

# Contribution to the Study of Three Potentially Invasive Species in the Lesser Antilles: The Case of Martinique

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## Abstract

The invasive species are the second biggest cause of biodiversity loss. Invasive species are detrimental to the proper functioning of all ecosystems. Island ecosystems are more affected by biological invasions than mainland ecosystems. In Martinique, several potentially invasive plant species are threatening the island's forests. These species manage to establish themselves in all three bioclimatic levels, leading to monospecific formations in certain regions. The analysis is based on a study of three potentially invasive species: *Dichrostachys cinerea*, *Spathodea campanulata* and *Triphasia trifolia*. A total of 48 floristic inventories were carried out in the island's three bioclimatic stages. The data obtained enabled us to characterize station individually. In addition, multivariate statistical analyses (AFC and ACP) were carried out using EXCEL and XLSTAT software to highlight similarities between inventories and determine relationships with environmental variables. The results obtained have enabled us to decipher the main life traits of these species, while establishing their ecological profile when they are placed in the same ecological conditions in the forests of Martinique.

## Keywords

Lesser Antilles, Martinique, Biodiversity, Potentially Invasive Species, *Dichrostachys cinerea*, *Spathodea campanulata*, *Triphasia trifolia*, Anthropization

## 1. Introduction

Urbanization has led to the progressive regression of forests [1]. This regression can be explained by a number of phenomena that erode biodiversity. These include the destruction of natural habitats [2] [3] and the population explosion of

invasive alien species [4]-[10]. This proliferation of invasive alien taxa is the second biggest cause of biodiversity loss and is also known as biological invasion.

Indeed, these taxa possess great ecological plasticity, enabling them to colonize various types of environment and develop ecological niches in a variety of environmental conditions [11]-[13]. During their expansion, they modify environmental characteristics, such as soil chemistry, and disrupt interactions with native plant communities, leading to a reduction in local biodiversity.

Because of their geographical isolation, floristic diversity and limited surface area, islands are particularly vulnerable to this phenomenon [14]-[21]. The island of Martinique is subject to the expansion of several potentially invasive plant species [22]-[30]. Previous work has shown that *Dichrostachys cinerea*, *Spathodea campanulata* and *Triphasia trifolia* are plant species with invasion potential in Martinique [22]-[24].

By studying three potentially invasive species (*Dichrostachys cinerea*, *Spathodea campanulata* and *Triphasia trifolia*) in the different bioclimatic zones of the island, we will be able to answer the following questions:

- Which of these species, *Dichrostachys cinerea*, *Spathodea campanulata* or *Triphasia trifolia*, influenced by the same ecological conditions, is the most competitive?
- What are their ecological profiles?
- What stages of plant succession do they belong to?

In order to answer all these questions, we focused our study on the analysis of several phytocenoses in communes on the island of Martinique corresponding to different stages of evolution and bioclimates (lower, middle and upper).

## 2. Materials

### 2.1. Study Area

Martinique is located at the centre of the Lesser Antilles and has a surface area of 1128 km<sup>2</sup>. It has two main seasons: the dry season (or Lent) and the wet season (or rainy season).

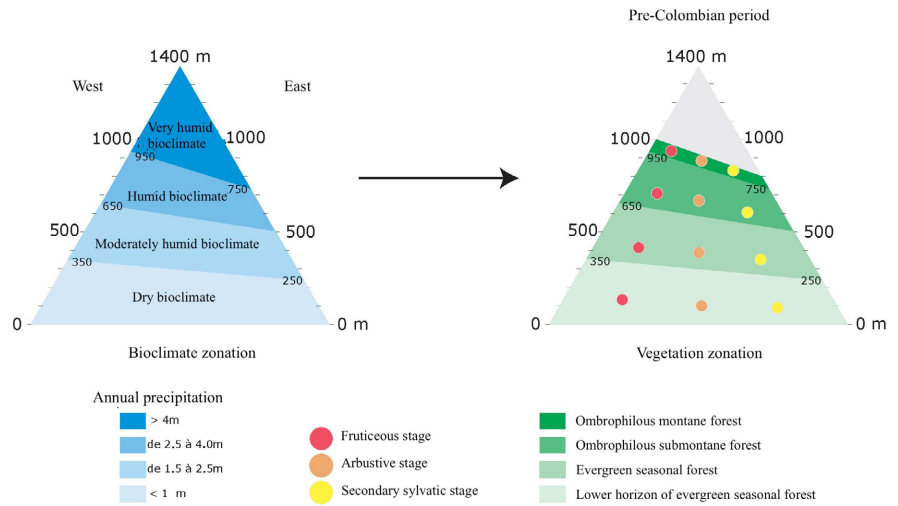
The island's highest point is Montagne Pelée, at around 1397 m. Its topography, marked by mountainous massifs, gives rise to a great diversity of vegetation, ranging from dry to hyper-humid zones (Figure 1). The island's forests, from coast to summit, are influenced by average rainfall variations that oscillate between 1500 mm and 4000 mm of water, or even more (Figure 2). These rainfall variations determine several bioclimatic stages: dry, sub-humid-humid, humid and hyper-humid bioclimates (Figure 1 and Table 1). Each bioclimate is associated with a specific forest type and a collection of characteristic species [22] [25] [30].

Our floristic surveys were carried out in the communes of Prêcheur, Morne Rouge, Schœlcher, Fort-de-France, Marin and Vauclin (Figure 3).

### 2.2. Study Species

#### 2.2.1. *Dichrostachys cinerea*

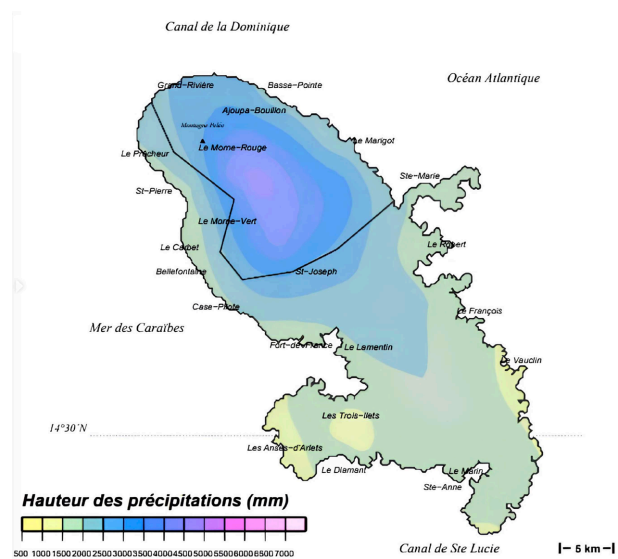
*Dichrostachys cinerea* or Saint-Domingue Acacia, is a shrub or small tree belonging



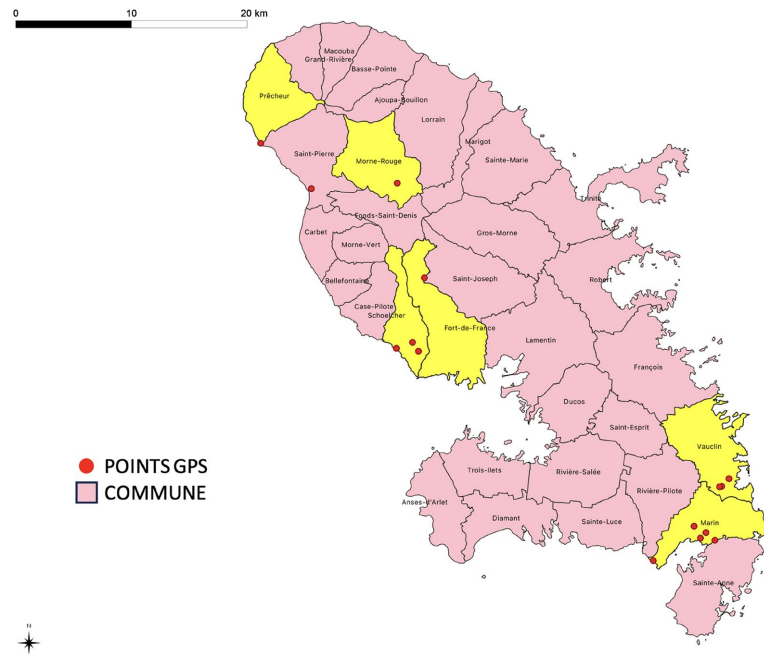
**Figure 1.** Bioclimatic grading in the Lesser Antilles [31].

**Table 1.** Ecosystem potential and bioclimates as a function of mean annual rainfall [32].

Altitudes	Average annual rainfall	Bioclimates	Ecosystemic potentialities
0 - 250 m	1500 mm	Dry	Seasonal evergreen forest of lower horizon and xeric facies (dry forest)
250 - 500 m	1500 - 2500 mm	Moderately humid	Tropical seasonal evergreen forest (mesophilous forest)
	2500 - 4000 mm	Humid	Tropical sub-montane ombrophilous forest (hygrophilous forest)
More than 500 m	More than 4000 mm	Hyperhumid	Tropical montane rainforest (mountain hygrophilous forest)



**Figure 2.** Average annual cumulative rainfall on the island of Martinique.



**Figure 3.** List of surveyed sites.

to the Mimosaceae family (including species like *Inga laurina* or *Samanea saman*) that was introduced to the Lesser Antilles in the 19th century. The species is native to Southern and Tropical Africa. It thrives in open, highly degraded areas or regions with poor soils. The bark of young shoots is green and densely puberulent, while that of adult shoots is brown with whitish lenticels [33]. The bipinnate leaves are made up of 10 to 30 pairs of linear-oblong or obtuse-leaflets.

The fragrant flowers have a bicoloured raceme inflorescence (**Figure 4**).



**Figure 4.** Inflorescences of *Dichrostachys cinerea* (Photo ABATI Y., 2017).

The fruits are glomerular pods, twisted or more or less curved or compressed, containing dark brown obovate seeds [30]. The species reproduces by suckering, by barochory [34] and also by zoochory (avichory, [35]). It occurs in different stages of vegetation evolution: herbaceous, shrubby, pre-forest, young forest and

secondary forest [23] [25]-[30].

Saint-Domingue Acacia also has many virtues. It is used in agroforestry for soil rehabilitation [36] [37].

The bark, roots and leaves are used to treat headaches and toothaches, snake bites and syphilis [38].

### 2.2.2. *Spathodea campanulata*

*Spathodea campanulata* or Gabon Tulip tree is a member of the Bignoniaceae family. It has been cultivated for ornamental purposes and is native to Africa [39]. The compound leaves are imparipinnate and have 4 to 9 pairs of leaflets with acuminate apices (Figure 5). The branches are marked with white lenticels. The scarlet-orange flowers with golden yellow margins are arranged in terminal racemes [33]. The inedible fruits contain a large number of seeds.

The species reproduces by anemochorous seeds and zoochory [40]. The Gabon Tulip tree establishes itself in the shrub, pre-forest, young forest, and advanced secondary forest stages [30] [41] [42].



**Figure 5.** Leaves and inflorescences of *Spathodea campanulata* (Left photo by ELY-MARIUS S., 2016; Right photo by ABATI Y., 2016).

### 2.2.3. *Triphasia trifolia*

*Triphasia trifolia* or Petite Citronnelle is a shrub in the Rutaceae family that was introduced for ornamental purposes in the 19th century [43]. The species favors open, shady environments. Twigs are thorny. The trifoliate leaves are broadly rounded at the tip, wedge-shaped or sometimes rounded at the base (Figure 6).

Fragrant flowers consist of white petals. Solitary or in axillary cymes, they are composed of six stamens. The ellipsoidal to globular fruits are edible. When ripe, they are dull orange-red or purple [44]. The species thrives in the shrub, pre-forest and young forest stages [45].

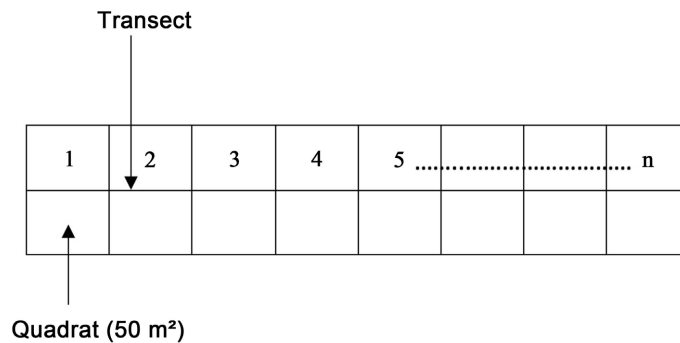
*Triphasia trifolia* establishes itself in shrub, pre-forest and young forest stages [45] and spreads by seeds that can be easily dispersed by animals, particularly birds (avichory) [35] [45]. The species is also used for its antifungal and antibacterial properties to treat colic or diarrhea [46] [47]. The fruits are used for coughs and sore throats [44]. In the French West Indies, infused *Triphasia trifolia* leaves are used as a vermicide [48].



**Figure 6.** Leaves and fruits of Petite Citronnelle (*Triphasia trifolia*) (Photo by ABATI Y., 2016).

### 3. Methods

The proposed method is based on floristic inventories. During these inventories, we delimit a study perimeter called a transect, divided into quadrats [1] (**Figure 7**). The surface area of the transect varies between 500 and 1000 m<sup>2</sup>, depending on the plant formations. We consider the following descriptors: scientific name, total height, height of 1st branching, and trunk diameter (measured at 1.33 m from the ground according to international standards: diametric class).



**Figure 7.** Representation of a transect composed of quadrats [41].

The ecological and structural parameters considered in this study are as follows:

- Absolute frequency  $f_a$ , *i.e.* the number of times a given species has been observed in quadrats or stations;
- Relative frequency  $f_r$ , the ratio of absolute frequency to the total number of quadrats in a transect or stations;
- Density corresponds to the number of individuals on the survey surface;
- The distribution index is defined by the formula:  $I_d = f_r * d$  (density, defined as the ratio between the number of individuals of the species in question and the survey area). It is used to assess how the species population occupies the space at the station;
- The index of dominance (ID) is used to determine the dominance of species among themselves, and is obtained by the following relationship  $ID = I_d * St$  (basal area);
- A factorial correspondence analysis (FCA) using XLSTAT software was used

to compare stations;

- Hierarchical clustering (CAH): Using agglomerative methods to analyze the hierarchical links between individuals and groups.

## 4. Results

### 4.1. Studies of Species-Bioclimate Relationships

#### 4.1.1. Lower Elevation Zone

The analysis carried out in the lower tier is based on the study of 34 inventories in which we have gathered all the stations where *Dichrostachys cinerea*, *Spathodea campanulata* and *Triphasia trifolia* have developed. The results obtained for the stations on the lower elevation zone are presented in the following table (Table 2):

**Table 2.** The main ecological and structural parameters for all the sites in the lower elevation zone.

Rank	Species	fa	fr	Number of individuals per species excluding regenerations and dead trees	Density (ind/m <sup>2</sup> )	Id	Total basal area per species	ID
	<i>Dead trees</i>	28	82%	1740	0.0859	0.0708	5.2268	3.70E-01
1	<i>Pisonia fragrans</i>	32	94%	1356	0.0670	0.0630	3.1131	1.96E-01
2	<i>Citharexylum spinosum</i>	24	71%	634	0.0313	0.0221	5.3962	1.19E-01
3	<i>Dichrostachys cinerea</i>	21	62%	1263	0.0624	0.0385	1.6066	6.19E-02
4	<i>Bourreria succulenta</i>	28	82%	1106	0.0546	0.0450	1.2704	5.71E-02
5	<i>Haematoxylon campechianum</i>	15	44%	399	0.0197	0.0087	2.6821	2.33E-02
6	<i>Capparis indica</i>	27	79%	825	0.0407	0.0324	0.6038	1.95E-02
7	<i>Erythroxylon havanense</i>	32	94%	558	0.0276	0.0259	0.7491	1.94E-02
8	<i>Croton bixoides</i>	24	71%	784	0.0387	0.0273	0.6558	1.79E-02
9	<i>Bursera simaruba</i>	26	76%	116	0.0057	0.0044	1.8025	7.90E-03
10	<i>Swietenia aubrevilleana</i>	12	76%	632	0.0312	0.0239	4.1724	9.96E-02
11	<i>Zanthoxylum monophyllum</i>	23	35%	434	0.0214	0.0076	1.3862	1.05E-02
12	<i>Tabebuia heterophylla</i>	15	68%	148	0.0073	0.0049	3.6457	1.80E-02
13	<i>Leucaena leucocephala</i>	11	32%	350	0.0173	0.0056	0.8065	4.51E-03
14	<i>Acacia sp</i>	13	38%	217	0.0107	0.0041	0.9302	3.81E-03
15	<i>Lonchocarpus punctatus</i>	11	32%	172	0.0085	0.0027	1.2188	3.35E-03
16	<i>Capparis flexuosa</i>	32	94%	283	0.0140	0.0132	0.1919	2.52E-03
17	<i>Gliricidia sepium</i>	9	26%	91	0.0045	0.0012	1.8815	2.24E-03
18	<i>Myrcia citrifolia</i>	7	21%	567	0.0280	0.0058	0.3225	1.86E-03
19	<i>Tabernaemontana citrifolia</i>	18	21%	259	0.0128	0.0026	0.2926	7.70E-04
20	<i>Swietenia mahagoni</i>	7	53%	96	0.0047	0.0025	1.3656	3.43E-03
21	<i>Acanthocereus tetragonus</i>	5	15%	307	0.0152	0.0022	0.5856	1.31E-03

## Continued

22	<i>Erithalis fruticosa</i>	7	21%	332	0.0164	0.0034	0.3279	1.11E-03
23	<i>Ficus citrifolia</i>	9	26%	30	0.0015	0.0004	2.8132	1.10E-03
24	<i>Triphasia trifolia</i>	18	26%	387	0.0191	0.0051	0.1914	9.69E-04
77	<i>Spathodea campanulata</i>	1	18%	11	0.0005	0.0001	0.2921	2.80E-05

Absolute frequency (fa) = presence of the species in the different quadrats; Relative frequency (fr) = Absolute frequency/by the number of quadrats; Density = number of individuals/survey area; Index of distribution (Id) = Relative Frequency \* Density; Index of dominance (ID) = Index of distribution \* basal area.

*Pisonia fragrans*, *Citharexylum spinosum*, *Dichrostachys cinerea*, *Bourreria succulenta*, *Capparis indica*, *Erythroxyton havanense*, *Croton bixoides* *Bursera simaruba*, *Swietenia aubrevilleana*, *Tabebuia heterophylla*, *Capparis flexuosa*, *Chiococca alba* and *Pisonia aculeata* are the most widely distributed species. In order of ecological importance, *Pisonia fragrans*, *Citharexylum spinosum*, *Dichrostachys cinerea* and *Bourreria succulenta* are the dominant species. These taxa have the highest dominance indices (DI) (Table 2).

*Dichrostachys cinerea* is relatively well distributed (fr = 62%; Table 2) and ranks third in Table 2 in terms of the Dominance Index. A total of 1263 individuals with diameters ranging from 2.5 to 15 cm were counted. Most of these were 2.5 (73.23%) and 5 cm (21.38%) in diameter. The remaining 5.39% were 10 and 15 cm in diameter.

*Triphasia trifolia* is much less widely distributed (fr = 26%; Table 2) and ranks 24th. 387 individuals of the species were observed (Table 2), most of them with small diameters (2.5 cm).

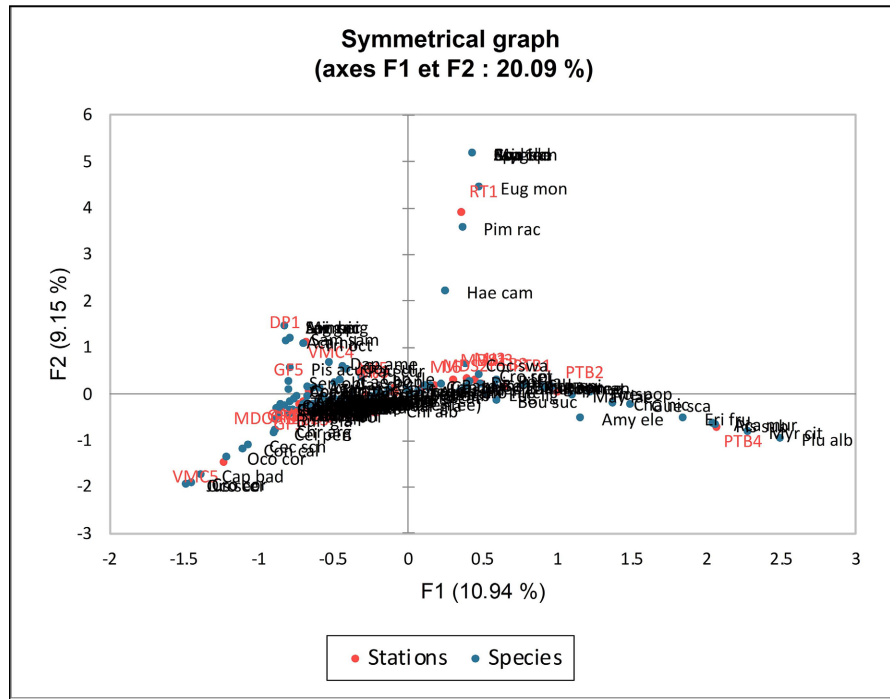
The results show that *Spathodea campanulata* is an erratic species, with 11 individuals observed at a single station (Table 2). Although the majority of *Spathodea campanulata* were found in the 2.5 cm to 5 cm diameter classes, two individuals measuring 45 and 60 cm were also counted.

The inertia of the first axis (F1) is 10.92% and that of the second axis (F2) is 9.17%. This corresponds to a maximum inertia of 20.09% (Figure 8). Axis 1 appears to oppose changes in floristic composition, while axis 2 differentiates the gradient of temporal evolution. Station PTB4 stands out from all the lower elevation zone stations, showing little or no similarity to them (Figure 8).

#### 4.1.2. Middle Elevation Zone

In the mid-elevation zone, 10 inventories were pooled to study the existing relationships between the three potentially invasive plant species in our study.

*Citharexylum spinosum*, *Pisonia fragrans* and *Triphasia trifolia* are the most widely distributed species in the middle elevation zone (Table 3). In terms of dominance index, *Citharexylum spinosum*, and secondarily *Swietenia macrophylla* and *Pisonia fragrans*, are the species that make the best use of environmental factors.



**Figure 8.** Mesological and temporal differentiation of all the stations in the lower elevation zone.

**Table 3.** The main ecological and structural parameters for all the sites in the middle elevation zone.

Rank	Species	fa	fr	Number of individuals per species excluding regenerations and dead trees	Density (ind/m <sup>2</sup> )	Id	Total basal area per species	ID
1	<i>Citharexylum spinosum</i>	6	60%	290	0.0443	0.0266	3.6845	9.79E-02
2	<i>Swietenia macrophylla</i>	4	40%	173	0.0264	0.0106	4.6407	4.90E-02
3	<i>Pisonia fragrans</i>	6	60%	553	0.0844	0.0507	0.7393	3.74E-02
	<i>Dead trees</i>	5	50%	218	0.0333	0.0166	1.5929	2.65E-02
4	<i>Mangifera indica</i>	3	30%	75	0.0115	0.0034	3.9422	1.35E-02
5	<i>Simarouba amara</i>	2	20%	259	0.0395	0.0079	1.6906	1.34E-02
6	<i>Inga laurina</i>	4	40%	256	0.0391	0.0156	0.5532	8.65E-03
7	<i>Cordia sulcata</i>	2	20%	171	0.0261	0.0052	1.3902	7.26E-03
8	<i>Ocotea coriacea</i>	3	30%	308	0.0470	0.0141	0.4732	6.68E-03
9	<i>Tabernaemontana citrifolia</i>	4	40%	191	0.0292	0.0117	0.2744	3.20E-03
10	<i>Myrcia splendens</i>	2	20%	316	0.0482	0.0096	0.2528	2.44E-03
11	<i>Spathodea campanulata</i>	3	30%	52	0.0079	0.0024	0.6813	1.62E-03
12	<i>Tabebuia heterophylla</i>	3	30%	29	0.0044	0.0013	1.0740	1.43E-03
13	<i>Samanea saman</i>	2	20%	35	0.0053	0.0011	1.2154	1.30E-03
14	<i>Andira inermis</i>	2	20%	33	0.0050	0.0010	0.9945	1.00E-03
15	<i>Haematoxylon campechianum</i>	4	40%	13	0.0020	0.0008	1.1074	8.79E-04

## Continued

16	<i>Cecropia schreberiana</i>	2	20%	27	0.0041	0.0008	0.9881	8.15E-04
17	<i>Eugenia ligustrina</i>	3	30%	179	0.0273	0.0082	0.0879	7.20E-04
18	<i>Erythroxylon havanense</i>	4	40%	71	0.0108	0.0043	0.1242	5.38E-04
19	<i>Casearia decandra</i>	4	40%	46	0.0070	0.0028	0.1797	5.05E-04
20	<i>Swietenia mahagoni</i>	2	20%	14	0.0021	0.0004	1.0755	4.60E-04
21	<i>Ceiba pentandra</i>	2	20%	39	0.0060	0.0012	0.3721	4.43E-04
22	<i>Sapium caribaeum</i>	1	10%	24	0.0037	0.0004	1.1801	4.32E-04
23	<i>Chrysophyllum argenteum</i>	3	30%	59	0.0090	0.0027	0.1556	4.20E-04
24	<i>Terminalia catappa</i>	3	30%	20	0.0031	0.0009	0.4055	3.71E-04
25	<i>Bursera simaruba</i>	4	40%	62	0.0095	0.0038	0.0962	3.64E-04
26	<i>Triphasia trifolia</i>	5	50%	85	0.0130	0.0065	0.0417	2.71E-04
57	<i>Funtumia elastica</i>	1	10%	19	0.0029	0.0003	0.0417	1.21E-05
75	<i>Dichrostachys cinerea</i>	2	20%	4	0.0006	0.0001	0.0049	6.00E-07

Absolute frequency (fa) = presence of the species in the different quadrats; Relative frequency (fr) = Absolute frequency/by the number of quadrats; Density = number of individuals/survey area; Index of distribution (Id) = Relative Frequency \* Density; Index of dominance (ID) = Index of distribution \* basal area.

*Spathodea campanulata* is sparsely distributed (fr = 30%; **Table 3**) and ranks 11th among mid-elevation zone in terms of Dominance Index (**Table 3**).

Despite the fact that the population abundance and distribution of *Triphasia trifolia* is greater than that of *Spathodea campanulata*, Petite Citronnelle is ranked 26th in **Table 3**. 85 individuals of the species are distributed in diameter classes between 2.5 and 5 cm. Specimens of the Gabon Tulip tree, on the other hand, fall into larger diameter classes.

The results show that *Dichrostachys cinerea* is an erratic species, with 4 individuals observed at two stations (**Table 3**). In these two phytocenoses, the presence of the species seems to be due to the presence of bovine species displaced by farmers during dry periods.

The inertia associated with the first axis is 22.01% and that of the second is 17.20%. For these two axes, the maximum inertia is 39.21% (**Figure 9**). The F1 axis appears to differentiate floristic compositions, while the F2 axis tends to discriminate the temporal evolutionary dynamics of the stations.

The distribution of sites and plant species is linked both to the stage of temporal evolution, which varies between the pre-silvicultural stage and the secondary silvicultural stage, and to population variations.

This AFC made it possible to group together all the stations with similar floristic composition and population structure. The station FROU9 differs from the other middle elevation zone and is characterized by several (11) singular species, including *Funtumia elastica*, *Homalium racemosum* and *Licania ternatensis* (**Figure 9**).





In terms of the F2 axis, stations CF1 and MCES2 have values in common, both characterizing phytocenoses at the young sylvatic stage and marked by the presence of species such as *Conostegia montana*, *Palicourea crocea*, *Swietenia mahagoni* and *Talauma dodecapetala*. However, the great distance observed between the two phytocenoses can be explained by the fact that 27 plant species are specific to station MCES2. Stations CF2 and CF3 have very similar values. They are characterized by species such as *Clidemia hirta* and *Hibiscus elatus*, which can only be observed in their phytocenosis.

#### 4.1.4. Global Analysis

A total of 48 floristic inventories were conducted on the island of Martinique, covering a study area of 29597.3 m<sup>2</sup>. Despite the lower elevation zone being more heavily impacted by anthropogenic activity, the other bioclimatic zones of the island are not spared. In addition to the fact that the three potentially invasive plant species in our study (*Dichrostachys cinerea*, *Spathodea campanulata* and *Triphasia trifolia*) have developed in this bioclimatic zone, they are also much more numerous. This ability to adapt can be seen for *Spathodea campanulata* in the upper elevation zone, where the number of individuals is much higher, and for *Triphasia trifolia* in the middle elevation zone.

Depending on the altitudinal gradient, we observed a variation in population abundance and plurality of potentially invasive taxa. In the lower tier, we counted 1661 potentially invasive species (all species combined), compared with 160 in the middle tier and 162 individuals in the upper tier (Figure 11).

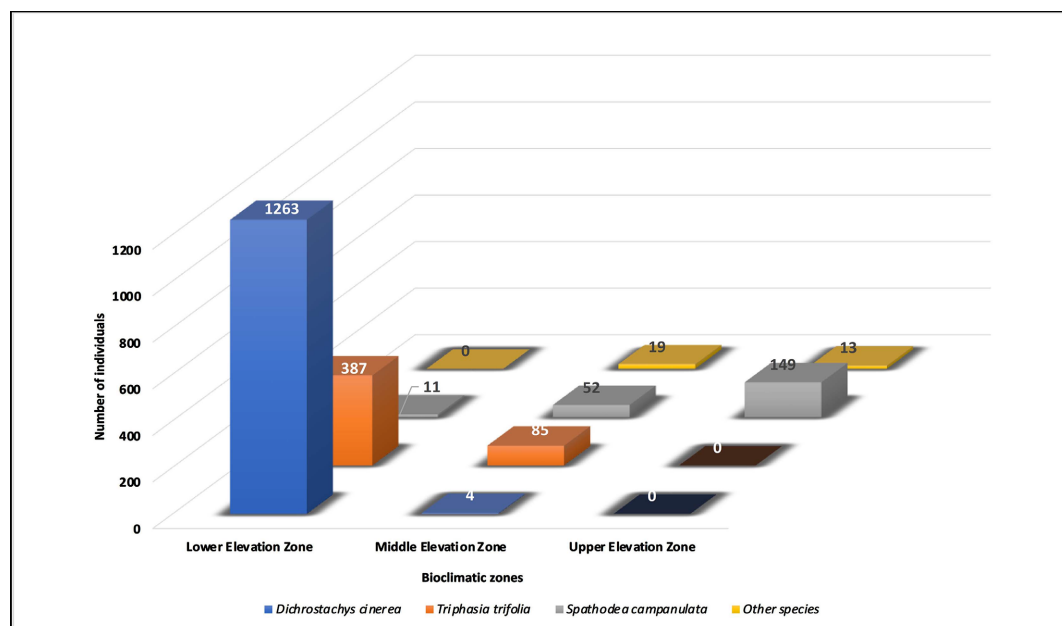


Figure 11. Abundance of potentially invasive plant species according to bioclimatic gradation.

Mesological factors condition the distribution of species and the multiplicity of phytocenoses. In his writings, Professor Philippe JOSEPH indicates that anthro-

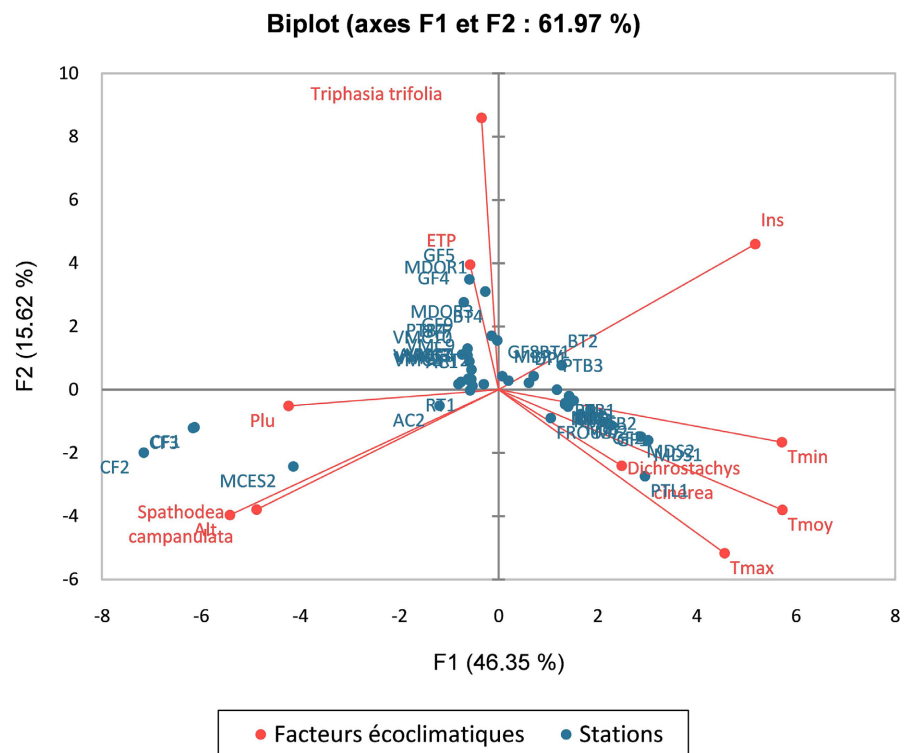
pogenic factors dictate the establishment and evolution of vegetation [45].

## 5. Discussion

### 5.1. Principal Component Analysis (PCA)

Principal component analysis of all the stations studied reveals major disparities in the presence of the three potentially invasive species at certain stations, across all levels (lower, middle and upper) (Figure 12).

*Spathodea campanulata* seems to favor areas with high rainfall and high altitude. *Dichrostachys cinerea* tends to favor areas with high temperatures and low altitudes, while *Triphasia trifolia* seems to fall somewhere in between (Figure 12).



**Figure 12.** Principal Component Analysis of all stations studied. Plu: Rainfall; Alt: Altitude; Ins: Insulation; ETP: Evapotranspiration; Tmin: Mean minimum temperature; Tmax: Mean maximum temperature; Tmoy: Mean temperature.

### 5.2. Ecological Profile

Using Professor Philippe JOSEPH's representation model, we assigned 5 stages of temporal evolution to the various potentially invasive species, based on their population abundance, frequency and density [45]. This representation was used in all bioclimatic stages.

#### 5.2.1. Lower Elevation Zone

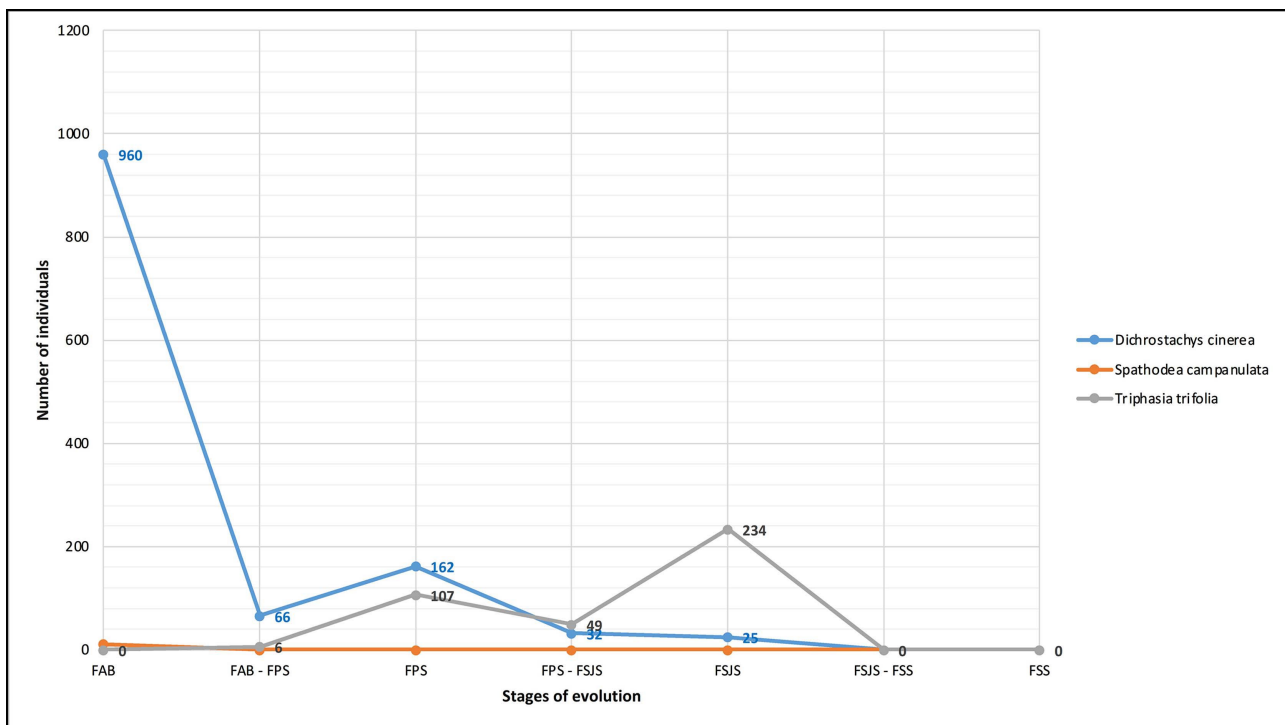
In the lower elevation zone, *Dichrostachys cinerea* and *Triphasia trifolia* are the most competitive species (Figure 13). *Spathodea campanulata* is a sporadic spe-

cies in this bioclimatic tier. In the pre-sylvatic or pre-sylvatic to young sylvatic plant communities, Petite Citronnelle and Saint-Domingue Acacia compete with each other. In shrubby or even pre-sylvatic plant formations, populations of *Dichrostachys cinerea* dominate (Table 5). It is able to dominate thanks to its tolerance of degraded soils [23] [33]. In more advanced stages of evolution (young sylvatic), *Triphasia trifolia* is dominant.

**Table 5.** Ecological profile of the three potentially invasive species in the lower elevation zone, Table inspired by the representation model of Professor Philippe JOSEPH [27].

Species	FAB	FPS	FSJS	FSS	FSST
<i>Dichrostachys cinerea</i>	+++	+++	++		
<i>Spathodea campanulata</i>	+				
<i>Triphasia trifolia</i>	+	+++	+++		

(+) sparse or erratic; (++) abundant; (+++) very abundant. (FAB) Shrub formation; (FPS) Pre-sylvatic formation; (FSJS) Young sylvatic formation; (FSS) Secondary sylvatic formation; (FSST) Late secondary sylvatic formation.



**Figure 13.** Population distribution of the 3 potentially invasive species of the lower elevation zone according to evolutionary stage. (FAB) Shrub formation; (FPS) Pre-sylvatic formation; (FSJS) Young sylvatic formation; (FSS) Secondary sylvatic formation.

### 5.2.2. Middle Elevation Zone

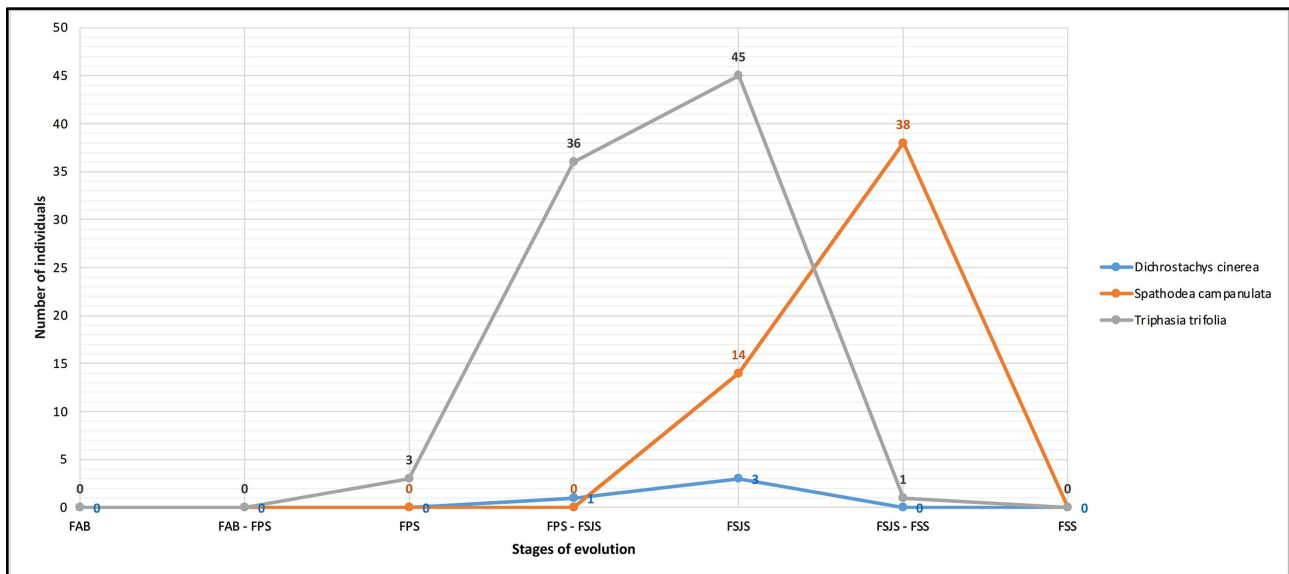
In the middle elevation zone, *Dichrostachys cinerea* is an erratic species. *Spathodea campanulata* and *Triphasia trifolia* are the most competitive species in this bioclimatic zone: their dominance varies according to the stage of temporal evolution of the sites. In young pre-sylvatic to sylvatic formations, individuals of *Tri-*

*phasia trifolia* are in the majority, whereas those of *Spathodea campanulata* are predominant in more advanced formations. In the young to secondary sylvatic formations in the gaps (Table 6 and Figure 14). *Triphasia trifolia* is better adapted to more advanced formations, such as young to secondary sylvatic forests, and grows mainly in subhumid to humid areas of the island.

**Table 6.** Ecological profile of the three potentially invasive species in the middle tier, Table inspired by the representation model of Professor Philippe JOSEPH [27].

Species	FAB	FPS	FSJS	FSS	FSST
<i>Dichrostachys cinerea</i>		+	+		
<i>Spathodea campanulata</i>				++	
<i>Triphasia trifolia</i>		++	+		

(+) sparse or erratic; (++) abundant; (+++) very abundant. (FAB) Shrub formation; (FPS) Pre-sylvatic formation; (FSJS) Young sylvatic formation; (FSS) Secondary sylvatic formation; (FSST) Late secondary sylvatic formation.



**Figure 14.** Population distribution of the 3 potentially invasive species of the middle elevation zone according to stage of evolution. (FAB) Shrub formation; (FPS) Pre-sylvatic formation; (FSJS) Young sylvatic formation; (FSS) Secondary sylvatic formation.

### 5.2.3. Upper Elevation Zone

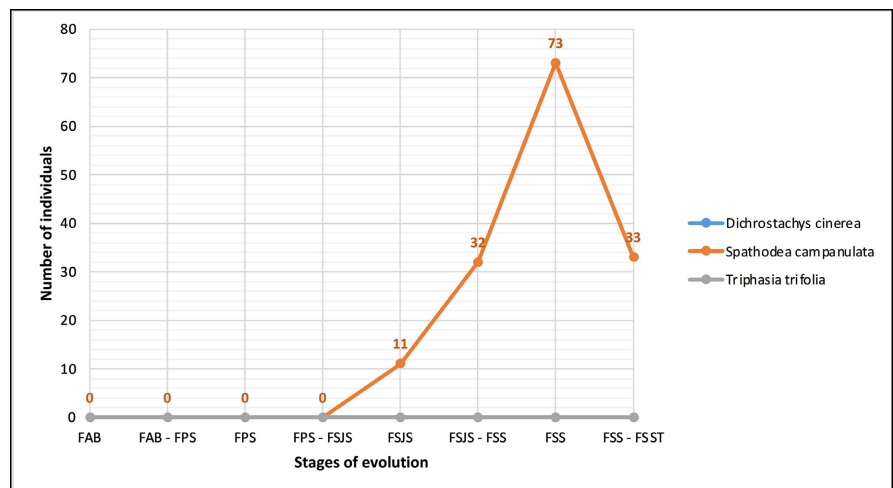
In the upper elevation zone, *Spathodea campanulata* is the only potentially invasive plant species to develop. In the submontane ombrophilous plant communities, conditions are not favourable for the development of *Triphasia trifolia* or *Dichrostachys cinerea*. At this bioclimatic level, anthropisation is not as prevalent as in the two previous levels and advanced formations are still dominant. In the upper elevation zone, *Spathodea campanulata* is the only potentially invasive plant species to develop. In the submontane ombrophilous plant communities, conditions are not favourable for the development of *Triphasia trifolia* or *Dichrostachys cinerea*. At this bioclimatic level, anthropisation is not as prevalent as in the two

previous levels and advanced formations are still dominant. Gabon Tulip tree alone dominates in young to late secondary sylvatic formations and seems to favour areas with high rainfall and high altitude (Table 7 and Figure 15) [24].

**Table 7.** Ecological profile of the three potentially invasive species in the upper elevation zone, Table inspired by the representation model of Professor Philippe JOSEPH [27].

Species	FAB	FPS	FSJS	FSS	FSST
<i>Dichrostachys cinerea</i>					
<i>Spathodea campanulata</i>			++	++	++
<i>Triphasia trifolia</i>					

(+) sparse or erratic; (++) abundant; (+++) very abundant. (FAB) Shrub formation; (FPS) Pre-sylvatic formation; (FSJS) Young sylvatic formation; (FSS) Secondary sylvatic formation; (FSST) Late secondary sylvatic formation.

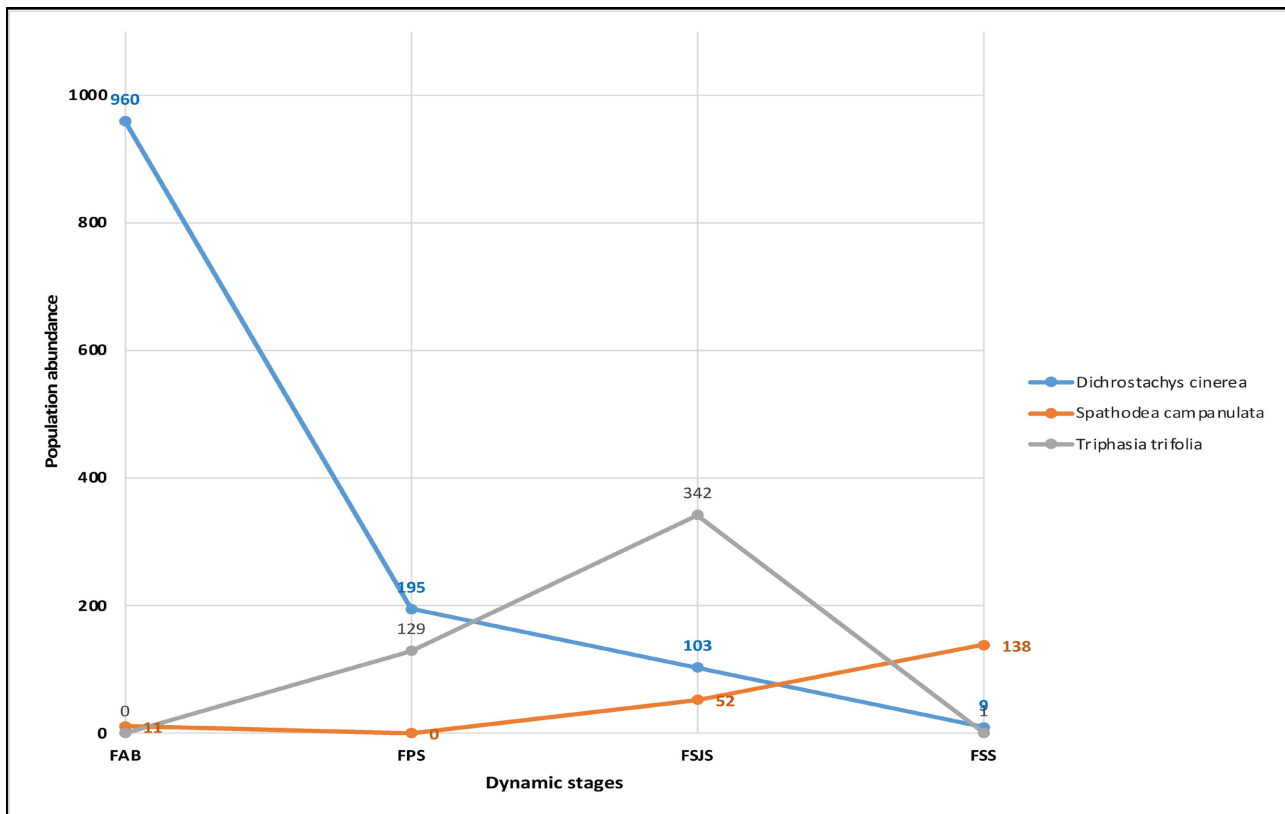


**Figure 15.** Population distribution of the 3 potentially invasive species of the upper elevation zone according to evolutionary stage. (FAB) Shrub formation; (FPS) Pre-sylvatic formation; (FSJS) Young sylvatic formation; (FSS) Secondary sylvatic formation; (FSST) Late secondary sylvatic formation.

### 5.3. Analysis of Bioclimatic Levels

Figure 16 shows a variation in the population abundance of the three species according to the stage of temporal evolution of each of the stations in which they were observed. *Dichrostachys cinerea* predominates in the lower elevation zone, in shrubby or even pre-silvicultural formations. We counted 960 individuals in the shrubby formations and 195 specimens in the pre-silvicultural plant communities (Figure 16). In the slightly more advanced formations of the middle level, i.e. pre-sylvatic to young sylvatic, the species *Triphasia trifolia* is dominant.

In the more advanced formations of the upper, secondary to late secondary sylvatic stage, we observed a decline in *Dichrostachys cinerea* and *Triphasia trifolia* and an increase in *Spathodea campanulata*.



**Figure 16.** Population distribution of the 3 potentially invasive species according to stage of evolution and bioclimatic stage. (FAB) Shrub formation; (FPS) Pre-sylvatic formation; (FSJS) Young sylvatic formation; (FSS) Secondary sylvatic formation.

## 6. Conclusions

This study, conducted on three potentially invasive taxa (*Dichrostachys cinerea*, *Spathodea campanulata*, and *Triphasia trifolia*), highlights the significant impact of biological invasions on island ecosystems. These species exhibit distinct ecological profiles and competition dynamics that vary according to the bioclimatic zones of the island, as well as the stage of development of the plant communities within these zones.

Based on our analysis, *Dichrostachys cinerea* proves particularly competitive in young vegetation formations, especially in the shrub and pre-forest stages of the lower elevation zone, where it is highly dominant. In contrast, *Triphasia trifolia* becomes more competitive in young to secondary forest formations, although its distribution remains more limited compared to *Dichrostachys cinerea* in this bioclimatic zone. As for *Spathodea campanulata*, although sporadic in the lower zone, it develops more significantly in more advanced forest formations of the upper zone, where it is the only potentially invasive species to be dominant.

The notable differences in the ecological profiles of the studied species, in terms of distribution, density, and dominance, are largely influenced by the bioclimatic and anthropogenic conditions of each zone [45].

It is crucial to continue monitoring the spread of these species and adopt suitable management strategies to preserve local biodiversity and mitigate the nega-

tive impacts on forest ecosystems.

In conclusion, although *Dichrostachys cinerea*, *Spathodea campanulata*, and *Triphasia trifolia* are not uniformly invasive across all bioclimatic zones of Martinique, their invasive potential remains a concern. Conservation efforts, as well as measures to control their spread, must be strengthened to prevent further disruption to the ecological balance of the island's forests.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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