



FUNDING PROPOSAL TO THE GREEN CLIMATE FUND

-IRES-CUBA-
**INCREASED CLIMATE RESILIENCE OF RURAL
HOUSEHOLDS AND COMMUNITIES THROUGH THE
REHABILITATION OF PRODUCTIVE AGROFORESTRY
LANDSCAPES IN SELECTED LOCALITIES OF THE REPUBLIC
OF CUBA**

APPENDIX 2.9 Invasion of Marabou (*Dichrostrachys cinerea*) and Climate Change in Cuba

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I. INTRODUCTION

The biology of the invasion of species is a young discipline that has generated an explosion of questions, hypotheses and diverse approaches, accompanied by hundreds of definitions related to species-habitat relationships, with the aim of understanding the ecological foundations of biological invasions. In order to carry out this work, the glossary of frequent terms on invasions of plant species, proposed for Cuba, was taken into consideration. (González-Oliva & Regalado, 2012).

The source itself asserts that the impacts of invasive species on ecosystems can affect: (1) composition, (2) structure and (3) functioning; with effect on the homogenization and landscape changes, the exclusion of native species with important impacts on the functional aspects of the ecosystem, among them the modification of trophic relationships, disturbance regimes, substrate-plant-animal interaction and alteration of ecosystem services. Invasions by exotic species affect the connectivity between natural areas and ecosystem services. (Colectivo de autores, 1993).

A species can be considered beneficial or harmful from an anthropocentric point of view, it is the case of plant species that affect the productive potential of the occupied surface or the volume of water handled by man. This damage can be measured as loss of agricultural yield per unit of cultivable area or productivity of a certain productive entity. On the other hand, the term transformer is used to classify the most aggressive invasive species that cause the greatest impacts and change the character, condition, form or nature of the ecosystems in a relatively large area with respect to the extent of the ecosystem. (León & Alain, 1951, Hemmer, 1979, Ricardo et al 1995.)

Dichrostachys cinerea (L.) Wight & Arn., Plant of the fabaceae family, known in Cuba as "marabou", is an exotic shrub of a very remarkable ecological plasticity, which has become the most striking pest in Cuban fields. This ability is favored by its ability to adapt to different edaphoclimatic conditions, which allows its successful propagation and persistence. Valdés & Vilamajó (2001) and Padrón (2002, 2004) give this issue great importance. (Pavel, Rodríguez, & Salabarría, 2017).

According to the Global Invasive Species Database (GISP), *Dichrostachys cinerea* is a spiny woody shrub, fast growing or bush that invades fields, vacant lots, roadsides and other disturbed areas. Originally from Africa, it was introduced in the West Indies during the 19th century. Adult plants live a long time, producing seeds that survive for a long time in the soil almost all year round. *D. cinerea* causes losses in agricultural production and its management implies frequent, heavy and costly work. "(GISP, 2019).

The national list of invasive plants in Cuba in 2015, considers *Dichrostachys cinerea* (L.) Wight & Arn. (marabou) among the 100 most harmful species, of greatest concern and transformative, already established in different ecosystems and localities of the country. According to Aguilera (2011), little has been scientifically documented of its ecology, its

dispersion mechanisms and its interactions with local biota, among other aspects of interest. (Oviedo & González, 2015).



Fig.1 Photo of area of the province of Las Tunas invaded by marabou.

Among the anthropogenic causes of the invasion of the marabou are the changes in land use, deforestation, bad agro-technical practices and management in agricultural and livestock areas, the lack of control of the species and material resources to face different plans in this respect, among others¹.

The objective of this work is to find the relationship between the characteristics of the changing climate in Cuba and the behavior of marabou (*Dichrostachys cinerea*), from deepening in the biology of the species, the physiological mechanisms of the plant, forms of dispersion, aspects associated ecological and how she responds to these climatic variables.

II. Development

II.1. Characterization of *Dichrostachys cinerea* (marabou).

Scientific Name: *Dichrostachys cinerea* (L.) Wight & Arn.

¹ Personal communication. Dr. Dalia Salabarría, January 16, 2019. Cuban scientist with vast experience in environmental research and management. Director of the GEF / UNDP project "Improving the prevention, control and management of invasive alien species in vulnerable ecosystems in Cuba". Most of the experts with whom we worked share this criterion.

Original publication. The species was originally published by Carlos Linneo (Sweden, 1707-1778) in his well-known work "Species Plantarum" of 1753 as "Mimosa cinerea". Then, in 1834, it was placed in the genus *Dichrostachys* by the Scottish botanists Robert Wight (1796-1872) and George Arnott Walker Arnott (1799-186 citatum: *Prodromus Florae Peninsulae Indiae Orientalis* 1: 271.1834).

D. cinerea is native to South Africa and is considered native in a large group of countries on the African continent, Asia and Australia (Bassler, 1998, Aguilera, 2011). In America, it can be located in Florida (United States), and in the islands: Cuba, Hispaniola (Santo Domingo and Haiti), Guadalupe, María Galante and Martinique (Acuña, 1974).

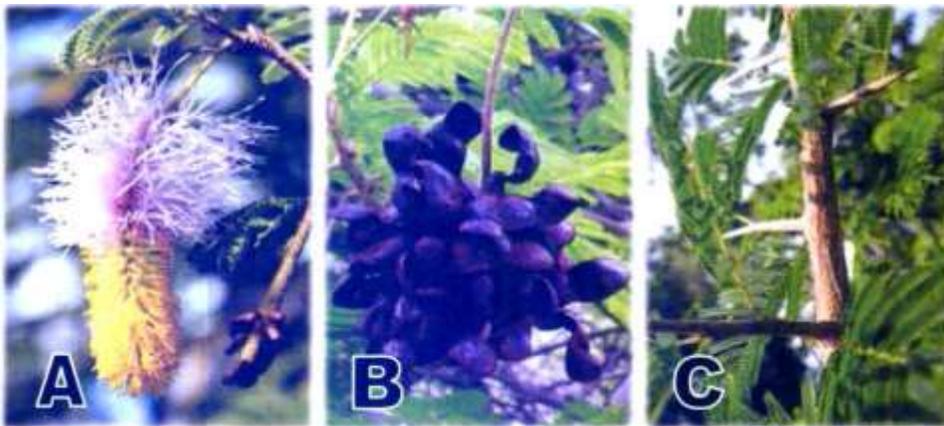


Fig. 2. *Dichrostachys cinerea*. Details of the inflorescence (A), nuts (B), branches and foliage (C). Photos: Image archive Project GEF / UNDP Invasive Exotic Species.

II.2. Introduction of the Species in Cuba and Current Distribution

II.2.1. Introduction of the Species in Cuba

Acuña (1974) reports that it became an invader in the country after the war of independence with an extraordinary aggressiveness, which coincides with that expressed by Roig (1915), who said that the introduction of the marabou did not occur before the ten years war, because the plant is not mentioned in any work of botany or Cuban agriculture. The author himself relates that Grisebach does not describe or mention it in his *Flora of the British West Indian Islands*, published in 1864, nor in his *Catalogus Plantarum Cubensium*, published in 1866. Nor is it written by Sauvalle in his *Cuban Flora*, which saw the light in 1873, nor Gómez de la Maza in his botanical Dictionary of vulgar Cuban and Puerto Rican names, and neither is there any allusion to this plant in the *Provincial Dictionary of Cuban Voices* of Pichardo.

There is no exact date of its introduction in Cuba. It seems undeniable that its introduction was not prior to the 10-year war. There are different versions: 1. about its introduction as an ornamental plant in Camagüey by Mrs. Montserrat Canalejo de Betancourt, widow of El Lugareño, in her farm La Borla, located on the outskirts of the capital, becoming one of the focal points of propagation. 2. In Taco-Taco, Pinar del Río, runs the version that was introduced by D. José Blaín, Dean of the Botanists, as a curious botanical species and 3. The plant was introduced and propagated by the foreign cattle that were brought after of the 1868 war to repopulate the cattle ranches.

II.2.2. Geographic distribution of *Dychrostachis cinerea* (marabou) in Cuba and in the intervention areas of the project.

The marabou in Cuba occupies approximately 1.5 million hectares, which means 15% of the national territory, and includes 18% of agricultural areas and 56% of livestock. (Aguilera, 2011).

The project implementation area (AIP) is presented in Figure 3, the distribution of idle land (covered with marabou) in the AIP, in both zones: eastern and central. The maps show the total marabou area, the growth dynamics of infested areas in the period 2007-2013 and the growth of the infested areas at the expense of crops such as sugarcane, various crops, natural pastures and forest. Figures 4 and 5. (Somoza & Colina, 2018).

The AIP is located in two zones: one in the north-central region of the country in the municipalities of Los Arabos (in the province of Matanzas) and Santo Domingo, Corralillo and Quemado de Güines (province of Villa Clara) with an area of 281,354 ha.; the second zone is located in the eastern region and includes the municipalities Jobabo, Colombia and Amancio Rodríguez in the southern zone of Las Tunas province with an area of 230 180 ha. The total geographic area of the AIP is 511 534 ha.



Fig.3 Illustrative Map of the project implementation areas²

² Fig. 3. Illustrative map of the project implementation areas. Taken from Annex_6_IRES_Pre-feasibility_Landscape Restoration Modules. FAO. Cuba. 2018

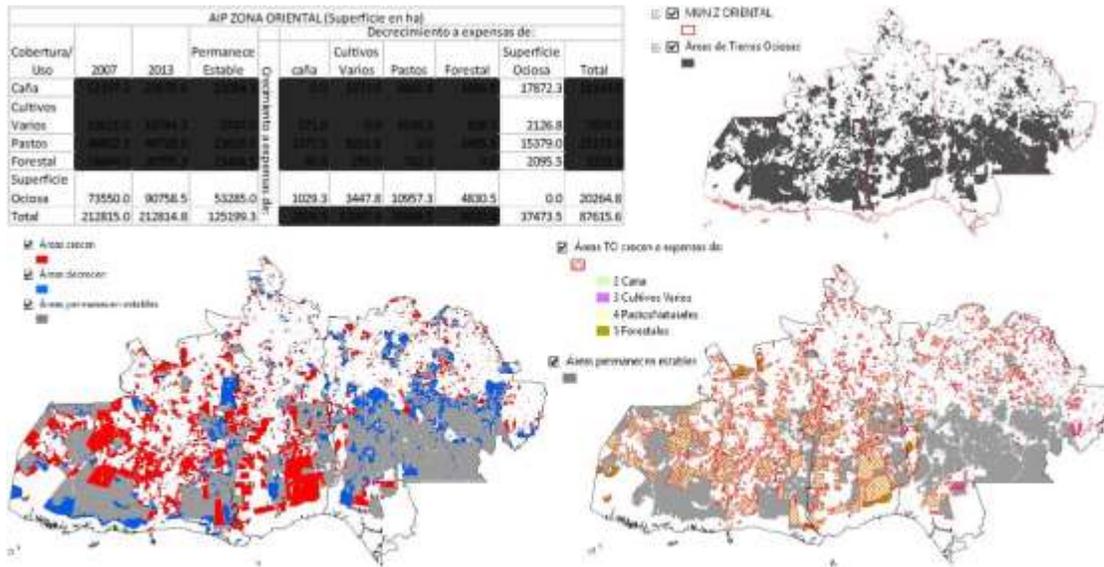


Fig. 4. Distribution of idle land areas (TO) in the East Zone AIP.

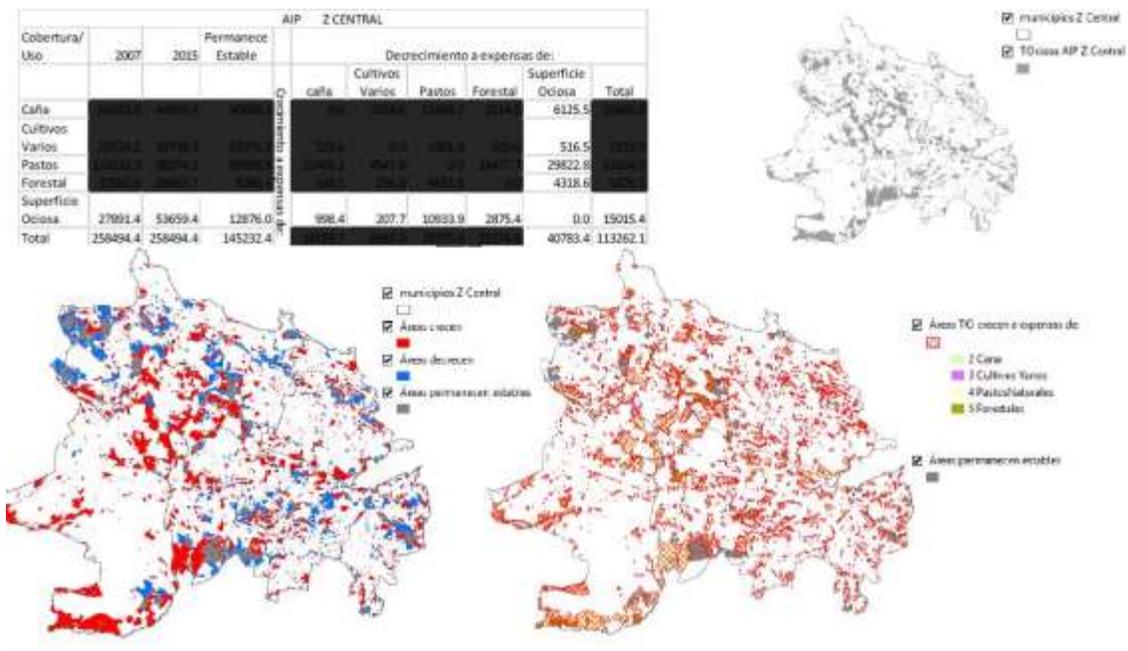


Fig. 5. Distribution of idle land areas (TO) in the AIP Central Zone.

III. Dichrostachys cinerea and the Climate

In Appendix 2.4. "Baseline study of adaptation and vulnerability for the implementation of the project" (Somoza, José, De la Colina, Armando, 2018) on pages 30-34 the synopsis is developed. I.1.5. Combination of climatic variables and their future impacts on the intervention zones of the Project. To approach the combined effects of climatic variables on the areas of the project's intervention area (AIP), the authors used statistical models (Panel Data and Ordinary Least Squares) (Hutchinson et al., nd), based on of two hypothetical assumptions:

- Marabou expansion and climate change are linked.
- The marabou area is less sensitive to climatic variations than the rest of the crops studied in the AIP (cane, various crops, pastures and forest).

"The use of the data panel model of fixed effect employed as a dependent variable, the idle surface as a function of the accumulated precipitation, maximum and minimum temperatures, relative humidity and the standardized precipitation index for the non-rainy period, the results offered empirical evidence that these climatic variables explain an important part of the general behavior of the idle surface in the AIP and reveals that the expansion of the marabou has an important climatic component.

The estimated parameters, both individually and as a whole were significant, which indicates that the model was used adequately and explained the relationship between idle surface (as a proxy of the marabou) and the climatic variables for both areas of the AIP. The effects of climate change have a greater impact on the yields of crops, pastures and forests than those produced on the marabou. In this sense it is possible to affirm that climate change affects the expansion of the idle surface (at the expense of sugarcane, pastures and other crops that are colonized by the marabou). There is a degree of positive certainty of the climatic influence in the expansion of the idle surface in the AIP in particular in the Eastern zone."

III.1. Relationship between the invasion of the marabou in Cuba in recent years and the changing climate

III.1.1. Methodology

For the realization of this work it was necessary to resort to triangulation methodology

(Rothbauer, 2008) (from sources, methods and researchers) to clarify aspects related to the hypotheses raised in the baseline of the project.

Methodological steps followed:

- Compilation of studies on fabaceae, in particular of *D. cinerea* in different environments (places of origin and where the species has been introduced).
- - Selection of Experts to be consulted on the subject - A multidisciplinary balance was achieved, where biologists, ecologists, agronomists, foresters, veterinarians, livestock, agro meteorologists, physicists, chemists, specialists in sustainable land management and geographers predominate. Of the preselected professionals, 15 classified in the category of experts. An approximation was made to the Delphi method.
- Application of the Survey (Appendix 2.9.1).
- Brainstorming³ with researchers who develop projects in these lines in the country (with more than 20 years as an average of experience in research and in direct work with the plant).

The scientific literature asserts that the deterioration of habitats is the main cause of biodiversity loss, it is ensured that under conditions of climate change, many species of plants and animals will become extinct as they cannot adapt to the new conditions. In contrast to this phenomenon it is observed that *Dychrostachys cinerea* (L.) Wight & Arn. (Marabou) continues to expand, under the conditions of Cuba, despite the adversities of the climate. This assertion is based on the following results:

III.1.2. Biology of the species, physiological mechanisms, forms of dispersion and associated ecological aspects

³ "Brainstorming" is a technique by which a group tries to find a solution to a specific problem by spontaneously exposing ideas (Osborn, 1963). It is a highly effective technique to maximize creative potential, not only to generate ideas, but also to determine which ideas are most likely to succeed in a specific area of interest (Baumgartner, 2007).

- *Dychrostachys cinerea* (L.) Wight & Arn. (marabou) It is found in an extensive ecological range and expresses a high phenotypic plasticity. This species is considered invasive even in some of the geographic sites proposed as the center of origin; for example, South Africa (in those places it has biological control). It continues to expand, in the conditions of Cuba, despite the adversities of the climate, which is attributed to its genetic endowment, which guarantees great capacity to "solve problems", given the expression of the phenotypic features and functional attributes that it exhibits. : sexual and asexual reproduction, abundant flowering and seed formation, color of the flowers and release of vortexes of the terpenic type for the attraction of various entomophilous insects, evergreen species, with high allopathic potential, possesses physical and chemical defenses, fixation of atmospheric nitrogen , great ability to position propagules in disturbed environments and occupy empty niches, accelerated growth and the absence or little presence of natural controllers. (Aguilera, 2011).⁴

- "It has become one of the worst pests of agricultural activity not only for its unbridled and invasive propagation, but also for the numerous thorns present in trunks and branches that makes it difficult to eliminate ... it is a woody shrub with a thick fibrous bark , usually 3 to 5 m high, which grows into compact, impenetrable masses. "(Manzanares, K. et al., 2018).

- "The plants grow very close together and are very thorny, forming forests or bushes so thick that they drown the other plants and once it is implanted it is very difficult to exterminate. Neither can they be used for cattle breeding, they cause indirect damage in uninfected areas, especially the deterioration of pastures and soil erosion, due to overgrazing that occurs when the total area decreases. "(Muñoz, Cruz & Ponce , 2001)⁵

- "The increasing tolerance of the species to aridity is based on morphological attributes: microfilia, wood density from medium to high, is facultative decidua, has a root system that can explore several layers of soils (different horizons). (Acosta, 2019)⁶.

⁴ Narciso Aguilera is Head of the Ibero-American Network of Fabáceas (University of Concepción, Chile). This researcher has studies of the behavior of the species in Cuba.

⁵ Eng. Diego Muñoz Cabrera *; Eng. Madelín Cruz Cruz * and M. Ponce Hernández, Dr C. **. Marabou. Suggestions for the Battle Researchers of the Experimental Station of Pastures and Forages (EPPF), Camagüey. ** Director of the EPPF and president of the Cuban Society of Production and Utilization of the Pastures of the ACPA, Camagüey. e-mail: eepfcm@eimanet.co.cu Edited by the Secretariat of Technology Transfer and Disclosure of the ACPA.

⁶ Acosta, Lorge, Lic. In Biology (2002), researcher with more than 20 publications related to the topic under analysis, member of the project "Multidisciplinary eco-friendly approaches to control and manage the marabou in the eastern

- "The marabou is a tree / leguminous shrub, resistant to droughts, although not to floods, with photosynthetic cycle C3 of warm climate and typical of dry places. The species seems very well adapted to seasonal climates with winter dry season. Such so-called savanna or seasonal climates with dry winter are predominant in Cuba. Due to its ability to metabolize soil nitrogen, as well as its heliophilic nature, its ability to take advantage of the effect of fertilization by carbon dioxide and its strategy of reproducing at a medium distance by means of shoots arising from its roots (which coexists with long distance reproduction through transport by seeds) make it highly competitive in colonization as a pioneer species of areas degraded by agricultural activity. Once the marabou plants have reached the level necessary to constitute a true ecosystem, the set of plants with their foliar cover extraordinarily limits the amount of solar radiation that reaches the ground and this prevents the growth and development of other potentially competitive species. Additionally, its morphological structure provides protection systems against herbivorous predators, capable of diverting their attention to other species that lack such protection systems (it is a spiny plant)⁷. (Rivero, 2019)⁸.

- "By not having natural controllers whether introduced or non-native, the populations are not regulated and can expand unlimitedly, provided that natural or anthropic disturbances facilitate it. Similar to the rest of the invasive fabaceae, *D. cinerea* releases allelochemical compounds capable of inhibiting the germination of spp. cohabitants native or naturalized; as well as interspecifically interfering with the growth of neighboring plants. The ability to fix atmospheric nitrogen is an extremely important feature to position in soils where spp. native and naturalized, whether or not of economic importance, they would not have an opportunity to survive. The traits and functional attributes of *D. cinerea* explain the invasive potential of this species; as well as its capacity to displace cohabitating plant species and occupy empty niches. "(Aguilera, 2019).

- Other characteristics of *D. cinerea* that benefit its expansion refer to its reproductive aspect: an adult, well-developed and healthy plant can approach the annual million of seeds

central region of Cuba" and student of the Doctorate in Animal Nutrition at the University of Ghent, Belgium

⁷ With its tortuous trunks, the marabou forms impenetrable ramified bushes, for its dreaded thick and sharp spines, up to two and a half centimeters long.

⁸ Rivero, Róger (2019) eminent Cuban scientist, physicist-agro meteorologist, Vice-president of the International Society of Agro meteorology. More than 20 years ago he studied the behavior of the marabou in Cuba.

produced, which are also highly viable (see Márquez, Chirino y Valdés in <https://www.monografias.com/trabajos53/crecimiento-marabou/crecimientomarabu.shtml> and Carmenate, Pérez, Paredes y Blanco, 2008), especially in open places and scarified by the digestive tract of ruminants, to which is added the polyembryony (approximately 30% of the seeds can emit from two to three embryos, according to Carmenate, Pérez, Paredes and Blanco, 2008a) and the reproduction capacity by portions of stems and roots (Carmenate, Pérez, Paredes and Blanco, 2008b).

- "D. cinerea produces a large number of viable seeds, with a very efficient dispersion mechanism (endozoochory, in the digestive tract of ruminants), it should be noted that these plants present as an advantage for their seeds that they are "sown" with fertilizer, provided by the stool of cattle in this case; Marabou does not have important seed predators, when closing the canopy, it limits the growth of other species." (Acosta, 2019).

- Another aspect is the strength of the root system, which makes it very competitive for its regrowth after fires, and favors its expansion. That can be easily verified by simple observation. Additionally, it obviously does not have in Cuba the natural enemies that limit its expansion in the areas of Africa where it is native and in other regions of the world where it has been introduced. (Méndez, 2019)⁹

- Its ability to metabolize atmospheric nitrogen through typical radicular associations of leguminous plants. (Rivero, 2019).

- This plant behaves very well under edaphoclimatic conditions that are unfavorable for other species; its seeds have a germination of 70% or more and up to 30% of polyembryony, which can be double, triple or quadruple; this means that its reproduction in this way (sexual) is easy and fast, it can also reproduce asexually by its stems and roots, which give rise to buds that quickly become plants, multiplying the population and forming a thick mass that grows vigorously.

- High re-growth capacity and to metabolize solar energy. As it is a very heliophilous species, this makes it use solar energy very efficiently, therefore, it grows, develops and establishes itself quickly, forming impenetrable forests in Cuba, because its stems and thorny branches make it difficult to control them. The emission by the plant of allelopathic substances also favors it in its invasion process. (Cruz, 2019).

- In our country pests or diseases that affect its normal development have not being found,

⁹ Dr. Isidro Méndez. PhD in Biological Sciences (1994), Plant Taxonomist, Phytogeographer, IUCN Red List Officer, belongs to the Cuban Plant Specialists Group. Monograph in the series "Flora of the Republic of Cuba".

and our insular conditions favor its excellent behavior. (Salabarría, 2019).

III.1.3. Effects of climate change that become advantages for the reproduction, growth, development and expansion of marabou under Cuban conditions.

- The changes recorded by the country's climate in the last 50 years consist of an increase in the average temperature of the air by 1 ° C, basically due to the increase in the minimum temperature by 1.9 ° C; the reduction of the day-night temperature differential; the modification of the rainfall regime, with an increase in rainfall in the dry period and its decrease in the wet; the reduction of annual accumulated rainfall by about 200 mm and, a greater frequency of extreme weather events (droughts and hurricanes) in the last 20 years.

- The studies carried out by Rivero et al., 2002 and 2010, allow to affirm that the potential agricultural and irrigated yields of the main crops will decrease progressively. "... On the other hand, the effect of climate change on weeds would also affect pastures in livestock areas, which in the case of Cuba are predominantly gramineous, benefiting harmful invasive alien species such as marabou (*Dycostrachys cinerea*). According to climatic scenarios (increments of 1-2 ° C in the mean t), a greater aggressiveness of many of the existing pests and the emergence of new ones is expected, giving the possibility of secondary species displacing the current primary species. "

- The observed variation in temperatures, global solar radiation and mean annual precipitation levels are not yet large enough to remove the marabou from its ecological comfort zone (Planos et al., 2013). In this regard (Méndez, 2019) considers that these conditions favor the expansion of marabou, native species of African savannas, notably more arid than the Cuban environment even in these adverse scenarios. In the livestock ecosystems (Cruz, 2019), "the adverse climatic conditions are favorable for the marabou and unfavorable for the forage and forage species characteristic of these ecosystems".

For Rivero, 2019 among the effects of climate change that favor the expansion of the marabou are:

- Fertilization by carbon dioxide due to the sustained increase in the atmospheric concentration of this gas (Wolf and Diepen, 1993).
- Extreme and prolonged droughts favor and will continue to favor the species. The progressive reduction of agricultural yields and the loss of competitive skills of agricultural crops with a certain life habit, as well as of forest species that today are typical of humid sites, favor the abandonment of land that "takes advantage of" the marabou, given its competitive advantages .
- Climate change eliminates several species that could compete for space.
- The overgrazing of livestock areas, as spaces for livestock are limited due to the own

infestation by marabou, given the maladjustment of other species.

- Climate change in Cuba consists of a rise in temperatures and a reduction in rainfall during the present century without much change in solar radiation. The association between temperature, solar radiation and rainfall leads to an increase in potential evapotranspiration and a decrease in average soil moisture. The increase in temperature alone leads to an increase in the rate of phenological development of the species. The morpho-anatomical peculiarities, its reproductive biology and its relationships with other elements of the Cuban biota make it increasingly competitive in the face of the effects of climate change. While many native species experience a significant reduction in their populations, the marabou will increase its invasive potential.

- "The conditions of changing climate, which our country has today, are advantageous because the marabou has an enormous plasticity, something that has been demonstrated by the studies carried out throughout our country. Resists long periods of drought, adapts perfectly to high temperatures and under those conditions reproduces, grows and develops. When the precipitations are abundant, as much in the rainy period as in the little rainy, it is also favored, because its cycle of development is not affected, it behaves even better, using the water for its normal functioning. The low temperatures, characteristics of the little rainy period, favor its flowering and subsequent fruiting. "(Cruz, 2019).

- Marabou is favored by high temperatures, low rainfall and strong winds (the latter contributes to the propagation of seeds), according to Pereda, 2019¹⁰. Likewise for "its high degree of adaptation to our seasonal climate with dry winter, with the ability to regenerate after intense periods of water stress. (Rivero, 2019).

- It has been found that the changing climate to which we have been subjected is closely related to the expansion of the species within natural and agricultural ecosystems in Cuba. In recent years, climate change has aggravated the process of expansion of the species. The invasion in Cuba by the marabou is part of a process that began with deforestation, the expansion of the sugar industry and livestock. At first, when the species was new arrival it had not expanded, it could have been removed, but later it was really impossible. All land

¹⁰ Dr. Jorge Pereda, a specialist in agricultural sciences has devoted a large part of his scientific career to researching the production lines of pastures and forages and the management of animal production systems. He is a member of the Multidisciplinary Approach project to control the invasion of *Dichrostachys cinerea* in the eastern center of Cuba.

without forest is highly vulnerable to being invaded. While the soils are fertile, control is economically feasible, but when they are not, it is totally unprofitable to implement control measures without expecting anything in return. (Méndez, 2019).

- During the years of domination by Spain and then by the United States, the country was deforested and its soils degraded. In 1959 there was only 14% forest cover. Many actions have been taken to reverse this situation, such as the application of a Reforestation Program that has made it possible to reach 31.1%¹¹, with a forest area of 3240.9 MH. Even so, the areas infested by marabou grow, because the species currently occupies approximately 1.5 million hectares, which shows that its expansion and establishment have been on the rise. It is unquestionable that the adversities of the changing climate have been favorable for the development and growth of marabou throughout the national territory.

III.1.4. Conditions of the future climate, marabou and food security in Cuba

- Changes in the values of the main climatic variables for subsistence crops (staple crops) planned for the middle of the century will be more harmful for such crops than for the marabou. This can be seen more clearly if we take into account that our main crops are or want to be grown under irrigation in climates that will become progressively more arid during this century (Rivero et al., 2005; Rivero et al., 2012) while all the well-known marabou locations reach a remarkable success in dry conditions. All unused, idle or badly cultivated lands could become marabou sites since that species does not have to be helped by man to thrive in the fields of Cuba. (Rivero, 2019).

- Climate change and the invasion of marabou are not the only causes, there are other factors that are also responsible for the difficulties that arise with food security, which go through the lack of material and financial resources, the need to extend good practices of production and consumption, among others.

- The control of the species constitutes in itself an important economic competition in relation to the financing available for the production of food of agricultural and livestock origin. In addition, the evaluations carried out in the country have shown that to the extent that the climate changes in the future (under any of the possible scenarios), the

¹¹ National Office of Statistics and Information. ONEI. 2017. Available at www.onei.cu

vulnerability of agricultural and livestock activities will increase, with decreases in their yields, of its productions and the surface suitable for its development. (Alvarez, 2019)¹².

- It is essential that appropriate measures be taken to ensure the deceleration or halting of the invading front, prevent *D. cinerea* from positioning itself in new ecosystems and agro ecosystems, and prevent the strengthening of the already established populations. If this is not guaranteed, undoubtedly the invasion of *D. cinerea* may negatively impact food security at unpredictable levels in the face of climate change, which, as mentioned above, can strengthen the invasive potential of *D. cinerea*. (Aguilera, 2019).

With the results of the survey an exercise was carried out (brainstorming) with the intention of deepening in the arguments offered by the respondents. It was a way to validate the answers. Consensus was reached among all participants regarding the criteria offered. The experts offered other considerations that will be treated in the following section, although they were not the initial objectives of the work.

III.2. Notes on the elimination and management of the areas invaded by marabou

There is consensus among the experts regarding the need to free the areas infested by marabou, rehabilitate the productive agroforestry landscapes and favor the capacity of these to produce food, plant forests, contribute to harmonize conservation with the sustainable uses of biodiversity and create subsistence and livelihood conditions, through more resilient options in the face of the effects of climate change.

Following are some aspects addressed by the experts during the investigation, which, given their importance, for the purposes of the project, will be summarized briefly below:

III.2.1. Marabou and Soil Protection

“The invasive species *Dichrostachys cinerea* (L.) has caused damage to the economy in terms of agricultural production, its expansion has led to the reduction of land usable by agriculture and livestock, in addition to the problems of the displacement of native species. The dismantling of the marabou is complex and if not carried out properly, degradation

¹² Arnaldo F. Álvarez Brito. Cuban scientist, works in the Institute of Agro-Forestry Research of the Ministry of Agriculture. The Cuban forestry sector and climate change stand out in the Anales Magazine of the Cuban Academy of Sciences Vol.4 No.2 2014. Álvarez Brito et al.

processes such as erosion and compaction can be intensified. On the other hand, the benefits that from the point of view of fertility, marabou propitiates the to the soil, may not be used "(Font, 2019).¹³

The study on the effect of marabou *Dichrostachys cinerea* (L.) on the quality of degraded brown sialitic soils in Camagüey, shows that the ICS soil quality index in the variant with marabou revealed that the permanence of the species *Dichrostachys cinerea* (L.) covering the soil, improved its properties significantly with respect to the rest of the variants, and that despite its aggressive nature, it can improve soil in degraded lands, due to the entry of significant amounts of carbon and nutrients. (Álvarez, Font and Castillo, 2018).

Therefore, it is recommended to pay special attention from the project interventions to the elimination process of the marabou, in order not to lose the fertility effect. On the other hand, given the germinal and invasive capacity of the marabou, to maintain the management and control technologies in an integral manner according to each place and to apply the quarantine measures for the case of transfer of the animals in livestock areas. The authors proposed an integral plan of management and control incorporating methods that allow greater efficiency, according to the time and phenological phase of the plant, considering the integrality and systematization of the actions over time. "The areas that are rescued must be cultivated, otherwise we are contributing to the propagation of the marabou." (Muñoz, Cruz & Ponce, 2001).

According to these experts, "once the marabou has been eliminated, the role played by the goats as a biological controller within the process is an important part of the integrated efforts to combat marabou. Because of their consumption habit of grazing, goats are attracted by tender shoots and green foliage, they are animals of great rusticity and resistance to diseases, hence manage to become excellent controllers once the plants are cut, which causes death for depletion of nutritional reserves. Something similar but much slower could be achieved after the cutting of the plants with the use of sheep and cattle. "

For experts, the solution must be based on the simultaneous use of mechanical, physical, chemical and biological methods. Herbicides work, but they are expensive and pollute the environment, although there are some recommended because they are more harmless to

¹³ Dr. C. Agrícolas Lisbet Font Vila. Agronomist Engineer. Directs the project "Multidisciplinary eco-friendly approaches to control and manage marabou in the central eastern region of Cuba" developed jointly between the University of Camagüey in Cuba and the University of Ghent, Belgium.

the environment; the cutting and burning are not entirely effective if there is any root left, this also harms the fertility of the soil and the contributions made by the marabou plant. The possibility of biological controllers must continue to be explored by science. This variant is considered as a challenge to research and to be achieved in the longer term, since the country has not yet achieved successful results on such matter.¹⁴

III.2.2. Other Uses of Marabou

In the opinion of the experts, the marabou that is eliminated should be given economic use, according to the possibilities and needs of each place where clearing is carried out. Some of the recommended uses are illustrated below.

Because of its extension in Cuba, it can be an important source of biomass for low-density solid fuel. It is already used for the production of electricity in sugar mills during the "non sugar harvest" (bioelectric) period.

The biomass of marabou (*Dichrostachys cinerea*) was subjected to chemical-physical characterization, using technical specifications of the European Committee for Standardization (CEN), and the main points of the pyrolysis process were determined by thermo-gravimetric analysis for its possible use as an energetic source. The study revealed that this biomass has adequate characteristics for its use as an energy source, a higher caloric power equal to 19100 kJkg⁻¹, 3.4% ash and a melting temperature of 1460°C, as well as low chlorine content and sulfur. (Abreu et al, 2010).

Its wood is widely used for the production of high quality charcoal¹⁵, although it is recognized as work carried out in difficult conditions, given the characteristics of the plant, and sometimes includes the participation of women. Figures 7 and 8.

¹⁴In this sense, the author is grateful for the collaboration of Silvia R. Ziller, Founder and Executive Director of the Horus Institute of Development and Environmental Conservation of Brazil, expert in exotic invasive species; that in personal communication suggests us to seek cooperation with South Africa to continue exploring the possibilities of establishing biological control in Cuba, since it would be a more viable and less expensive technique to control the marabou in the future. The expert agrees on the need that in the integral management during the elimination process the chemical control of the outbreaks be considered, so that it is viable for the farmers and restorers of environments to contain the marabou, as well as other invasive plants.

¹⁵ At present, Cuba exports marabou coal at an external market Price of \$ 300.00 USD/t.



Fig. 7. Coal production in Las Tunas. Fig. 8. Coal oven. Published in Granma Newspaper, Friday, January 9, 2004.

The wood of the marabou -very hard- is used for woodwork, fences or billboards and rustic constructions, and also as firewood. The marabou is of some use as a beekeeping plant and a source of protein feed for livestock, especially sheep and goats.

According to studies carried out by Redimio Pedraza¹⁶ and collaborators (2019): "One of the biggest drawbacks to continue developing cattle ranching in Cuba and specifically in the province of Camagüey is the high rate of marabou infestation, a plant that affects approximately 50% of livestock areas (MINAGRI, 2000; Funes-Monzote, 2001). Its possible use as food for ruminants, directly in grazing (Muñoz et al, 2000) or as forage, has also been valued. However, the feasibility of their use is not well founded, in part because of the limited information available on their nutritional value. "Although the leaves of *D. cinerea* have a higher crude protein content than grazing for grazing, their nutritional value is

¹⁶ Redimio Pedraza is a livestock engineer, Dr. C. Veterinary and MSc. in Animal Nutrition. He has numerous scientific works published on marabou as animal feed. He is the scientific leader of the project "multidisciplinary eco-friendly approaches to control and manage the marabou in the central eastern region of Cuba" in the area of use as animal feed.

affected by the presence of tannins, which suggests that only physiologically prepared animals can make better use of this foliage . It is recommended to continue more detailed studies of the nutritional value at different times. "

In some rural areas of Cuba, the bark of this plant, rich in tannins, is used as an antiseptic. Pérez and Herrera 1990 state that it has medicinal properties; may be used for timber, honey, food, industrial and for artisanal purposes.

Conclusions

1. There is scientific evidence to support that the expansion of marabou in Cuba is closely related to the effects of climate change. The work done confirms that during the last years, climate change has aggravated the process of expansion of the species.
2. *D. cinerea* (marabou) is in an extensive ecological range and expresses a high phenotypic plasticity, its resistance to drought, given its genetic fond, makes it less vulnerable and allows it to occupy the space left by susceptible species. Climatic alterations keep the marabou in ecological comfort zone, hence it becomes a substitute for other less resistant plants.
3. The changing climate increases and will further increase the vulnerability of food production, if the marabou has marked adaptive advantages with respect to the national flora, particularly on crops, and if its control constitutes an important economic competition in relation to Food production, we must expect it to compromise food security, although this is not only due to the future climate.
4. While *Dichrostachys cinerea* (marabou) is established in the agro-productive landscapes (as a result of the invasion of these ecosystems), it prevents the production of food and other uses of the spaces, with effects of an economic and social nature, as well as limits the provision of goods and services in ecosystems. Once the plant is eliminated, there are multiple uses, mainly for energy purposes in bioelectric plants, such as charcoal of excellent quality, as wood for different purposes, among others.

Recommendations

1. The project foresees the replacement of the marabou with more resilient agroforestry modules. It is important that the reconversion of the agro-productive landscapes be achieved by immediately cultivating the land, once the marabou plants have been

eliminated, and follow the integrated control and management measures to avoid reinfestation of the areas.

2. The importance of carrying out the process of elimination of the plants in an eco-friendly way should be taken into account, avoiding possible degradation by erosion or compaction, so that the soil does not lose the properties and improvements provided by the plant, fertility among them.
3. After clearing, economic use of the wood and other components of the plant must be achieved, according to the priorities and needs identified. In all cases it should be foreseen that this is a strong and sustained work, so in the project this aspect should be considered in order to create better working conditions and provide adequate means to those who do it.
4. The need to continue exploring biological control options to face the problem of the invasion by marabou is raised as a challenge, for which it is recommended, from scientific research, a closer approach to countries where the plant exists, even in different environments.
5. Dissemination, training and environmental education in the areas of project implementation should be reinforced in order to integrate local communities, together with farmers, specialists and technicians in the monitoring, control and management of the species in the process of reconversion of the agro productive landscapes.20

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APPENDIX 2.9.1

SURVEY FOR EXPERTS TO SUPPORT TECHNICAL CRITERIA AIMED AT REPLACING THE MARABOU BY PROJECTS OF GOOD AGROFORESTRY PRACTICES IN ZONES INVADED BY THE SPECIES.

Dear Mr./Ms.: _____ Institution: _____

It is our purpose to let you know that we have taken your professional expertise into consideration and wish to have your valuable opinions on the subject we are considering. The aim is to explain the possible relationship between the expansion of the marabou at present time and the effects of climate change in Cuba.

The official list of invasive plants in Cuba in 2015 considers *Dichrostachys cinerea* (L.) Wight & Arn. (marabou) among the most aggressive species already established in different ecosystems and localities of Cuba. Among the anthropogenic causes of the invasion of the marabou are the changes in land use, deforestation, bad agro-technical practices and management in agricultural and livestock areas, the lack of control of the species and material resources to face different plans in this respect, among others.

It is our team's interest to delve into other aspects associated with the expansion of the marabou; in this case, the climatic factors. We thank you, according to your experience, to answer the following questions:

1. Given that the deterioration of habitats is the main cause of biodiversity loss, it is ensured that under conditions of climate change many species of plants and animals will be extinguished by not being able to adapt to new conditions. In contrast to this phenomenon, it can be observed that *Dichrostachys cinerea* (L.) Wight & Arn. (Marabou) continues to expand, under the conditions of Cuba, despite the adversities of the climate.

a) Do you agree with this statement? Kindly explain

b) From the ecological point of view, what factors cause the marabou to displace other species of plant formations in which it dominates

2. What effects of climate change become advantages for the reproduction, growth, development and expansion of marabou under Cuban conditions?

3. a) Characterize aspects of the biology and physiological mechanisms of the plant that you consider make it possible for the marabou to colonize agro ecosystems so aggressively

b) Could these aspects be favored by climate change? Kindly explain

4. Do you consider that the rate of expansion of the species in Cuba in recent years could be related to the current effects of climate change?

5. Do you consider that, if measures are not taken in relation to future weather conditions, the marabou could compromise food security in the country? Kindly explain.

Thank you very much.