

Distribution of the Invasive Plant Species *Chromolaena Odorata* L. in the Zamboanga Peninsula, Philippines

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Abstract. The ecology of the highly invasive plant species *C. odorata* is poorly studied in the Philippines in spite of the fact that it is hard to eradicate, a nuisance in plantations, and known to harm domesticated animals and decimate native plant species. In order to determine the distribution of the species and local ecological factors, we estimated in 75 transect lines the percentage cover of *C. odorata* and other plant species growing around it, and concurrently determined soil parameters (soil type, pH, total nitrogen, total phosphorus, total potassium, and % organic matter) in three Provinces of the Zamboanga Peninsula, Southern Philippines. Multivariate Canonical Correspondence Analysis (CCA) revealed no significant relationship between soil parameters and the abundance of *C. odorata* suggesting eurytopy to edaphic conditions. Peak abundance of *C. odorata* was associated with reduced abundance of native plant species, but coconut, banana, mango and tree plantation environments appeared to promote growth and the competitive edge of *C. odorata*. This study demonstrates that through a multivariate approach we were able to discern that *C. odorata* is a highly adaptable species that pose a threat to native plant biodiversity, and that its distribution and spread seem to be supported by plant monoculture systems.

Keywords: *Chromolaena odorata* L., invasive plant species, biodiversity, multivariate analysis, ecology

1. Introduction

Chromolaena odorata (L.) King and Robinson 1987, a species of Asteraceae Family and known in English as Siam weed, is a perennial shrub, native to Central and South America [1]. Reported as one of the world's most invasive, it is considered to be a serious weed in central and western Africa, India, Australia, Pacific Islands, and Southeast Asia [2]. This species has a wide tolerance to various climates, having already invaded five continents including Asia, North and South America as well as North and South Africa [3]. It can quickly establish and smother plant crops, forestry and native vegetation [4]. It is unpalatable and noxious and may cause death if ingested by domesticated animals [5]. It was recognized as the most problematic weed in coconut plantations in Sri Lanka as early as 1944, and has become a problem in rubber, palm oil, tea, coffee, cashew, teak and other plantation crops in Asia since then [6]. The geographical distribution of *C. odorata* is known to be limited to regions within 30° N and 30° S latitudes in areas with a rainfall of 200 cm and above and where air temperature ranges from 20°C to 37°C [7].

According to Awanyo [8], *C. odorata* is viewed as a major agronomic problem in many tropical countries. It expands rapidly at the onset of the rainy season [9], and forms impenetrable tangles that may ultimately shade out indigenous vegetation [10]. Through physical smothering and allelopathy, *C. odorata* reduces vegetation heterogeneity in grasslands and forests [11]. It is one of the most important invader species in the savanna biome in South Africa [12]. The plant's ability to thrive in a wide variety of soils in the tropics, and its short juvenile stage, flowering in dry season, prolific seed production, and strong ability to resprout after burning during land preparation all contribute to its invasiveness [13], [14], [15].

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Its distribution and abundance is least studied in the Philippines. Hence, this study has two aims: the first is to determine the distribution and estimate the abundance of the species in the Zamboanga Peninsula of Mindanao, Southern Philippines, in order to come up with a baseline information about its level of invasion in the area; and the second is to determine the possible relationship between selected soil parameters and other plant species with the abundance of *C. odorata*.

2. Materials and Methods

2.1. Plant collection and identification

This study was conducted on July-December 2010 (rainy season) at three Provinces of Zamboanga Peninsula, namely, Zamboanga del Sur, Zamboanga del Norte and Zamboanga Sibugay (Fig. 1). Eight to ten municipalities per Province were randomly assigned as sampling sites. Three 10-m transect lines per site were laid parallel to the right side of main thoroughfares. A total of 75 transect lines were sampled in the three Provinces. Percentage abundance of all plant species, including *C. odorata*, was computed as the length (in meters) intercepted by each species within a transect line. Biomass (kg dry weight/sqm) of large colonies of *C. odorata* was recorded. The location of each site was recorded using a Garmin Nuvi 200 Global Positioning System (GPS). Fresh samples and photographs of plant each species were taken for identification purposes. Taxonomic identification of plants followed the publications by Madulid [16], and Francis [17].

2.2. Soil parameters

From a sampling site, 100g of soil sample was collected, air-dried and stored in clean plastics bags. All samples were brought to the soil laboratory of the Department of Agriculture, Regional Office, Zamboanga City for the analysis of pH; organic matter content; total N, P, and K; and soil type.

2.3. Multivariate Analysis

The gradient length of the species-abundance data was derived using Detrended Correspondence Analysis (DCA), and if longer gradient lengths (>4) were obtained, the relationship between square root-transformed environmental and species-abundance data was analyzed using the constrained nonlinear ordination Canonical Correspondence Analysis (CCA) available in the software CANOCO version 4.5 [18]. Monte Carlo simulation was used to test for the statistical significance of the relationship, and stepwise multiple regression (Forward Selection) was used to identify statistically significant environmental variables [18]. Tukey's Honestly Significant Difference (HSD) test was used to compare means between soil parameters.

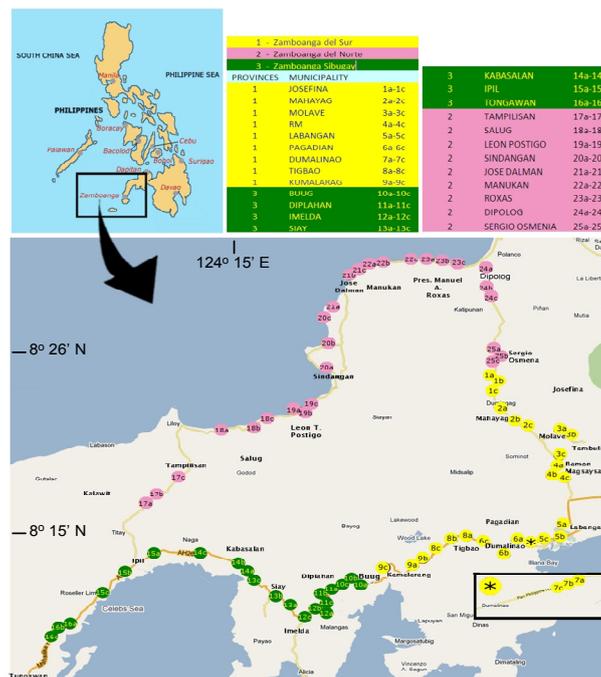


Fig 1: Map of *C. odorata* sampling sites (circles) in the Zamboanga Peninsula. Inset is the map of the Philippines with

the Peninsula enclosed in a rectangle. Sites 1-9, 10-17, 17-24, are parts of Zamboanga del Sur, Zamboanga Sibugay, and Zamboanga del Norte Provinces, respectively.

3. Results and Discussion

Chromolaena odorata was found in open well-drained ground like dry and exposed slopes, and in abandoned fields and pastures throughout the Zamboanga Peninsula. Essentially all sites have already been invaded with *C. odorata*. Our dry weight biomass estimates ranged from 0.46 - 1.27 kg per sq. m. for large colonies of the species. Thirty six plant species were recorded as associates of *C. odorata* (Table 1). Except for very tall species like coconuts and trees, other plant species associates had very low percentage abundance (e.g., all shrubs had percentage cover of < 3%).

Soil characteristics varied between sampling areas (Table 2). Mean soil pH in the sampling sites was acidic which ranged from 5.41 to 6.30. Mean organic matter was fairly low (0.9-1.62%). Total nitrogen was within the range of 0.05-0.80 ppm.

Table 1. Mean percent abundance (\pm SD, n = 7) of plant species that grow with *C. odorata* at different sampling areas in Zamboanga Peninsula. Codes for each species are used in the multivariate canonical correspondence analysis.

Species	Common Name	Code	Zamboanga Sibugay	Zamboanga del Sur	Zamboanga del Norte
<i>Acacia auriculaeformi</i> L.	acacia tree	Aau	0.00	0.00	0.95 \pm 2.52
<i>Andropogon aciculatus</i> Retz.	love Grass/amorsiko	Aac	0.00	0.71 \pm 1.89	0.71 \pm 1.31
<i>Athyrium esculentum</i> Retz.	fern	Aes	0.00	0.48 \pm 1.26	0.72 \pm 0.89
<i>Alocasia macrorrhiza</i> L.	elephant ear/badiang	Ama	0.00	0.48 \pm 1.26	0.14 \pm 0.38
<i>Annona muricata</i> L.	guyabano	Amu	0.48 \pm 1.26	0.00	0.00
<i>Amaranthus spinosus</i> L.	kulitis	Asp	0.48 \pm 1.26	0.00	0.00
<i>Bambusa spinosa</i> Roxb	bamboo	Bsp	0.00	1.90 \pm 3.39	0.95 \pm 2.52
<i>Chrysophyllum caninito</i> L.	star apple	Cca	0.00	0.95 \pm 2.52	0.00
<i>Colocasia esculenta</i> L.	gabi	Ces	0.00	0.00	0.24 \pm 0.63
<i>Citrus maxima</i> Merr.	pomelo	Cma	0.00	0.00	0.95 \pm 2.52
<i>Cocos nucifera</i> L.	coconut	Cnu	9.90 \pm 4.72	9.04 \pm 9.51	9.29 \pm 9.13
<i>Carica papaya</i> L.	papaya	Cpa	0.00	0.00	0.95 \pm 2.52
<i>Digitaria ciliaris</i> Retz.	crabgrass	Dci	0.00	0.00	0.24 \pm 0.63
<i>Eleusine indica</i> L.	yardgrass/palagtiki	Ein	0.00	1.19 \pm 1.59	0.95 \pm 1.89
<i>Ficus benjamina</i> L.	balete	Fbe	0.24 \pm 0.63	0.00	0.95 \pm 2.52
<i>Gmelina arborea</i> Roxb.	gemilina tree	Gar	10.39 \pm 4.61	8.09 \pm 4.23	2.95 \pm 3.85
<i>Gliricidia sepium</i> Jacq.	madre de cacao	Gse	2.05 \pm 2.13	3.10 \pm 3.52	0.00
<i>Hyptis capitata</i> Jacq.	knobweek/butones	Hca	0.00	0.00	0.24 \pm 0.63
<i>Imperata cylindrica</i> L.	cogon grass	Icy	1.91 \pm 2.24	5.47 \pm 4.68	3.09 \pm 4.35
<i>Ipomoea triloba</i> L.	kamu-kamote	Itr	0.00	0.48 \pm 1.26	0.00
<i>Jatropha curcas</i> L.	tuba-tuba	Jcu	0.00	0.00	0.14 \pm 0.38
<i>Leucaena leucocephala</i> L.	ipil-ipil	Lle	1.67 \pm 2.15	2.86 \pm 1.58	0.00
<i>Manihot esculenta</i> Crantz	cassava	Mes	1.19 \pm 2.49	0.00	0.48 \pm 1.26
<i>Mangifera indica</i> L.	mango tree	Min	0.86 \pm 1.86	2.86 \pm 2.84	2.38 \pm 3.83
<i>Moringa oleifera</i>	malungay	Mol	0.00	0.00	0.48 \pm 1.26
<i>Musa paradisiacal</i>	banana	Mpa	3.57 \pm 2.62	6.67 \pm 3.47	7.63 \pm 5.09
<i>Mimosa pudica</i> L.	makahiya grass	Mpu	0.24 \pm 0.63	0.48 \pm 1.26	0.00
<i>Nephrolepis cordifolia</i> L.	sword fern	Nco	0.00	0.48 \pm 1.26	0.48 \pm 1.26
<i>Paspalum conjugatum</i>	carabao grass	Pco	6.43 \pm 5.04	3.57 \pm 3.90	3.09 \pm 3.25
<i>Psidium guajava</i> L.	guava	Pgu	0.62 \pm 1.25	0.71 \pm 1.31	0.48 \pm 1.26
<i>Sorghum halepense</i> L.	batad-batadan	Sha	0.00	1.67 \pm 4.42	4.29 \pm 4.07
<i>Stachytarpheta jamaicensis</i> L.	bastard vervain	Sja	0.00	0.00	0.48 \pm 1.26
<i>Swietenia mahagoni</i> L.	mahogany tree	Sma	4.05 \pm 4.51	4.53 \pm 3.15	5.24 \pm 7.17
<i>Syzygium malaccense</i> L.	tambis	Sml	0.00	0.00	0.24 \pm 0.63

<i>Saccharum officinarum</i> L.	sugarcane	Sof	0.00	0.00	0.14 ± 0.38
<i>Wedelia trilobata</i> L.	yellow dots	Wtr	0.00	1.67 ± 3.19	3.33 ± 8.81
<i>Chromolaena odorata</i> L.	hagonoy	Hag	54.29 ± 6.86	39.3 ± 11.02	46.60 ± 15.35

Table 2. Mean soil parameters (± SD, n = 7) and soil type at three sampling sites in the Zamboanga Peninsula. Values with the same superscript letters are not significantly different (Tukey's test, $p > 0.05$).

Soil Factors	Zamboanga Sibugay	Zamboanga del Sur	Zamboanga del Norte
pH	5.41 ^a ± 0.13	5.25 ^a ± 0.19	6.30 ^b ± 0.20
organic matter (%)	1.62 ^a ± 0.16	0.90 ^b ± 0.06	1.50 ^a ± 0.17
total nitrogen (ppm)	0.08 ^a ± 0.01	0.05 ^b ± 0.01	0.08 ^a ± 0.01
total phosphorus (ppm)	trace	10.14 ± 0.43	0.23 ± 0.04
total potassium (ppm)	500 ^a ± 29.30	425 ^b ± 29.66	250 ^c ± 29.33
soil type	loam	sandy-loam	sandy-clay-loam

Total phosphorus was lowest in Zamboanga Sibugay, and total potassium was lowest in Zamboanga del Norte. Loam soil type was common in all sites.

The gradient length generated by DCA was 4.1, and this prompted the use of the constrained CCA. No significant relationship between soil parameters and vegetation with both first ($F = 1.46$, $p > 0.57$) and all canonical axes ($F = 1.08$, $p > 0.25$) were generated by CCA. These results suggest that *C. odorata* has no specific preference for soil parameters and types. The CCA triplot further shows that the species tends to be of maximal abundance in the presence of plantation species, including: *Musa paradisiaca* (banana), *Cocos nucifera* (coconut), *Swietenia mahagoni* (mahogany tree), *Mangifera indica* (mango), and *Gmelina arborea* (gemilina) (Fig. 2).

The heavy infestation of *C. odorata* in various areas of Zamboanga Peninsula seems to be favoured by an acidic soil and the range of soil parameters measured in this study. Soil pH is not a limiting factor in the germination and growth of *C. odorata* because it can grow in a wide range of pH, between 4 to 8, and is adapted to a wide range of soil conditions which is a common characteristic for many weed species [6].

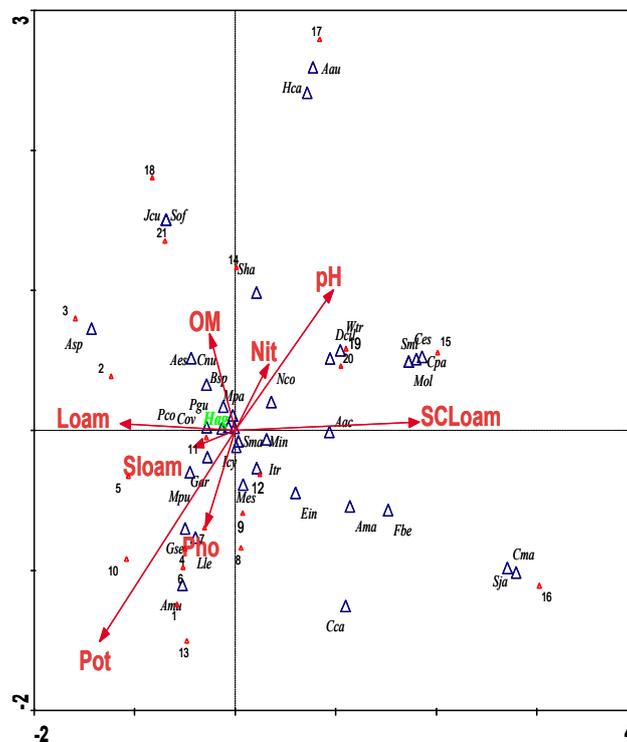


Fig 2: Canonical Correspondence Analysis (CCA) triplot showing the relationship between selected soil parameters (arrows) and % abundance of *C. odorata* (Hag) and associated plant species. Small triangles represent sampling sites. Big triangles represent plant species (see Table 1 for species codes). Soil parameters: pH, organic matter (OM), nitrogen (Nit), phosphorus (Pho), potassium (Pot), soil types: loam (Loam), sandy-loam (Sloam), sandy-clay-loam (SCLoam).

This study reveals that the unutilized lighted spaces in between plantation trees are mainly occupied by *C. odorata* supporting the findings that this species preferred open sunny habitats and was conspicuously absent in dense shady forests [19]. The high abundance in our sampling sites was very likely due to ideal exposure to sunlight which is needed for germination, seedling growth, flowering and fruiting of the species.

Abundance and successful invasion is probably more biologically influenced (e.g., the allelopathic ability of *C. odorata*) rather than by local edaphic conditions. Highly invasive plant species combine reproductive, competitive and dispersal traits [20]. The highly invasive *C. odorata* grows aggressively and, suppresses other vegetation by easily forming a thick cover at a short time [21], and accumulates soil-borne fungi that act as pathogens on native plants [22]. The robustness of the species was demonstrated by its rapid regrowth at the onset of rainy season following a moderate El Niño in February to May 2010 where most *C. odorata* were found to be wilting in several areas of Zamboanga Peninsula.

In conclusion, this study has shown that *C. odorata* has infested the three Provinces of the Zamboanga Peninsula because its life history is supported by soil properties of the area, and the occurrence of plantation species. The invasiveness of *C. odorata* may also be attributed to the production of large quantities of propagules and its capability to suppress the native vegetation.

4. Acknowledgement

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