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Mitigation Strategies for the Environmental Impact of Informal Settlements Over the Papagayo protective Forest in the Northwest of Guayaquil City

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ABSTRACT

The city of Guayaquil presents a constant economic growth and therefore a high demand for human labor, which leads to national migration from areas with lower labor supply, to the city, this generates an accelerated urban development and a high capital gain in consolidated areas of the city, so that the new inhabitants especially poor people to be forced to look for a habitat, and not having access to housing in a consolidated area with all basic services, seek areas with informal settlements whose cost are affordable for such dwellers. The objective of this study will be to generate a strategic mitigation plan for the environmental impact, taking as a study base the informal settlements on the papagayo protective forest in the northwest of Guayaquil. In this work, I've made a diagnosis of the current state of the Papagayo protective forest was made, in which information on the flora and fauna of the area was compiled and classified according to the level of affectation to which it has been subjected, in addition to the impact generated by informal settlements that directly affect the study area. Based on the study of concepts and theories of human settlements, environmental impacts, quantification of activities developed by the population through land use and parceling of the territorial surface affected by human settlements on the Papagayo Protected Forest using the ARCGIS geographic information system, complemented with the Analytical Hierarchy Process (AHP), a tool that facilitates complex decision making, which allows establishing the impact levels of flora and fauna, obtaining mitigation strategies for the environmental impact, improving the quality of life of its inhabitants and increasing the green area index of the area.

Keywords: Exemplary paper, Human systems integration, Systems engineering, Systems modeling language

INTRODUCTION

Guayaquil is a port city characterized by being one of the most important ports in the country and the region, it is also a city with a high rate of industrial manufacturing, generating a high labor requirement, this being an elemental source of its economic dynamics which generates a high migratory

flow to it, so the demand for housing in the city is high, the city's residential supply is oriented especially to people in the middle and upper socioeconomic classes, which means that low-income inhabitants have no other alternative but to settle in sectors where they can find a place to live near the city, and in most cases, they do not consider it important that the site be legalized and have basic infrastructure for living.

Since 2000, there has been a disproportionate growth of informal settlements from Av. Perimetral towards the northwest of the city of Guayaquil, which was developed without urban criteria or proper infrastructure or appropriate land use, encouraged by poor public policies, high demand, and the presence of leaders who invaded the land and sold it at low prices, being occupied most of the land, informal settlements reach the so-called Papagayo Protective Forest, This is national protection land declared by the Ministry of Environment and Miduvi through executive decree No. 791 on Tuesday, September 18, 2021 (MAE, 2012), where any human settlement of any kind is prohibited, but given the circumstances of lack of space to settle, the invaders are occupying more and more of the protected area every day and thus generate a fragmentation of the protected forest. Fragmentation is considered as a process of partial destruction of a natural habitat, resulting in several forest fragments of various shapes, sizes, and degrees of isolation which results in the interruption of ecological connectivity and is the main threat to biodiversity conservation and generation of environmental services (Tobar & Ibrahim, 2010).

METHODOLOGY

In this paper, a diagnosis of the current state of the Papagayo protective forest was made, as well as a classification of the flora and fauna immersed in it, in addition to the impact generated by informal settlements on it. Based on the study of concepts and theories of human settlements, environmental impacts, land use according to the activities carried out by the population, complemented with the Analytical Hierarchy Process (AHP), which is applied for the execution of the work, in order to improve the quality of life of its inhabitants and increase the index of green area in the area.

Environmental Impacts and Land Used in Protected Forest "Papagayo"

The georeferenced cartography based on orthophotos and in situ information will make it possible to determine the number of plots that currently exist within the area delimited for the Protected Forest. Likewise, it will be possible to define the areas with the greatest extension of land, in order to establish where the greatest number of informal settlements are located.

AHP as a Strategy Selection Methodology

For the analysis of the AHP hierarchical analysis process, a hierarchical structure matrix is established using the Saaty scale, which allows comparison between two alternatives with respect to a selected criterion. These comparisons will be based on information obtained in the field, such as surveys,

Table 1. Matrix of selection criteria.

	Criteria Matrix	Determining Elements
Factor 1	Cost	Characteristic determinant items
Factor 2	Local mitigation	Restoration to the local ecosystem
Factor 3	Execution time	Estimated execution time
Factor 4	Local infrastructure	The type and amount of existing infrastructure

Table 2. Quantification of land use in the study area.

Land use	Area (has)	Percentage
Human settlements	19.73	0.55%
Dry forest	2563.60	71.17%
Camp	4.48	0.12%
Army camp	9.71	0.27%
Mining extraction	0.54	0.01%
Easement strip	32.49	0.90%
Future settlements	164.50	4.57%
Coal production	1.39	0.04%
Local neighborhoods	736.66	20.45%
Chorrillo terminal	59.63	1.66%
Daule Santa Elena transfer	9.39	0.26%
Total	**3602.11**	**100.00%**

studies in geo-referenced information systems, such as parceling, existing fauna and flora, current land use, satellite images.

The next step is the selection of 4 previously established criteria (table 1), which have been classified according to their cost, expected mitigation level, execution time, existing local infrastructure, for the determination of their scale of judgment of the paired comparison matrix, values will be established determined by data obtained from field work, surveys, experiences with quantitative and qualitative data.

RESULTS

Diagnosis of the Study Area

Table 1 shows the percentages of land use that are currently being used in the Papagayo Protected Forest, 28.83% has been intervened by human activities, of which 20.45% is being used for private crops, in addition to the fact that 19.73 hectares have been invaded by human settlements, it was also found that 164.50 hectares (4.57%) of the territory of the Protected Forest is currently being prepared for future invasions (table 2).

The percentages of land use were quantified according to the use that is currently being made in the study area (image 1), in addition to the environmental impact that is being exerted in different areas (image 1), concluding that the strip located parallel to the Daule Santa Elena water transfer, is currently subject to a constant invasion, without the inhabitants respecting the

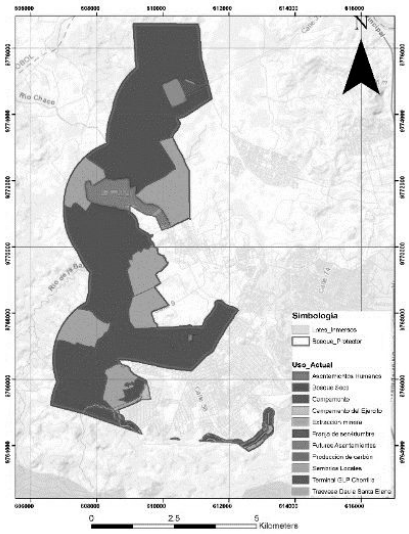

Figure 1: Current land uses of the Papagayo Protected Forest.

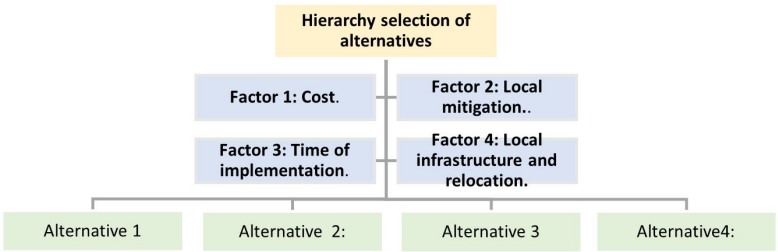

Figure 2: AHP hierarchical structure.

areas of the Protected Forest and the easement strip established by Executive Decree No. 607, which defines the Reserved Security Area in the "Delimitation of the Reserved National Geographic Spaces under the control of the Armed Forces" in order to control the disorderly, informal and dispersed expansion, as well as to protect the Transfer Canal threatened by the presence of settlements around it, and for this purpose, there are reserve and protection corridors of three hundred meters (300mt.) wide, one hundred and fifty meters (150mt.) on each side of the axis of the canal, in an extension of approximately 22.85 km, counted from the mouth of the Daule River to its intersection with the urban boundary of Guayaquil (Miduvi, 2010).

SELECTED STRATEGIES

Four alternative implementation guidelines were determined that are focused according to sociocultural and human settlements, biophysical, economic and mobility, connectivity and energy components, which will be structured in a chronological order of implementation based on a paired selection criterion according to the AHP analytical hierarchy process (Image 2).

Table 3. Paired comparison matrix.

Numerical Qualification	Verbal Scale	Scale Description
1	Equally preferable or important	Both elements contribute equally without significant change.
3	Moderately important in relation to the other element	Empirically and by previous experience, it favors in relation to the other.
5	Strongly more important and preferable in relation to the other element	Empirically and from previous experience, it strongly favors the other.
7	Very strongly important in relation to the other element	The element strongly dominates the other, proven in practice, judgment, and experience.
9	Extreme importance in relation to the other element	THE element extremely dominates the other to the greatest extent possible
2-4-6-8	Intermediate values between adjacent trials	Its scale is indifferent between one element and the other.

Once the selection alternatives have been determined, as well as the selection criteria and hierarchy level to be established, the paired comparison matrix is projected with its respective judgment scale and its corresponding nomenclature detailed in table 3 below.

Next, the judgment scale is determined in the paired comparison table for each of the selection alternatives, in relation to the given criteria (Cost, mitigation, execution time, local infrastructure), the same procedure is performed with the selection alternatives, the subscripts have been normalized to establish the coordinates of the matrices with the values of i=x , j=y, applying these criteria we obtain the summation (At) of each of the ratings using the following formula: $\mathrm{At}_j = \sum_{i=1}^{4} \mathrm{Alt}_{ij}$, with this the normalized matrix (Mn) is established which each cell is obtained with the formula $\mathrm{Mn}_{ij} = \mathrm{Alt}_{ij}/\mathrm{At}_j$, then the sum of normalized vectors $\mathrm{Wn}_i = \sum_{j=1}^{4} \mathrm{Mn}_{ij}$ is obtained; to which the averages of each one are determined and which could also be expressed in percentage with base 100 (table 4).

Then, the RC index is calculated, which is designed to establish that the judgments taken present inconsistencies if the index is greater than 0.10, so it is a unit of measurement to reconsider or modify the values of the judgment scale of the paired comparison matrix, so that values less than 0.10 are a sign of reasonable levels of inconsistency. For the calculation of the validation of the Consistency Ratio, the value of $\lambda_{\max}$ must be determined, applying the following formula: $\sum_{j=1}^{n} a_{ij} w_i = \lambda \max \sum_{i=1}^{n} w$, coupling it to the matrix,

Table 4. Paired comparison matrix.

Criterion 1: Cost											
	Alternative				Normalized Matrix (Mn)				Vector Sum (Wn)	Prom. *(Wp)*	%
	Alt. 1	Alt. 2	Alt. 3	Alt. 4							
Alt. 1	1	1	1/3	3	0.188	0.318	0.132	0.188	0.825	0.206	0.206
Alt. 2	1	1	1	7	0.188	0.318	0.395	0.438	1.338	0.334	0.334
Alt. 3	3	1	1	5	0.563	0.318	0.395	0.313	1.588	0.397	0.397
Alt. 4	1/3	1/7	1/5	1	0.063	0.045	0.079	0.063	0.249	0.062	0.062
Total (At)	5.333	3.142	2.533	16.000	1.000	1.000	1.000	1.000	4.000	1.000	1.000

Table 5. Random consistency index table.

No. of elements	**1**	**2**	**3**	**4**	**5.000**	**6.000**
Consistency Index Random (IA)	0	0	0.58	0.89	1.110	1.240

the following equations are obtained.

$$\sum_{j=1}^{n} \mathrm{At_{ij}} \mathrm{Wp}_i = \lambda \max \sum_{i=1}^{n} \mathrm{Wp}_i \quad (1)$$

$$\sum_{i=1}^{n} \mathrm{Wp}_i = 1 \quad (2)$$

$$\boldsymbol{\lambda max} = \sum_{j=1}^{n} \boldsymbol{At_{ij} Wp_i} \quad (3)$$

It then calculates the consistency index (CI), by applying the formula: CI= (λ_"max" −n)/(n−1), the random consistency index (CI) is the consistency index of a randomly generated matrix of paired comparisons (Saaty, T.L., 1980), the same depends on the number of items being compared, and the standardized values are detailed in table 5.

The formula CR=IC/IA is used to calculate the consistency ratio (CR), where a value ≤ 0.10 gives a reasonable consistency guideline and a CR > 0.10 gives inconsistency in decision making. For the determination of the results and level of hierarchy of execution, a results matrix (Table 6) is made, in which the results of the average vectors (Wp) of each one of the alternatives in relation to the given criteria are summarized; and a weighting row (Pr) is established, which is given by the Average Vectors (Wp) of the criteria comparison matrix, with these values the prioritization values (Pz) are established, which are obtained from the sum product of the vectors of each of the alternatives by the weighting level determined in the criteria comparison $\mathrm{Pz}_i = \sum_{j=1}^{4}$ Alt x Pr detailed in the table 6.

Table 6. Validation of judgment scale by consistency ratio (CR).

RESULTS							
Criteria Alternatives (Alt)	**Cost**	**Local Mitigation**	**Execution Time**	**Local Infrastructure and Relocation**	**Prioritization (PZ)**	**%**	**Priority of implementation (PE)**
Alternative 1	0.206	0.237	0.171	0.095	0.192	19%	3
Alternative 2	0.334	0.569	0.055	0.152	0.404	40%	1
Alternative 3	0.397	0.128	0.401	0.676	0.321	32%	2
Alternative 4	0.062	0.066	0.373	0.078	0.083	8%	4
Weighting (PR)	0.113	0.566	0.046	0.274	1.000	100%	

CONCLUSION

The strategic plan and mitigation for environmental protection against informal settlements should be focused on 4 fundamental axes: Control and prevention of future settlements, eradication and relocation of current settlements., repair, reforestation, and restoration of affected flora and fauna and Generation of plans and strategies for the management, care and incentive to care for the affected areas and their surroundings.

The mitigation of the environmental impacts already caused on the Protected Forest must be contemplated for its recovery in the medium and long term, with a policy of prevention of future sources of environmental impacts, as well as a reforestation plan focused especially on the areas where the impact has induced a degradation of the flora and fauna. Considering that one of the causes that promotes the development of settlements is migration from the countryside to the city, as well as family and social fragmentation, it is recommended that the competent institutions establish public policies to facilitate access to decent housing for this type of population.

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