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Bromeliads of the Aguarongo Protective Forest-Ecuador and Adaptation to Climate Change

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Abstract: This research tries to demonstrate the relevance of the vegetal species of *Bromeliaceae* within the ecosystem of the BPA (Aguarongo protective forest), a protected area of great importance for our country since it represents a large reserve of plants native to the area, this study was prepared in order to raise awareness and encourage future research within the protected areas of the country. For our purposes, we started from a series of site visits to the forest to gain access to the areas of study and delimit the chosen areas; then we proceeded to count and do the necessary calculation to determine abundance and diversity for which we applied the methodology of the diversity and richness of species indexes by Shannon-Wiener and Simpson with the species *Tillandsia complanata* and *Racineae tetrantha* being predominant in the forest. Given the diversity and quantity of found species of bromeliads in the Aguarongo, a mass abundant flora is established and it takes the picture of the carbon from the cities and adjacent villages to improve the conditions of the air in the forest, an essential element in the fight against climate change.

Key words: Climate change, bromeliads, biodiversity, ecosystem, preserve

INTRODUCTION

Aguarongo protective forest has a very important significance for the communities of adjoining parishes such as San Juan, Zhidmad, Jadan, San Bartolome and Santa Ana, belonging to the province of Azuay, Ecuador, as it represents the main source of water supply for irrigation and human consumption besides providing other goods such as fodder for livestock in times of scarcity, medicinal plants and a diverse array of smaller mammals, birds and insects that make this forest a biodiverse paradise of invaluable natural wealth.

Awareness of this situation, coupled with the obvious problems of diminishing flows of water, led to the communities in the area, especially the administering boards of drinking water to pose the need to initiate practices to conserve, restore and sustainably use forest resources. Epiphytes may represent more than one third of the plant species of a forest area and so they considerably increase the richness of the forests and jungles. They occupy a very important place in the nutrient cycle and have a strong influence over a portion of the fauna, since some of these plants, especially bromeliads, provide a habitat for insects, mites, crustaceans, mollusks and even small amphibians (Mondragon, 2002), therefore their presence contributes to larger animals to go to the grove, especially birds and reptiles that can find water and food in its leaves. In short, the existence of bromeliads in the woods indicates that very different living beings find appropriate environmental conditions there.

Aguarongo forest was declared "protective vegetation area No. 10" by means of the ministerial agreement No. 292, posted to the official record No. 255, August 22, 1985. The Aguarongo forest is one of the few fragments of Andean forest remaining in the Andean mountains of the province of Azuay, corresponding to low Montano humid forest, bhmb3. It is a refuge for characteristic fauna and flora of these habitats. Although, its biotic diversity is impoverished, mainly due to the hunting of animals, removal of plants and deforestation, it still represents a biological richness that deserves conservation efforts (Guarnizo and Flores, 2008).

According to the Aguarongo Center of Environmental Management located in the parish of the canton Jadan Gualaceo, the most representative plant of this area is the Aguarongo, a bromeliad species that gives the name to the environmental management center. About 564 species of trees which trunks exceed 10 cms in diameter such as the "zarares" and the "chachacos", many of them as old as 400 are found in the forest. They support life for plant associations of the lower area, constituted of what is commonly referred to as chaparros (Asteraceae, bromeliads, huicundos, gentianas, etc).

Rapid climate changes that have occurred worldwide during the past 30 years have led to numerous changes in

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the distribution and abundance of species, already causing alterations in a variety of ecosystems (Jallo, 2013; Rivera, 2013). According to Thomas *et al.* (2013), a minimum climate change would result in the extinction of 18% of the known species and a change of species of up to 35%. According to the IPCC report 4, approximately 20-30% of plant and animal species would possibly be at increased risk of extinction if the average global temperature exceeded 1.5-2.5°C. The speed of climate change varies in small and large geographic scales and usually increases with distance from the equator. Locally, the speeds and directions of climate change vary with topography and the proximity to large bodies of water. Forest species and forest communities vary in their resistance and resilience to climate change and their ability to adapt.

The next work rises from the need to consider the rich flora of the Aguarongo forest as a mega diverse ecosystem. Bromeliads are a species of great importance for insects, small animals and the ecosystem in general, since they house plenty of water that provides the necessary conditions for their development. This research undertook a study of the existing bromeliads in the forest and determined their importance for the ecosystems that inhabit it, since bromeliads, especially those of the genus Tillandsia, contain large amounts of water and nutrients that serve as food for several species of insects and frogs in the area. Some epiphytes bromeliads feed on the water that slips out of the trunk and foliage of trees as well as organic matter that accumulates in their leaves arranged in the form of tank. Vehicular traffic, industries and other anthropogenic activities have increased atmospheric pollution. The change in the use of soil, deforestation and advances of the agricultural frontier, also contribute to climate change. This situation required the study of important species such as bromelias that transform CO_2, provide water, prevent soil erosion and present conditions for life to develop.

The method used is based on indexes of diversity and biological wealth by Shannon and Weaver (1949) and by Simpson which help determine the wealth of the subjects studied and the distribution thereof throughout the forest.

Biodiversity or biological diversity is defined as "the variability among living organisms from all sources, including, among others, organisms, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; This includes diversity within species between species and of ecosystems.

Species richness: The richness of species richness is the number of species in a community. It has been used as an indicator of the ecological integrity and is one of the most used measures to assess effects of contaminants in the communities, since reduction of species is the most consistent response to disturbances (Clements and Newman, 2002). To calculate it, the following equation is used:

$$R_{Magalef} = \frac{S-1}{\ln|N}$$

Where:
R = Wealth
S = Number of species in the sample
N = Total number of individuals in the sample

It is used when you have the same number of species in the samples that you want to compare (Clements and Newman, 2002).

Diversity index: Diversity of species can be defined as the number of species in a unit area. It has two main components: the richness (number of species) and evenness (number of individuals of a single species).

Usually, indexes of diversity that respond to the richness of species and the distribution of individuals among species are used in biological assessments (Clements and Newman, 2002). The estimation is carried out through different indexes; the most used are the Shannon-Wiener and Simpson indexes. The Simpson index ($\hat{\lambda}$) is relatively insensitive for rare species but highly sensitive for dominant species (Clements and Newman, 2002). It can be calculated with the following equation:

$$\hat{\lambda} = \sum_{i=1}^{S} \frac{1}{p_i^2}$$

Where:
$\hat{\lambda}$ = Diversity measure
p_i = Proportion of the species (i) in the sample

The value range of $\hat{\lambda}$ is 1 to S where S = species richness (Clements and Newman, 2002).

MATERIALS AND METHODS

The materials used for the field trips are: camera, GPS, measuring tapes, rubber boots, milestones or stakes and tape to delimit the zone of bromeliads count and office materials such as: notebooks, pencils, pens, etc.

Sampling design: Random samples were taken in four different zones of the Aguarongo Protective Forest. Zone 1 belongs to the path where you can find the "Mirador The Bromeliads" with coordinates E74210.12M, N9680208.31m. Zone 2 is located in the "Mirador los cerros" with coordinates E74155.2M, N9680201.2m. Zone 3 and 4 were taken totally at random out of the trails and have the coordinates E74262.42M, N9680187.99m for Zone 3 and E742000.26M, N9679670.12m for Zone 4.

For sampling, we proceeded to delimit an area of 25 m^2 (researchers) which was marked with a yellow ribbon and then proceeded to count the species of bromeliads that were within the area, taking into account that for this type of sampling limitations of 100×25 m areas were performed and then we proceeded to count the trees that have Bromeliads, collect samples, dry them and analyze them in the laboratory (Zavala-Molina, 2002). According to the methodology posed by Zavala in her work called "inventory of bromeliads epiphytes of misty forest of the mountain El Volcan, El Paraiso, Honduras" where a count of species is performed, it was decided to attach this technique to our area of study taking into account adverse ground conditions such as: the steep slope, the thick vegetation and in certain cases, streams that hampered the mobility in the chosen areas, so it was decided to limit the area of study to 25 m. Then, we proceeded to carry out the count of species considering only those that had the characteristics to serve for climate regulation, habitat or food for species, understanding by this that only plants that could receive water within themselves and that according to the criterion of the researchers were of relevance to the project would be taken into account.

After obtaining a total of species we proceeded to perform a general and systematic botanical study, taking into account physical traits (leaves, flower, fruit, size) to classify taxonomically.

Taxonomic classification: Taxonomic classification was based on studies conducted in the Aguarongo protective forest such as the study by Eliana Rivera Delgado made in the year 2013 in which an inventory of bromeliads existing in the forest.

RESULTS AND DISCUSSION

In Table 1 you can observe the species of bromeliads found in each area, the total number of species, the richness of the same and in addition the results of the indexes of diversity.

The Zone 1 or zone "Mirador Las Bromeliads" is the richest in species. As already mentioned in the methodology, species richness is the total number of species found but not the number of plants; the total number of species found were: 8 in Zone 1, 7 in Zone 2, 3 and 6 in Zone 4 which is the least rich in species of bromeliads. Zone 1 also has the largest number of individuals, 65 in total.

The most diverse species and with greater numbers of individuals are *Tillandsia complanata* and *Racineae tetrantha*. The difference is particularly noticeable in Zone 1. On the other hand, Aguarongo appears in the areas 2, 3 and 4 with an entire number of

Table 1: General table of results obtained according to the species and area

Scientific name	Zone 1	Zone 2	Zone 3	Zone 4
Puya raimondi	0	4	3	1
Tillandsia fendleri	6	4	2	0
Racinaea monticola	3	0	2	0
Racinaea tetrantha	12	6	4	3
Vriesea cilíndrica	0	1	0	1
Pitcairnia pungens	2	0	0	0
Tillandsia stenoura	4	0	3	2
Puya sp.	0	1	0	0
Tillandsia complanata	29	7	12	6
Tillandsia maculata	2	0	0	0
Tillandsia biflora	7	5	2	3
Species richness	8	7	7	6
Total number of individuals	65	28	28	16
Dmg	1,67689281	1,80060977	1,80060977	1,8033688
Simpson	0,26106509	0,18367347	0,24234694	0,234375
Diversity	0,73893491	0,81632653	0,75765306	0,765625

Tillandsia complanata-Aguarongo 2016

Fig. 1: The most diverse species and greater numbers individuals

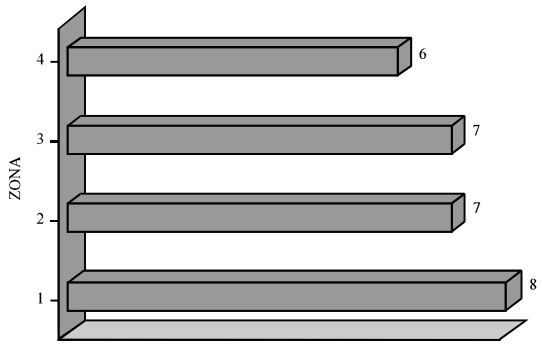

Fig. 2: Results of the richness of species

8 individuals; it is necessary to stress that the Aguarongo is a very big plant and covers a lot of space, the proposed area is small and not many individuals are found there but in fact many Aguarongo plants exist there and the protective forest gets its name after them (Fig. 1-3).

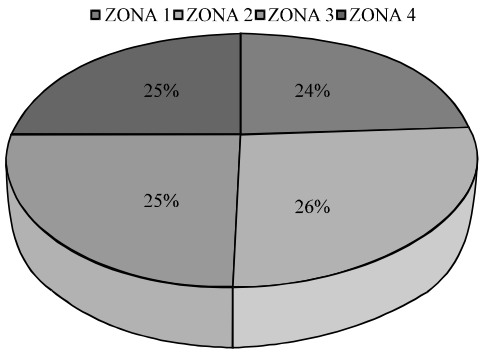

Fig. 3: Results of the species richness in percentage by area

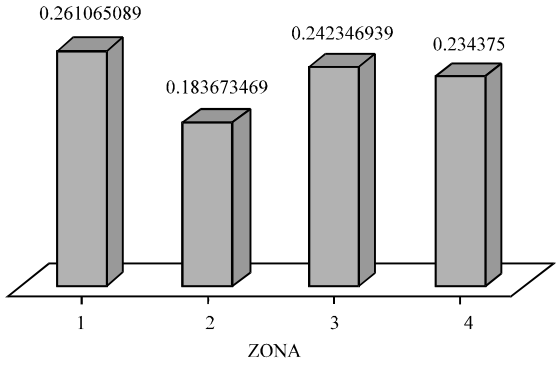

Fig. 4: Simpson idex

Species diversity can be defined as the number of species in a unit area. The graph shows us clearly that there is similarity between the percentage of species diversity in each area which indicates that the Aguarongo protective forest is very rich and diverse in terms of bromeliads (Fig. 4).

CONCLUSION

The results show that the forest has a great diversity of species of bromeliads, *Tillandsia complanata* being the predominant species, particularly in Zone 1 which corresponds to "Mirador las Bromelias" area. The variety of flora in bromeliads also entails a diverse presence of fauna since there are many species of insects, reptiles and amphibians that inhabit this plant. It is also necessary to emphasize the importance of the Bromeliad as a food source for the spectacled bear, a native endangered mammal of the area. The presence of bromeliads in the forest ensures storage of water and constitutes a major contribution to biodiversity in terms of wildlife to such an extent that in a single area of sampling we established the presence of 65 specimens of bromeliads which indicates a high level of diversity according to the statistical methods used.

After obtaining the results and corroborating the abundance and diversity of species of bromeliads in the BPA, we can say that their contribution to maintaining the conditions of wet forests are essential for keeping the balance of the ecosystem because their contribution to the water cycle is of the utmost importance for the climate of the place as well as its role as host to insects and amphibians that play a vital role within the food chain, without mentioning that they serve as food for the spectacled bear (*Tremarctos ornatus*), a staple species of the forest that is in danger of extinction. This is why the great importance of these plants in the fight against climate change can be determined (Smith and Smith, 2001).

The deterioration of the forest causes negative impacts on the populations that benefit from the water sources of the BPA, so it is our duty to preserve the water resource practicing techniques for mitigation and adaptation to global problem relating to climate change. The importance of the Bromeliaceae family within the Aguarongo protective forest constitutes a key point of balance inside of this ecosystem as the disappearance or alteration of the mentioned plant would cause a loss in chain reaction of all of the organisms that depend on it, so it is of great value to raise awareness and develop scientific studies around these habitats.

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