that is unique because of its even form. The Quill is also a beautiful example of an ash-volcano (Westermann 1957). This one originates from the Holocene (Holocene: 10.000 years – present day). The unique form took shape in the last phase, when there was no lava-flow anymore, but magma was exploding and blown away as a spray by gas pressure. Especially the last eruptions must have been violent, since only loose material was thrown out. The entire top, crater, slopes and the base of the volcano are covered with loose material. The largest blocks are lying on the edge and on the bottom of the crater. Lower on the slopes the material gets finer and The Kultuurvlakte is covered for the greater part by volcanic ashes. The finer material was blown in western direction by the trade wind. Thus the base of the volcano lies on the remains of the old volcano. The various strata of ejected material can still clearly be seen in the coastal cliff. The Round Hill probably is a small adventitious crater, which afterwards was covered with ashes. In historical times there were no further eruptions. The cone of the volcano however, shows little erosion, which indicates a relatively recent sleeping phase (Westermann 1957).On the south side of The Quill we find a totally different rock of sedimentary origin. These are two slabs

reclining against the slope of the volcano: The White Wall (270 m) and The Sugar Loaf (73 m). They consist of limestone originating from corals and shells, alternated with some volcanic material. Their age is determined to be roughly 70.000 to 21.000 years old (Westermann & Kiel 1961). The limestone was originally formed at the bottom of a shallow sea near the then still small Quill-volcano. The horizontally constructed slabs were forced upwards during the active phase of the volcano and were turned over by a plug of lava (now hardened) (Westermann 1969).

3.4. Other Dutch Caribbean

3.4.1. St. Marten

(= St. Maarten + St. Martin)

LAND AREA 86 km^2; HIGHEST MOUNTAIN Pic Paradis, 424 m (French part)
HUMAN POPULATION 14,000; CAPITAL Philipsburg

St. Maarten is located at 63º N and 18º W (De Palm 1985). The island, like Saba and St. Eustatius is part of the island arc of the Lesser Antilles, extending from the Virgin Islands to Venezuela (Westermann 1957). St. Marten is the largest of the three Windward Islands of the Netherlands Antilles, and has an area of about 86 km² (De Palm 1985). However, since 1648 it is divided in two parts: the present Netherlands Antilles part and the French part. The northern and largest part is French (with an area of ±52 km²) and the southern and smallest part belongs to the Netherlands Antilles (area of ±34 km²). Several uninhabited small islands fall under the jurisdiction of both parts of St. Marten. Tintamarre, also called Flat Island, Ile Pinel, Little Key and Green Key at the eastern side of the main island and Great Key in Simpson Bay Lagoon belong to French St. Martin. Pelican Key, also called Guana Key, Molly Beday and Hen and Chickens at the eastern side of the main island, and Little Key in Simpson Bay Lagoon belong to the Netherlands Antillean part of St. Maarten.

CLIMATE
The climate of St. Maarten is tropical (the average temperature in the coldest month is above 18º C) and according to the system of Köppen falls between a savannah and a monsoon climate (Stoffers 1956). The average rainfall is 1008 mm per year (1961-1990; CBS, 1996), but the deviation of yearly rainfall is large. In 1994 for instance, there was only 658 mm of rain, whereas in 1992 it was 1273 mm. The monthly rainfall is very irregular too. No clear wet or dry season can be distinguished. Every dry month can be wet, and every wet month can be dry. The average values over a large number of years do indicate however, that February and March are the months with the least rain, while most rain falls in September, October and November. In those wet months the average rainfall is trice as much as in the dry months. There are no hills of sufficient height to stop the clouds; this is why there is no big difference in rainfall between the higher and lower parts of the island. Nevertheless Stoffers (1960) suggests that on top of Sentry Hill there is more rainfall than lower on the slopes and according to the ECNAMP report (1980) too, there is supposed to be considerable more rainfall in the hills in the middle part of the island than in the lower parts. The official figures give no definite answer. The figures published by CBS are collected at a rain-station at Princess Juliana Airport. The average yearly temperature is 26.8 ºC (1961-1990; CBS, 1996). The temperature variation over the year is small. January and February are on an average the coldest months with 25.2º C, and August and September are on an average the hottest months with 28.2º C. (1961-1990; CBS, 1996). The dominant wind direction is east (De Palm 1985). St Marten is located in the Atlantic hurricane zone. On average one tropical storm or hurricane passes at a distance of less than 200 km each year. In September 1995 the centre of a severe hurricane, called Luis, passed over St. Maarten. This hurricane caused severe damage.

TOPOGRAPHY
St. Marten has an irregular shape because of the many large and small bays and lagoons along its coast. The lagoons are closed off from the sea by sandy embankments. Simpson Bay Lagoon is the largest lagoon. The island has a great many beaches. Most of the sandy beaches are on the south- and northwest coast. The Landscape is hilly except in the Low Lands on the west side. Three hilly ridges run over the island in a northwest direction. The highest top is the top of Mount Paradise at 400 meters on the French side. Flagstaff is the highest hill on the Netherlands Antillean side, reaching 386 meters.

GEOLOGY
The oldest rock strata of St. Marten are about 50 million years old (Westermann 1957). These strata were deposited in the ocean. They consist of rubble from erosion of the small volcanic islands in the area on the one hand, and of marine deposits on the other hand. These strata were folded and lifted upwards by tectonic forces in later periods. They were temporarily above sea level. These oldest rocks, the Pointe Blanche Formation consist of very hard, partly pebbly tuffs. These were most resistant against eroding forces and now remain as two parallel ranges rising from the island. The highest tops belong to this formation: Fort Hill (220 meters), Cole Bay Hill (215 meters), Sentry Hill (344 meters), Saint Peters Hill (317 meters), Flagstaff (386 m), Mount Paradise (400 m), and Naked Boy Hill (300 m). This period of uplifting was accompanied by rising magma. During the course of a period of local subsidence of the earth's crust in the Miocene (30 to 16 million years ago), the Pointe Blanche strata were submerged below sealevel. During the coldest period of the ice age in the Pliocene (1 mln to 10.000 years ago) sea level was at least 36 meters lower than at the present time. Anguilla, St. Barths and St. Marten were then part of one big island. On this island a giant rodent (*Amblyrhiza inundata* (De Palm, 1985) lived. Remains of this animal are found in St. Marten as well as Anguilla. At the end of the Pliocene (± 10.000 years ago) the ice masses melted and seal evel rose. The island was flooded and only the highest parts, the present islands Anguilla, St. Barths and St. Marten remained above sea level. These islands are now situated on a submarine plateau, with a maximum depth of 36 meters and called the Anguilla Bank. Great Salt Pond and Great Bay are actually a drowned valley in which at the spot where Philipsburg is situated now, a layer of marine shell sand was deposited. The other bays and lagoons are also drowned valleys. The youngest rocks were formed in the sea. They are coral reefs, which due to a small rise of the island are now situated 5 to 6 meters above sea level. They only take up a small area mainly at the east coast of the island

3.4.2. Aruba

LAND AREA 193 km^2; HIGHEST MOUNTAIN Jamanota 188 m
HUMAN POPULATION 105,000; CAPITAL Oranjestad

Aruba belongs to the Leeward Antilles and has an arid climate. The landscape is characterised by cactuses. Aruba’s tropical marine climate shows little seasonal variation, with an average annual temperature of 27 °C, varying from about 26 °C in January to 29 °C in July (Wikipedia 2011). Rainfall averages 510 mm or less annually, and the island’s residents rely on one of the world’s largest desalination plants for most of their drinking water. The rainy season occurs between October and December. Permanent rivers are absent. The main mountains are Jamanota, Canashito and Hooiberg, the remainder of the island is flat. The central part of the island mainly consists of rocks of volcanic origin (diabase, tuffs, conglomerates, schists), surrounded by limestone formations. Wild goats and donkeys roam free on the mountain.
The island has hardly any natural resources, arable land covers a little over 10% of the area. The economy relies almost exclusively on tourism.

3.4.3. Curacao

LAND AREA 444 km$^{2;}$ HIGHEST MOUNTAIN Christoffelberg 372 m
HUMAN POPULATION 142,000; CAPITAL Willemstad

Curaçao belongs to the Leeward Antilles and has a semiarid climate with a dry season from January to September and a wet season from October to December. The temperatures are relatively constant with small differences throughout the year. The trade winds bring cooling during the day and the same trade winds bring warming during the night. The coldest month is January with an average temperature of 26.5 °C and the warmest month is September with an average temperature of 28.9 °C. The year's average maximum temperature is 31.2 °C. The year's average minimum temperature is 25.3 °C. Curaçao lies outside the hurricane belt, but is still occasionally affected by hurricanes, as for example Omar in 2008. Precipitation averages 550 mm per year, with a high in the months of October (84 mm) to December (100 mm). The driest month is March (Wikipedia 2011). The highest point is the Christoffelberg which is 372 m high and lies in the reserved wildlife Christoffelpark. The eastern part of the island is flatter and lower, broken by the flat-topped Tafelberg at Santa Barbara. Just west of town, lie three sharp hills known as 'Drie Gebroeders' (three brothers).
Most of the western and southeastern countryside is made up of gently rolling volcanic hills. Eroded rock washed down from the hills forms a rich soil. The island's plantations grew up in the surrounding valleys. Flora and fauna in these areas is particularly rich. Other rocks are of sedimentary origin, while the entire north coast is made up of four limestone terraces.
The main vegetation is xeric scrubland, with various forms of cacti, thorny shrubs, evergreens, and the island's national tree, divi-divi.
The island has little resources and a large proportion of the economy relies on tourism. 375 km off the coast of Curaçao, to the south-east, lies the small, uninhabited island of 'Klein Curaçao' (little Curaçao). It has been denuded by guano mining and flora is being re-established.

4. Naturalised and invasive exotic plants

4.1. Results

4.1.1. Alphabetical list of invasive plant species

This chapter describes the records from literature, complemented with our findings. We concentrate on the species that are actually present. This includes plant species present in large amounts, causing ecological damage; plants present in smaller amounts and not yet having shown a negative impact on biodiversity (established); and finally plants that are there in small amounts only and of which a tendency to invasiveness is known.

A table with the status (exotic, established, naturalised, invasive) per island is given in Appendix II. Since most species in this list show invasive properties here or elsewhere, only those plants that show invasiveness on the particular island are indicated as such.

Summaries are given in tables 3 and 4.

Table 3. Number of invasive plants per invasive phase and per island

	Type	Aruba	Bonaire	Curacao	Saba	St Eust.	St Mart.
	Exotic	8	8	5		1	1
	Established	8	12	14	16	15	11
	Naturalised	19	17	22	11	14	18
	Invasive	6	10	12	14	10	8
	Total	41	47	53	41	40	38

It must be emphasised that the ranking established/naturalised/invasive is in part subjective. When plants are established, *i.e.* they are able to maintain one or more stable populations through reproduction, and not massively reproducing nor causing any negative impact on economy or nature (*i.e.* being invasive), then it is a matter of scale and time before they can be regarded as naturalised.

Table 3 and 4 are referring to the 65 species mentioned in 4.1.1. (as well as in Appendix II). These are preliminary results as comprehensive and accurate inventories are lacking. Due to the limited time available for prospecting, not all species could be given the attention necessary, and only Bonaire, Saba and St Eustatius could be visited. Therefore a series of known or suspect invasive plant species (over 80 in number) are enumerated in 4.1.3.

More thorough plant inventories shall be made to obtain a more complete picture.

Table 4. Invasive plants arranged per plant type and per island

Type	Aruba	Bonaire	Curacao	Saba	St Eust.	St Mart.
Fern				2	1	
Grass	9	11	12	7	7	9
Herb	4	4	4	5	6	6
Shrub	5	7	7	6	4	6
Succulents	4	4	6	5	4	4
Tree	15	16	18	8	11	8
Vine	4	5	6	8	7	5
Total	41	47	53	41	40	38

Most invasive plant types are represented on all islands. With few exceptions there do not seem many plant groups with a strong preference for a particular type of island. A clear exception is the group of ferns that can only grow well with sufficient moisture, which can only be found on the mountains of the Windward Islands. Bonaire and Curacao seem to be particularly liable to have invasive shrubs and trees. These islands also have a larger proportion of grasses. Saba and St Eustatius have relatively many vines. Curaçao has the highest total number (53) of invasives; which in part may a reflection of the more intensive naturalists' activity and being the home base of Carmabi.

Nomenclature is following the GRIN database, from the Germplasm Resources Information Network at http://www.ars-grin.gov/.
Presence on the islands is indicated by the following abbreviations: Aruba (A), Bonaire (B), Curacao (C), or ABC; and Saba (SA), St. Eustatius (SE), St. Maarten (SM), or SSS.

Agave sisalana Perrine (C, SE) – Sisal, pita vlas

Native to Mexico (Howard 1979 vol 3). Imported to Curaçao for fiber production but the experiment failed (Arnoldo 1971). Mentioned as cultivated on Curaçao, St. Maarten and St. Eustatius (Boldingh 1913). Naturalized on Curaçao (Arnoldo 1971). Found also on St. Maarten (Howard 1979 vol 3). Reproduction is primarily vegetative by bulbils and a plant can bear up to 2000 bulbs (Langeland *et al.* 2008). It is fast growing, drought tolerant and adaptable to a variety of soil conditions and climates. It grows well in sandy soils and in full sun to partial shade (Langeland *et al.* 2008).

Albizia lebbeck (L.) Benth. (ABC, SSS) – Barba di jonkuman, lebbeck

This tree is native to tropical Asia and was introduced into the Caribbean as early as 1782 (Dunphy & Hamrick 2005). It is a prominent species in both natural and disturbed habitats throughout the region (Kairo *et al.* 2003). It was introduced to all six Dutch Caribbean islands as well, and has become naturalized on Curaçao and the Windward Islands (Stoffers 1973, Arnoldo 1971, De Freitas, unpubl. data). Typical traits which give *Albizia* an invasive edge, include perfect flowers, generalist pollinators, retention of fruit on the tree, nitrogen fixation, use of pioneer habitat, high seed production, high growth rates, and multiseeded fruits (Dunphy & Hamrick 2005). It is present on St. Eustatius in the English Quarter (Boldingh in Stoffers 1973), on Saba in The Bottom (Stoffers 1973).

Aloe vera (L.) Burm.f., syn. *A. barbadensis* Mill. (ABC, SSS) – Sentebibu, aloe, Barbados aloes, common aloes

Figure 5. *Aloe vera* on Bonaire

The plant is native of the Mediterranean (Arnoldo 1971). Established/naturalized on all six Dutch Caribbean islands (Arnoldo 1971). Boldingh (1909; 1913) reports it for the ABC islands and only for St. Eustatius and St. Maarten. It is also present on Saba near the harbour.

Antigonon leptopus Hook. et Arn. (ABC, SSS) – Coral vine, corallita, bellísima
(for a more detailed treatment see 4.1.2)

Figure 7. *Antigonon leptopus*, an attractive climber (St Eustatius)

Elsewhere in the Caribbean, this species is invasive in Antigua, Bahamas, the Dominican Republic and Haiti (Kairo *et al.* 2003). In Curacao, Bonaire and Aruba, this species only thrives in areas with heavy disturbance by man, and generally penetrates undisturbed vegetation only in very limited numbers. In Curacao the species has been found in a few relatively undisturbed areas such as Roi Rincón and the Higher Terrace of Noordkant, probably associated with the illegal dumping of garden clippings. It is surprising that it has not become more widely spread as its seeds have become an important food of the native pigeons. On St. Eustatius *A. leptopus* has been found in three vegetation types and is dominant in one of these (De Freitas *et al.* The landscape ecological vegetation map of St. Eustatius, in prep.). In 2007 the vine covered 15-20 percent of the total land area of St Eustatius (Figure 38). On Saba it invades roadside areas, habitats heavily disturbed by goats and areas affected by erosion such as along the road through Fort Gut (Debrot pers. obs.).

Arivela viscosa (L.) Raf., syn. *Cleome viscosa* L., *Polanisia viscosa* (L.) DC. (ABC, SSS) - Wild massamby, kaya-kaya

This weedy herb is native of the Old World tropics (Stoffers 1982). Naturalized on all six Dutch Caribbean islands (Boldingh 1909, Stoffers 1982, Van Proosdij 2001). It occurs mostly in open places and disturbed locations. It is a weed of roadsides, waste grounds, cultivated fields, sandy and rocky seashores. It is widely naturalized from central United States southward through Central America, the West Indies, and northern South America (Howard 1979). On St Eustatius it forms a pest in horticultural fields (pers.obs. Van der Burg). It was already established on the Windward Islands at the beginning of the 20th century (Boldingh 1909, 1913).

Figure 6. *Arivela viscosa* op St Eustatius

Asystasia gangetica (L.) T.Anderson, syn. *Asystasia coromandeliana* Nees, *Justicia gangetica* L., *Ruellia zeylanica* J.Koenig ex Roxb. (ABC, SSS) - Chinese violet

Figure 8. *Asystasia gangetica* on Saba

Native of tropical Africa and India (Langeland *et al.* 2008), now a pantropical weed (Arnoldo 1971; Howard 1989 vol 6). In the Caribbean region naturalized in Central America, Puerto Rico, and the Virgin Islands (Langeland *et al.* 2008). Naturalized throughout the Pacific. Cultivated on ABC & St. Maarten (Arnoldo 1971). Is naturalized on beaches in St. Maarten (Arnoldo 1971), along roadsides in Saba (pers.obs. Van der Burg) and in hedges bordering vegetable gardens in St. Eustatius (pers.obs. Van der Burg). Introduced in Florida in 1930 possibly as an ornamental/ground cover, and found naturalized by 1970. (Langeland *et al.* 2008). It is a very vigorous ground cover and can be very invasive in developed or natural landscapes. If supported by hedges it can grow up to 2 m high in Suriname (Van der Burg, pers.obs.). A very successful colonizer that has invaded across a wide geographical range due to its fast establishment, rapid growth rate and early flowering. Naturalized in many of the Hawaiian islands in disturbed forest communities (Langeland *et al.* 2008). Its entry is prohibited in Australia where it is considered a weed that poses a significant threat to biodiversity (Langeland *et al.* 2008). This species can be highly invasive. It can smother any vegetation with its herbaceous layer. On the Pacific Islands it has caused major disruptions in native ecosystems (GSID 2011). It is adapted to a wide range of environmental conditions and will tolerate drought, full sun to partial shade, direct exposure to salt spray and a variety of soils (Langeland *et al.* 2008). It is extremely competitive and can absorb significant amounts of soil nutrients and form extensive, viable seed banks. Reproduces by vegetative fragments and seed, and flowers and sets fruit early in its life cycle (at only 45 days old) and can produce hundreds of explosive capsules per plant. As seeds mature, germination percentages increase and temperature requirements become less sensitive (Langeland *et al.* 2008).

Azadirachta indica A.Juss (ABC, SE, SM) - Neem

(for a more detailed treatment see 4.1.3)

Figure 9. Neem tree on the flanks of The Quill (St. Eustatius)

This species has been widely introduced in tropical regions for wood production (e.g. Campbell 2005) and as an ornamental of medicinal value and is listed as an invasive in Puerto Rico, Antigua, Barbuda and the Dominican Republic (Kairo *et al.* 2003), as well as other areas where it is not native (e.g. Campbell 2004). For Australia, where it is also spreading rapidly, the assessment of its potential impact remains inconclusive (Csurshes 2008). Once introduced it is typically not used for its intended purpose (Judd 2004). Due to its invasive properties, the Peace Corps which formerly promoted the species, now discourages its propagation (Judd 2004).The species is very drought resistant, and in both Curacao and Bonaire and St. Maarten the species is therefore able to invade dense vegetation, requiring little disturbance for it to spread. Its seeds are dispersed by rats (*Rattus rattus*) and native birds (e.g. *Mimus gilvus*) (AOD, pers. obs.). In the 1980s reported for only Anguilla, Antigua, St. Kitts, Montserrat and Guadeloupe (Howard vol 1).

Balanites aegyptica (L.) Delile (B, C) - Lamunchi shimaron, korona di Hesus

This species is native to the arid areas of West and Central Africa. It has been introduced into cultivation in Latin America and India. The wood is very valuable for charcoal production and the leaves are fruits are important food source for goats, camels and other wildlife. The fruit is edible and can be made into a beverage. The seed kernel can be made into bread and soup and contains an edible oil. Several parts of the plant can also be used in combatting pests (Firewood crops 1983). It has a wide ecological distribution, but is mainly found on level alluvial sites with deep sandy loam and free access to water (Schmidt and Jøker 2000). It was introduced in Curacao in 1885 (Arnoldo 1971) and, while formerly distributed from the eastern to mid-central parts of the island, it is now also found on the western side at Knip (De Freitas, Dolfi pers. obs.)

Bambusa vulgaris Schrad. ex J.C.Wendl. (SA) - Bamboo

Native to tropical Asia, but widely introduced into tropical and subtropical regions of the world (Howard 1979). Several Asiatic species have been imported to the region for commercial purposes and have become naturalized themselves (Kairo *et al.* 2006). *Bambusa vulgaris* is the most widely cultivated exotic species in the region and is naturalized on Saba (NYBG 2011). Howard (1979) mentions it only for Guadeloupe, Martinique, and Grenada.

Bothriochloa ischaemum (L.) Keng, syn. *Dichantium ischaemum* (L.) Roberty (B, C) – Yellow bluestem

An Asiatic species now widely introduced in the warmer parts of the world. Originally introduced in the Americas as a pasture grass and is now widespread as a casual roadside, ditch bank, fields and wasteland grass (Stoffers 1963, Howard 1979). Stoffers (1963) mentions it only for Bonaire and Curaçao.

Botriochloa pertusa (L.) A.Camus (SSS) – Pitted bluestem, hurricane grass, 'Donna grass'

(For a more detailed treatment see 4.1.5)

A native of the warmer regions of Africa, India and China; introduced in the Americas (Howard 1979). Open grassy areas, often in disturbed areas Howard (1979) mentions it for Anguilla, Antigua, Nevis, Dominica, St. Lucia, Grenada and Barbados. It is less palatable than the native grasses which it outcompetes, especially on St. Eustatius (Figure 50).

Caesalpinia bonduc (L.) Roxb. (SSS) – Grey nicker

Probably native of eastern Asia (Stoffers 1973). Shrub common on sandy beaches in the tropics and subtropics. In Saba to be found occasionally at higher elevations. Invasive on all three Dutch Windward Islands (Boldingh 1909; Stoffers 1973). Observed on all three islands and especially aggressive on St Eustatius and along the beach on St Martin (Team obs.).

Figure 10. *Caesalpinia bonduc* on St Eustatius forming impenetrable thorny mats overgrowing the local vegetation

Calotropis procera (Aiton) W.T.Aiton (ABC, SSS) - Katuna di seda, liberty tree, sprainleaf

Native of the Old World Tropics but widely introduced and naturalized through the New World tropics, including the West Indies. Common and scattered in dry coastal forest, waste places, heavily grazed pastures and beaches up to 200 m (Little et al. 1974). In Boldingh (1909) already indicated as naturalized/established on the Windward Islands. Also naturalized/established on the ABC islands (Stoffers 1982). Overgrazing by donkeys leads to a monoculture of this species on Bonaire. It clearly responds strongly in conjunction with introduced grazers.

Figure 11. *Calotropis* forest caused by overgrazing at the donkey sanctuary on Bonaire (photo: Debrot)

Catharanthus roseus (L.) G.Don. (ABC, SSS) – Madalena, churchyard blossom, Madagascar periwinkle

Figure 12. *Catharanthus roseus*, naturalised on Saba (near harbour)

Believed to be native to Madagascar but widely cultivated, escaped and spreading in tropical and subtropical areas (Howard 1989 Part3). Naturalized on all Dutch Caribbean islands (Stoffers 1982). It is particularly abundant on Saba (Team obs., Figure 12).

Cenchrus ciliaris L., syn. *Pennisetum ciliare* (L.) Link (ABC) - Buffel grass

This species, native to Africa, the Middle-East, India, and Indonesia has been widely introduced for livestock grazing (and erosion control and revegetation) in arid and semi-arid areas in e.g. the U.S.A. and Australia (GISD 2011). One of its competitive advantages on poor and infertile soils is based on its robust root system; its swollen stem base accumulates carbohydrate reserves, so the loss of leaf surface area after drought is not fatal to the plant and allows regrowth in favourable conditions GISD 2011). Buffel grass' dominance and resistance to fire, drought and heavy grazing on arid soils make it a suitable arid zone pasture grass. In Australia, the south-western United States and Mexico (where it has been introduced as a pasture grass and for erosion control) Buffel grass often forms extensive dense monocultures excluding native species and promoting intense and frequent fires. It changes plant communities by encouraging and carrying wildfires through communities that are not adapted to fire. It burns readily and recovers quickly after fire (GISD 2011).

It establishes itself readily in grasslands and expands into other habitats, particularly alluvial flat habitat. It invades hilly areas the slowest. It has a significant negative impact on plant diversity and the fauna as well (Eyre et al. 2009, Smyth *et al.* 2009) and has been identified as a serious invader in Texas (Flanders et al. 2009), Mexico (Gutierez *et al.* 2009), Puerto Rico (Kairo et al. 2003) as well as Hawaii as well where it invades and destroys native grassland ecosystems (Daehler & Carino 1998). It forms pure stands in open areas on the ABC islands. It is not tolerant to shade (Tropical forages 2011).

Chenopodium murale L. (ABC, SE, SM)

This herb of up to 1 m high (Holm et al. 1997) is native to Africa (Mediterranean region), temperate Asia (Cyprus, Israel, Jordan, Lebanon, Syria, Turkey), and Europe (GRIN 2011). Chenopodium murale grows in moist soil (Halvorson & Guertin 2003, Felger 1990, Parker 1972) and disturbed areas (Felger 1990). It is adapted to many ecological conditions but favours soils rich in nitrogen (Holm et al. 1997). It can grow on shaded or open sites (Holm et al. 1997). Established on St. Maarten and St. Eustatius (Boldingh 1909) and the ABC islands (Boldingh 1913; van Proosdij 2001).

Figure 13. *Cleome gynandra* on St. Eustatius

Cleome gynandra L., syn. *Gynandropsis gynandra* (L.) Briq. (ABC, SSS) - Yerba di kaya, massamby

Naturalized on all six Dutch Caribbean islands (Stoffers 1982; Boldingh 1909, 1913, 1914). A native of tropical Africa and Asia; introduced into tropical America (Stoffers 1982). It is a weed of waste grounds, fields, roadsides, wet or dry woodlands or wood clearings, and rocky and sandy shores (Howard 1988). It is invasive in the Dominican Republic (Kairo *et al.* 2003).

Clitoria ternatea L. (ABC, SSS) - Sapatu di la reina, blònchi di kokolishi, bonchi di palomba, jamaní tabaku

Native of the Old World tropics and widely established in the new World (Howard 1988 Part 1). Adapted to a wide range of soil types (from sands to heavy clays) of moderate fertility but is extremely well adapted to heavy clay alkaline soils, and especially on clay soils which are too shallow for leucaena (*Leucaena leucocephala*). Adapted to pH 4.5-8.7 but prefers medium to high pH . Some tolerance to salinity has been suggested by some authors (Tropical forages 2011).

Established on ABC islands and also the Windward Islands (Stoffers 1979, van Proosdij 2001). In Boldingh (1913) it is only mentioned as cultivated for all six Dutch Caribbean islands. Seedlings do not compete well with existing vegetation and therefore the chances of it becoming naturalized are slim (Tropical forages 2011).

Figure 14. *Clitoria ternatea* (St Eustatius)

Cordia sebestena L. (ABC, SSS) – Karawara spaño, scarlet accordia

Probably native to the Bahamas and the Greater Antilles and introduced elsewhere as an ornamental (Howard 1989 part 3). Boldingh (1913) mentions this species as cultivated on all six Dutch Caribbean islands. Naturalized in Puerto Rico (Kairo & Ali 2006). Established/naturalized on Curacao (pers. obs. De Freitas) and Klein Bonaire (Debrot 1997).

Cryptostegia grandiflora (Roxb.) R. Br. (ABC, SSS) – Palu di lechi, Cordondi San Francisco, Rubber vine

See also 4.1.2.2.

Cryptostegia is native to the island of Madagascar and tropical Africa and was introduced in warmer regions of the world as an ornamental and for the production of rubber (Starr *et al.* 2003). *Cryptostegia grandiflora* is a self-supporting, many-stemmed vine that is capable of growing over trees up to 15m high, smothering and pulling them down. It occurs in dry and moist forests in disturbed situations where there is temporary or permanent water, such as in rainforest openings and along roadsides. *C. grandiflora* is poisonous to stock when consumed. It decreases water catchments due to increased transpiration resulting in a loss of trees and native vines, which in turn leads to a loss of biodiversity and habitat (www.issg.org). It disperses by means of windborn seeds, water courses and hooves of animals (Starr *et al.* 2003). Each pod can contain up to 450 seeds and can produce more than 8000 wind-dispersed seeds in a single

Figure 15. *Cryptostegia* planted as ornamental (St. Eustatius)

reproductive event (Grice 1996; Starr *et al.* 2003). Ninety percent of seeds will germinate within 10 days of moisture becoming available (Grice 1996). Plants can begin to germinate after about 200 days and seeds remain viable for approximately 12 months (Starr *et al.* 2003).

Kairo *et al.* (2003) indicate it as naturalized and invasive in the Caribbean. Boldingh (1913) mentions it as cultivated for the ABC islands and Saba. Arnoldo (1971) mentions it as invasive for the ABC islands and cultivated in Saba. Kairo *et al.* (2003) mention it as naturalized on St. Marten. Boldingh (1909) mentions it as cultivated but does not mention any specific island. It was introduced for rubber production during World War I (Arnoldo 1971). On Curacao this plant is found almost everywhere and shows a strong preference for gullies (Winkel 2003). The plant is naturalized near the harbour on Saba (Team obs.) and along the road through Fort Gut (Debrot, pers. obs.) and planted on St Eustatius near the oil terminal (Team obs.). On the latter island no spontaneous escapes could be observed.

Figure 16. Vegetable field infested with *Cyperus rotundus* (St Eustatius)

Cyperus rotundus L. (SE) – Nutsedge, purple nutsegde

On St. Eustatius, on a vegetable farm, many fields are infested with *Cyperus rotundus* L., Cyperaceae, Purple Nutsedge (Figure 16). This species is a notorious weed all over the World, often

leading to complete abandon of fields. Strict precautions are necessary to prevent it from further spreading.

Dactyloctenium aegyptium (L.) Willd. (ABC, SSS) - Pia di warawara, habriman, Maria bendemi

Introduced into the Americas (Howard Vol. 3 Monocot 1979). A common weed in pastures and along roadsides disturbed sites (Stoffers 1963). Already naturalized on all six Dutch Caribbean islands (Boldingh 1909, 1914).

Delonix regia (Bojer) Raf. (ABC, SSS) – Flamboyan, July tree

This species is native of Madagascar. It is one of the most extensively planted ornamental tree in tropical and subtropical regions throughout the world (Little & Wadsworth 1964). It invades natural vegetation in Puerto Rico, Barbados and the Dominican Republic (Kairo *et al.* 2003).

Echinochloa colona (L.) Link (ABC, SM)

(commonly misspelled "*E. colonum*")

Introduced in the Americas, although Howard (1979) indicates that it may be native to North America; a common weed in tropical and subtropical areas (Stoffers 1963). From Stoffers (1963) it can be concluded that it is at least naturalized on the ABC islands and St. Martin. According to Howard (1979) also on St. Martin. It is a weed of disturbed areas (Howard 1979).

Eleusine indica (L.) Gaertn. (B, C, SSS) - Kamuchi, pia di galiña, goose grass

Native of the warmer region of the Old World and introduced in the Americas where its is a common weed (Stoffers 1963; worldwide in temperate and tropical regions (Howard 1979).It prefers moist, usually disturbed and cultivated sites (Howard 1979). It is invasive in the Dominican Republic (Kairo *et al.* 2003). According to Boldingh (1909) and Stoffers (1963) it is invasive on the three Windward Islands. According to Stoffers (1963) invasive on Aruba, and Curaçao. Boldingh (1913) mentions only Curaçao and Bonaire.

Epipremnum aureum (Linden & André) G.S. Bunting, syn. *E. pinnatum* (L.) Engl. cv. '*aureum*' (SA) – Pothos, Tonga vine.

Native to Solomon Islands and China to tropical Asia (Langeland *et al.* 2008). Pothos vine is cultivated for ornamental purposes and readily escapes cultivation in tropical areas (Langeland *et al.* 2008). It climbs up tree trunks and into the forest

Figure 17. *Epipremnum* on Saba

canopy, primarily in disturbed areas and along roadsides, smothering native plants. The plant is poisonous when eaten and can cause minor skin irritation when touched (GISD 2011). It is highly drought tolerant and fast growing and tolerates a variety of soils including saline soil. It rappidly acclimates to changing light conditions and can survive in very low light to full sun (Langeland *et al.* 2008). It is naturalized and invasive in Bermuda (Kairo *et al.* 2003). It has become a notorious invader in Florida in less than 40 years (Langeland *et al.* 2008).
A climbing herb present on Saba, opposite the ranger's hut at the beginning of the mountain trail (team obs.). It is probably a recent escape from cultivation and said to occur at different locations already.

Eragrostis ciliaris (L.) R.Br. (ABC, SSS) –

Widespread in the warmer regions of the world apparently introduced in the Americas (Howard 1979). Open grounds and waste places and a common weed around urban settings (Stoffers 1963). Invasive on all six Dutch Caribbean islands (Stoffers 1963).

Euphorbia tithymaloides , syn. *Pedilanthus tithymaloides* (L.) Poit. (B?, C, SSS) – Prikichi, milkbush, slipperplant

Milkbush or *Pedilanthus* is found from Florida to Venezuela (Arnoldo 1971). Boldingh (1913) mentions it as cultivated for Curacao and natural on the Windward Dutch Caribbean islands. It is invasive in drier areas of Dominica (Lack *et al.* 1997).On Curacao it has been observed in the wild at several locations such as Daaibooi, Rif St. Marie, the Higher Terrace areas of Hato, and at Malpais. The species does not appear to spread rapidly and therefore offers perspectives in terms of eradication and control by means of local manual removal. Is still used as an ornamental species on Curacao in landscape projects (De Freitas, pers. obs).

Also on St. Eustatius, on the slopes of Boven many plants are found. It is clearly established (in the strict sense that it is growing and reproducing), and spreading.
It is also said to be present on Bonaire but, despite quite accurate indications of people, could not be found. The Dutch Caribbean Biodiversity Explorer (2011) mentions it for St. Eustatius and St. Marten.

Figure 18. *Euphorbia tithymaloides* (St. Eustatius)

Ficus microcarpa L.f., syn. *F. retusa* auct. non L.f. (C) – Laurel fig, Chinese banyan

Ornamental that is native to India and Malaysia. Invasive in Bermuda (Kairo *et al.* 2003) and believed to be naturalized throughout its cultivated range in Florida where it was introduced in the beginning of the 20th century but started to spread only in the 1970s after the apparent accidental introduction of species-specific pollinating wasps (Langeland *et al.* 2008). Escaped in Curaçao (pers. obs. Debrot) and this is probably due to the presence of specific tiny wasps it requires for its pollination (Langeland *et al.* 2008). Arnoldo (1971) mentions it as cultivated on Curaçao.

Gossypium hirsutum L. (ABC) / *G. barbadense* L. (SSS) – Katuna, creole cotton

Originally from Central America, Mexico, and the Greater Antilles. Cultivated in many parts of the world as a commercial agricultural crop. Found wild in many parts of the caribbean (Howard 1989 vol 5). De Palm (1985) mentions *G. hirsutum* as naturalized on ABC islands and *G. barbadense* as cultivated on the Windward Islands.

The species is very common on Bonaire, but does not seem to create large problems, although it can become quite abundant (Figure 19). *G. hirsutum* L. (cotton). Also on Curaçao, to the West of Ascencion.

Figure 19. *Gossypium* along a road in Bonaire

Indigofera tinctoria L. (B, C, SA, SM) - True indigo, inigo

Cultivated in the West Indies and now naturalized in most islands (Stoffers 1979). Boldingh (1909) does not mention this species for the Windward Islands and Boldingh (1913) mentions this species only for Curaçao. Howard mentions it for St. Martin (and St. Kitts) and a number of other Lesser Antilles. Stoffers (1979) also mentions it as naturalized on Bonaire. It was found to be present on Saba (Team obs.).

Native of the Old World; introduced and naturalized in the New World (Howard1988 vol 4). The plant was one of the original sources of indigo dye. Today most dye is synthetic, but natural dye from Indigofera tinctoria is still available, marketed as natural coloring. The plant is also widely grown as a soil-improving groundcover (Wikipedia 2011). *I. tinctoria* is one of the five most frequently cultivated indigo species throughout the tropics and has been so for many centuries (Canon & Canon 1994).

Figure 20. *Indigofera* on Saba

Jasminum fluminense Vell. (B, C, SSS) – Hasmin, jasmin

An ornamental native of tropicaL West Africa Africa and widely distributed in the tropics (Stoffers 1982; Howard 1989 Vol 6; Langeland *et al.* 2008). This species is also reported as invasive in the Bahamas (Kairo *et al.* 2003). Is found especially in the native vegetation in more humid areas with significant soil development. Boldingh (1913) & Arnoldo (1971) mention it as a cultivated species for all six islands of the Dutch Caribbean. Its invasive character on Curaçao has become evident only in the last few decades (De Freitas, pers obs.). It is an aggressive, troublesome and difficult-to-control weed. It has vigorously invaded intact, undisturbed hardwood forests in south Florida. It can climb high into the tree canopy of mature forests, completely enshrouding native vegetation and reducing native plant diversity. It is very adaptable and will also grow near coast where protected from salt spray (Langeland *et al.* 2008).

Kalanchoe diagremontiana Hamet et Perrier de la Bathie, syn. *Bryophyllum diagremontianum* (Raym.-Hamet & H. Perrier) A. Berger (ABC, SA) – Lenga di kacho, mother-of-millions

Naturalized on Saba, this species is native to Madagascar (Arnoldo 1971). Recent studies have shown it to have high invasive potential for semi arid areas such as the ABC islands (Herrera & Nassar 2009). It can produce massive amounts of seeds and reproduces clonally as well, Young rooted plantlets are cloned from the leaves and drop from the adult plant but the species has not been seen to flower yet in the Leeward Dutch Islands (Arnoldo 1971).

Figure 21. *Kalanchoe diagremontiana* near Kralendijk, Bonaire (Photograph by A.O.Debrot)

While it does not spread rapidly once present, experience in Curacao indicates that it is difficult to eradicate, possibly the best method being by the use of fire (Debrot, pers. obs.). It is naturalized in the ABC and is widespread along country roads in Curacao and Bonaire (Debrot, pers. obs.) including conservation areas as the result of dumping garden clippingsa nd successive asexual reproduction. The plant was observed on Saba (Team obs.).

Kalanchoe pinnata (Lam.) Pers., syn. *Bryophyllum pinnatum* (Lam.) Oken (SSS)– Mother-in-law, loveplant

Kalanchoe pinnata is a succulent plant native to Africa and India which has been introduced to many temperate and tropical regions of the world as an ornamental. In several of these regions, the species is widely naturalised and regarded as invasive. It forms dense stands in dry and disturbed areas. In French Polynesia, *Kalanchoe pinnata* has been declared a threat to biodiversity (GISD 2011). *K. pinnata* is reported as naturalized in Bermuda (Kairo *et al.* 2003). It is mentioned by Boldingh (1909) for all three Windward islands. The plant was observed flowering on Saba (Team obs.).

Figure 22. *Kalanchoe pinnata* flowering on Saba

Lawsonia inermis L. (A, C) – Reseda, miminet, henna

The species is probably native to East Africa and India (Howard 1989 vol 5). Boldingh (1913) mentions it as cultivated for all six Dutch Caribbean islands (see also Howard 1989 vol 5). According to Arnoldo (1971) and van Proosdij (2001) it is naturalized on Curaçao and Aruba in several areas. It is widely grown throughout the tropics and frequently escaped and naturalized (Howard1989 vol 5). It has been used since the Bronze Age to dye skin (including body art), hair, fingernails, leather, silk and wool (Wikipedia 2011, Cannon & Cannon 1994). It is naturalized in the West Indies where it is known as West Indian mignonette (Cannon & Cannon 1994).

This species has spread through seasonal gully habitat throughout the island of Curacao and is present in low-lying areas bordering salinas such as at Janthiel, Ascencion, Malpais, Hofi Pastoor and De Savaan.

Leucaena leucocephala (Lam.) De Wit (ABC, SSS) – Tumbarabu, mimosa, tantan

This species is a perennial shrubby tree legume native to Mexico and Central America and has been widely introduced as a fodder crop in the tropics and now is truly pantropical (Langeland *et al.* 2008; National Academy of Sciences 1980). It is able to survive on steep slopes, in marginal soils and in areas with extended dry seasons and very low rainfall (250 mm). It is highly resistant to pests and diseases (National Academy of Sciences 1980). Produces enormous quantities of seed and fruits yearround (Langeland *et al.* 2008). Boldingh (1913) mentions it as cultivated for all six Dutch Caribbean islands and naturalized on the SSS islands (see also Boldingh 1909). It has high invasive potential (Raghu et al 2005). In the Caribbean, this species is invasive in Jamaica, Bahamas, Haiti, Dominican Republic, Bermuda, Puerto Rico (Kairo *et al.* 2003).

Figure 23. *Leucaena leucocephala* in Emilio Wilson Estate (St. Marten)

In Curacao it has spread extensively and is also found inside the Christoffel Park. Is not found on limestone formations (de Freitas, pers. obs). Its foliage contains mimosine, toxic to

ruminants if consumed in excessive amounts, and it is highly resistant to pests and diseases (Firewood crops 1980). According to Arnoldo (1967) its deep roots permit it to survive dry seasons well. Arnoldo does not mention it as invasive: he even recommends it to be planted more to serve as food for goats and sheep, and also because it is very resilient after coppicing. Arnoldo (1967) only mentions it is as naturalized near Julianadorp.

It is common on all islands, especially on St. Eustatius where it begins to dominate areas near Venus Bay and on St. Marten in the Emilio Wilson Estate and surroundings (Figure 23).

Leucaena leucocephala is a so-called 'conflict tree'. On the one hand it is widely promoted for tropical forage production and reforestation, while at the same time it is spreading naturally and is widely reported as a weed. It can form dense monospecific thickets and is difficult to eradicate once established. It is extremely fast growing and has immense biomass production. Masses of fibrous surface roots cause increased root competition. Toxic allelochemicals such as mimosine are released from leaf litter and suppress understory growth (Langeland *et al.* 2008). It produces also deep roots to 5 m that exploit underground water. It renders extensive areas unusable and inaccessible (Langeland *et al.* 2008) and threatens native plants.

Luffa aegyptiaca Mill., syn. *Luffa cylindrica* M.Roem. (C) - Sebete di pober.

Escaped on Curaçao (Arnoldo 1971; van Proosdij 2001). Probably native to tropical Asia and Africa, but cultivated and subspontaneous in the tropics generally (Howard1989 vol 6)

Mangifera indica L. (ABC, SSS) - Mango

Native to indo-Malesia, but widely cultivated and naturalized throughout the tropics (Howard 1989 vol 5). Cultivated on all six Dutch caribbean islands (Boldingh 1913). Naturalized/escaped on Saba, St. Eustatius and St. Martin (Boldingh 1909). This species is invasive in Antigua and Puerto Rico (Kairo *et al.* 2003).

Megathyrsus maximus (Jacq.) B.K.Simon & S.W.L.Jacobs, syn. *Panicum maximum* Jacq. (C, SSS) – Gini grass, Guinea grass, green panic grass

This important tropical forage is native to tropical West Africa and is cultivated and naturalized in the tropics of both hemispheres (Stoffers 1963; Howard 1979 vol 3). It is reported as invasive in Jamaica, Puerto Rico and the Dominican Republic (Kairo *et al.* 2003). Formerly considered the most important cultivated forage grass in tropical America and is now a weed throughout the Americas. It possesses strong allelopathic activity and thrives in full sun to deep shade (Langeland *et al.* 2008). A serious weed in Australia, Bermuda, Costa Rica, Cuba, Ecuador, Mexico, Puerto Rico,

Figure 24. *Megathyrsus maximum* (Saba)

Africa and Venezuela (Langeland *et al.* 2008). Can be toxic to mammals and causes pollen allergies and contact dermatitis in humans (Langeland *et al.* 2008). *Panicum maximum* is naturalised on the Windward Islands (Boldingh 1909) and also present on Curacao (Stoffers 1963, Arnoldo 1971).

Melaleuca quinqenervia (Cav.) S.T.Blake (-) – Paper bark, white bottlebrush tree, cajeput

This species is invasive in Puerto Rico, the Bahamas, Jamaica and the Dominican Republic (Kairo *et al.* 2003). Using climatic modelling, Watt *et al.* (2009) found considerable scope for further invasion potential within the Caribbean, Central and South America and the Gulf coast in southern USA.

Native from Burma through Malaysian Peninsula to Molucca Islands and also to Australia. This ornamental tree is fast growing and resistant to wind, drought, fires and salt water. Planted and naturalized in tropical areas. Scattered in the West Indies (Little *et al.* 1974). This species is invasive in Puerto Rico, the Bahamas, Jamaica and the Dominican Republic (Kairo *et al*. 2003).

The broad-leaved paper bark tree can reach heights of 25 meters and hold up to 9 million viable seeds in a massive canopy-held seed bank (GISD 2011). Formerly promoted as late as 1970 as one of Florida's best landscape trees. This tree grows extremely fast, producing dense stands that displace native plants, diminish animal habitat and provide little food for wildlife (Langeland *et al.* 2008). It prefers seasonally wet sites, but also flourishes in standing water and well-drained uplands. It flowers and fruits all year and flowers within two years from seed (Langeland *et al.* 2008). Present on Bonaire, Curacao and St Eustatius.

This tree species is notoriously difficult to control, however, bio-control (integrated with herbicidal and other methods) holds a promising alternative to traditional control methods. (GISD 2011). Three biological control agents have helped to reduce the acreage it occupies in Florida significantly while others are being tested or studied (Langeland *et al.* 2008). It resprouts easily from stumps and roots (Langeland *et al.* 2008).

It is reported to be a source of respiratory problems due to the presence of abundant volatile oils in the leaves and pollen, although there is no empirical evidence to support this (Langeland *et al.* 2008).

Melinis repens (Willd.) Zizka, syn. *Tricholaena repens* (Willd.) Hitchc., *Rhynchelytrum repens* (Willd.) C.E.Hubb. (ABC, SA, SM) - Natal grass, yerba de Natal

Native to Africa (Langeland *et al.* 2008) and now widespread in the Americas and there frequent on open roadsides and on dump sites (Howard 1979 vol 3). Invasive in the Dominican Republic (Kairo *et al.* 2003). It can occur across a wide variety of habitats (both disturbed and natural), can form dense monocultures in native vegetation and grows well in arid or semiarid areas (Langeland *et al.* 2008). It can also tolerate many soils, including limestone, sand, nutrient-depleted soil and soil contaminated with heavy metals. It can also tolerate strong winds and acute erosion (Langeland *et al.* 2008). It reproduces quickly from wind-dispersed seed (Langeland *et al.* 2008). It is recognized as a worldwide grass weed and is invasive in Australia, New Zealand, Southeast Asia, China, throughout the Pacific and Indian Ocean Islands, Japan, the Mediterranean, and South and Central America (Langeland *et al.* 2008). It is present on all three Leeward islands as well as Saba and St. Martin (Stoffers 1963; van Proosdij 2001).

Moringa oleifera L. (B, C; SSS) – Benbom, moringo

Boldingh (1909) mentions it for St Eustatius, Saba and St Martin, where he observed them along roads.

Figure 25. *Moringa oleifera* on Saba

Probably native to northern India and Pakistan (Howard 1988 vol 4). Cultivated and persisting after its introduction into the New World Tropics. Introduced to the West Indies by the French around 1782 (Howard 1988 vol 4). Arnoldo (1971) mentions escapes from cultivation on Bonaire and Curacao, and cultivated on Aruba and the Windward islands. This observation of escapes on Bonaire and Curacao cannot be confirmed however (De Freitas). The trees are usually close to roads in urban areas. A cultivated tree was observed on Saba (Team obs.)

Nephrolepis hirsutula (G.Forst.) C.Presl, syn. *Nephrolepis multiflora* F.M.Jarrett ex C.V.Morton (SA) – Scaly swordfern

This is an Old World species naturalized sporadically in the Antilles, Mexico to Peru, and Brazil. It is reported as invasive in the Bahamas and Dominican Republic (Kairo et al. 2003). Lellinger (2002) found it to be common along roadsides, in hurricane-damaged moist forest and rain forest on Saba. Kairo *et al.* 2003 considers the plant invasive in the Bahamas and the Dominican Republic. Howard (1977) warns that identification of this species in the West Indies is doubtful and probably concerns a small form of *Nephrolepis biserrata*.

Lellinger (2002) points out that *Nephrolepis multiflora* is often dominant and persistent in formerly cultivated fields. The native tree ferns (*Cyathea arborea* and *C. muricata*) seem incapable of germinating and growing through *Nephrolepis* mats and can therefore not put into motion normal successional processes (Lellinger 2002). Slocum *et al.* (2006) have developed a strategy for dealing with anthropogenic fern thickets in similar habitats in the Dominican Republic. Several clearly different species of *Nephrolepis* have been observed by the team on Saba. In the absence of good reference material (floras, herbarium) no definite identification could be made.

Figure 26. ***Nephrolepis cf. hirsutula*** **on Saba.**

Oeceoclades maculata (Lindl.) Lindl. (C, SE, SA) – Monk orchid

Oeceoclades maculata is a terrestrial orchid which originates from Africa. It appears to be of relatively recent introduction to the French Antilles and Florida, and is a species with invasive behaviour. Its self-fertilising mode of reproduction and profuse production of air-dispersed seed are factors that assists its spread (GISD 2011, Langeland *et al.* 2008). Cohen & Ackerman (2009), describe it as an aggressive exotic which is most abundant in forests with moderate historical disturbance but found along the spectrum of land-use history up into to old growth forest. It has a remarkable ecological amplitude including both moist to wet and dry forests and has a preference for deep shade and flat terrain (Cohen & Ackerman 2008, Langeland *et al.* 2008). It grows on limestone, in leaf litter, on decaying wood and in humus-rich soil. On average 50% of the flowers set fruit, but each fruit can produce thousands of microscopic, wind-dispersed, buoyant seeds that are up to 98% fertile (Langeland *et al.* 2008). It Puerto Rico it was first noted in the mid-1960s and has rapidly spread throughout the island (Cohen & Ackerman 2008).

Panicum maximum Jacq. – see *Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L.Jacobs

Panicum purpurascens Raddi - see *Urochloa mutica* (Forssk.) T.Q.Nguyen

Parthenium hysterophorus L. (ABC, SSS) - Basora di liber, whitehead, Santa Maria feverfew

Van Proosdij (2001) mentions it for all three Leeward islands f the Dutch Antilles, Howard vol 6 (1989). Boldingh (1909) notes it both for all three Winward islands. *Parthenium hysterophorus* is an annual herb that aggressively colonises disturbed sites. Native to Mexico, Central and South America, Parthenium hysterophorus was accidentally introduced into several countries including Australia, India, Taiwan and Ethiopia. In some areas it has become an extremely serious agricultural and rangeland weed (GISD 2011). *P. hysterophorus* has proved to be toxic to many people as a contact poison causing oedema and swelling with strong itching (Howard1989 vol 6).

Figure 27. *Parthenium hysterophorus* on St. Eustatius

This species is an early successional species typical of tilled fields in Curacao, Bonaire and Aruba. It is also found in vegetable growing fields on St Eustatius (team obs., 2011). Ellison & Bareto 2004 indicate that the fungal pathogens *Puccinia abrupta* Dietel and Holw. var. *partheniicola* and *P. melampodii* have been used as biological control agents against this species.

Pennisetum purpureum Schumach. (ABC, SM) – Napier grass, elephant's grass, hierba elefante

Cultivated on ABC and St. Martin (Stoffers 1963, Arnoldo 1971). A known fodder grass from tropical Africa (Arnoldo 1971), cultivated as a forage plant in the warmer parts of the world, occasionally persisting as an escape (Howard 1979 vol 3). In Florida invasive in both disturbed as natural areas (Langeland *et al.* 2008). Invasive on Bahamas and Puerto Rico (Kairo *et al.* 2003). Also naturalized and weedy in California, Hawaii, Puerto Rico and the Virgin islands (Langeland *et al.* 2008). Grows well on a wide range of soils and in many habitats, very drought resistant; can form "reed jungles" in rich, moist soils. Forms dense clumps by extensive tillering, propagated vegetatively by root crown divisions or rhizome and stem fragments. Able to persist in changing conditions due to an extensive, deep fibrous root system. Does not readily produce viable seed in many countries (Langeland *et al.* 2008).

Philodendron giganteum Schott (SA, SE)

Philodendron giganteum is present on Saba and St. Eustatius (Howard 1979 vol 3). On The Mountain ('Mt Scenery' Saba) and the Quill, St Eustatius (Boldingh 1909). Distributed in Tropical America and is native to Dominica, Guadeloupe, Martinique, Montserrat, Saba, St. Eustatius, St. Kitts, St. Vincent (Broome *et al.* 2011). On Saba it massively invades abandoned farmland on the slopes, smothering all other vegetation and entering the natural vegetation (team obs., Figure 28).

Figure 28. *Phildendron giganteum* as invasive (Saba)

Prosopis juliflora (Sw.) DC. (ABC) – Mesquite, indju, cuihi, kuida

Native from southeastern United States south through Mexico and Central America to Colombia and Venezuela. Through West Indies, apparently introduced and naturalized, from Bahamas and Cuba to Barbados and Trinidad and in the ABC islands (Boldingh 1913, Little & Wadsworth 1964, Stoffers 1973). In secondary, dry communities at lower altitude; very common in thorny thickets, cactus-thorn scrub and Croton-Lantana-Cordia thickets (Stoffers 1973). This tree is salt-resistant and is found in salina and mangrove vegetation (Beers *et al*. 1996, De Freitas, pers. obs.). It may be native in the ABC islands which are located close to its natural range in arid norther Venezuela. *Prosopis* has been introduced to many Caribbean islands but has become naturalized in the Dominican Republic and is invasive in Puerto Rico (Kairo *et al.* 2003). It is considered an aggressive invader and is to be tried only in very arid problem sites. It should be kept off the islands where it is not yet present. Elsewhere the problem it causes might be too immense. The tree is found growing from sea level to 1,500 m

Figure 29. *Prosopis juliflora* (Bonaire)

and thrives on a variety of soils provided that root growth is not impeded. The plant's roots penetrate to great depths in search of soil moisture.

Psidium guajava L. (ABC, SSS) – Guava, guyaba

Native to tropical America, generally cultivated and extensively naturalized in tropics and subtropics of both Old and New World Tropics (Howard 1989 vol 5; Langeland *et al.* 2008). This fruit tree and ornamental has been introduced to practically all Caribbean islands (Boldingh 1913), naturalized on SSS (Boldingh 1909; Arnoldo 1971) but has become invasive in the Bahamas, Puerto Rico and Bermuda (Kairo *et al.* 2003). It grows rapidly and invades a variety of habitats including coastal areas. Tolerates shade and forms dense thickets. It flowers and fruits all year and has high seed production (Langeland *et al.* 2008).

Pteris longifolia L. – Longleaf brake
Pteris tripartita Swartz (SA)
Pteris vittata L. (SA) – Chinese brake, ladder brake

The genus *Pteris* contains a number of ferns present in the Caribbean. The three named here are known or suspected invasives. The correct identification is difficult and people may mix up the species. Therefore, and because of similar biology and behaviour, they are treated collectively here. *P. longifolia* is a fern recorded from Bermuda, Puerto Rico and the Virgin Islands (USDA 2011b). Other locations are Hawaii and Alabama, USA. According to Stoffers (1962) the species is native to the Caribbean and from Mexico to Brazil.

Figure 30. *Pteris cf. vittata* on Saba

Pteris vittata is native to the Old World Tropics and cultivated as an ornament; introduced and naturalized in Florida and southern United States, Virgin Islands, Trinidad and perhaps other localities (Howard 1977 vol 2). Chiefly on old walls and calcareous banks at lower elevations (Howard 1977 vol 2). Stoffers (1962) states that is widespread in tropical America and maybe found on the Windward Islands and is closely related to *P. longifolia* from which it differs chiefly in its more strongly ascending, non-articulate pinnae. In south Florida it is one of the most frequently occurring non-native plants (Langeland et al. 2008). Naturalized throughout the Caribbean, Central and South America, Italy, South Africa and New Zealand; rapidly spreading through India and other tropical areas (Langeland et al. 2008). Its spores cause allergic reactions in humans and spore extracts are damaging to human DNA.

Pteris tripartita is an Old World species that is widely naturalized in the Antilles and South America. Lellinger (2002) reports it along trails in Saba. It grows on wooded hillsides and shaded banks at mid elevations (Howard 1977 vol2).

Figure 31. *Ricinus communis*, castor (Bonaire)

Ricinus communis L. (ABC, SSS) – Castor, karpata

Castor is a perennial shrub that can assume a tree-like status if it establishes in a suitable climate. It is frequently found invading riparian areas where it displaces native vegetation, during early succession, after which it disappears. The seed of this species is toxic to a variety of species including humans. Consuming only a few seeds can be fatal. Kairo *et al.* (2003) report this species as naturalized in Curacao. It is frequent along roads in Bonaire (Team obs.).

Sansevieria hyacinthoides (L.) Druce, syn. *S. guineensis* Willd. (ABC, SSS) - Yerba di kolebra, rhamni

Figure 32. *Sansevieria sp.* on St. Marten

S. hyacinthoides is native of South Africa and widely cultivated, present on all six Dutch Caribbean islands, and commonly escaping and persisting (Boldingh 1909, 1913, Howard 1979). It is not mentioned in Arnoldo (1971). Introduced to Florida around 1800 as an ornamental and fiber crop and escaped in the wild and deemed a public nuisance by 1951 (Langeland *et al.* 2008). One of the six "worst plant invaders" in the Florida Keys (Langeland *et al.* 2008). Quickly escapes cultivation and penetrates native vegetation, forming extensive

underground rhizome beds and dense aboveground thickets (Langeland *et al.* 2008). Can set seed and spread by rhizomes from garden waste (Langeland *et al.* 2008). Naturalized in Puerto Rico, the Virgin Islands, Central America and Australia (Langeland *et al.* 2008).. Restrictions apply in Sanibel Island and Miami-Dade (Langeland *et al.* 2008). Grows well in sandy ground and in full sun to partial shade. It is drought tolerant, with crassulacean acid metabolism that may allow improved drought and heat resistance (Langeland *et al*. 2008). Vegetatively reproduces from leaf cuttings as well as rhizomes (Langeland *et al.* 2008). Tough, leathery leaves and stout, extensive rhizomes make plant difficult to control and manual removal may be required (Langeland *et al.* 2008). May take 6-12 months to die after herbicide applications and follow-up treatments are often necessary (Langeland *et al.* 2008).

Sansevieria trifasciata Prain (ABC, SSS)

Native to Africa and southeast Asia (Kingsbury 1988). Naturalized on St. Maarten and cultivated on the other five Dutch Caribbean islands (Arnoldo 1971, Howard 1979 vol 3). The species is easily confused with *S. hyacinthoides*.

Scaevola taccada (Gaertn.) Roxb. (B, C) - Beach naupaca

In its native range in the tropical and subtropical pacific and Indian oceans, this species is a dominant shrub in coastal strand communities (Goldstein *et al.* 1996). It is a hardy plant used widely as an ornamental in beach landscaping and used for habitat restoration in the Pacific (Komdeur & Pels 2005). Elsewhere in the region, the species is invasive in the Bahamas (Kairo *et al.* 2003) and Cayman Islands (GISD 2011). In Curacao and Bonaire it is rapidly invading strand vegetations and may replace the rare native species *Scaevola plumieri*, which plays a similar ecological role in the tropical and subtropical atlantic (*S. taccada* is especially abundant on the beaches of Klein Bonaire, whereas *S. plumieri* is most abundant on Bonaire at Sorobon. *S. plumieri* is further found sporadically along the shores of Curacao (*e.g*. Rif, Piscadera) and Klein Curacao where this native species has been successfully used for habitat restoration Debrot, pers. obs). Manual eradication would seen feasible, if accompanied by a prohibition for use in landscaping. The native *S. plumieri* should be used for landscaping instead.

Figure 33. *Scaevola taccada* on Bonaire

Schinus terebinthifolia Raddi (C) - Brazilian pepper

This species is an aggressive invader native to South America and has invaded most habitats in Florida, from upland pine forests to freshwater salt marshes and mangrove forests (Ewe *et al.* 2007). It was introduced there in the mid 1800s but not recognized as a threat until the 1950s (Donelly *et al.* 2008). By 1997 it occupied some 700 thousand acres throughout the state of Florida. Its invasion has been significantly aided by changes in soil properties caused by agricultural disturbance (Li & Norland 2001). Like many other invaders, the species uses allelopathic chemicals to its advantage where the species in its invasive range have not had the opportunity to develop co-evolved defensive strategies (Donelly *et al.* 2008). Its salinity tolerance may provide it significant advantages to native species in the mangrove-terrestrial transition zones. In the greater Caribbean it is reported as invasive in the Bahamas, Puerto Rico and Bermuda (Kairo *et al.* 2003). The species is not mentioned by Arnoldo (1964). In Curacao in recent years only a few specimens were noted spread in the area of Jan Thiel (lagoonal area on the leeward coast). Perspectives for eradication are still good.

Senna bicapsularis (L.) Roxb., syn. *Cassia bicapsularis* L. (ABC, SA, SE) – Yellow candlewood, brusca dushi, trommelstok

Figure 34. *Senna bicapsularis* on Bonaire

Native of the Old World tropics, this shrub or small tree is present on Bonaire (team obs.) as well as on Aruba and Curacao (Arnoldo 1964, Van Proosdij 2001), It is now also found on Saba, especially near the harbour, and on St. Eustatius (team obs.).

Senna italica Mill., syn. *Cassia obovata* Collad. (ABC, SA, SM)– Seneblá

Native of the Old World tropics. Common weed on waste places (Stoffers 1973). Established on ABC islands and St. Maarten (Boldingh 1909; Stoffers 1973; van Proosdij 2001; pers. obs. De Freitas on Aruba).

Syngonium podophyllum Schott (SA) – Arrowhead vine

Syngonium podophyllum is an ornamental vine native to Central and parts of South America that has established invasive populations in the United States, South Africa, Singapore, the Carribbean, and on several Pacific islands. It may establish dense populations that displace native plants and grow over native trees (GISD 2011). The plant invades natural forest on Saba (Team obs.). The species is not mentioned by Arnoldo (1964).

Figure 35. *Syngonium podophyllum* on Saba

Tabebuia heterophylla (DC.) Britton (ABC, SSS) - White cedar

Kairo *et al.* (2003) indicate this species as invasive in the Dominican Republic. It has also become a problem in areas of the Pacific (Global Invasive Species Database 2010). The species has long been introduced in the ABC islands and is now naturalized on the island of Klein Bonaire. Prospects for eradication are very good as numbers are very limited (pers. obs., Debrot). In Boldingh (1913) it is mentioned as *Tecoma leucoxylon* Mart. for the Windward Islands (SSS) and is not mentioned as cultivated for these islands.

Figure 36. *Tabebuia heterophylla* on St. Eustatius

Tecoma stans (L.) Juss. ex Kunth (ABC, SSS) - Yellow bells, yellow elder, trumpetbush

Figure 37. *Tecoma stans* on Saba

Tecoma stans originates from South America and is mentioned as cultivated for all six islands of the Dutch Caribbean in Boldingh (1913) and Arnoldo (1971).Tecoma stans is a shrubby tree (tropical America: Arnoldo 1971) that prefers dry disturbed habitats. In the Pacific and Indian Ocean it is reported to develop thick stands to the exclusion of native species (GISD 2011). While at this point it is not yet invase in Curacao, it has naturalized to suitable habitat in many places on the island. Kairo *et al.* (2003) indicate this species as invasive in the Dominican Republic. *Tecoma stans* can form dense stands competing with native vegetation on the Cayman Islands (Varnham 2006, GISD 2011).

Tithonia diversifolia (Hemsl.) A.Gray (SA) – Mexican sunflower

Tithonia diversifolia is an herbaceous stoloniferous perennial which can reach 2 to 3 m high. Originally from Mexico and Central America, it is planted and cultivated in many countries for its attractive flowers. *Tithonia* tolerates heat and drought and can rapidly form large herbaceous shrubs. Naturalised in some Pacific islands, it is found along roadsides and in disturbed areas. Rapid vegetative reproduction and significant production of lightweight seeds allow *Tithonia* to quickly invade disturbed habitats. In forming dense stands, it prevents the growth of young native plants. *Tithonia* is invasive in some parts of Africa and Australia and in many Pacific islands (GISD 2011). *Tithonia* was observed on Saba (team obs.)

Urochloa mutica (Forssk.) T.Q.Nguyen, syn. *Brachiaria purpurascens* Raddi, *Panicum purpurascens* (Raddi) Henr. (ABC, SSS) - Paragras, Para grass, hierba de Pará

Para grass, probably a native of tropical South America, can grow to heights of two meters, it is found growing in wet fields, ditches and gullies from sea level to 700m. It forms dense monotypic stands by layering of trailing stems and can overgrow shrubs and native vegetation in the habitats it invades. It also has a mild allelopathic effect. It can tolerate brackish water and interfere with stream flow due to its highly aggressive invasive habit (GISD 2011). Cultivated and naturalized in the tropics and subtropics as a forage grass (Stoffers 1963). Present on all six Dutch Caribbean islands (Stoffers 1963). Habitat: low, moist meadows, mostly as an escape from pasture plantings (Howard 1979).

Ziziphus mauritiana Lam. (A, C, SE, SM) – Indian jujube, Indian plum

Native to Asia and Africa, cultivated and frequently naturalized from southern Florida and California through Mexico, Central America and the West Indies to South America (Howard 1989 vol 5). Naturalised in Barbados, Jamaica, Guadeloupe, Martinique and Puerto Rico (Kairo *et al.* 2003). Naturalized/Escaped on St. Eustatius and especially St. Maarten; cultivated on Aruba (Arnoldo 1971; Boldingh 1909; Stoffers 1984) and Curacao (Debrot, pers. obs.). Stoffers (1984) does not mention its occurrence on St. Eustatius. It was frequent on St Marten, for instance in Emilio Estate (team obs.).

Ziziphus spina-christi (L.) Desf. (ABC) – Christ's thorn, apeldam, pomme cerette

Ziziphus spina-christi is originally from western Asia and northern Africa; in 1885 introduced from Palestine into Curacao and naturalized (Stoffers 1984). *Z. spina-christi* is mentioned as cultivated on Curacao by Boldingh (1913). Arnoldo (1962) mentions it for Aruba, Bonaire and Curacao. It is naturalized on Aruba and Curacao (Arnoldo 1971). Van Proosdij (2001) adds that it is also escaping into the wild.

4.1.2. Most important problem species

Our review of the large number of exotic plants that have established themselves, are naturalized or are invasive show that the most serious problem species are *Antigonon leptopus, Cryptostegia grandiflora, Azadirachta indica* and *Bothriochloa pertusa.*

Here we discuss options and make recommendations on how to deal with these problem species. Some are so abundant on certain islands that complete eradication is impossible. This is for instance the case with *Antigonon* on St Eustatius. Others like *Cryptostegia* seem to cause problems only on the Leeward islands. There eradication or control shall be taken seriously before the loss of biodiversity becomes serious and the costs of control become prohibitive. In any case, the spread of these plants should be contained (mitigation. Finally there is a large group of plants with known invasive properties, causing damage elsewhere, but which are not showing such behaviour on in the Dutch Carribean Netherlands yet. These species shall be prevented from entering the islands (see 4.1.3).

4.1.2.1. Antigonon (Corallita, Bellísima, Coral vine)

4.1.2.1.1. Description

Antigonon leptopus Hook. et Arn., Polygonaceae, is the most problematic invasive plant in Caribbean Netherlands, most notably on St. Eustatius. There it covers whole areas overgrowing the natural vegetation and going up as high as over tree tops, thus smothering them to death (Figure 40).

4.1.2.1.2. Occurrence

Native of Central America (Arnoldo 1971), this ornamental escapes from gardens. This attractive vine has established itself many years ago in disturbed habitats, especially wasteland and abandoned agricultural fields. Despite extensive search by the team on Bonaire, St. Eustatius and Saba as well as asking around, it appears not to enter dense vegetations of the nature parks. It stops at the boundaries, indicating that it needs some disturbance or open area to germinate and establish itself. Once established it is very difficult to eradicate, since it forms underground tubers that go as deep as up to 2 m (Ernst & Ketner 2007).

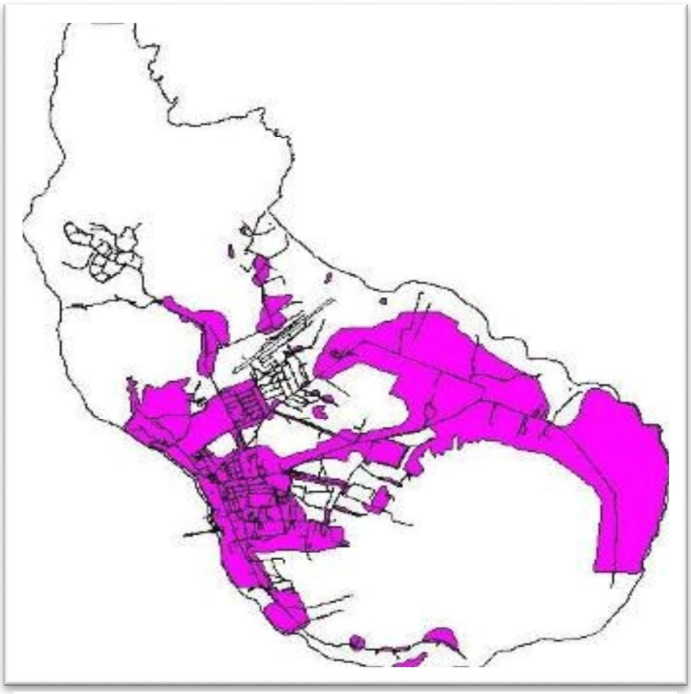

Figure 38. Distribution of *Antigonon* in 2007 (Ernst & Ketner 2007)

It is not clear how the seeds (strictly nuts, so fruits) are being transported. Langeland *et al.* (2008) report that the seeds are dispersed by animals such as birds and pigs); Burke & DiTommaso (2011) mention that they are buoyant and can spread via runoff water. The seeds are mechanically very tough (woody pericarp) and can survive in soil for many years, and new seedlings can be expected for

Figure 39. *Antigonon* climbing over the fence (Bonaire)

a number of years after the clearing. The fruits stay long on the plant. Once on the ground they are reported to decay from fungus and insects, and only a few seedlings are observed (Stenapa 2007). The seeds have become an important food of the native pigeon *Columba corensis* (Debrot pers. obs.), but since pigeons usually digest seeds completely (having a grinding stomach with stones) they do not disperse the seed, on the contrary. This contradicts the observations by Langeland *et al.* (2008).

Ernst & Ketner (2007) report that dispersal of the plant is mainly through 'stem and root cuttings and tubers'. In heavily infested areas up to 280 tubers per m2 were found. It is quite possible however, that these tubers originate from seeds rather than 'cuttings'.

Research into the biology of the coral vine seems to be essential for an effective eradication programme.

Figure 40. *Antigonon* covering trees and shrubs (St. Eustatius)

4.1.2.1.3. Options

Attempts to develop eradication methods using boiling water (Ernst & Ketner 2007) did not result in a permanent solution because the tubers cannot be reached. Fields cleared with bulldozers show an almost immediate reappearance of coral vine from the underground parts. Chemical control with the systemic herbicide glyphosate is an option. Efficacy of this herbicide will be best when applied at young regrowing shoots. No biological control options are available.
It is our view that a permanent solution can only be found if the treated land is freed from all above ground parts and this is being followed up during a number of years thereafter. This could be in the form of grassland or permanent agriculture or horticulture. In addition, the coral vine must be removed from the surroundings. Minimum soil disturbance which is the case with established grassland or maximum control in the case of intensive horticulture, therefore seem the best options. All these measures will also be a prerequisite for attempts to re-establish nature, as planting indigenous trees and shrubs will fail due to the competitiveness of coral vine.

Figure 41. Antigonon infested with mealy bugs (St. Eustatius)

One option could be to cover areas in which the coral vine has been removed by large plastic sheets so that regrowth can be prevented. Reforestation of those areas can be done by making small holes in the sheets in places where the indigenous plants (trees) will be planted.

Although there seem to be very few cases of coral vine entering undisturbed natural habitats, this may prove to be just a matter of time: they have been observed in the trees at the edges and since the seeds disperse quite freely, it is important that action is taken. Also, disturbance by man and livestock are pervasive and persistent problems on all islands. Practically no areas are free from disturbance.
Cattle and goats have not been observed eating it, so foraging can be no essential part of a solution. On St. Eustatius the plant has been observed to be predated by mealy bugs (Figure 41).

4.1.2.1.4. Recommendations

Recommendation 1: Coral vine or corallita shall be removed from trees and shrubs in the neighbourhood of natural vegetations as soon as possible (Bonaire, Saba). On Statia a larger effort would be needed. Eradication is not possible, but mitigation and saving indigenous trees should have the highest priority.
Recommendation 2: Coral vine growing on trees on St. Eustatius shall be cut at the base as soon as possible to prevent further damage to the native trees.
Recommendation 3: Removed plant parts (shoots and soil with roots and tubers) should not be dumped in the environment, e.g. on slopes out of the villages.
Recommendation 4: Chemical control with systemic herbicide like glyphosate (Roundup©, Triclopyr) is best carried out on plants recovering from cutting: these take up the active ingredient more rapidly and transport them to the roots and tubers.
Recommendation 5: In order to remove the coral vine permanently from an area it needs a number of years of close attention. One option is to grow quality grass and have cattle (cows,

donkeys, sheep or goats) graze it intensively. Another is to start farming or horticulture again using an intelligent sequence of crops (and maybe fallow in combination with intensive control). Finally, in some cases the use of plastic sheets to smother the plants may be prove effective.
Recommendation 6: The biology of the coral vine is not well understood. Especially the main forms of dispersal are unclear. Seedling germination and establishment and tuber formation must be studied in experimental setups as well as in nature.

4.1.2.2. Cryptostegia (Palu di leche, Rubber vine)

4.1.2.2.1. Description

Cryptostegia grandiflora R.Br., Apocynaceae, originates from Madagascar. It is a strong vine of 10-20 m length and branching. It produces hundreds of small seeds with a tuft of long hair per flower (Each pod containes 300-350 individual seeds, Grice 1996, QNRME 2004) that with a light wind can spread for many kilometers (figure 43). More than 90% of seeds will germinate within 10 days after planting in moist media. Few, if any, seeds survive for more than 12 months in the soil (Grice 1996). Notwithstanding, there are no observations of large amounts of seedlings anywhere in the Caribbean Netherlands. This may in part be explained by the gradual opening of the fruits and the wide spread of the seeds by the wind. The spreading and establishment seem less effective than one would expect. This may be due to the fact that most seeds reach unfavourable (dry) habitats. As all seeds, they require moist conditions to germinate.
The plant contains latex full of glycosides and is therefore not eaten by any local animal. It is reported to have killed weaners and even bulls that ate the leaves (QNRME 2004).

Figure 42.Native cactuses becoming overgrown by *Cryptostegia* (Bonaire)

Figure 43. Fruit of *Cryptostegia*. Each fruit half contains 100-150 seeds (Saba)

The vines grow several m per season and form a massive blanket over the native vegetation of cactuses, trees and shrubs. Once established, the vine is difficult to combat because of its perennial woody stems and similar underground parts. Moreover, the established thickets are impenetrable. It prefers riparian habitats, but can also grow in much dryer conditions where it may form impenetrable thickets. Grown as an ornamental it grows as small shrubs or bushes with only few

vines. This last habit can be observed in St. Martin (French side) along the main road (Figure 45) and on St. Eustatius near the oil terminal (team obs.).

Figure 44. Shrubs and trees completely overgrown by *Cryptostegia* (Bonaire)

4.1.2.2.2. Occurrence

On Bonaire it is found to grow prolifically near gullies ('Rooien'), and in the drier areas north of Rincón. It is not yet found in Washington Slagbaai National Park. On Klein Bonaire it is limited to a small number of plants and could be manually extirpated relatively easily (Debrot 1997).
On St. Eustatius it is only known as ornamental and not found or established outside these plantings. It is rarely found in downtown city and near the oil terminal where they stand along the road for many years already without creating offspring in the surroundings.

Figure 45. *Cryptostegia* planted along the coastal road in French St. Martin.

On Saba it is not yet considered a problem, although it is well established along the slopes near the harbour, where it assists in preventing erosion (Van 't Hof, pers.com.). It is a site that should be observed carefully. It is also found in the vicinity of Scout's Place.

On St. Marten it can be found along the NW coastal road (Figure 45); we did not see any escapes in the direct surroundings of this group of plants

4.1.2.2.3. Options

The plant is a notorious weed of Australia ranging between the "20 Weeds of National Significance". Many efforts have been made there during the past decades since its introduction around 1875. This includes the use of fire, which is not very successful, because the plants do regrow from the perennial stems. Bush fires, which are a natural occurrence in Australia, will only affect young seedlings and plants and thus may delay spreading (Grice 1997). Fires do not seem a viable option on the islands.
Another attempt in Australia was the introduction of natural enemies, like a leaf-feeding moth, *Euclasta whalleyi* Popescu-Gorj and Constantinescu (= *Euclasta gigantalis* Viette) and a rust fungus *Maravalia cryptostegiae* (Cummins) Ono (McFadyen & Harvey 1990). These seem to have been relatively successful (Mo *et al.* 2000, QNRME 2004).
In the early stages the moth was found to defoliate large patches of vine, but the last few years this effect became less in part due to its parasitisation by a native wasp. The risk exits of the wasp attacking native species that contain latex in their leaves.
Rubber vine rust, which was released between 1995 and 1997, has had a significant impact. It has been found on rubber vine in all areas but is less prevalent in the dryer western areas. It was observed to affect leaves but also the damages stubs after clearing, hampering them to grow out (QNRME 2004).

4.1.2.2.4. Recommendations

Recommendation 7: The self-propagating population on the hill slopes above the harbour of Saba should be monitored carefully. The plants have a shrubby habit and do not really overgrow or smother vegetation, but may act as a source for further spread over the island.
Recommendation 8: On Bonaire a campaign should be started to fight the spread of *Cryptostegia*. This can still be done by cutting the vines and burning them (or removal of all fruits). The stubs could be treated with glyphosate. Introduction of leaf cutters or rust fungi does not seem necessary at this stage. It has only recently spread to Klein Bonaire and very limited in number (Debrot 1997). Eradication on this island would seem relatively simple and should be carried out as soon as possible.
Recommendation 9: Rangers at Washington Slagbaai NP (Bonaire) should be extra vigilant for the presence of *Cryptostegia* and remove them before they start fruiting.

4.1.2.3. Azadirachta indica (Neem)

4.1.2.3.1. Description and occurrence

Azadirachta indica A.Juss., Meliaceae, native of India has been introduced in many countries as a so-called 'multipurpose tree'. This species has been widely introduced in tropical regions for wood production (e.g. Campbell 2005) and serve as an ornamental of medicinal value. It is listed as an invasive in Puerto Rico, Antigua, Barbuda and the Dominican Republic (Kairo *et al.* 2003), as well as in other areas where it is not native (e.g. Campbell 2004). For Australia, where it is also spreading rapidly, the assessment of its potential impact remains inconclusive (Csurshes 2008). In Bonaire it is especially appreciated for its fast growth, its lush foliage providing deep shade, its modest water requirement, and it is said to keep mosquitos out of the house. The tree has multiple uses, and the tree is especially planted for shade and medicinal uses. It is also said that planting the tree next to the house will keep mosquitos away. When establishing gardens in new zones people want a few trees around the house for shade. In the

Figure 47. *Azadirachta indica*, neem tree, escaping from a garden (Bonaire)

absence of large plantable young indigenous trees, landscapers tend to choose the neem tree to satisfy the wishes of customers. In a few years it will grow to 5-10 meters high. Disadvantage is that the tree produces fruits profusely. These are eaten by rats (*Rattus rattus*) and native birds (e.g. *Mimus gilvus*, Debrot pers.obs.), dropped elsewhere and the seeds germinate readily. Thus, the surroundings of a mature tree tend to become dominated by seedlings. This is a burden to gardeners, who need much time clearing them. This labour is not available for the surrounding nature, which results in an invasion of neem. Due to its invasive properties, the Peace Corps which formerly promoted the species, now discourages its propagation (Judd 2004).

Figure 46. Neem trees in Bonaire, with seedlings (left)

4.1.2.3.2. Options

The issue is controversial, because the situation is still not growing out of hand: the trees are not yet found very far from human settlements but are already invading ruderal and natural habitat. On Bonaire seedlings and young specimens were seen at Lima are found along the

coastal road from Barkadera to Tolo. A specimen of approx. 1 m was seen amongst the natural limestone vegetation of Lima. There were reports of neem seedlings in Washington Slagbaai (Bonaire), which could not be confirmed, and there are certainly no mature trees there yet. Likewise, it is said that neem is present at the Quill (St. Eustatius). One or two trees were observed, so there is ample opportunity to contain the problem by removing these (including the roots).
On Saba, the neem tree is rarely planted (none were observed by the team). No problems with escapes are known and none were found.

4.1.2.3.3. Recommendations

Recommendation 10: The spread of *Azadirachta* far from human settlements shall be controlled by cutting trees that establish themselves 'in the wild' before they start bearing fruit. This means before they reach a height of 4-5 m. The trees must be removed including the roots because it will otherwise return via coppice and root suckers.

Figure 48. Neem tree on the slope of The Quill (St. Eustatius)

Recommendation 11: The general public and specific and relevant organizations and knowledgeable persons should be asked to report occurrences in nature of this species to relevant organisations that will be responsible for the eradication of the specimens in nature.
Recommendation 12: Nurseries with indigenous shade trees shall be established, e.g. by the Dept. of LVV.

4.1.2.4. Botriochloa pertusa (Indian couch grass, hurricane grass, 'Donna grass')

4.1.2.4.1. Description and occurrence

The story goes that *Bothriochloa pertusa* (L.)A.Camus, Poaceae, arrived on St. Eustatius with hurricane Donna (1960), hence it is locally known as 'Donna grass'. Whether true or not, it marks the time from when on it became an important invasive. Now it is present all over the island and covers large parts, especially in the E and SE like English quarter. There abandoned farmland has now completely been converted into a sort of prairie with Donna grass as main component (Figure 50). Other plants and shrubs are disappearing and do not seem to be able to compete. The grassland provides no good grazing at present because the turf is not managed correctly (R. Hensen, pers. comm.). This grass is not fit for the present form of extensive grazing on St. Eustatius, resulting in tall growth and unpalatable flowering stems.

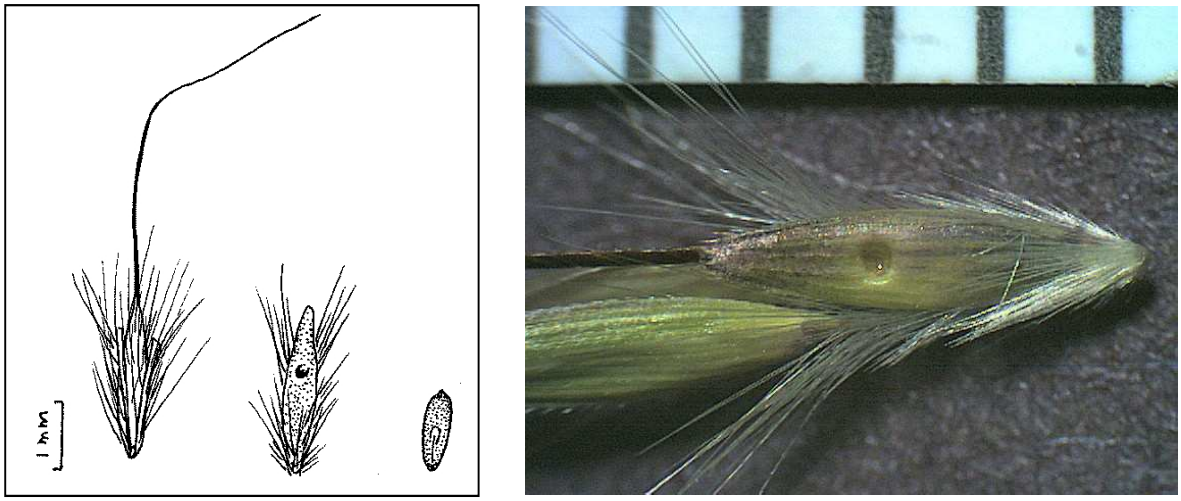

Figure 49. Left: Line drawing of florets and seed (original Joost van der Burg); right: Floret. Source: Grasses and Sedges and Rushes of Palm Beach and Martin Counties, Florida

Figure 50. *Bothriochloa*-dominated terrain with remains of vegetation

Indian couch grass, if correctly managed, is nevertheless generally appreciated for a number of characters: it is not very demanding, it provides a dense closed turf, it competes well with weeds, provides good quality forage and tolerates heavy grazing (Pastures Australia website, http://www.pasturepicker.com.au/Html/Indian_Bluegrass.htm). Disadvantages are that it is a small short grass which does not provide ample fodder in the dry season, and it becomes unpalatable after flowering.
The grass has also been noticed on Saba and St Martin.

Figure 51. Patches presumably grazed by donkeys are showing recovery of green foliage (St. Eustatius) (The broadleaf plants are mostly *Jatropha gossypifolia*)

4.1.2.4.2. Options

Eradication of this grass is no option: it is spread all over the windward islands. Mitigation and control seem the only options.

4.1.2.4.3. Recommendations

Recommendation 13: *Bothriochloa* grass needs fertilisation and intensive grazing, which leaves it longer in a vegetative state. When managed in this way, cattle will eat all of it so that it will not get bushy and will remain a closed turf. To achieve this, animals shall be allowed only on restricted patches, before they are moved on to a next plot. This is known as intensive rotational grazing (Whiteman 1980). This can be done with goats, but these are said to be 'picky' and do not eat all grass. This seems to favour *Bothriochloa* resulting in their uncontrolled increase. So it is important to force the goats to browse all grass available. Cows will not be able to browse it off shortly enough. It seems that donkeys browse the grass more intensively (Figure 51), but also here fencing should be applied to create a good pasture.
Recommendation 14: Research needs to be carried out to develop management systems with optimal fertilisation and grazing intensity.

4.1.3. Potential invasives, weeds and flora contamination

Pantropic weeds like *Argemone mexicana* L.*, Arivela viscosa* (L.) Raf. (*Cleome viscosa* L.), *Parthenium hysterophorus* L. and many others are a great burden to vegetable growers. These however are not invasives in the strict sense because they do not normally spread into nature and can be contained with common agricultural practices.

The list below contains species of which invasiveness is known or suspected elsewhere, but for which not sufficient information is available about their potential threat to the Caribbean Netherlands. Some are present but do not show signs of invasiveness yet. It is proposed that these species will be considered during future surveys.

The species marked with an asterisk (*) are, if imported from elsewhere (*e.g.* from Florida), a threat to biodiversity mainly through genetic contamination via cross breeding.

[Islands are abbreviated as A, B, C, SA, SE, SM or ABC, SSS]

Abrus precatorius L. – Rosary pea, paternosterboontje (B?, C, SE)

Abutilon hirtum (Lam.) Sweet – Hairy abutilon (ABC)

Achyranthes aspera L. (ABC)

Alysicarpus vaginalis (L.) DC. – Alyce clover, buffalo clover (C, SSS)

Annona muricata L. - Soursop (SSS)

Bergia capensis L. (B)

Boerhavia diffusa L. – Red spiderling (B, C, SA)

Bourreria succulenta Jacq.* - *Watakeli, palu di lora, mata di yuana,* chink, bambora (ABC, SSS)

Bursera simaruba (L.) Sarg.* -*Pal'i sia kòrá, Pal'i siya còrá,* West Indian birch (ABC)

Caesalpinia pulcherrima (L.) Sw. – Tuturutu, pride of Barbados (ABC, SSS)

Carica papaya L. – Papaya (SA, SE)

Cassia alata see *Senna alata*

Casuarina equisetifolia L. – She-oak (..)

Chamaecrista absus (L.) H.S.Irwin & Barneby – Tropical sensitive pea (ABC)

Citrus aurantiifolia (Christm.) Swingle – Lime (SA)

Coccoloba uvifera (L.) L.* - Sea grape (ABC, SSS)

Coccoloba swartzii Meisn.* - Kamalia, dreifi sihamron, red wood (ABC, SSS)

Commelina diffusa Burm.f. - Creeping spiderwort (SSS)

Commelina erecta L. – Watergrass (SSS)

Conocarpus erectus L.* – Buttonwood (grey form) (B, C)

Crotalaria incana L. – Silver rattlepod (SA)

Cucumis anguria L. - Kònkòmer chikí, concomer chikito, Pumpkin (ABC)

Cucumis dipsaceus C.Ehrenb. ex Spach – Kònkòmer/concomber shimaron, hedgehog gourd (ABC)

Cynodon dactylon (L.) Pers. – Brakgras salu, Bermuda grass (ABC, SSS)

Cyperus alternifolius L. – Umbrella plant, parapluplant (SM)

Cyperus nanus Willd. – Indian flatsedge (ABC)

Desmodium triflorum (L.) DC. – Three-flowered beggarweed (C, SE, SM)

Dioscorea alata L. – Yams, Greater yams (SA, SE)

Dioscorea trifida L.f. – Cush cush (SA, SM)

Eichhornia crassipes (Mart.) Solms – Water hyacinth (C)

Eugenia uniflora L. – Honeyberry, Surinam cherry (SA)

Euphorbia maculata L., syn. *Chamaesyce maculata* (L.) Small – Spotted spurge (ABC)

Hura crepitans L. – Sandbox tree (SM, SE)

Hydrilla verticillata (L.f.) Royle – Hydrilla, Florida elodea (A)

Ipomoea carnea Jacq. – Bush morning glory (A, C)

Lantana camara L. aggr.* - Flor di sanger, beishi, mata di sanger, common lantana (ABC, SSS)

Launaea intybacea (Jacq.) Beauverd - Kolo di konènchi, salada andeivi, langa di baca, (ABC, SE)

Leonotis nepetifolia (L.) R.Br. – Sabadía, a nase di kerkhòf, adonis abbot, (B, C, SA, SE)

Luffa sepium (G.Mey.) C.Jeffrey (C)

Martynia annua L. – Cat's claw (A, C)

Melia azedarach L. – Cape lilac, bead tree (SSS)

Melicoccus bijugatus Jacq. *('Melicocca bijugata')* - Kinnup tree (SSS)

Mirabilis jalapa L. – Beauty of the night, nachtschone (SA, SE)

Momordica charantia L. – Bitter gourd (A?, C, SSS)

Mucuna pruriens (L.) DC. – Velvet bean (SA)

Nerium oleander L. – Oleander (SA)

Nicotiana tabacum L. – Tobacco (ABC, SE, SA?, SM?)

Ocimum americanum L. – Yerba di hole, American basil (C, SM)

Ocimum Xafricanum Lour. – Hoary basil, lemon basil (B, C)

Ocimum gratissimum L. – Yerba di hole blanku, anis (ABC)

Oxalis corniculata . – Creeping oxalis, gehoornde klaverzuring (C, SSS)

Oxalis debilis Kunth in Humb. - Shamrock (SA)

Parkinsonia aculeata L. – Bonch'i strena, Wondertree, Jeruzalem thorn (ABC, SE, SM)

Pennisetum setaceum (Forssk.) Chiov. – Fountain grass, siergras (C, SA, SM)

Phlebodium aureum (L.) J.Sm. – Gold-foot fern (SA)

Pisonia aculeata L. – Cockspur vine (B, C, SA)

Pistia stratioides L. – Water lettuce (C)

Plectranthus amboinicus (Lour.) Spreng. – Soup thyme, stingy thyme, Cuban oregano (SA, SM)

Plumbago scandens L. – Toothwort (ABC)

Rhoeo spathacea Sw. (syn. *R. discolor* (L'Hér.) Hance) – Boat lily, oysterplant (SA)

Rhynchosia minima (L.) DC. – Yerba di lagadishi, jumby bean, least snout bean (ABC, SSS)

Senna alata (L.) Roxb. (S) – Christmas candle, ringworm bush (ABC, SSS)

Sesbania bispinosa (Jacq.) W.Wright – Prickly sesban (B, C)

Sesbania sericea (Willd.) Link – Papagayo (SM)

Setaria verticillata (L.) P.Beauv. – Bristly foxtail (C, SM)

Sorghum halepense (L.) Pers. – Aleppo grass, Johnson grass (C, SA, SM)

Sphagneticola trilobata (L.) Pruski, syn. *Wedelia trilobata* (L.) Hitchc. - .Creeping daisy, creeping oxeye (SA)

Spathodea campanulata P.Beauv. – African tulip tree (SA)

Swietenia mahagoni (L.) Jacq.- Mahok, mahogany (C)

Syzygium jambos (L) Alston – Jambos, rose apple (SSS)

Tamarindus indica L. – Tamarind (C, SSS)

Taraxacum officinale F.H.Wigg. aggr. – Dandelion (..)

Terminalia catappa L. – Almond, amandelboom (ABC, SSS)

Thespesia populnea (L.) Sol. ex Corrêa – Otaheiti, palu santu, seaside mahoe (ABC, SM)

Thevetia peruviana (Pers.) K.Schum. – Yellow oleander (SA)

Thunbergia alata Bojer ex Sims – Suzanne-met-de-mooie-ogen (SA)

Thymophylla tenuiloba (DC) Small – Dahlberg daisy (C, SA)

*Tradescantia (*incl*. Zebrina)* spp. – Wandering Jew and others (SA)

Tridax procumbens L. – Coat buttons, tridax daisy, erva de touro (A, C, SA, SM)

Triphasia trifolia (Burm.f).) P. Wilson – Lime berry (SA, SE)

Washingtonia robusta H.Wendl. – Washingtonia palm, Mexican fan palm (C)

Wedelia trilobata see *Sphagneticola trilobata*

4.2. Recommendations/priorities

Based on the literature review and the field observations in combination with the interviews recommendations are made that are either more generally relevant for the Dutch Caribbean (4.2.1) or more specifically for one of the islands (4.2.2-4.2.4).

4.2.1. General recommendations

The general recommendations are made with respect to the different phases in the invasion process (see 2.1.1). Before an exotic has been introduced *prevention* is the most important action, i.e. keep the chance that exotic species may be introduced as low as possible. As soon as a first introduction has been realised and the exotic still occurs at low densities at few sites, *eradication* after first observation will be the most important action. Finally, if an exotic has already spread over different sites or even different habitats and has increased in densities, eradication might not be an achievable option anymore. Then *containment* and *population management* will be the most relevant actions to minimise the negative impact *(mitigation)*. In general, prevention will generate the most cost-effective options to avoid problems due to invasive exotic plants (Davis 2009).

Prevention

- Prevention plans need to be developed for species that pose a potential threat. To this end Black Lists need to be adopted and enforced. Appendix II will offer a good start for this and may be extended with species from the list in paragraph 4.1.3. Separate lists must be developed for the Leeward and Windward Islands respectively, since they differ much in climate, especially when considering the rainforests on St. Eustatius and Saba. An organization should be given the responsibility to report and follow trends.
- Policy needs to be developed and regulations made so that unauthorised import of exotic plants (*i.e.* without an import permit) becomes an offence and legal measures can be taken. An effective enforcement will be very important. At this moment there is only very little opportunity (including budget) for inspections to prevent introduction of exotic species in transports by planes or ships. We observed that only on St Eustatius outgoing luggage is checked manually by customs officers. All islands should have the availability of more expertise on plants and animals in general and invasives in particular, combined with a stronger law enforcement. To this end, each island should have an agricultural department with adequate staff. Such a unit should work closely with the police and customs to protect nature from invasives. A permit system should be introduced for businesses to import new plant species to an island and import of plants by private persons should be better controlled.
- The efficacy of prevention actions will highly depend on public commitment. Communication and education are therefore key issues. Several stakeholders indicated that short radio messages will be a very effective way to communicate the risks of exotic species. Education programmes at primary and secondary school are also essential. We heard about successful lessons on the risk of exotics and the value of natural en cultural native plant species. However, these lessons have an occasional character. It is highly recommended to implement them in the formal education curricula.
- Information material needs to be developed especially for the new locals about the dangers of introducing exotic plants and the advantages of planting indigenous trees and other plants.
- Local trees must be promoted, by using them along city roads and by stimulating landscapers to use them for parks and gardens. Nurseries should be started to grow native trees to a certain height that will make them more attractive to plant in denuded and

disturbed areas and also for shade around the houses. At present there is a lack of knowledge about local tree species that are well adapted to an environment with drought, hurricanes and grazing goats, and still grow well. Research in collaboration with local experts (*e.g.* landscapers) should fill these knowledge gaps.

Eradication after first observation

- Rapid first observation of an exotic plant after introduction into the wild is essential for the success of an eradication action. Therefore 'Watch lists' (or 'Grey lists') need to be developed. Since the difference in climates, these watch lists will partly differ between islands and at least differ between Bonaire (and the other two Leeward Islands) and the Windward islands. Appendix II can be used to make a start with such watch lists.
- We observed that at present rangers have very little time and opportunity to make inspections of such first introductions. It is recommended to make such inspections a structural part of their work programme.
- A more thorough field survey has to be made to be able to get a complete picture (qualitatively as well as quantitatively) of all exotic, established and naturalised species, especially on the Windward Islands.
- A Flora for basic inventories, including those concerning exotics, is missing for the Windward Islands and shall be made. To this end, a liaison shall be established between Dutch universities and institutes and local authorities and ngo's.

Containment/population management

- Management plans need to be developed for the control *Antigonon*, *Cryptostegia* and neem to be able to stop further spreading and to mitigate the impact on nature. Such plans shall include regulations against transport and disposal of garden waste, measures to reduce the populations, priorities concerning which sites to control by priority, and last but not least information campaigns to create awareness and to get the support and involvement of the public.
- Research on the life cycle of invasives and experiments for their control have to be carried out. Control is often not effective. This is partly due to insufficient attention to the problems, but also due to lack of knowledge about the life cycle of the various species.
- Because the island communities are small with people having close relationships, and because it is a sensitive issue, the goat (and other feral animals) problem can not be solved by local authorities. For these animals it is advised that this issue is tackled by outsiders (*i.e.* from the Netherlands). A team of experts, composed of legalists, veterinarians, biologists, agriculturists, should go to the various islands, discuss the issue with all stakeholders and come with an approach that is tailored to each island. For exotic plants the issues are clearly less sensitive. However, policymakers should stay aware of possible public or political sensitivity with respect to containment of *e.g.* the neem tree (which as many uses) and look for possibilities to effectively respond to this attitude.
- Though in general non-chemical control of exotic plants will be a preferable option, use of herbicides might be required in certain situations. We found that stakeholders involved in plant protection are generally not aware of the legal aspects concerning which active ingredients and formulations are allowed. Since the new status of the Caribbean Netherlands the former law "Voorschriften bestrijdingsmiddelen" has been made valid for Bonaire, St Eustatius and Saba. This means that every person who would like to import a crop protection agent has to inform the local authority (Rijksdienst Caribisch Nederland) three months before. The Dutch Minister of Economic Affairs, Agriculture and Innovation may reject the request to import the product, may give a restricted permission to import or may simply allow import. If the Minister does not respond within 3 months after submission of the request, import is allowed without restrictions. We recommend that these regulations concerning the import and use of crop protection products like herbicides, are made broadly known among the stakeholders dealing with crop protection, as well as the public in general.

Some other general recommendations

- Since agriculture and horticulture have markedly decreased in importance in the Dutch Caribbean the last decades, the islands consists of many environments that are highly invasible (see 2.1.1.). Activities to promote a way of small-scale sustainable agriculture and horticulture, that both combine well with green tourism, are therefore relevant. See also the recommendation specifically made for St Eustatius.
- Now that the BES islands are more strongly linked to the Netherlands as a whole, and now that special funds for development are no longer available because of this, it is important that civil society organisations (ngo's) twin with sister organisations in the Netherlands. The latter usually have better knowledge and access to funds and can help the BES islands to access these, *e.g.* by supporting them to write project proposals. These organisations can also mutually benefit from each other's' knowledge and experience.
- In the Netherlands several funds are available to support interaction between education on the one side and NGOs and institutions in the field of nature management, cultural inheritance and art on the other. Schools and NGOs should become more familiar with the funds and get experience in submitting proposals, again preferably together with twin institutions in the Netherlands. These funds may facilitate education on the importance of nature and cultural inheritance in general, and more specifically on the risks of exotic species and the relevance of utilizing native plants. An example of such a collaborative project may be a booklet in Dutch, Papiamento and English about local trees in the Netherlands and the Dutch Caribbean, respectively. This booklet should deal with the biology of these trees, but also aspects of cultural value and cultural inheritance.

4.2.2. Aruba

Although the field trip did not include Aruba, based on literature and knowledge of the team, it can be concluded that the problems in Aruba, Bonaire and Curacao are largely comparable. The islands have a similar dry climate and successful invasives are therefore often the same (Appendix II) and of the same magnitude (Table 3). The nature of Aruba also heavily degrades because of roaming grazing animals.

Figure 52. Visit to the ngo Mangazina di Rei

4.2.3. Bonaire

The above listed general recommendations are all relevant for Bonaire. More, specifically organisations like Stinapa, Mangazina di Rei and the farmer cooperation Kriabon will benefit of support in writing and submitting project proposals, such as for funding activities for prevention actions and for raising public awareness of the risks of exotics on the one side, and the ecological and cultural inheritance values of native species on the other and their possible advantage in reforestation.

4.2.4. Curacao

Although the field trip did not include Curacao, based on literature and knowledge of the team, it can be concluded that the problems in Aruba, Bonaire and Curacao are largely comparable. The islands have a similar dry climate and successful invasives are therefore often the same (Appendix II) and of the same magnitude (Table 3).

4.2.5. St. Eustatius

The above listed general recommendations are all valid for St Eustatius. The following recommendations are have specifically been formulated for this island.
St Eustatius lacks a flora and a detailed vegetation map. Both should be produced to allow effective early observations of exotic plants.
A Nature Policy Plan (Natuurbeleidsplan) needs to be developed for St Eustatius. This plan should include special precautions regarding invasives and the indication of valuable and protected areas. More natural parks may be indicated, besides Signal Hill.
An agricultural school (including education on green tourism, nature conservation, erosion control and reforestation) on St. Eustatius could stimulate young people to consider agriculture for a living. The Windward Islands are now almost entirely dependent on external sources for their primary needs. Agriculture is disappearing from the islands because youngsters are not stimulated to continue or enter into agriculture (or animal husbandry or horticulture).

4.2.6. Saba

The above listed general recommendations are all valid for Saba. Also Saba lacks an up to date flora. A landscape ecological vegetation map is in preparation (De Freitas et al.). The island has a unique vegetation: ranging from dry vegetation types along the coast to rain forest at the top. It is important that this rainforest gets an official status as National Park. In the past agricultural activities (like potato and banana growing) have occurred on the slopes and some are still going on (Figure 53). It is important that the area is protected from such activities in future and assisted to recover by avoiding invasives such as *Philodendron giganteum* (Figure 28) to establish. This will include compensation of the owners of land on the slopes.

Figure 53. Partly abandoned fields on the slopes of Mount Scenery (Saba)

Saba has a very successful mosquito eradication programme which is both highly effective and has a broad commitment in the local community. This mosquito programme may serve as good example to other prevention and containment programmes, *e.g.* with respect to prevent the dumping of garden plants on the slopes.

4.2.7. St. Marten

Although our visit essentially consisted of one day trip around the island, it could be observed that very little nature is left. The population and dwellings seem to invade nature in many places. There seem to be little restrictions to building and construction. The most relevant restriction for nature is the one that forbids to build within 50 m from the shoreline. There is little appreciation for nature and nature preservation; ngo's have difficulty functioning and surviving. The only habitat one seems to be interested in is below sea level. There are no terrestrial natural parks. The only one that comes close to that is the Emilio Wilson Estate, which serves as an educational park. 80% of the island is private property. There is hardly any agriculture. At school there is much attention for nature.

The St. Maarten Nature Foundation has plans to establish a land park in the hills and/or along the eastern coastline where original vegetation and nice scenery is visited by hikers.
Since the relation to the Netherlands has changed, no funding will become available for projects. This means that all will end by 2013.

Recommendations:

- Policy should support the activities of ngo's active in nature preservation.
- The establishment of protected areas need priority.
- Information for the public needs to be developed.
- More native trees should be planted, like on St Thomas.
- Twinning with Amsterdam could be an option.
- Project funding could come from the EU.

5. General conclusions

The islands Bonaire, St Eustatius and Saba are in a special position with regard to invasives: on the one hand they have a natural isolation due to a wide sea surrounding them, on the other hand, when invaders arrive (and there is frequent inter-island traffic), they usually do not face a large biodiversity that is able to counteract. Most land is heavily affected by human activity, often resulting in patches of bare land. This in combination with the fact that at these islands agriculture and horticulture have markedly decreased in importance the last 50 years, makes that there are many spots where these invaders easily establish themselves and from where they can disperse. Particularly vulnerable spots are wastelands near harbours where ships arrive with all kinds of merchandise, and where tourists and (new) locals bring in plants they found elsewhere.

Comparing the impact of exotic animals and plants, the effects of especially goats and in some aspects cats, is generally larger than those of exotic plant species. However, an exotic species as coral vine (*Antigonon*) has a large negative impact on the ecological quality of a large part of St Eustatius. Therefore, it is important to be alert with respect to the risk of exotic invasive plants and, depending on the stage of introduction and invasion, attention shall be paid to actions to prevent, eradicate or contain the population. Official Black Lists (prevention) and Watch Lists (containment) need to be developed by experts and adopted and implemented by the authorities.

Active reforestation is necessary in order to prevent open spaces in which exotic species can establish themselves (Booth *et al.* 2010) and to full up spaces where the exotics have been eliminated.

This study has resulted in the formulation of general or in some cases more detailed recommendations. We hope that these may contribute to further improvement of both policy development and practical management with respect to exotic plants. For all the recommendations we made, public awareness and commitment are essential aspects. Another main observation in this respect is that many stakeholders we have interviewed were highly aware of the relevance of nature in general and more specifically concerning the local economy (green tourism) and the problems exotic species may cause. However, several of them perceived the change in status of the islands to Dutch area as problematic with respect to obtaining funding for specific projects, such as concerning education programmes on exotics. Support in finding their way in funding programmes and assistance in writing and submitting proposals, will allow both the local authorities and NGOs to increase their contribution to prevention and effective management with respect to exotic invasive plants.

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Appendixes

I. List of consulted stakeholders

03-Apr		arrival Bonaire
04-Apr	Stinapa Bonaire	Elsemarie Beukenboom, directeur
		Fernando Simal
	Rijksdienst Caribisch Nederland (RCN)	Paul C. Hoetjes
		Pieter van Baren
	Dienst Regionale Ontwikkeling Bonaire (DROB)	Peter Montanus
		Frank van Slobbe
	LVV	Raymond Emers, hoofd
	Green Label Landscaping NV	Ap van Eldik
		Johan van Berk
05-Apr	Tourism Cooperation Bonaire (TCB)	Brigitte de Bruin
06-Apr	Landbouwer	Popo Morales
	Stichting KibraHacha	Jan Jaap van Almenkerk
		Edshell Martha
07-Apr	Hoofd projectbureau / ex-chef kabinet Gezaghebber	Niels Bots
	Cooperatieve Vereniging Kriabon	Agnes Joosten (Wolter de Palm)
	Mangazina di Rei	Christiaan Danilo
	Washington National Park Bonaire (WNSP)	Jose "Junny" Janga, Manager
		George "Kultura" Thodé
08-Apr	Gezaghebber (Governor)	Glenn A.E. Thodé
	Gedeputeerde (Commissioner)	Delno L.A. Tromp
	Dutch Caribbean Nature Alliance (DCNA)	Nathaniel Miller
09-Apr	BON>CUR>SXM>EUX	aankomst St Eustatius
	LVV	Roberto R. Hensen
	Green Blend NV	Laurens Duiveman
	Stenapa	Kate Walker
		Hannah Madden
		Claire Blair
11-Apr	Edu partners	René Reehuis
12-Apr	LVV, o.a. Hoofd DOW	Gershon A. Lopes
		Bernard Schmidt
		Winston Tearr, Hoofd Openbare Werken
		Cyril Tearr
	Hazel's Vegetable Garden	Hazel Tearr
13-Apr	Gedeputeerde (Commissioner)	Clyde van Putten
	Pogue Agri Partners Inc	
14-Apr	Adviseur Planningbureau	Siem Dijkshoorn
	Adviseur vd gezaghebber / projectleider regionale ontwikkelingsplan	Marianne Schrama
14-Apr	Gezaghebber	Gerald Berkel

15-Apr	EUX>SXM>SAB	aankomst Saba
	Nature ranger (gids op alle dagen op Saba)	James Johnson
	Min of Agriculture	Michael Hassell
16-Apr	Saba Conservation Foundation (SCF) & Sabapark	Gregoor van Laake, ranger
		Kay Wulf, hoofd
17-Apr	Bioloog, voormalig manager en voorzitter SCF	Tom van 't Hof
18-Apr	Agricultural Department (LVV)	Michael Hassell
	Saba Horticultural Foundation (SHF)	Peter Rudolf Johnson
	Saba Conservation Foundation (SCF)	Susan Hurrell, education officer
	Planningbureau	Bobby Zagers, hoofd
	Gezaghebber (Governor)	Jonathan Johnson
	Gedeputeerde (Commissioner)	Chris Johnson
	Eilandsecretaris	Menno van der Velde
	Dirrecteur middelbare school	Michiel Boeke
19-Apr	SAB>SXM	Aankomst St Maarten
20-Apr	Emilio Wilson Estate Foundation / Environmental Protection in the Caribbean (EPIC)	Rueben J. Thompson, project manager
	V.R.O.M.	Hendrik-Jan G. van Ieperen, hoofd
21-Apr	St. Maarten Nature Foundation	Tadzio Bervoets
		vertrek naar resp. Curacao en Nederland

II. Alien plants with invasive behaviour relevant for the Caribbean Netherlands

Preliminary list. Most species listed have invasive properties; those listed here as invasive demonstrate this property on the island mentioned.

		Exotic	(not reproducing)					
		Established	(reproducing)					
		Naturalised	(spreading)					
		Invasive	((potentially) spreading on a massive scale)					
		Native	(omnipresent since ages)					
Scientific name	**Common name**	**Type**	**Aruba**	**Bonaire**	**Curacao**	**Saba**	**St Eust.**	**St Mart.**
Agave sisalana	Sisal	Succulent						
Albizia lebbeck	Barba di jonkuman	Tree						
Aloe vera	Sentebibu	Succulent						
Antigonon leptopus	Bellisima, corallita	Vine						
Arivela viscosa	Wild massamby, kaya-kaya	Herb						
Asystasia gangetica	Chinese violet	Herb						
Azadirachta indica	Neem	Tree						
Balanites aegyptica	Lamunchi shimaron	Tree						
Bambusa vulgaris	Bamboo	Tree						
Bothriochloa ischaemum	Yellow bluestem	Grass						
Bothriochloa pertusa	Donna grass; hurricane grass	Grass						
Caesalpina bonduc	Grey Nicker, nickerberry	Vine						
Calotropis procera	Katuna di seda	Shrub						
Catharanthus roseus	Madalena	Herb						
Cenchrus ciliaris	Buffel grass	Grass						
Chenopodium murale		Herb						

Scientific name	Common name	Type	Aruba	Bonaire	Curacao	Saba	St Eust.	St Mart.
Cleome gynandra	Yerba di kaya, massamby	Herb						
Clitoria ternatea	Sapatu di la reina	Vine						
Cordia sebestena	Karawara spanjo	Tree						
Cryptostegia grandiflora	Palu di lechi, rubber vine	Vine						
Cyperus rotundus	Purple nutsedge	Sedge						
Dactyloctenium aegyptium	Pia di warawara	Grass						
Delonix regia	Flamboyan	Tree						
Echinochloa colona		Grass						
Eleusine indica	Kamuchi, pia di galiña	Grass						
Epipremnum aureum	Pothos, Tonga vine	Vine						
Eragrostis ciliaris	Gophertail grass	Grass						
Euphorbia tithymaloides	Prikichi	Succulent						
Ficus microcarpa	Laurel fig	Tree						
Gossypium spp.	Katuna, cotton	Shrub						
Indigofera tinctoria	Inigo, indigo	Shrub						
Jasminum fluminense	Jasmin, hasmin	Vine						
Kalanchoe daigremontiana	Lenga di kacho	Succulent						
Kalanchoe pinnata	Mother-in-law	Succulent						
Lawsonia inermis	Miminet, henna	Shrub						
Leucaena leucocephala	Tumbarabu, tan tan	Tree						
Luffa aegyptica	Sebete di pober	Vine						
Mangifera indica	Mango	Tree						
Megathrysus maximus	Geuni gras, Guinea grass	Grass						
Melaleuca quinquinervia	Cajeput, paper bark	Tree						
Melinis repens	Natal grass	Grass						
Moringa oleifera	Ben bom, moringa	Tree						
Nephrolepis multiflora	Scaly swordfern	Fern						

Scientific name	Common name	Type	Aruba	Bonaire	Curacao	Saba	St Eust.	St Mart.
Oeceoclades maculata	Monk orchid	Succulent						
Parthenium hysterophorus	Basora di liber	Herb						
Pennisetum purpureum	Napier grass, elephant's grass	Grass						
Philodendron giganteum	Elephant's ear	Vine						
Prosopis juliflora	Indju, kwihi, mesquite	Tree						
Psidium guayava	Guyaba, guava	Tree						
Pteris spp.	Fern	Fern						
Ricinus communis	Karpata, castor	Shrub						
Sansevieria spp.	Yerba di kolebra, rhamni	Succulent						
Scaevola taccada	Beach naupaka	Shrub						
Schinus terebinthifolius	Brazilian pepper	Tree						
Senna bicapsularis	brusca dushi, trommelstok	Tree						
Senna italica	Seneblá	Shrub						
Syngonium podophyllum	Arrowhead vine	Vine						
Tabebuia heterophylla	White cedar	Tree						
Tecoma stans	Kelki hel	Tree						
Tithonia diversifolia	Mexican sunflower	Shrub						
Urochloa mutica	Para grass	Grass						
Ziziphus mauritiana		Tree						
Ziziphus spina-christi	Apeldam	Tree						