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# ECOLOGY OF A POTENTIALLY INVASIVE SPECIES IN MARTINIQUE: TRIPHASIA TRIFOLIA

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## SUMMARY

The demographic development, the trade exchanges as well as the increasing human needs represent a major threat to biodiversity. These phenomena caused the extinction of a large number of plant species creating ecological conditions favourable to the appearance of new species harmful to the native ones. In fact, the lands and forests of the Lesser Antilles have gradually been damaged, resulting in regressive forests. In Martinique, the forests undergo a significant degree of anthropization facilitating the installation of invasive species. Triphasia trifolia is one of these invasive species. Introduced from Southeast Asia as an ornamental plant, the species has become naturalized and colonizes the coastal areas to the detriment of indigenous populations. Inventories in the xeric south of Martinique (the commune of Vauclin), allowed us to decipher the main life characteristics of Triphasia trifolia.

## KEYWORDS

Triphasia trifolia, Lesser Antilles, Martinique, anthropization, biodiversity, invasive, invading

## ACADEMIC DISCIPLINE

Ecology, biogeography, botany

## SUBJECT CLASSIFICATION

Plant physiology, Ecology

## TYPE (METHOD/APPROACH)

Experimental

## INTRODUCTION

The invasive alien species are the second major cause of biodiversity loss [1]. The numerous invaded sites correspond to the anthropized regions, due to the modification or even destruction of the habitats (terrestrial or aquatic). An invasive species is an allochthonous species whose introduction by man (voluntary or accidental) threatens the habitats, the ecosystems and their components. The negative consequences can be ecological, financial and/or medical [2, 3].

The biological invasion process generally follows the following sequence: introduction - acclimatization, naturalization and invasion. The passage from one stage to another requires the crossing of a physical, biological or climatic barrier [4]. These steps follow the so-called "three-tenth" rule, which states that one-tenth of the foreign species become introduced, one tenth of them become naturalized and only one-tenth of them become invasive [5, 6, 7]. The introduced plant species which manage to become naturalized can cause numerous disturbances. They also tend to modify the ecological conditions of the environment in order to develop and expand their own species populations, thus causing the progressive regressions of native species. The invasion of a species is often accentuated by the dysfunction of the ecosystem in which it is proliferating. This is due to the highly competitive nature of the invasive species which are capable of reducing the abundance and richness of the local species [8].

We should remember that a species introduced into a given region is considered naturalized when it is able to develop and reproduce in a spontaneous way without human intervention [9].

The jussies (*Ludwigia peploides* and *Ludwigia grandiflora*) are two examples of hydrophytes (aquatic plant species) that form dense monospecific populations [10]. During their growth, they can alter the functioning of all the organisms evolving within the same biotope. These modifications can create conditions unfavourable to the life of other organisms [11]. The *Miconia calvescens* (Melastomataceae) is a terrestrial plant species which caused the almost total disappearance of the tropical forests flora in the French Polynesia: more than 65% or approximately 70 000 ha [12, 13]. In fact, due to their geographical isolation and limited surface area, the insular ecosystems (islands) are the most threatened by invasive alien species [14]. Their forests are often composed of many introduced plant species, some of which are referred to as "potential harmful plants" [15]. In fact, most island ecosystems are strongly influenced by human actions [15, 16]. The latter are not without consequences on biodiversity and constitute one of the causes of landscape transformation, diminution of the natural resources but also dissemination of allochthonous plant or animal species on all the surface of the globe, some of which become invasive [17].

Knowledge of the plant species used and their impact on the West Indies ecosystem is a fundamental issue in controlling the spread of invasive species and the protection of the indigenous plant population in their natural range.

The island of Martinique has circa 1,536 native species and 236 introduced naturalized ones [18]. The problem of invasive alien species is a multi-year research effort. Philippe JOSEPH (1999) was one of the first to study this phenomenon in Martinique [19]. His numerous research works allowed us to establish the ecological profile and invasion potentialities of many species in particular Funtumia elastica (Apocynaceae). This species represents a greater threat to biodiversity than other potentially invasive species because it is able to acclimate and grow in the presence or absence of light energy within certain ecosystems. It is a species classified as semi-heliophilous. Philippe JOSEPH (2012) listed a dozen potentially invasive species in Martinique (Bambusa vulgaris Schrad. ex Wendl. Castilla elastica Sessé, Dichrostachys cinerea (L) Wight & Arn., Eichhornia crassipes (Mart.) Solms, Funtumia elastica (P. Preuss) Stapf, Mimosa malocentra (C. Mart.) Benth., Oeceoclades maculata (Lindl.) Lindl, Pistia stratiotes, Spathodea campanulata (P. Beauv.), Thunbergia grandiflora (Roxb, ex Rottl.) Roxb, Triphasia trifolia (Burm.f.) P. Wilson) [15, 18]. Most of these invasive plants, which may be xerophytic, mesophilic or hygrophilous, tend to develop in degraded areas and form more or less monospecific populations.

The purpose of this article is to study the main life traits of Triphasia trifolia, including its ability to compete with the native species.

# MATERIALS

## General remarks

The trade exchanges between Martinique and the rest of the world for food and industrial production (sugar cane: Saccharum officinarum: Poaceae), banana (Musa species: Musaceae), the means of transport, the tourist activities have led to the introduction of plants originating mainly from Asia, Africa and America (Figure 1, [20]). However, not all introduced plants become invasive. In fact, a species cannot be invasive in itself, it is only a population of species in a given location that is invasive [21]. Which implies that a species may be invasive and have a negative impact in a given region or place while another population of the same species may have a beneficial use in another location without presenting any risk [22, 23, 24].

**Table 1. Examples of vectors of voluntary and/or accidental introductions**

**(Table inspired by "Invasive alien species in the French overseas collectivities", [25])**

| Voluntary introductions | | Accidental introductions |
|---|---|---|
| **Direct introductions into the environment** | **Introductions after culture or captivity** | Sea and air freight<br>Ballast water |
| Agriculture<br>Forestry<br>Horticulture<br>Cattle breeding<br>Fish Release<br>Mammal Release<br>Hunting<br>Biological control<br>Soil Improvement<br>Agricultural development | Botanical Gardens Escapees<br>Private gardens<br>Plant nurseries<br>Zoos<br>Livestock farming<br>Beekeeping<br>Aquariums<br>New pets<br>Research Units | Ship hulls<br>Personal Vehicles<br>Transportation and construction machinery<br>Agricultural products<br>Seeds<br>Building materials (earth, gravel, sand)<br>Wood<br>Packaging materials<br>Postal mail<br>Waste |

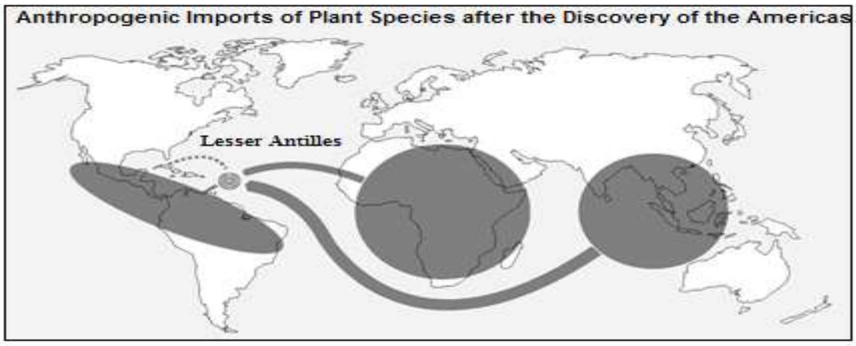


**Figure 1. Origin of Invasive Species [20]**

## The study site

The island of Martinique, located in the island arc of the Lesser Antilles has a total area of 1,128 $km^2$. It is characterised by a humid tropical climate marked by two seasons: the dry season (or Lent) corresponding to the drought period from May to November and a wet (or rainy) season from February to April. Its highest point is the peak of Montagne Pelée at 1,397 m. The mountain massifs give rise to bioclimatic conditions which result in several types of vegetation ranging from dry to hyper-humid. From the littoral to the summit the annual average rainfall variability can range from 1,500 mm to 4,000 mm or more.

The climax forests that dominated the entire island [26], have gradually regressed due to anthropogenic activities following the French takeover in the 17th century.

The south of Martinique is severely degraded, a fact which facilitates the installation and development of invasive species. Our studies have therefore concentrated on the south of Martinique.

The study site is located in the south-east of Martinique: the Morne Carrière location (commune of Vauclin (Figure 2).

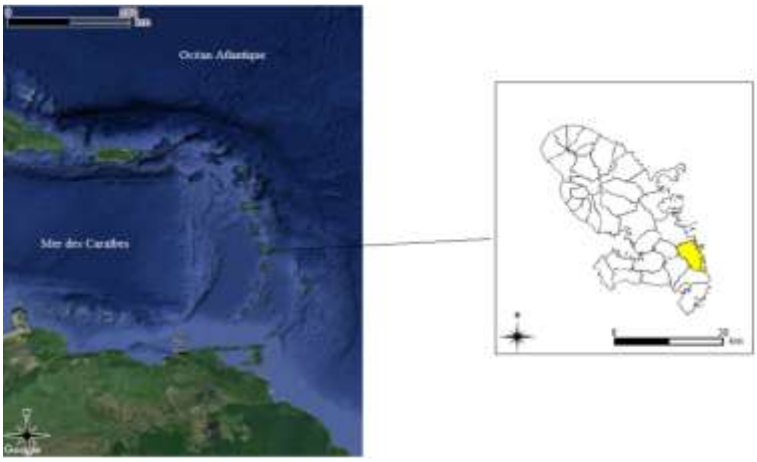

**Figure 2. The island of Martinique in the West Indies arc and location of the study area (Vauclin commune)**

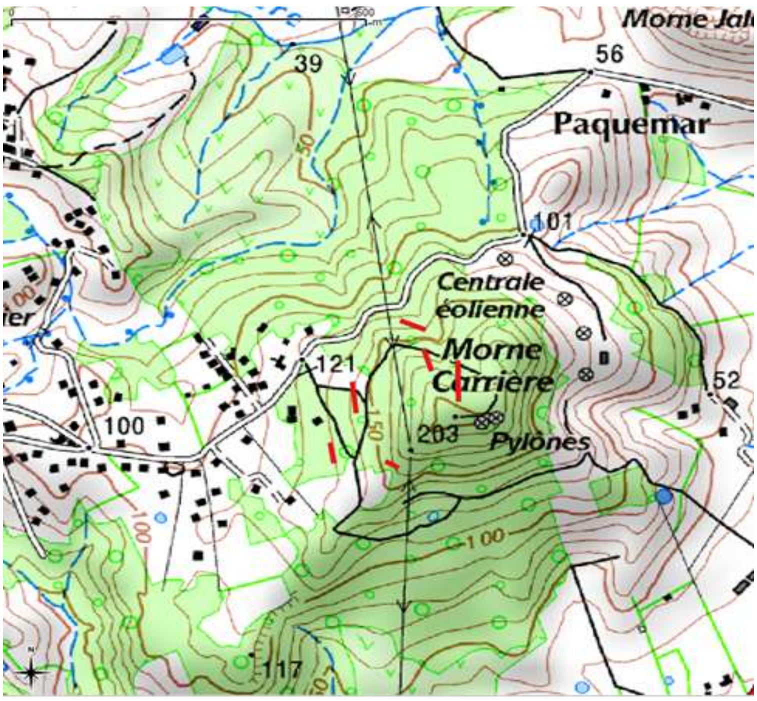


**Figure 3. Georeferenced study stations in the commune of Vauclin (in July 2015)**

The minimal and maximal average temperatures are 23°C and 28°C [annual average over 30 years (1971 - 2000)] [27]. In the researched zone, the annual rainfall is little more than 1,500 mm. This corresponds to a dry bioclimate. The ecosystem potentialities allow the development of a seasonal evergreen forest of lower horizon and xeric characteristics [26]. Due to their topography, some areas are relatively more humid. [28].

**Table 2. Ecosystem and bioclimatic potential as a function of the annual mean rainfall, [28]**

| Average annual rainfall | Bioclimates | Ecosystem potential |
|---|---|---|
| 1,500 mm | Dry | Seasonal evergreen forest of lower horizon and xeric characteristics (dry forest) |
| 1,500 - 2,500 mm | Moderately humid | Tropical seasonal evergreen forest (meso-philic forest) |
| 2,500 - 4,000 mm | Wet | Tropical sub-montane ombrophilous rainfor-est (hygrophilous forest) |
| more than 4,000 mm | Hyper-humid | Tropical ombrophilous montane rainforest (montane hygrophilous forest) |

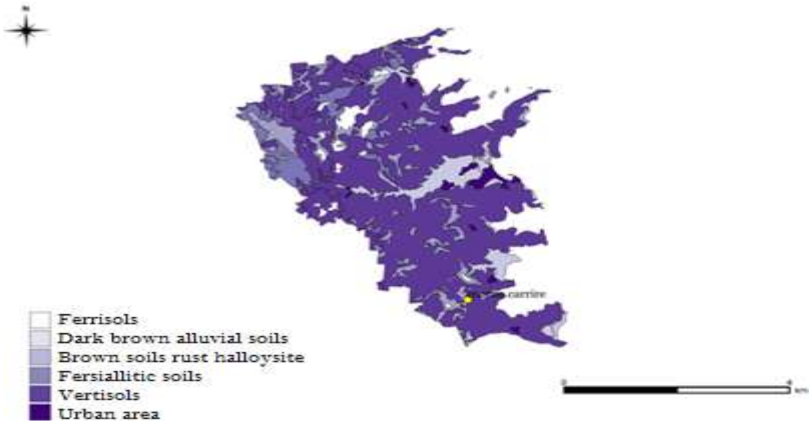


**Figure 4. Pedological map of the commune of Vauclin. The study site is indicated by a yellow dot on the map**

We see two types of soil at Morne Carrière (the study site): dark brown alluvial soils and vertisols (Figure 4). The vertisols develop in dry climatic zones marked by a high water deficit during the dry season (annual rainfall less than 1,500 mm) [20, 29, 30].

## Triphasia trifolia (Rutaceae): Some descriptive elements

Shrub or arbust (it can grow up to 4 m tall) of the Rutaceae family (the lemon and orange tree family), the Small lemongrass (Triphasia trifolia) is native to South-East Asia (India) and has been introduced in many geographical areas as an ornamental plant (gardens, forest edges, hedges, windbreaks, cover crops).

The species was originally brought to the Virgin Islands by gardeners to create dense pleasant smelling hedges [31]. Formerly introduced as an ornamental plant, in the United States (Texas in 1933; [32]), in Barbados and Florida (in 1913), the latter became naturalized due to its semi-sciaphilous or semi-heliophilous behaviour and its capacity to create impene-trable thickets.

This species has many medicinal uses in South-East Asia: it is an antifungal and antibacterial plant used to treat colic, diarrhoea [33, 34]. The fruits are used for cough and sore throat [35]. In the French West Indies, Triphasia trifolia infusions are used as a vermicide [36].

In Martinique, it is traditionally grown in gardens (from which it probably escaped). It is found in the natural environment, at altitudes between 0 and 200 m. The populations of this plant gradually increase and slowly develop to the detriment of other species, so it can be considered potentially invasive. It is quite aggressive and occupies a broad ecological spectrum because it has the capacity to grow in sunny open areas as well as in shady areas under canopy cover [31]. *Triphasia trifolia* setles in the shrub, pre-forest and young forest stages [15] and spreads through seeds that can be easily dispersed by animals including birds (avichory[1]) [15, 37].

[1] Seed dissemination by birds

**Figure 5. Inflorescences of *Triphasia trifolia* [38]**

**Figure 6. Infructescence of Triphasia trifolia**

This species tends to form dense, spiny, impenetrable monospecific units. It has twigs with axillary spines in pairs in the leaf axils. The leaves are trifoliolate, shiny and dark green with short, puberulent petioles. The terminal leaflet foliole is longer than the lateral leaflets (L 1-2 cm x l 4-10 mm). The leaves give off an odour of resin when rubbed. The fragrant white flowers have three petals (L 12-16 mm x l 5-6 mm). They are solitary flowers or in groups of two or three in the leaf axils. They have six stamens. The orange or red fruit is edible, ripe and has a pleasant sweet taste [35].

# METHODS

We carried out floristic inventories to characterise the main ecological traits *of Triphasia trifolia* and to decipher its relations with the other species. Within transects divided into quadrats (Figure 7) corresponding to minimal areas ranging from 500 to 1,000 m², we took into account the following descriptors: species, number of individuals, total height and height of the first branch, trunk diameter (measured at 1.33 m above the ground according to international standards).

The transects have been placed in such a way as to take into account the different dynamics and ecological stages of the vegetation formations.

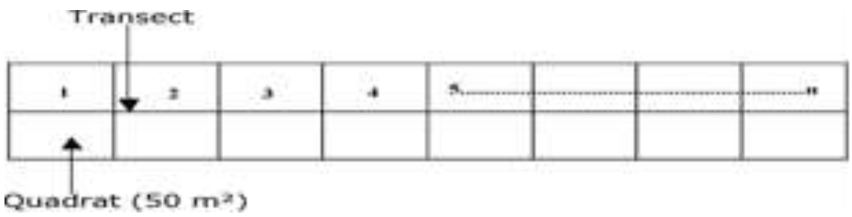


**Figure 7. Representation of a transect composed of quadrats**

There are many interconnections between each of the descriptors (qualitative and quantitative data) set out in the previous section. These are highlighted by indicators ($f_a$, $f_r$, $I_d$ and $I_D$, etc. [26, 39]). These markers have been defined:

- to estimate the distribution of species within each quadrat using the absolute frequency ($f_a$);
- to estimate the distribution of species as a percentage (relative frequency $f_r$);
- to assess the distribution of species between the quadrats and study stations using the distribution index ($I_d$) expressed by $I_d = f_r * D$ (density, defined by the ratio between the number of individuals of the species considered and the $S_t$ basal area);
- to determine the dominance of the species among themselves using the Dominance Index (ID) which is obtained by using the following formula: $ID = I_d * S_t$ (basal area).

# RESULTS

## General characteristics of the stations

The following section presents the data relating to the study stations accompanied by elements of analysis.

**<u>Station 1 (500 m²)</u>**

**Table 3. Key Ecological and Structural Parameters (Station 1)**

| Rank | Species | fa | fr | Number of individuals per species excluding regeneration and excluding dead trees | Density (ind / m²) | Id | Total basal area per species | ID |
|---|---|---|---|---|---|---|---|---|
| 1 | *Lonchocarpus punctatus* | 5 | 100% | 25 | 5.00E-02 | 5.00E-02 | 4.76E-01 | 2.38E-02 |
| 2 | *Citharexylum spinosum* | 5 | 100% | 21 | 4.20E-02 | 4.20E-02 | 4.63E-01 | 1.95E-02 |
| 3 | *Pisonia fragrans* | 5 | 100% | 98 | 1.96E-01 | 1.96E-01 | 8.35E-02 | 1.64E-02 |
| 17 | *Triphasia trifolia* | 3 | 60% | 3 | 6.00E-03 | 3.60E-03 | 1.47E-03 | 5.30E-06 |

Absolute frequency (fa) = presence of the species in the different quadrats; Relative frequency (fr) = Absolute frequency / per number of quadrats; Density = number of individuals / survey area; Distribution Index (Id) = Relative Frequency * Density; Dominance index (ID) = Distribution index * land surface (basal area)

This is a young (strongly anthropized) secondary predominantly tropical seasonal evergreen pre-forest formation of lower horizon and xeric characteristics. The predominant species are in order of importance Lonchocarpus punctatus, Citharexylum spinosum and Pisonia fragrans. These three species have a very high relative frequency (100%). However, both species Lonchocarpus punctatus and Citharexylum spinosum show a significantly higher total land area (≈ 0.5) than Pisonia fragrans. Triphasia trifolia, the naturalized species has a rather high relative frequency (60%), but it has low density and a total basal area well below that of the previous species

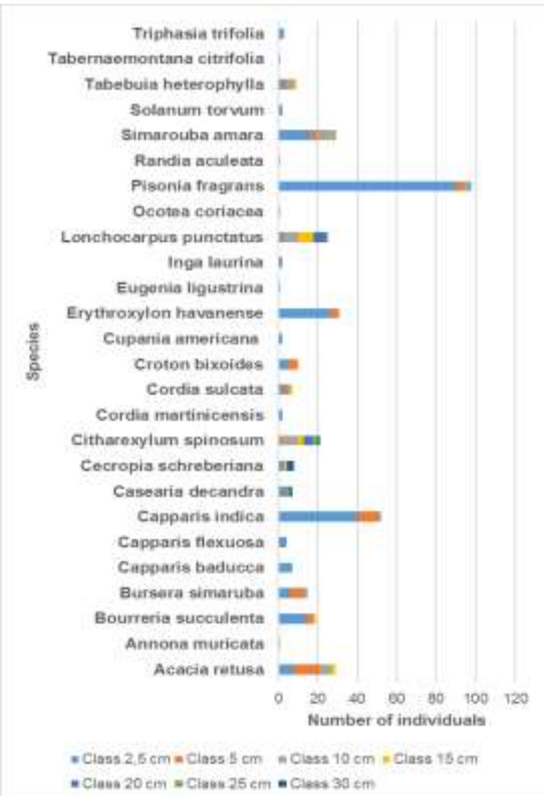


**Figure 8. Diameter distribution of live trees (diameter ≥ 2.5 cm, Station 1)**

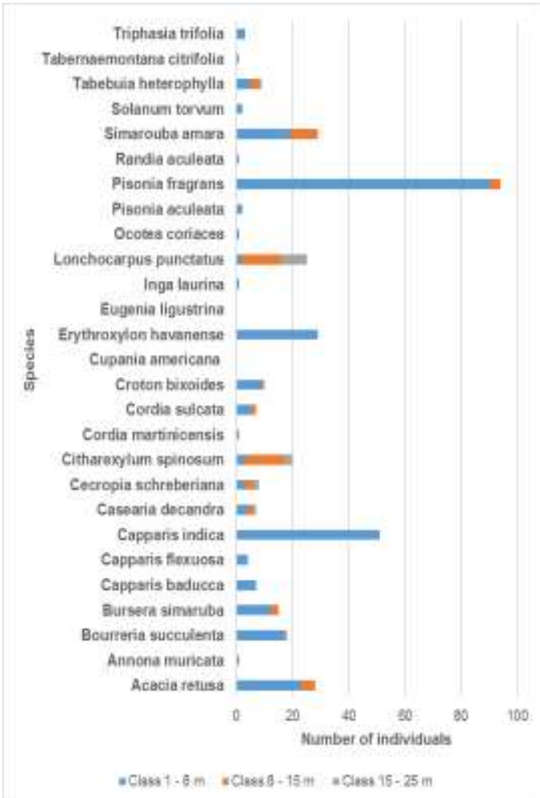


**Figure 9. Distribution of the height of live trees, (heights ≥ 1 m, Station 1)**

Figures 8 and 9 describe the distribution of the diameters and heights of the plant communities of station 1. Most of the individuals recorded in this station have diameters between 2.5 and 5 centimetres and heights between 1 and 8 meters. This station has not yet reached its level of maturity, it is composed mainly of populations of very small sections and low heights. The species are gap species that appear in regressive formations (*Bursera simaruba*, *Lonchocarpus punctatus*, *Pisonia fragrans*). The predominant plant matrix is composed mainly of regeneration plants, except for some trees which have practically reached their optimum morphogenetic development level (*Bursera simaruba*, *Casearia* will descendra, *Cecropia schreberiana, Citharexylum spinosum, Lonchocarpus punctatus, Simarouba amara* and *Tabebuia heterophylla*) with diameters up to 30 centimetres. The populations of *Lonchocarpus punctatus* and *Citharexylum spinosum* are the two species with the highest distribution and dominance index. They belong to past formations and are essentially composed of individuals with sections between 10 and 20 cm. These populations are marked by a relatively small number of individuals per species compared to *Pisonia fragrans*. The *Pisonia fragrans* is therefore the most competitive species in this station.

**Station 2 (1,000 m²)**

**Table 4. Key Ecological and Structural Parameters (Station 2)**

| Rank | Species | fa | fr | Number of individuals per species excluding regeneration and excluding dead trees | Density (ind / m²) | Id | Total basal area per species | ID |
|---|---|---|---|---|---|---|---|---|
| 1 | *Citharexylum spinosum* | 9 | 90% | 74 | 7.40E-02 | 6.66E-02 | 1.02E+00 | 6.77E-02 |
| 2 | *Pisonia fragrans* | 10 | 100% | 170 | 1.70E-01 | 1.70E-01 | 2.81E-01 | 4.78E-02 |
| 3 | *Simarouba amara* | 10 | 100% | 81 | 8.10E-02 | 8.10E-02 | 1.56E-01 | 1.26E-02 |
| 19 | *Triphasia trifolia* | 9 | 90% | 10 | 1.00E-02 | 9.00E-03 | 4.91E-03 | 4.42E-05 |

Absolute frequency (fa) = presence of the species in the different quadrats; Relative frequency (fr) = Absolute frequency / per number of quadrats; Density = number of individuals / survey area; Distribution Index (Id) = Relative Frequency * Density; Dominance index (ID) = Distribution index * land surface (basal area)

This young forest formation to tropical seasonal evergreen pre-forest formation with a lower horizon and xeric recolonization facies is dominated by the Pisonia fragrans population. This sylvatic unit is marked by two phytocenoses at different levels of evolution. One of these phytocenoses is characterised by a structured young structured sylvatic formation marked by several secondary heliophilous species (Annona muricata, Capparis baducca, Pisonia fragrans, Simarouba amara, Tabebuia heterophylla). The other is represented by regenerations of species associated with the fruit stage (Eugenia ligustrina, Pavonia spinifex, Randia aculeata). The predominant species are in order of importance Citharexylum spinosum, Pisonia fragrans and Simarouba amara. Triphasia trifolia is better represented in this station and exhibits numerous regenerations (circa ten per quadrat or a total of about fifty) have been recorded (Figures 10 and 11).

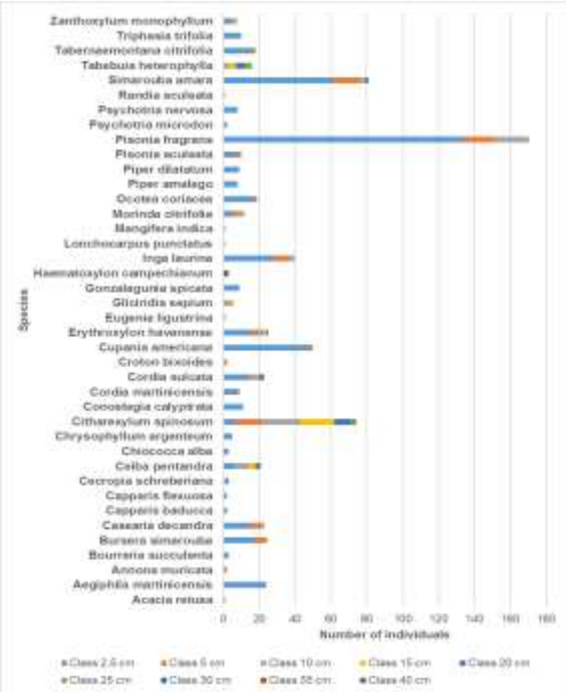

**Figure 10. Diameter distribution of live trees (diameter ≥ 2.5 cm, Station 2)**

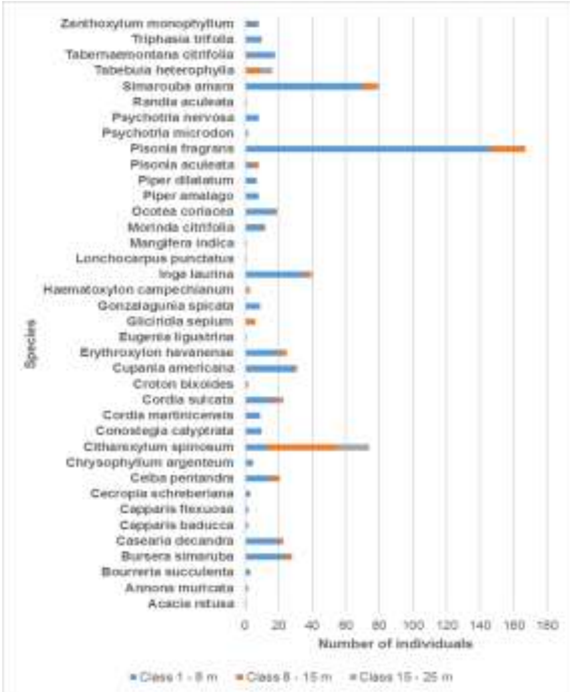

**Figure 11. Distribution of height of live trees, (heights ≥ 1 m, Station 2)**

**Station 3 (900 m²)**

**Table 5. Key Ecological and Structural Parameters (Station 3)**

| Rank | Species | fa | fr | Number of individuals per species excluding regeneration and excluding dead trees | Density (ind / m²) | Id | Total basal area per species | ID |
|---|---|---|---|---|---|---|---|---|
| 1 | *Citharexylum spinosum* | 9 | 100% | 120 | 1.33E-01 | 1.33E-01 | 9.46E-01 | 1.22E-01 |
| 2 | *Simarouba amara* | 9 | 100% | 68 | 7.56E-02 | 7.56E-02 | 2.77E-01 | 2.09E-02 |
| 3 | *Tabernaemontana citrifolia* | 9 | 100% | 111 | 1.23E-01 | 1.23E-01 | 1.11E-01 | 1.40E-02 |
| 9 | *Triphasia trifolia* | 6 | 67% | 34 | 3.78E-02 | 2.52E-02 | 1.67E-02 | 4.2E-04 |
| 31 | *Dichrostachys cinerea* | 1 | 11% | 1 | 1.00E-03 | 1.00E-04 | 1.96E-03 | 2.42E-04 |

Absolute frequency (fa) = presence of the species in the different quadrats; Relative frequency (fr) = Absolute frequency / per number of quadrats; Density = number of individuals / survey area; Distribution Index (Id) = Relative Frequency * Density; Dominance index (ID) = Distribution index * land surface (basal area)

This plant community is a seasonal tropical evergreen plant formation of inferior horizon and xeric facies at the pre-sylvatic stage. The preponderant populations consist in the following species: *Citharexylum spinosum, Simarouba amara* and *Tabernaemontana citrifolia*. Unlike the two secondary heliophilous species, *Simarouba amara* is a heliophilic species of forest gaps. This reflects the fact that the plant matrix of this station consists essentially of regenerations. Moreover, within the plant population, we note another invasive species *Dichrostachys cinerea* (Mimosacea) also called Santo Domingo

Acacia (a single individual of 5 cm in diameter was recorded in the station). Given its ecological functioning within the forest population, this heliophilous ruderal species is considered as a dynamic inhibitor [20]. It is not one of the predominant species but its sole presence testifies to the degradation of the site. Among the regenerations, we counted 150 *Triphasia trifolia* individuals.

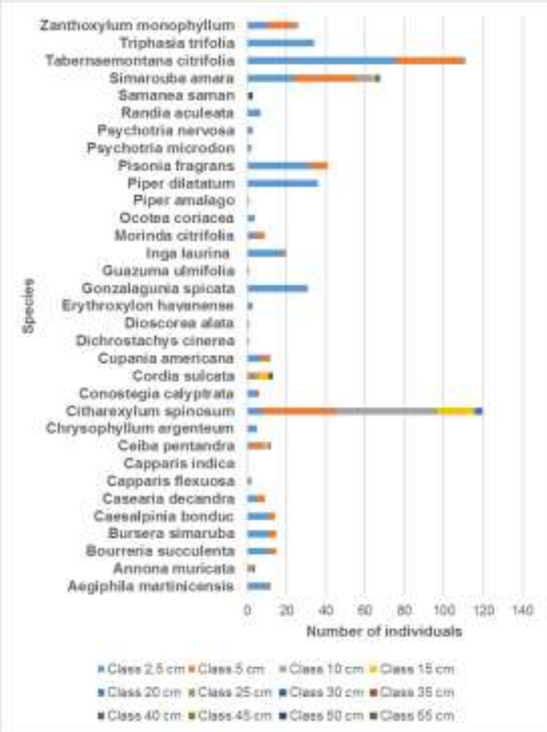


**Figure 12. Diametric distribution of live trees (diameters ≥ 2.5 cm, Station 3)**

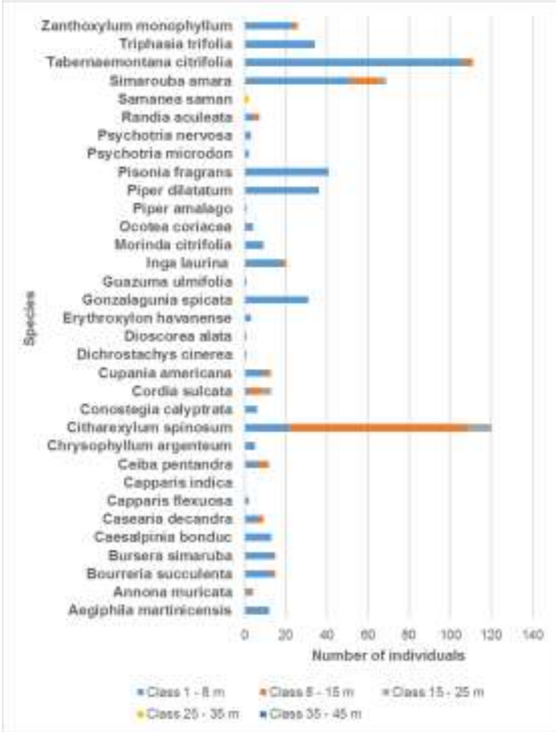


**Figure 13. Distribution of heights of live trees, (heights ≥ 1 m, Station 3)**

**Station 4 (1,000 m²)**

**Table 6. Key Ecological and Structural Parameters (Station 4)**

| Rank | Species | fa | fr | Number of individuals per species excluding regeneration and excluding dead trees | Density (ind / m²) | Id | Total basal area per species | ID |
|---|---|---|---|---|---|---|---|---|
| 1 | *Croton corylifolius* | 4 | 80% | 85 | 1.70E-01 | 1.36E-01 | 1.84E-01 | 2.51E-02 |
| 2 | *Pisonia fragrans* | 5 | 100% | 36 | 7.20E-02 | 7.20E-02 | 1.13E-01 | 9.18E-03 |
| 3 | *Capparis baducca* | 4 | 80% | 89 | 1.78E-01 | 1.42E-01 | 5.10E-02 | 7.27E-03 |
| 32 | *Triphasia trifolia* | 1 | 20% | 1 | 2.00E-03 | 4.00E-04 | 4.90E-04 | 1.96E-07 |

Absolute frequency (fa) = presence of the species in the different quadrats; Relative frequency (fr) = Absolute frequency / per number of quadrats; Density = number of individuals / survey area; Distribution Index (Id) = Relative Frequency * Density; Dominance index (ID) = Distribution index * land surface (basal area)

This is a seasonal tropical evergreen formation of inferior horizon and xeric facies at the pre-sylvatic stage. The predominant species are in order of importance *Croton corylifolius*, *Pisonia fragrans* and *Capparis baducca*. These three species are all secondary heliophilous species characterised by 2.5-25 cm diameters (*Pisonia fragrans*). Other species *Bursera simaruba*, *Ceiba pentandra* and *Citharexylum spinosum* have higher diametric distributions and heights (Figures 14 and 15). In addition to these three individuals, the plant matrix of the station exhibits very low diameters (between 2.5 and 5 cm) and heights (between 1 and 8 m). We also noted the presence of *Justicia secunda* (we counted 79 specimens): a fairly rare species of the Acanthaceae family, probably escaped from cultivation [18]. The *Triphasia trifolia* species is present but much less distributed (Table 6) in the quadrats of this station.

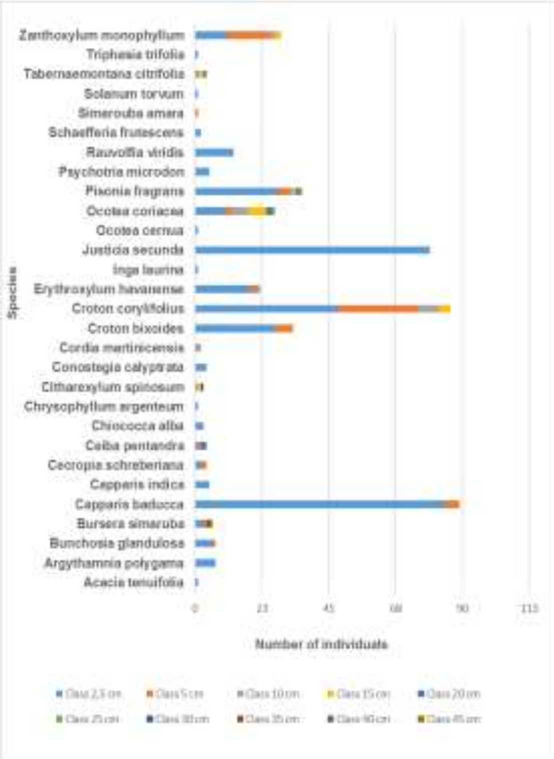


Figure 14. Diametric distribution of live trees (diameters ≥ 2.5 cm, Station 4)

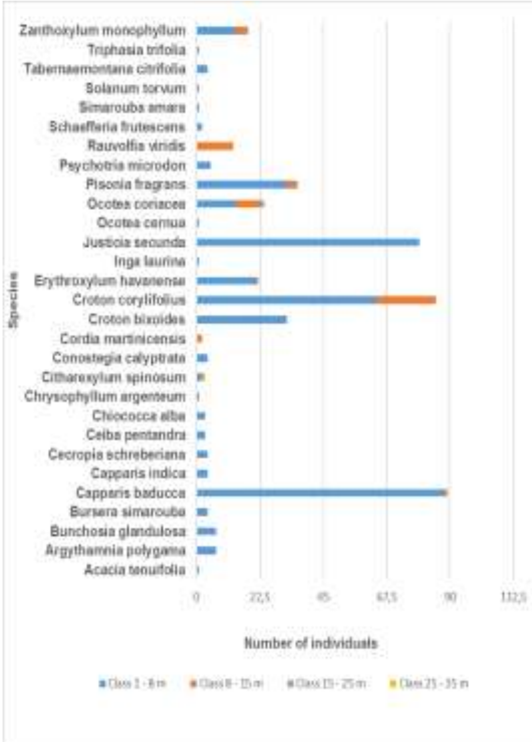


Figure 15. Distribution of heights of live trees, (heights ≥ 1 m, Station 4)

**Station 5 (1,000 m²)**

**Table 7. Key Ecological and Structural Parameters (Station 5)**

| Rank | Species | fa | fr | Number of individuals per species excluding regeneration and excluding dead trees | Density (ind / m²) | Id | Total basal area per species | ID |
|---|---|---|---|---|---|---|---|---|
| 1 | *Pisonia fragrans* | 10 | 100% | 270 | 2.70E-01 | 2.70E-01 | 4.33E-01 | 1.12E-01 |
| 2 | *Croton corylifolius* | 10 | 100% | 113 | 1.13E-01 | 1.13E-01 | 1.90E-01 | 2.15E-02 |
| 3 | *Morisonia americana* | 9 | 90% | 176 | 1.76E-01 | 1.58E-01 | 1.04E-01 | 1.65E-02 |
| 28 | *Triphasia trifolia* | 2 | 20% | 5 | 5.00E-03 | 1.00E-03 | 2.45E-03 | 2.45E-06 |

Absolute frequency (fa) = presence of the species in the different quadrats; Relative frequency (fr) = Absolute frequency / per number of quadrats; Density = number of individuals / survey area; Distribution Index (Id) = Relative Frequency * Density; Dominance index (ID) = *Distribution index * land surface (basal area)*

This tropical seasonal tropical evergreen floristic unit of inferior horizon and xeric facies in the mature shrub stage is dominated by a large population (270 individuals per species excluding regeneration) of *Pisonia fragrans* whose diameters essentially range between 2.5 (85%) and 5 cm (circa 2%) (Table 7). The dominant population is, in order of importance, composed of Pisonia fragrans, Croton corylifolius, and Morisonia americana. All three species are undergoing morphological growth (260 individuals per species except regeneration and excluding dead Pisonia fragrans trees, 113 for Croton corylifolius and 176 for Morisonia americana) and form a dense low height matrix ranging from 1 to 8 meters (Figure 16). The plant matrix is mainly composed of individuals with small sections and small sizes (Figures 16 and 17). As in the previous station (station 4) Triphasia trifolia is very little distributed within the quadrats.

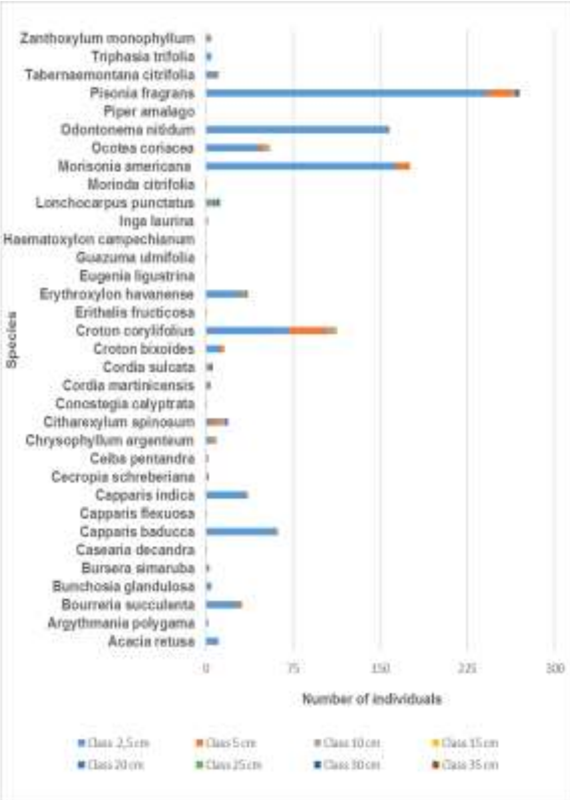


**Figure 16. Diametric distribution of live trees (diameters ≥ 2.5 cm, Station 5)**

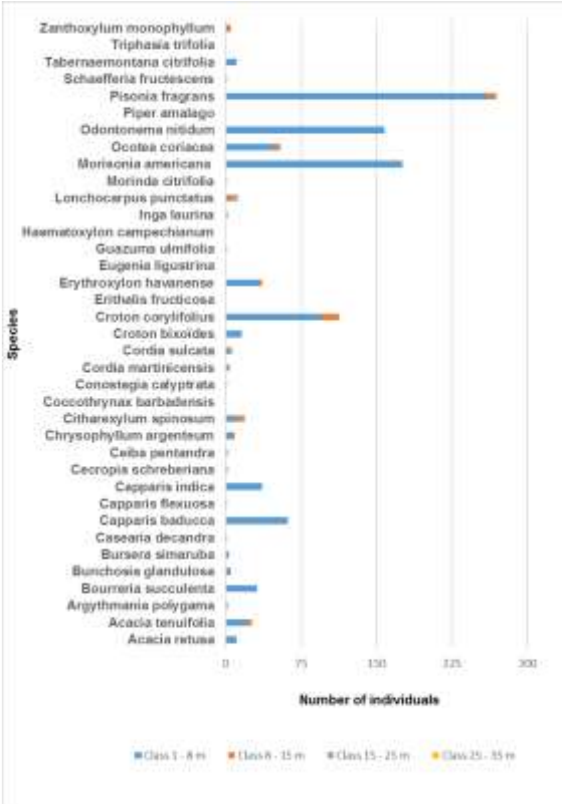


**Figure 17. Distribution of heights of live trees, (heights ≥ 1 m, Station 5)**

**Station 6 (1,000 m²)**

**Table 8. Key Ecological and Structural Parameters (Station 6)**

| Rank | Species | fa | fr | Number of individuals per species excluding regeneration and excluding dead trees | Density (ind / m²) | Id | Total basal area per species | ID |
|---|---|---|---|---|---|---|---|---|
| 1 | *Cordia sulcata* | 10 | 100% | 122 | 1.22E-01 | 1.22E-01 | 9.02E-01 | 1.11E-01 |
| 2 | *Mangifera indica* | 10 | 100% | 28 | 2.80E-02 | 2.80E-02 | 9.10E-01 | 2.55E-02 |
| 3 | *Inga laurina* | 10 | 100% | 75 | 7.50E-02 | 7.50E-02 | 1.04E-01 | 7.80E-03 |
| 25 | *Triphasia trifolia* | 6 | 60% | 8 | 8.00E-03 | 4.80E-03 | 3.92E-03 | 1.89E-05 |

Absolute frequency (fa) = presence of the species in the different quadrats; Relative frequency (fr) = Absolute frequency / per number of quadrats; Density = number of individuals / survey area; Distribution Index (Id) = Relative Frequency * Density; Dominance index (ID) = Distribution index * land surface (basal area)

This barely structured tropical secondary evergreen (mesophilic) forest formation has undergone a high degree of anthropization. It is composed of two strata: the first is composed of heliophilous species of sylvatic gaps (Cordia sulcata and Inga laurina); the second is composed of regenerations of pioneer heliophilous species (Bourreria succulenta and Erythroxylon havanense). The population's dominant species are in order of importance Cordia sulcata, Mangifera indica and Inga laurina. The population of Mangifera indica belongs to a past formation and is characterised by high diameter individuals (45 cm in diameter) and heights between 15 and 25 m. Cordia sulcata has a relatively high number of individuals and has a significant basal area and dominance index. Triphasia trifolia is much more abundant and distributed over the whole quadrat. The majority of the individuals present in this station have weak sections (77% of the recorded species have a diameter of 2.5 cm and 10% of 5 cm) with heights between 1 and 8 m (Figures 19 and 20).

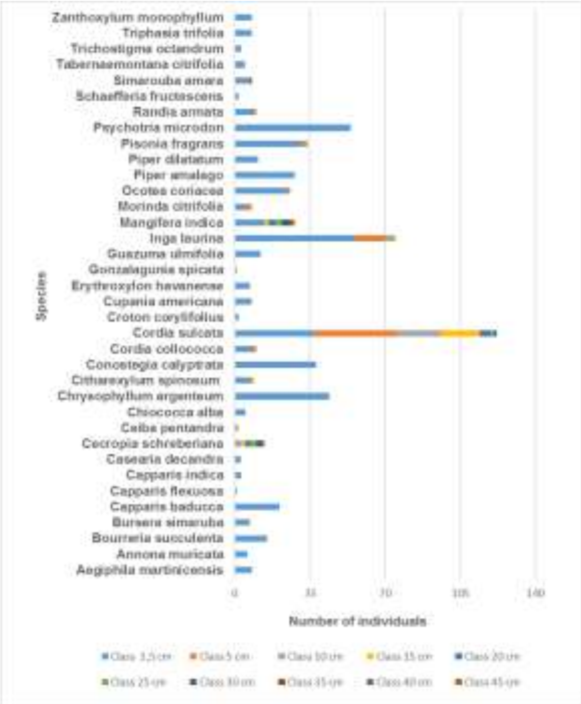


**Figure 19. Diametric distribution of live trees (diameters ≥ 2.5 cm, Station 6)**

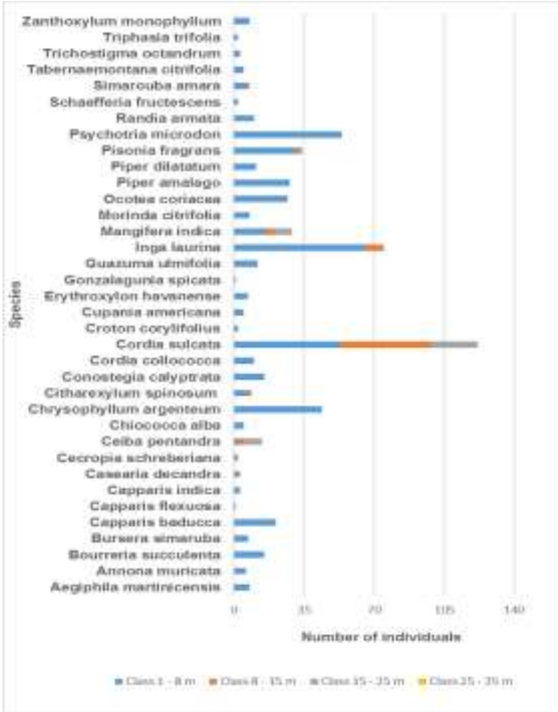


**Figure 20. Height distributions of live trees, (heights ≥ 1 m, Station 6)**

Dominance ratio of species for all study stations

**Table 9. Ecological and structural parameters for all stations**

| Species | fa | fr | Number of individuals per species excluding regeneration and excluding dead trees | Density (ind / m²) | Id | Total basal area per species | ID |
|---|---|---|---|---|---|---|---|
| *Citharexylum spinosum* | 6 | 100% | 246 | 4.56E-02 | 4.56E-02 | 2.68E+00 | 1.12E-01 |
| *Pisonia fragrans* | 6 | 100% | 649 | 1.20E-01 | 1.20E-01 | 9.92E-01 | 1.19E-01 |
| *Cordia sulcata* | 5 | 83% | 171 | 3.17E-02 | 2.64E-02 | 1.33E+00 | 3.50E-02 |
| *Simarouba amara* | 5 | 83% | 187 | 3.46E-02 | 2.89E-02 | 6.36E-01 | 1.83E-02 |
| *Croton corylifolius* | 3 | 50% | 200 | 3.70E-02 | 1.85E-02 | 3.75E-01 | 6.95E-03 |
| *Tabernaemontana citrifolia* | 6 | 100% | 150 | 2.78E-02 | 2.78E-02 | 2.13E-01 | 5.90E-03 |
| *Inga laurina* | 6 | 100% | 140 | 2.59E-02 | 2.59E-02 | 2.01E-01 | 5.21E-03 |
| *Lonchocarpus punctatus* | 4 | 67% | 38 | 7.04E-03 | 4.69E-03 | 8.16E-01 | 3.83E-03 |
| *Capparis baducca* | 5 | 83% | 181 | 3.35E-02 | 2.79E-02 | 9.77E-02 | 2.73E-03 |
| *Mangifera indica* | 2 | 33% | 29 | 5.37E-03 | 1.79E-03 | 9.11E-01 | 1.63E-03 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Morisonia americana* | 2 | 33% | 176 | 3.26E-02 | 1.09E-02 | 1.04E-01 | 1.13E-03 |
| *Triphasia trifolia* | 6 | 100% | 61 | 1.13E-02 | 1.13E-02 | 2.99E-02 | 3.38E-04 |
| *Dichrostachys cinerea* | 1 | 17% | 1 | 1.90E-04 | 3.00E-05 | 1.96E-03 | 6.06E-08 |

Absolute frequency (fa) = presence of the species in the different quadrats; Relative frequency (fr) = Absolute frequency / per number of quadrats; Density = number of individuals / survey area; Distribution Index (Id) = Relative Frequency * Density; Dominance index (ID) = Distribution index * land surface (basal area)

The most distributed species in all stations are in order of importance: *Pisonia fragrans*, *Citharexylum spinosum*, *Cordia sulcata*, *Inga laurina*, *Tabernaemontana citrifolia* and *Triphasia trifolia* (Table 9). Among the species mentioned above, two of them (*Pisonia fragrans* and *Citharexylum spinosum*) have considerably higher total land surfaces and dominance indices. These species are the most competing in terms of environmental factors. *Triphasia trifolia* and *Dichrostachys cinerea* are two woody plants with small section diameters. They are characterised by very low land masses, average distribution indices as well as relatively low dominance indices.

We compared the dominance of the competitive species (*Triphasia trifolia*) in all the stations with respect to the preponderant species of the plant population.

**Table 10. Species dominance indices for all stations**

| Species ID | ID Station 1 | ID Station 2 | ID Station 3 | ID Station 4 | ID Station 5 | ID Station 6 |
|---|---|---|---|---|---|---|
| *Lonchocarpus punctatus* | 2.38E-02 | 9.82E-08 | 0.00E00 | 0.00E00 | 2.85E-03 | 0.00E00 |
| *Citharexylum spinosum* | 1.95E-02 | 6.77E-02 | 1.26E-01 | 1.15E-04 | 1.24E-03 | 1.25E-04 |
| *Pisonia fragrans* | 1.64E-02 | 4.78E-02 | 1.52E-03 | 9.18E-03 | 1.17E-01 | 1.12E-03 |
| *Simarouba amara* | 2.92E-03 | 1.26E-02 | 2.09E-02 | 7.85E-07 | 0.00E00 | 3.63E-04 |
| *Tabernaemontana citrifolia* | 1.96E-07 | 1.48E-04 | 1.40E-02 | 2.15E-04 | 6.48E-05 | 2.45E-05 |
| *Croton corylifolius* | 0.00E00 | 0.00E00 | 0.00E00 | 2.51E-02 | 2.15E-02 | 1.96E-07 |
| *Capparis baducca* | 3.85E-05 | 7.85E-07 | 0.00E00 | 7.27E-03 | 1.78E-03 | 1.73E-04 |
| *Morisonia americana* | 0.00E00 | 0.00E00 | 0.00E00 | 0.00E00 | 1.65E-02 | 0.00E00 |
| *Cordia sulcata* | 3.46E-04 | 2.71E-05 | 2.67E-03 | 0.00E00 | 2.06E-04 | 1.10E-01 |
| *Mangifera indica* | 0.00E00 | 9.82E-08 | 0.00E00 | 0.00E00 | 0.00E00 | 2.55E-02 |
| *Inga laurina* | 1.57E-06 | 2.19E-03 | 3.22E-04 | 1.96E-07 | 3.14E-06 | 7.80E-03 |
| *Triphasia trifolia* | 5.30E-06 | 4.42E-05 | 4.20E-04 | 1.96E-07 | 2.45E-06 | 1.89E-05 |

**Figure 21. Histogram of the Dominance Indices (ID) of species for all study stations**

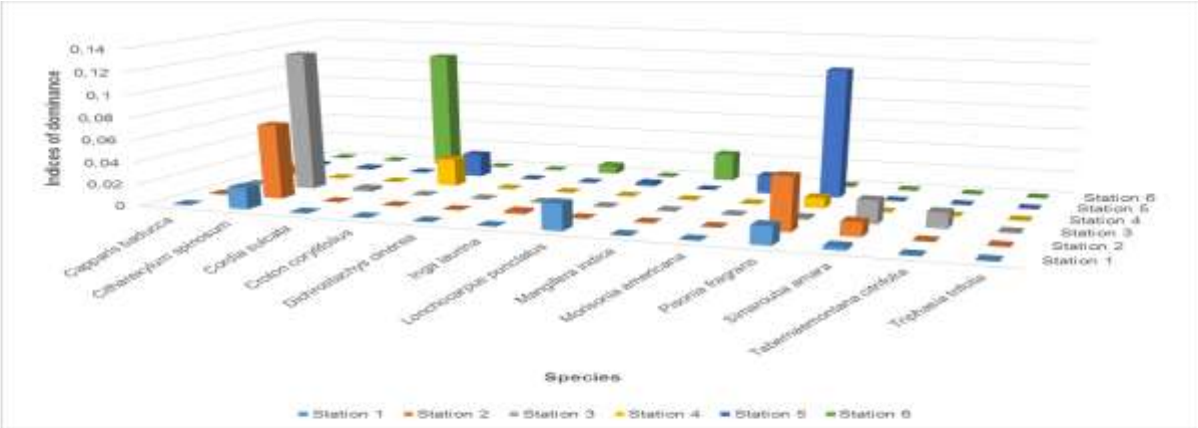


Figure 21 describes the relative dominance of the predominant species in the six stations presented above. The absence of columns in the graph results in a zero dominance index. The most important dominance indices values were found in the individuals with the highest land area (Table 10). This is the case for the following species: *Lonchocarpus punctatus* (Station 1), *Citharexylum spinosum* (Stations 2 and 3), *Pisonia fragrans* (Stations 2 and 5), *Simarouba amara* (Station 3), *Croton corylifolius* (Stations 4 and 5), *Cordia sulcata* (Station 6) and *Mangifera indica* (Station 6) (Figure 21).

Triphasia trifolia has very low dominance index values (of the order of $10^{-4}$ to $10^{-6}$). The highest index (ID) was recorded for station 3 ($4.2.10^{-4}$) (Table 10). This reflects the fact that this station is severely degraded and the most affected by anthropization. It was also in the latter that we recorded the most important individuals and regenerations (Table 5).

The low values obtained are explained by the fact that the recorded individuals have small sections. However, the species was recorded in each of the inventoried stations.

## DISCUSSION

The study area comprises 89 plant species divided into 25 families and 76 genera. The different stations belong mainly to young forests at the pre-forest or shrub stage.

**Figure 22. Areas biologically and physically disturbed by anthropogenic activity (Photos taken at Morne Carrière - Vauclin)**

The degraded nature of these stations is due to anthropization (Figure 22). The site is marked by the presence of a lot of garbage (tires, fishing nets, etc.) which clearly illustrates the degradation level of the stations. These disturbances create ecological dysfunctions which favour certain naturalized allochthonous species from a demographic point of view.

**Photo 5.2: Seasonal tropical evergreen formations of lower horizons and xeric pre-forest to young forests characteristics (Photos taken at Morne Carrière - Vauclin)**

In general, 78% of the surveyed individuals (73) correspond to the plant species indigenous in the Caribbean and therefore Martinique, 12% (11) to naturalized species or crop escapes in the Lesser Antilles. The remaining 10% (9) of the entire surveyed populations regards species introduced for cultivation.

Among the species naturalized in the Lesser Antilles, we have identified two naturalized and potentially invasive species in Martinique belonging to two distinct families: Mimosaceae Dichrostachys cinerea and the Rutaceae Triphasia trifolia.

The Dichrostachys cinerea can be found in very degraded environments: we recorded a single 5 cm diameter individual (Figure 12). It is mainly disseminated anemochorously. The Santo Domingo Acacia (Dichrostachys cinerea) appears at the herbaceous and shrub stage [15] and tends to form dense and impenetrable thickets. It does not possess a precise flowering period, in fact, this species flowers almost all the year. Its seeds have the characteristic of persisting in the soil for long periods of time (circa five years) [41]. This taxon should be monitored because it could pose a threat to the development of other native species.

Triphasia trifolia was observed in all the surveyed stations and 61 mature individuals (excluding seedlings and dead trees) were recorded (Table 9). These individuals had diameters not exceeding 2.5 cm. In view of the results Triphasia trifolia seems to be expanding. In fact, we counted more than 300 seedlings in all stations.

In short, Triphasia trifolia's gradual and rapid increase in population will lead in the future to the establishment of dense carpet-forming monospecific populations and will ultimately eliminate previously present species, and especially the native species.

## CONCLUSION

Martinique is an island system with a small area characterised by strongly anthropic vegetation exposed to the development of invasive species. The dry coastal forests seem to be the most prone to these invasions [9].

Although today Martinique is not experiencing an ecological catastrophe similar to that caused by *Miconia calvescens* (French Polynesia) or *Clidemia hirta* (Wallis and Futuna), many native species such as *Funtumia elastica* or *Triphasia trifolia* must be carefully monitored, despite the fact that for the time being the landscapes are moderately affected by the introduced species and the ecosystems are still able to resist them [42]. Anthropization is therefore one of the factors to be considerably taken into account because it is the source of physical and biological perturbations in the environments.

The *Triphasia trifolia* species represents a great threat to the development of Martinique's native species since its expansion dynamics is mainly linked to the numerous anthropic activities. This species largely colonizes the xeric coastal zone and in a few years could prove to be dominant in this type of biotope. The data collected on the study site show that the number of regenerations and the rate of release (zoochorie) are two elements that will guarantee its ecological success. In fact, apart from the fact that this shrub has negligible biomass (low diametric classes and therefore low land areas), its global distribution will continue to grow gradually over time within the various stations of the study site. In view of its ecological development, we can conclude that *Triphasia trifolia* has the ecological profile and character of a plant naturalized in the study area to the extent that the species has invaded all sites unoccupied by native species.

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