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Restoration of Woodland in Inhabited Rural Mountainous Areas and Landscape Transformation in a Vulnerable Environment: The Case of the Village of Vallue, Palmes Region, Haiti

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Abstract

Biodiversity is under threat in Haiti. FAO, in its 2020 report on the state of the world's forests, indicates that forest coverage in Haiti represents 12.6% of its territory; thus, this lack in wooded areas increases its vulnerability to natural disasters. To try recovering in losses of forest coverage and biodiversity at the local level, the organization of farmers in Vallue a rural area of Petit-Goâve (a city in the western department), has mobilized its members, taped to its resources and embarked into reforestation projects while helping to improve habitat in the village. This research analyzes the relationship among biodiversity resources in reforestation projects involving native and exotic species, habitat and landscape transformation in an environment that is vulnerable to natural disasters with the goal to seek for solutions that can benefit rural communities. A field investigation is conducted with 156 families who live in the village and a series of satellite images are analyzed to evaluate the percentage of forest coverage. The results obtained indicate habitats are destroyed by disasters that regularly hit the region; reforestation projects that include exotic species do not have adverse effects on native ones and wooded areas are improved in the village of Vallue. Furthermore, the landscape retains a visual quality that can facilitate the valorization of the territory. It is proposed that reforestation projects with plants that resist to high winds to be used and develop a bio-reactive habitat that may reduce the vulnerability of rural families living in areas too often struck by hurricanes.

Keywords: biodiversity, bio-reactive habitat, landscape, natural disaster, regenerative development, secondary succession

1. Introduction

The concept of biodiversity on standpoints of vegetation coverage and specie richness, has been, as mentioned by Martin, C. et al. (2021) the subject of numerous studies on landscape fragmentation; rural habitat has also been studied. However, the integration of these three concepts does not seem to be reported which could make it possible to evaluate the impact of reforestation projects that use indiscriminately, endemic, exotic and native species in inhabited environments that exhibit diverse biodiversity and landscape.

During the 18th century, when natural history became a modern science, the notion of biodiversity referred to the diversity of living species (Núñez, I. et al. 2003). It was with Charles Darwin (1809 - 1882) that natural history made a considerable leap by stating that variations in wild species are possible; thus, paving the way for the theory of natural selection. To explain this theory and specie diversity, Harvey, G. M et al. (2020) approaches it from the perspective of a process of gradual accumulation of changes throughout evolution. Considering the theory on diversity of species, the concern for their conservation has arisen while being aware of the difficulty of accurately assessing the importance of this diversity (Núñez, I. et al., 2003).

The interest in protecting biological diversity dates back a long time, and the creation of Yellowstone Park in the United States of America in 1872 marked the beginning of this approach. A century later, with the objective of slowing down the extinction of plant and animal species, UNESCO, through the 1972 Convention on the Protection of the World Cultural Heritage, launched the mobilization for the protection of natural resources through the

creation of natural parks and protected areas around the world; however, the WWF (2020) informs us that the Latin American region, one of the most important in terms of biodiversity on the planet, has lost 94% of its biological stock. According to the FAO, the unsustainable consumption of plants and animals, both wild and domestic, in the Latin American region will lead to their extinction. In fact, today consumer's diet consists of only 200 plants compared to the approximately 7,000 that made up our great parents' diet (UN News, 2019).

The United Nation (UN) Decade (2021 – 2030) for Ecosystem Restoration is "a call for massive and global restoration of degraded ecosystems" (Waltham N. J. et al., 2020) and through this program, the Bonn Challenge has been undertaken, landscape restoration activities in the Americas and the Caribbean region under the Restoration Opportunity Assessment Methodology (ROAM). By considering that thirteen Latin American and Caribbean countries participate in this program, the global reforestation commitment will reach about twelve million hectares. Since 1997, the Dominican Republic has been promoting the restoration and reforestation of its entire territory through its Quisqueya Verde National Plan project, which allows for the reforestation of approximately 6,000 hectares per year (CCAD, 2021). However, natural disasters inflict considerable damage to the forests, while also contributing to the enrichment of biodiversity and the dispersal of some exotic species.

In response to the loss of forest coverage and biodiversity around the world, reforestation projects are being carried out with both native and exotic plants. In Costa Rica, exotic plants have been used as a strategy for ecological restoration of degraded forests. The execution of these programs has contributed to the recovery of more than 150,000 hectares of land at the national level (Sandoz, M. A. M., 2010). In Peru, with the participation of local communities, specifically with the peasant organization of San Ignacio de Kiuñalla, scientific knowledge combined with ancestral are used to restore degraded forests and revalue them (Mogrovejo, R. K., 2020). In Mexico, on the other hand, in the Las Cañadas Reserve, restoration techniques are combined with passive and active to revitalize the forests. The former consists of undertaking activities that aim to protect the selected site from alterations and the latter includes the establishment of mixed plantations, removal of exotic species or direct planting in secondary forests (Trujillo-Miranda, A. L. et al., 2018). While it appears that the use of exotic plants can be positive in the restoration of degraded forests, their impacts on the agricultural sector can be devastating and lead to significant economic losses as reported by Fantle-Lepczyk, J. E. et al., (2022). Therefore, it is extremely difficult to curtail the invasion of exotic plants, a natural process associated with the dynamics of living systems, accentuated by human activities in natural environments that over the centuries, has dispersed many species in territories despite the natural barriers that existed (Aguirre Muñoz, A. et al., 2009). However, the same anthropic activities that contribute to the fragmentation of wooded areas into units, can serve as a barrier against this invasion as long as these units are sufficiently distant and isolated from each other (Vidra, R. L., 2004). The current needs of humans mean that their constant presence in natural environments serves as a propagator of exotic species in the natural environment. Unfortunately, the native species do not necessarily have the defense mechanisms that can allow them to face off invasive species putting them in a situation of extinction (Aguirre Muñoz, A. et al., 2009) and the ecology as a discipline that emerges at the end of the nineteenth century and defined by McDonnell, M. J. (2011) as "the study of organism and their environment" provide the tool to a better understanding of the interdependence between man and natural resources.

Since ancient times, the concept of urban gardens existed and has been developed in the Sumerian cities in the Mesopotamian region (~2600-1900 b. J-C) (Besnier, M-F., 2000). The modern era, the ecological movement in cities has accelerated in the last decades of the twentieth century both in some metropolises and in the periphery where community gardens as well as small-scale animal husbandry have occasionally developed Faliès, C. y Mesclier, E. (2015). The proliferation of exotic plants has increased in a dynamic of return to nature by integrating elements of biodiversity, following in the footsteps of Frederick L. Olmsted (1822-1903) (Hoffman, H., et al., 2004) considered as the father of the integration of landscaping in architecture. Outside of cities and during the construction of service infrastructures, water reservoirs, or territorial protection, military fortifications, elements of flora are used for camouflage purposes (Clergeau, P., 2020). This enrichment of biodiversity in the urban area has spread to the rural environment. The appearance of the environmental movement during the 1970s will contribute to the development of alternative habitat projects (Mazel, I., 2017). In France, after decades of depopulation of the rural environment, the opposite movement was initiated during the 1980s, satisfying the need of city dwellers for large spaces without giving up the opportunities of services offered by the city (Mazel, I., 2017). In contrast to the return to the rural environment that brings with it exotic plants, projects aimed at improving the rural habitat in the fight against CHAGAS, Sesma, M. et al. (2019) reported that in the province of Cordoba in Colombia, ignoring the local culture and architecture, have contributed to the abandonment of plantations whose species were used in the construction of the habitat and these are replaced by materials from outside the region. The rural habitat in this sense retains an architecture that responds to the environment as well

as. the importance of local cultural values in the construction process, as well as the climatic and landscape parameters (Ryan, O. C., et al., 2014). Sánchez (2010) suggests, from the point of view of environmental psychology, that the rural habitat should meet the requirements of functionality and that the modifications made for functionality should allow the separation of domestic and productive activities. In Senegal, for example, the habitat is rounded or square in shape, using locally available materials such as stabilized earth, curly millet stalks, and woven bamboo (Brasseur, G., 1976). Taking into account the cultural values, the project "*Vivienda fértil: una vivienda rural, sostenible y adaptable*", developed by the University of La Salle, Colombia is an example. This project proposes a rural peasant habitat adapted to the environment of Cundinamarca and Boyacá, which support the assertion of Moreno Clavijo, P. A., et al., (2020) that "the chosen architecture thus responds to the functions of living and generating essential spaces that meet the needs of rural life".

At a more sophisticated level, to bring the habitat closer to nature, the concept of biomimicry in architecture is developed and allows to take maximum advantage of the behavior of plants in their respective environment. Invented by Frank L. Wright in 1936, organic architecture aims at the complete integration of the building in its environment. Another trend in this current is biomorphic architecture, which it simply refers to the organic forms of plants and animals without concern for ecological issues (CEEBIOS, 2018). These anthropogenic activities associated with others of the industrial era that accentuate land usage have profoundly altered the ecosystems of the natural environment. These ecosystem alterations impact landscape quality and restoration activities that can help recover some of the ecological functions (IUFRO, 2018). All over the world, for the needs of ever-increasing populations, cities and industries are expanding towards natural environments; in a study on the evolution of the process of land usage in the eastern part of the island of Puerto Rico by López-Marrero, T. (2003), it is shown that for the period between 1977 and 1995, the rate of urbanization increased by 7.3% to the detriment of the forest in the considered area. To stop this erosion of biodiversity, different interventions are carried out in the natural environment both for the purpose of re-establishing secondary forests, restoring woodland coverage and to meet the habitat needs of the populations present in these territories. These interventions transform the landscape that Berg, L. S. (1913) defines as "an area in which climate, water, soil, vegetation and human activity are organized in a harmonious geographical whole in such a way that they can be reproduced in the same geographical area". This arrangement of elements is specific for each observer of a natural or cultural landscape. Depending on his social and cultural background, his appreciation of a landscape will be different, as his preferences will be. According to Roger, A. (1997), the contemplation of the contemporary real landscape is marked by an ideal landscape transmitted from generation to generation in various ways. The landscape is also shaped by natural disasters that recurrently strike countries on all continents. On a global level, Lutoff, C. (2020) citing the *Center for Research on the Epidemiology of Disasters* (CRED), informs that statistics from 2015 report more than 8,600 natural disasters between 1994 and 2015 that caused more than 1.5 million deaths. In its 2021 report, the Emergency Event Database (EM-DAT (Note 1)), ED-MAT (2022), listed 432 extreme events associated with natural disasters, resulting in 10,492 deaths and affecting 101.8 million people.

Regularly struck by natural disasters, Haiti has experienced from 1954 to 2021 nearly twenty of these adversities among them more than 90% meet the criteria of the EM-DAT to be considered as natural disasters. In an environment marked by the recurrence of natural events categorized as catastrophic, biodiversity resources, anthropic achievements as well as projects of forest restorations suffer damages that disrupt many natural cycles. Long before natural disasters were recorded at the national level, the mountains of Haiti served as a refuge for the enslaved population, who later continued to occupy them and derive their livelihoods from (Moral, P., 1957). As time evolved, a dispersed occupation of the territory was established, while maintaining a certain balance in the ecosystems (Benoit, C., 1995). After the independence of the country in 1804, in order to ensure the functioning of the state, successive governments continued to exploit forest resources, which facilitated the establishment of new human settlements in mountainous areas, thus contributing to the acceleration of deforestation on one hand, as it happened with Reynolds Mining Co. in the city of Miragoane (Enquet'action., 2020). On the other hand, mountainous regions as well as native forests were contracted to exploit wooden resources and develop industrial crops such as agave for sisal and rubber trees for rubber as reported by Gilbert, M. (2016). When these contracts expired, the exploitation of natural resources continued by the population, added to this is the cutting of trees to access land for agriculture and produce crops that they consume and sell to urban populations. Over time, incomes from crop selling could not support family living conditions, populations in mountainous areas increased the cutting of trees to produce charcoal whose annual consumption at the national level is between 3 and 4 million metric tons (Racicot, A., 2011).

In the Anthropocene era, the planet's resources are used to such an extent that the biodiversity integrity index (BII) at the global level has fallen to 79% well below the proposed 90% limit according to WWF (2020). In the case of

Haiti, a country that is more than 80% mountainous (MDE., 2019), its governmental leaders have prioritized an environmental policy that favors the production of lumber and then transform land areas into agricultural plantations (Bellande, A. 2009). This policy has led to an accelerated reduction in forest coverage, which fell to 7% between 2001 and 2017 (MDE., 2019) and which the FAO, in its report (FAO FRA, 2020) on the state of the world's forests, established at 12.6%. This low forest coverage results in accelerated loss of biodiversity, erosion and loss of soil fertility, reduction in provision of ecosystem services and an increase in vulnerability of populations due to natural disasters. Between 1954 and 2021 about 18 natural disasters (hurricanes, floods, earthquakes) among them 10 are qualified as major according to the criterion of number of deaths set by the EM-DAT. According to the FAO, after the tropical cyclone Matthew (2016) on the Caribbean countries, between 15% to 20% of the trees in the departments of Grande-Anse and Nippes in Haiti, were uprooted or broken, thereby reducing the forest coverage of the region (Tardieu, L. F. X., 2018). The impact of natural disasters on environments and human settlements is becoming increasingly severe. Projects to restore degraded natural areas and forests must take into account the negative impacts that the species used may have on ecosystems and the landscape. In addition, it is important that habitat improvement projects in mountainous areas are adapted to both environmental conditions and local cultural values. To reverse this situation, some regional communities have organized themselves to invest into reforestation projects at local level; the Organization of Peasants of Vallue (APV) falls in this category. Established in the Palmes region, APV has undertaken reforestation activities using both native and exotic plants. In addition to its interventions to protect the natural environment, APV also intervenes on reinforcement and building of rural habitats in order to improve the housing conditions of its members, considering the high risk of the territory to natural disasters.

The present research aims to evaluate the impact of reforestation projects that use native and exotic plants undertaken by local organizations in their efforts to restore the land cover in their community. The transformation of degraded land into wooded area is carried out by introducing various plant species nearby the rural habitat constructed in the framework of a project to improve the quality of life in rural mountainous region. However, anthropogenic interventions may trigger a negative response by visitors, considering the visual quality of the landscape.

2. Materials and Methods

In the course of this study, the approach is as follows: 1) prioritizing of research concepts such as biodiversity of plant species 2) emphasizing works carried out on the problem of reforestation, from endemic, native and exotic plants, in tropical countries where reforestation activities are taking place 3) analyzing rural habitat projects in mountainous regions, within the framework of reforestation activities, as well as habitat projects developed after a natural disaster struck a vulnerable territory, particularly in southern countries and 4) characterizing habitats presented in the study based on architectural styles that keep a synergy with the ecology in order to maintain an impact on the landscape transformation.

After delineating the study area, a field survey questionnaire is developed. From the total population of the studied area, a representative sample (156) of heads of household is established. To collect information from the sampled heads of household, a group of six (6) young people living in the area selected for the study are recruited and trained to conduct the survey. They are equipped with gauges scaled in centimeters to determine the diameters of trees in the immediate vicinity of the sampled habitat, cellular telephones equipped with cameras that allow them to photograph the surveyed habitat. These photographs are later used to categorize the habitat by architectural styles. In addition to the survey questionnaire, an interview guideline was developed to gather information from leaders of organizations in the studied area. The interviews were conducted directly by the author of this study.

To estimate the impact of reforestation projects considered in this investigation, aerial imagery in the optical frequency spectrum collected by Sentinel-8 satellite from the European Space Agency (ESA) is used. The 3-channel (Red, Green and Blue) RGB images were obtained from the National Center for Geospatial Information (its acronym in French: CNIGS), an entity under the Ministry of Planning and External Cooperation of the Haitian government. The RGB images used, cover the period from 2004 to 2012 as mentioned in the table reported in Figure 1. Most of the images were taken at daytime under clear sky conditions as depicted in the RGB image in Figure 1, collected in 2004, that also displays its decomposition into the red, green and blue channels. Each sub-image is of dimension 128×128 pixels with a range-resolution of 10 cm. Meta data that describe the orbit of the satellite, give its speed, altitude, orientation, its viewing geometry, etc. and also are reported the geolocation coordinates (latitude, and longitude) of points on the earth surface captured in the image that allow location of the area for which the study is being conducted. Analysis of the images is realized via **Matlab** R2023a that allows graphical representation of the multi-channel images and the study of the luminosity of pixels from each channel that exceed a threshold of 150 from the range of 0 to 255 that defines the intensity map. Later, the pixels that

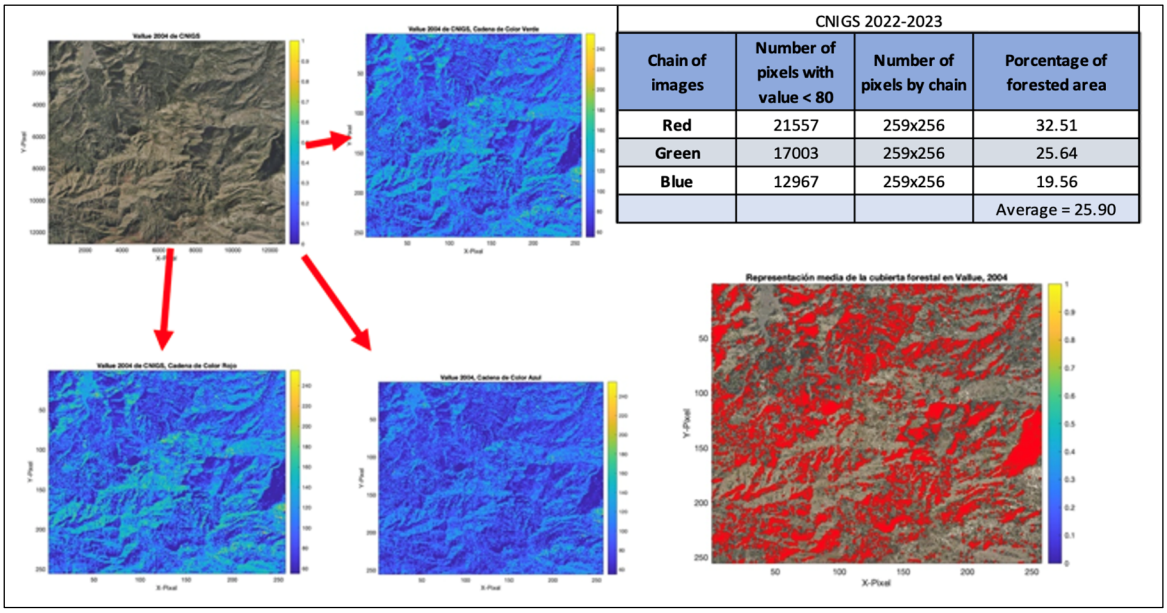
exceed the threshold are mapped to the RGB image and those that correspond to the green color are selected and tabulated to estimate the percentage of woodland surface in the studied area, i.e., Vallue. The woodland surface is represented by the red dots in RGB image depicted in Figure 1. Statistical analyses carried out from the data are also conducted using the software **SPSS** Version 29.0.0.0 (241).

3. Experimental Results

Analyses conducted from information gathered from the field survey on reforestation activities, construction or rehabilitation of family habitats and their contributions to reduce or increase the exposure of the studied area to natural disasters are summarized in the following subsections.

3.1 Reforestation Projects

• Reforestation activities, in general, have contributed to the increase in woodland area in the territory of Vallue Village from 17.66% in 2014 to 25.90% in 2022-2023, far exceeding the national average of 12.6% as reported in the table displayed in Figure 1.



CNIGS 2022-2023			
Chain of images	Number of pixels with value < 80	Number of pixels by chain	Porcentage of forested area
Red	21557	259x256	32.51
Green	17003	259x256	25.64
Blue	12967	259x256	19.56
			Average = 25.90

Figure 1. Evolution of woodland area in Vallue, Petit-Goave, Haiti

• The exotic species (41.0%) in reforestation projects do not seem to have a negative impact on the native flora presented in the area of study.

• Among the 16 exotic species used, 2 of them, or 12.5% of the population, are considered problematic (invasive and hydrophilic) and are eliminated from the reforested area although a few specimens remain along accessed roads.

• In the process of construction or reinforcement of rural habitats, a reorganization of the land topography from a selected construction site, including the cutting of trees with more than 20 cm in diameter is carrying out. They are further replaced by both native and exotic species, contributing to the improvement of woodland areas.

• The tree species planted in the vicinity of the habitat are there to enhance the value of the property and improve the woodland cover but not to act as windbreaks, which would have contributed to even partial protection of the habitats at the time of tropical storms.

3.2 Habitat Construction and Natural Disaster

• The study has revealed the existence of tree main architectural styles of habitat in Vallue, namely: the rustic style of habitat is constructed from biotic and abiotic materials obtained directly from the surrounding site; the traditional habitat incorporates in its construction natural resources, timbers, stone for the masonry as well as modern material such as cement, galvanized sheet metal and finally the modern style where concrete, reinforcement steel, concrete slab, glass windows, electrical and hydraulic installations are present. Their distribution is presented in Figure 2.

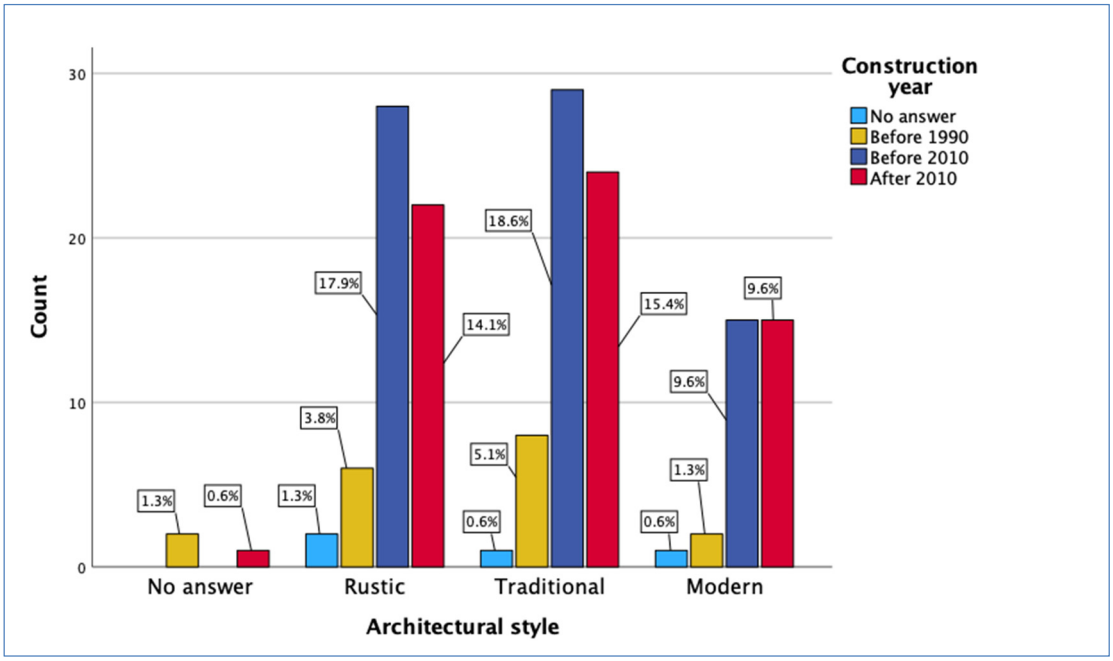


Figure 2. Distribution of habitats by architectural style and period of construction

• The traditional style of rural habitat is, with 39.7%, the most prevalent in the territory. Along with modern-style habitat, they are the most affected by natural disasters, cyclones and earthquakes, with a level of destruction or damage of 84% after the passage of Hurricane Matthew, in 2016, according to the results obtained from the field survey realized during the present study.

3.3 Landscape Transformation and Visual Quality

• The fragmentation of the studied area is low in term of road access network that consists of a total of 15 km and does not a great impact in the transformation of the landscape. All three architectural styles discussed earlier are served by all three access road categories, paths for motor vehicles, motorcycles and pedestrians; however, the rustic housing is most widely served by pedestrian path (17.9%) followed by the traditional style (12.8%) and finally 5.1% for the modern habitat, as presented in Figure 3.

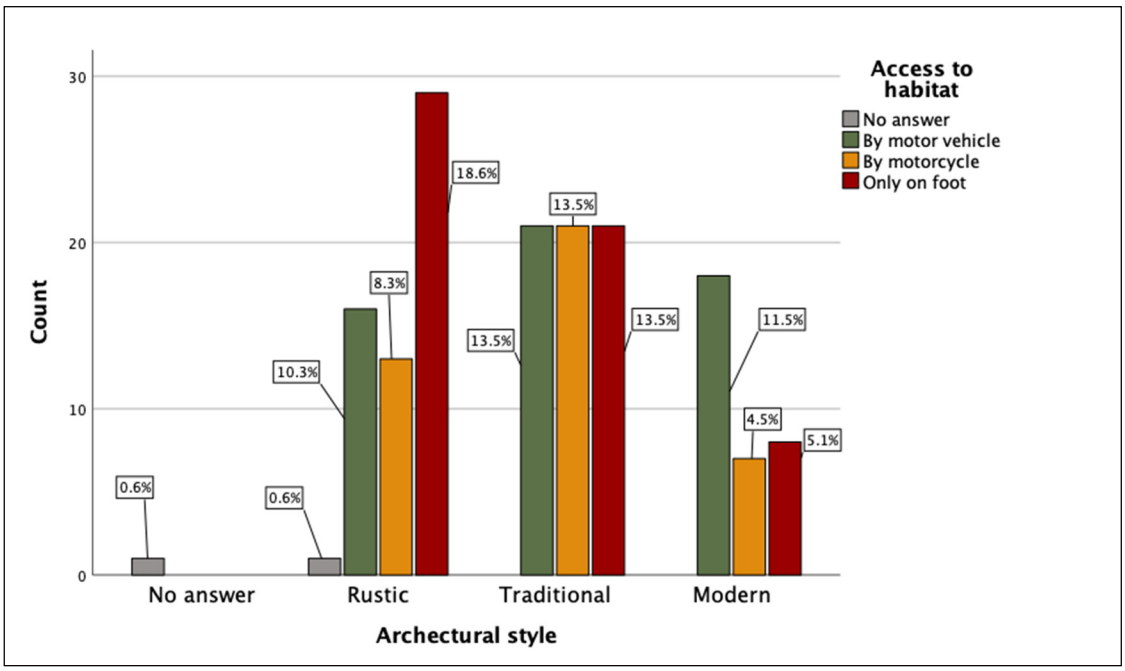


Figure 3. Access modes to habitats in relation to architectural style

• Anthropic activities, in particular agriculture and livestock, contribute most to the transformation of the landscape, and 57% of the population surveyed actively are engaged in these activities.

• The importance given by the population to tree planting around their habitats, as observed in the survey, is aimed to add value to their property and contribute to the woodland cover of the territory. Their understanding of the landscape does not go beyond the visible elements of natural resources and colonial remains. The visual appreciation is based on the aesthetic aspect of the place based on the low or high density of the wooded coverage.

• From the analysis of the data of the survey on the visual quality of the landscape realized with the students in Tourism and Heritage from the State University of Haiti (for its acronym in French UEH) of a series of twelve photographs taken from tree different landscapes, (agriculture, woodland and humanized), the 2 most appreciated landscapes by the evaluators from the group of 12 photographs are woodland and humanized, they are shown in Figure 4.

Figure 4. The two most appreciated landscapes from the survey with the university students. (on the left: Jansizo Woodland landscape and on the right: Gran Plas humanized landscape)

• The landscape data analyzed by the software SPSS with the results of the humanized landscape of Gran Plas, presented in the diagrams of Figure 5, demonstrate that the appreciation of the landscape does not differ within the group of evaluators composed of male and female university students.

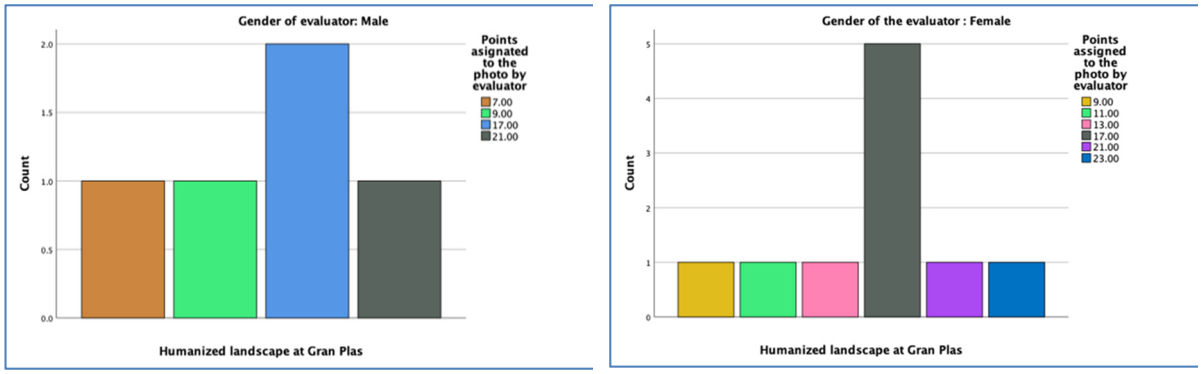


Figure 5. Appreciation of students of the University of landscapes according to gender (diagram on the left: Male students; diagram on the right: Female students)

4. Discussion

In the area covered by this study, some 400 families were identified and a sample of 156 were selected to carry out a field survey. In order to determine the attachment of the surveyed family to the territory, the respondents were asked about their region of origin. It was found that 96.8% of the population originated from the village of Vallue and the remaining 3.2% from the Palmes region. The answers to the question on the status of the occupant on the habitat indicate that 84.0% are owners, 12.8% are heirs and 3.2% are tenants.

During the period covered by the study, 1990 - 2022, APV carried out reforestation campaigns for 24 years in eight the nine localities that form the village namely: Bois Gency, Branchiro, Penoyer, Floket, Gran Plas, Platon Patat, Saint-Martin, Ti Plas, Zamor, with the exception of the locality of Denoyer, that did not participate in these activities. On the other hand, the localities of Flokèt and Ti Plas have been the most active in the reforestation campaigns carried out by APV.

The species used in the reforestation campaigns are divided between native (17.31%), exotic (14.1%) and mixed (58.31%). The use of exotic species did not have any undesired impacts, such as genetic mutations in species already present in the studied area. On the other hand, the use of these species has contributed to the improvement of the woodland coverage that has increased from 17.66% in 2014, dropped to 15.01% in 2017 and finally increased to 25.90% in 2022. However, it is important to study, in the future, the possible effects of the presence of exotic species on native ones in terms of natural hybridization and/or anthropic activities.

The decrease in wooded area calculated for the year 2017 is probably due to the passage of Hurricane Matthew in 2016. The reduction of the wooded coverage at the level of the departments that were hit by this natural disaster is estimated by the FAO, between 15 to 20% (Tardieu, L. F. X., 2018). The reforestation efforts in fruit and forest species provided by the population of the studied area are regularly threatened by these disasters. In contrast, species such as casuarina (*Casuarina*) and bamboo (*Bambusoideae*) have been only slightly affected, mainly due to their physical characteristics that allow them to better withstand to strong winds that come with cyclones. Greater use of these species in reforestation projects can help reduce the loss of woodland surface.

The passage of Matthew in 2016, a category 4 hurricane with winds of 240 km/h, over the studied area resulted in losses of 85% of the 246 inventoried habitats, all architectural styles included.

Anthropic activities, including agricultural activities, that occur in the studied area do not contribute per se to its deforestation. The 3 kilometer of concrete road and 12 kilometer of dirt road serve only 35.3% of the habitats. The dominant landscape units are firstly agricultural with scattered habitats, followed by pockets of secondary forest and finally a humanized unit that includes clustered habitats and basic service infrastructures, such as schools, health centers, recreational areas among others.

The reforestation activities and habitat rehabilitation projects in rural mountainous areas in the village of Vallue have impacted the territory and its landscape. The evaluation of the visual quality of the landscape shows that its attractiveness is based mainly on the quality of biotic and abiotic resources. The landscape with a higher level of anthropization has attracted little interest and can be considered as a banal one.

5. Conclusion

The presence of human settlements in mountainous ecosystems in the village of Vallue offers a traditional pattern of occupation territory in Haiti. The continuous presence of the population, although dispersed, has contributed to the degradation of the environment due to the realization of anthropic activities, mainly agriculture and lumber and charcoal production. This degradation is accentuated by initiatives of city type dwellers with the goal to bring the city to the mountain through habitat and certain amenities specific to cities. The development of anthropic activities for the benefit of agriculture, housing and associated infrastructures is encroaching on wooded areas, and the natural disasters that regularly strike the region also have a negative impact on biodiversity resources and habitats.

This work has shown that reforestation efforts using native and exotic species have a positive impact on the woodland coverage of the area of study. In addition, a more efficient use of exotic species with specific physical characteristics, can further contribute to the protection of natural and built heritage, at the time of cyclones and earthquakes that may give rise to the development of a bio-responsive habitat, thus demonstrating a certain ability to evolve, as expected by Mang, A. et al. (2016) to a higher level of creativity and better respond to natural hazards, which affect cyclically vulnerable territories like those in Haiti.

Although no negative impacts of exotic species on native ones have been found so far; however, a study on potential cross-breeding between them should be conducted. In addition, species with the required flexibility characteristics should be identified and evaluated for use in the development of a bio-reactive habitat.

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Conflicts of interest

No conflict of interest.

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Note

Note 1. EM-DAT: Is an international organization that compiles information about natural disasters. Natural phenomena, such as hurricanes, cyclones, earthquakes, tsunamis, etc., are considered natural disasters when the number of deaths reaches ten people.