# Determination of Hemeroby in Peru and its Relationship with Natural Factors and Human Intervention in the Biophysical Environment

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Roberto Santos, Dr.[1], Paula Santos, B.Sc.[2], and Ciro Rodriguez, Dr.[3]
[1]Universidad Nacional Federico Villareal , Perú, rtsgueudet@gmail.com
[2]Universidad de Palermo, Argentina, paulafsantos2797@gmail.com
[3]Universidad Nacional Mayor de San Marcos, Perú, crodriguezro@unmsm.edu.pe

***Abstract* — This document proposes the calculation of Hemeroby in Peru, examining the levels of relation of Hemeroby with the departmental factors of regional naturalness in the 24 Departments of Peru. The methodology used considers the data from the National Institute of Statistics and RapidEye™ satellite images corresponding to the year 2019. Pearson statistical analysis, ANOVA and regression analysis were used as statistics. The article shows that the Departments with the highest Hemeroby in Peru are San Martín (57.93), Lambayeque (57.65), while those with the lowest Hemeroby are Moquegua (44.07), Ica (45.24). The mean of Hemeroby in Peru is 53.28 with a calculated error deviation of 0.878. A strong positive correlation between the variable "Natural pasture area / departmental area" and the variable " Altitude of the capital of the Department" (CC = .818, p <.001); and, with the variable "Differential of the psychometric fan" (CC = .838, p <.001) were found. Also founded a positive correlation between the variable "Altitude of the capital of the Department" and the variable "Differential of the psychometric range" (CC = .877, p <.001) This research serves as a platform to identify critical points of increasing anthropogenic influence in rapidly developing regions of Peru.***

*Index Terms*— **Hemeroby, Sustainability, Anthropometric Influence, Environment.**

## I. Introduction

The characteristics of this study are based on the objective of establishing the levels of Hemeroby in the 24 Departments of the Peruvian territory. The general hypothesis that arises is that the departmental factors of regional naturalness of human intervention in Peru are related to the Hemeroby.

In the last 100 years, the exponential growth and economic development of populations has markedly increased the productive activities of human beings [1-3]. The different human activities have gradually transformed the surface of the planet [4-5]. The care of the environment has gained importance in recent times due to issues related to the affectation of the biophysical environment, pollution and climate disorders [6-9].

The word Hemeroby is composed of two Greek words; the word "hemeros" (related to the cultivated or domesticated); and the word "bios" (referring to life). The term Hemeroby began to be studied with Jalas in 1955 to classify plant species according to the degree of participation over the total number of species evaluated. The Hemeroby degree is "an integrative measure" that identifies the levels of human activities in ecosystems [11].

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Studying the indicators of forest systems related to human activity, it has been possible to find an index of naturalness for these systems [12-15]. The variables of temperature, precipitation; and, the proportion of natural habitats, affect plants introduced by humans and native plants [16-18].

The spatial distribution of soils in natural settings and in large-scale anthropogenically influenced ones can be explained using variables influencing human activities [19-21]. In countries with increasing anthropogenic activity, this approach makes it possible to recognize areas of change in the naturalness of the soil surface; and, it also has the potential to prevent actions that affect soil protection [22-24].

Temporal factors are equally important as spatial scales in understanding the impacts of human activity [25-27]. The adaptive response capacity to the modification of the landscape (fragmented habitats) generates an “extinction debt” or a “colonization credit” [25, 28-30].

The values of indicators with human impact, such as Hemeroby, can have important applications in the practice of conservation and monitoring of ecosystems [31-35].

Studies on the fragility of ecological systems in the coastal plain of Rio Grande do Sul - Brazil, explained that the daylily allows the classification of covers based on the level of separation between the different degrees of naturalness. The research contributed to the identification of 5 thresholds of naturalness based on indicators that arise from human activities. The integration of indicators made it possible to identify the predominant fragmentation structures and possible methodological refinements, explaining that agricultural crops dominate ecological processes in all coastal regions; and that the propensity for compaction of natural remnants affects the diagnosis of the intensity of land use [57].

Studies on the day-life in Germany explained the concepts related to "closeness to nature" and "day-life", establishing a Model to explain two initiators of day-life; that, until then, the national tracking and monitoring systems of land use in Germany did not have an indicator to reflect the naturalness of the landscapes. The research based its data on information from satellite images and mapping the potential of existing natural vegetation. The research suggests that the results in the values of daylily, in different temporal states, can be used to estimate the cumulative impact of changes in the surface use of the soil in the benefit of environmental sustainability [56.]

Satellite images and landscape patterns can be related to the Hemeroby index to analyze the distribution of human activity and its effect on the fragmentation of the landscape pattern [36-39]. As a result of concerns about the detrimental effects of human activity on the topsoil, many researchers have explained the need to base the collection of telemetry data and pooled socioeconomic data on an "interference index" that identifies human activity in specific spaces [40-44].

An important part of remote sensing as a contribution to research related to the use of territorial spaces (regions and cities) dependent on nature by humans, have served to identify anthropic disturbances [36, 39, 41,43, 45- 48].

In view of the above, it is very possible to relate the anthropometric actions of the human being with its corresponding affectation in the landscapes, modifying them by intervening in them. It is imperative to find tools to better explain the contradictions that are generated between aspects of ecosystem protection and economic development. This will be useful for those in charge of putting comprehensive policies into practice that incorporate actions to improve the way land is used and its corresponding economic development in the Departments of the country. This research presents a methodology that allows the identification of the Hemeroby as an influence of the anthropometric actions of the human being for ecological sustainability in territorial planning processes. The questions raised in this research are: What is the distribution of Hemeroby in Peru? What is the set of characteristics of the landscape pattern in Peru? and, How have the landscape patterns been modified by human action in Peru?

## II. Methods and Materials

### A. Data analysis

For the hypothesis test, linear regression analysis was used to find the main significant incidences between the variables of the Regional Factors and the Hemeroby in Peru [58]. Table I identifies the selected variables taking into account the dimensions studied.

TABLE I
DEFINITION OF VARIABLES, ACRONYM, SOURCES AND UNIT OF MEASURE

| **Dimension /** Variable | Acronym | Source | Unit of Measure |
|---|---|---|---|
| **Natural** | | | |
| Department Capital Altitude | ALTcd | INEI, 2021 | m |
| Psychometric Fan Differential | DAP | INEI, 2021 | °C |
| Protected Natural Landscape | PROT | INEI, 2021 | % |
| Natural pasture area / Departmental area | APN/AD | MINAGRI, 2019 | % |
| **Environmental** | | | |
| Total agricultural area / departmental area | AAT/AD | MINAGRI, 2019 | % |
| Agricultural area in use / total agricultural area | Aacc/AT | MINAGRI, 2019 | % |
| Landscape heterogeneity and structure | LCDI | Authors | n ha-1 |
| Heterogeneity and Structure of Agricultural Units | UADI | Authors | n ha-1 |
| Unused agricultural area / Departmental area | AAsc/AD | MINAGRI, 2019 | % |
| **Human activity** | | | |
| Roads / Agricultural area in use | V/AAcc | MINAGRI, 2019 | ha km-1 |
| Roads / Total Agricultural Area | V/AAT | MINAGRI, 2019 | ha km-1 |
| Internal roads / External roads / 1000 ha of agricultural area in use | RSG | MINAGRI, 2019 | km km-1 ha-1 |
| km of river / 1000 ha | RIO/1000 | MINAGRI, 2019 | km ha-1 |
| Urban area | AU | MINAGRI, 2019 | ha |
| Urban area / habitant | AU/Hab | MINAGRI, 2019 | m2 n-1 |
| External potential for cargo transfer | PETC | Authors | km ha-1 |
| Internal potential for cargo transfer | PITC | Authors | km ha-1 |
| Internal routes / External routes | Vi/Ve | MINAGRI, 2019 | km km-1 |
| **Government activity** | | | |
| State Density Index | IDE | PNUD, 2019 | Index |
| Human development Index | IDH | PNUD, 2019 | Index |
| Human Development Index adjusted for inequality | IDHajD | PNUD, 2019 | Index |
| **Dependent variable** | | | |
| Anthropogenic influence – Hemeroby | *M* | The Authors | Index |

Source: Authors

### B. Hemeroby (M)

The calculation of the Hemeroby is based on area statistics that include the evaluation of the levels of transformation and human action impact on the landscape and the geosphere. Although the discussion on the selection, and evaluation of the criteria that lead to the specification of the levels of Hemeroby still continues, one can distinguish six to seven levels of Hemeroby with respect to the degree of naturalness [10]. Table II shows the degrees of Hemeroby according to the degree of naturalness.

TABLE II
HEMEROBY DEGREES, ACCORDING TO DEGREE OF NATURALITY

| **Hemeroby degree** | **Degree of naturalness** | **Human impact** |
|---|---|---|
| Ahemeroby | Natural | None |
| Oligohemeroby | Close to the natural | Limited removal of wood, grazing, immissions through air and water |
| Mesohemeroby | Semi natural | Occasional clearing and ploughing, clear felling, occasional light fertilization |
| β-euhemeroby | Relatively far from natural | Application of fertilizers, lime and pesticides, drainage through ditches |
| α-euhemeroby | Far from being natural | Deep plowing, drainage, pesticide application and intensive fertilization |
| Polyhemeroby | Strange to natural | Unique destruction of the biocenosys and coating of the biotope with external material at the same time |
| Metahemeroby | Artificial | Biocenosys destroyed |

Source: Authors

For the calculation of Hemeroby, the incorporation to the data process is proposed, the area belonging to the different levels of Hemeroby [10]; the Hemeroby index - *M*, is calculated with (1):

$$M = 100 \sum_{h=1}^{m} \left(\frac{f_m}{m}\right) h \qquad (1)$$

***m***: *is the quantification of the different stages of Hemeroby*
***fm***: *is the ratio of the area of the stage m*
***h***: *is the linear value of the Hemeroby - h = 1 (minimum); and, h = n (maximum).*

From this, it follows: Mmax=100 if the entire test area has a maximum Hemeroby, that is, all types of covers, are of the "*metahemeroby*" grade. If there is no human impact, Mmin will be equal to 1 / m. The Natural Degradation Potential (NDP) was related to the Hemeroby, we proceeded to characterize how the human being uses the soil surface (Table III) that identifies the loss of naturalness of the resource "*nature / naturalness*" [49].

TABLE III
DEFINITION AND DESCRIPTION OF THE CLASSES OF HEMEROBY AND THE POTENTIAL FOR NATURAL DEGRADATION (NDP)

| **Hemeroby, intensity (%), NDP[1/]** | **Hemeroby degree** | **Description (typical ecosystems and vegetation, types of human influence)** |
|---|---|---|
| H0<br>0%<br>PDN = 0.0 | ahemeroby | No human influence, for example:<br>- rocky regions, peat bogs and virgin tundra in some parts of the territory |
| H1<br>10%<br>PDN = 0.1 | oligohemeroby | Small to moderate human influence, for example:<br>- only indirect human influence through deposition of emissions into the air<br>- salty grasslands, growing dunes and peat bogs<br>- had little influence on primary forests and their levels of natural succession (i.e. only felling of individual trees, 'Plenterwald', with no introduction of atypical local species) |
| H2<br>20%<br>PDN = 0.2 | oligohemeroby a mesohemeroby | Small to moderate human influence, for example:<br>- extensively managed forests (little timber extraction, trees of different ages on the same site)<br>- extensively drained wetlands<br>- restored bogs<br>- some wet grasses |
| H3<br>30%<br>PDN = 0.3 | mesohemeroby | Moderate human influence, for example:<br>- moorland and heath<br>- managed forests<br>- grasslands and extensive meadows moderately managed and poor in nutrients<br>- shrubs and herbaceous vegetation along pristine lakes and rivers<br>- permanent fallow land, fallow pasture (i.e., infrequent cover and mowing (0.2-0.5 / year)) |
| H4<br>40%<br>PDN = 0.4 | mesohemeroby a β-euhemeroby | Moderate to strong human influence, for example:<br>- intensively managed forests and young secondary forests, forests frequented near recreation areas, forests with a large proportion of non-natural conifers<br>- forests and shrubs in parks, shrubs and hedges in agricultural areas, shrubs and herbaceous vegetation along reconstructed lakes and rivers<br>- extensive orchard meadows<br>- extensive use permanent grasslands (i.e., 0.5-1.0 cuttings / year, no fertilizers, no pesticides) |
| H5<br>50%<br>PDN = 0.5 | β-euhemeroby | Strong human influence, for example:<br>- atypical coniferous forests of the site, younger reforestation<br>- orchard Meadows<br>- natural vegetation of perennials<br>- permanent grasslands (pastures or meadows) managed with medium intensity (i.e. 1.5-3.0 LU / ha (LU = livestock units), not plowed, 1-2 cuttings / year, fertilization according to nutrient removal) |
| H6<br>60%<br>PDN = 0.6 | β-euhemeroby a α-euhemeroby | Strong to very strong human influence, for example:<br>- planting hedges and shrubs (for example, in gardens, along roads, etc.)<br>- ruderal meadows, meadows with diverse species<br>- permanent grasslands (pastures or meadows) managed more intensively (i.e., 1.5-3.0 LU / ha, plow max. 0.2 / year, 2-3 cuttings / year, fertilization slightly exceeds nutrient removal) |
| H7<br>70%<br>PDN = 0.7 | α-euhemeroby | Very strong human influence, for example:<br>- tree nurseries<br>- intensive gardening and cultivation of special crops (i.e., fruits, vid)<br>- annual ruderal vegetation<br>- rotating pastures, arable land, gardens, which are managed according to the principles of extensive integrated or organic agriculture (i.e.,> 3 LU / ha, plowed 0.2-3.0 / year,> 3 cuts / year, fertilization exceeds slightly nutrient removal, pesticide application max 0.3 / year) |
| H8<br>80%<br>PDN = 0.8 | α-euhemeroby a polyhemeroby | Very strong human influence to mainly artificial, for example:<br>- relics of vegetation within urban or industrial areas, gravel vegetation<br>- intensively managed arable land and gardens (i.e., plow> 3 / year, fertilization significantly exceeds nutrient removal, pesticide application ~ 0.3 / year) |
| H9<br>90%<br>PDN = 0.9 | polyhemeroby | Mainly artificial, for example:<br>- landfills<br>- partially urbanized areas (railways, streets, etc.)<br>- surfaces covered with new materials<br>- strong and durable modification of biotopes |
| H10<br>100%<br>PDN = 1 | metahemeroby | Purely artificial, for example:<br>- Completely sealed, constructed, or contaminated surfaces (i.e., no plant habitat) |

1/ Natural Degradation Potential
Source: Authors

The result of this relationship is that a linearity can be established between the values between 0 and 1 of the Hemeroby and the proposed characterization factors [49]. The NDP was calculated using (2):

$$\boldsymbol{NDP}_{\ bioreg\ i} = \boldsymbol{area\ in\ use}_{\ t\ iype,\ bioreg\ i} \times \boldsymbol{NDP}_{type\ i} \qquad (2)$$

***NDP*** $_{bioreg\ i}$ : *Is the identification of the loss of naturalness in the geographical space analyzed i [m$^2$ x year].*

***area in use*** $_{type\ i,\ bioreg\ i}$ *: Area used for type i soil in the geographical space analyzed i [m$^2$ x year].*

***PDN*** $_{type\ i}$ *: Potential natural degradation for soil type i.*

## C. *Type of research and materials*

Research is defined as applied because it aims to contribute to the accumulation of knowledge. Research focuses on developing solutions to the country's environmental problems. The focus of this research is quantitative when collecting data to try to test the hypothesis based on the measurement of numerical values that could establish relationship patterns through statistical analysis [50].

*1) Research level*: It is associated with the descriptive and correlational. Descriptive because the effects generated by human intervention influenced by departmental factors and regional naturalness that exist in the country are described; and, it is correlational, when evaluating and analysing the statistical relationship between the variables [51].

*2) Method*: Deductive, inductive, analytical, and synthetic. It is deductive because it allows generalization from the study of particular cases and allows progress in the knowledge of the actions that are analyzed. It is inductive because the reasoning used flows from particular to general lines. It is analytical because, starting from an absolute whole, the particularities of each part that make up the whole can be known and explained. Finally, it is synthetic because from the statistical analysis it allows to find conclusions to understand the present state [52, 58, 59].

*3) Research Design*: Transversal. It is considered as non-experimental since the present investigation does not manipulate the variables since the present study does not contemplate the manipulation of the variables since the events already happened at the time of data collection. It is cross-sectional because the variables are not modified, only a single measurement is made [53].

*4) Population*: Due to the scope of this research, the population includes: the types of vegetation cover and land use, the water network, the road network, urban and rural areas; conforming, different degrees of naturalness in the diversity of the Peruvian territory. In one way or another, humans intervene in the biophysical environment of the different regions of Peru.

*5) Sample*: Corresponds to the biophysical environments of the twenty-four (24) Departments of Peru, covering the entire territory, the sample corresponds to the entire population, living species and human interventions in the national territory.

*6) Variables*: Due to the characteristics of the research (not experimental), the identification and selection of factors are related to each other and are not associated with probabilities [10]. Table IV shows the operationalization of the variables.

TABLE IV
OPERATIONALIZATION OF THE STUDY VARIABLES

| Variable | Conceptual Definition | Dimension | Operational Definition | Instrument |
|---|---|---|---|---|
| Variable 1: Departmental and Regional Naturality Factors of Human Activity. | Each Department has characteristics of relief, altitude, types of vegetation cover, road network, water network and characteristics related to public and private activities. | Natural | Aspect conditions related to geography and natural spaces in each Department of Peru. | Data matrix |
| | | Human activity | Human interventions as a population group that are carried out in the Peruvian territory considering how they affect the naturalness of a given space. | Data matrix |
| | | Government activity | State interventions that reflect development and that are carried out in the Peruvian territory taking into account the levels of indicators of human development and density of the State. | Data matrix |
| | | Ambiental | Climate and environmental conditions comfortable for human life. | Data matrix |
| Variable 2: Biophysical Environment of the Regions of Peru. | Spaces that can be characterized and statistically evaluated based on their properties, land use skills and socioeconomic characteristics of the population that inhabits them. | Hemeroby (*M*) | Degree of transformation and human impact on the landscape and the geosphere. | Equation (1) |

Source: Authors

## D. Instruments

For the Variable X, "Departmental and Regional Naturality Factors of Human Intervention", the following sources were used:

1. RapidEye™ satellite images processed by the UGPS of MINAGRI financed by IDB.
2. National Agrarian Censuses of 1972, 1994 and 2012 issued by the National Institute of Statistics - INEI.
3. Socioeconomic reports from the National Statistics Institute – INEI.

Equation (1) was used for variable Y, "Biophysical Environment in the Regions of Peru", (1) described was used.

## E. Procedures

*1) Data analysis*: The research aims to establish the degree of correlation between the various indicators of the dimensions corresponding to the variables under study. In figure 1, the relationship between the variables is observed.

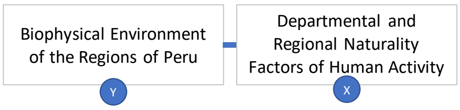


Fig. 1. Data analysis between variables. Source: Authors

Since the research seeks to know the incidence between the variables under study, the linear regression analysis has been calculated. Figure 2 shows the design for data analysis, according to the dimensions of the variables.

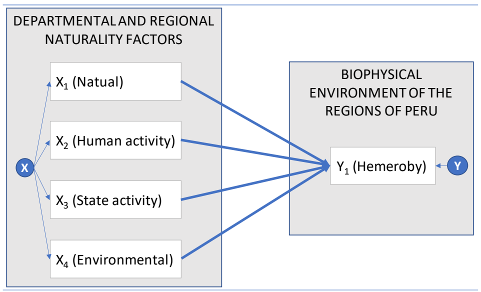


Fig. 2. Design for data analysis, according to dimensions of the variables studied. Source: Authors

In Table V, the relationship between the degrees of Hemeroby described by [10] and the classification and coverage area of the RapidEyeTM satellite image data on the surface of the Peruvian territory is presented.

TABLE V
RELATIONSHIP BETWEEN THE DEGREES OF HEMEROBY AND THE SURFACE CHARACTERISTICS ANALYZED

| **Hemeroby grade** | **Category associated with RapidEye$^{TM}$ satellite imagery data** |
|---|---|
| Oligohemeroby | Artificialed territory |
| Mesohemeroby | Clouds |
| | Other Lands |
| | Cloud Shadow |
| | Wasteland lands |
| β-euhemeroby | Continental Waters |
| | Wetlands |
| | Natural Forest |
| | Natural Pastures |
| | Ravines |
| | Rivers |
| α-euhemeroby | Rural town centers |
| | Agricultural Land with Cultivation |
| | Uncultivated Agricultural Land |
| Polyhemeroby | Departmental route |
| | Railroad track |
| | National road |
| Metahemeroby | Urban area |
| | Unspecified road * |
| | Street |
| | Neighbourhood road |

* Roads, private roads, internal roads, economic activities, among others. Source: Authors

The statistical analyses of Pearson, ANOVA and regression analysis of the data with information from the 24 Departments of Peru are presented.

## III. Results

Table VI shows the calculation of Hemeroby using equation (1) for the 24 Departments of Peru.

TABLE VI
DETERMINATION OF HEMEROBY IN PERU, ACCORDING TO DEPARTMENTS

| **Department** | **Oli** | **Mes** | **b-euh** | **a-euh** | **pol** | **meta** | **Hemeroby** |
|---|---|---|---|---|---|---|---|
| Huancavelica | 0,04 | 14,22 | 32,75 | 6,37 | 0,13 | 0,32 | 53,82 |
| La Libertad | 0,24 | 26,01 | 6,40 | 18,85 | 0,11 | 0,78 | 52,39 |
| Moquegua | 0,08 | 40,11 | 2,42 | 1,05 | 0,08 | 0,33 | 44,07 |
| Pasco | 0,04 | 6,41 | 43,66 | 5,89 | 0,05 | 0,22 | 56,26 |
| Piura | 0,06 | 14,68 | 26,01 | 13,75 | 0,07 | 0,71 | 55,27 |
| San Martín | 0,07 | 5,52 | 39,23 | 12,78 | 0,03 | 0,31 | 57,93 |
| Ucayali | 0,02 | 1,74 | 52,20 | 3,15 | 0,01 | 0,08 | 57,20 |
| Ancash | 0,09 | 26,98 | 16,01 | 5,87 | 0,09 | 0,40 | 49,44 |
| Arequipa | 0,16 | 32,13 | 12,20 | 1,87 | 0,05 | 0,43 | 46,84 |
| Cajamarca | 0,08 | 25,56 | 7,82 | 18,55 | 0,07 | 0,34 | 52,41 |
| Ica | 0,24 | 38,87 | 0,36 | 5,16 | 0,06 | 0,55 | 45,24 |
| Madre de Dios | 0,02 | 0,32 | 55,64 | 1,26 | 0,01 | 0,04 | 57,29 |
| Puno | 0,07 | 3,97 | 44,58 | 8,66 | 0,05 | 0,34 | 57,64 |
| Cuzco | 0,01 | 7,07 | 45,58 | 2,40 | 0,06 | 0,28 | 55,40 |
| Junín | 0,03 | 7,15 | 42,62 | 5,81 | 0,05 | 0,44 | 56,10 |
| Lambayeque | 0,02 | 8,00 | 34,91 | 13,63 | 0,07 | 1,01 | 57,65 |
| Lima | 0,08 | 28,19 | 13,16 | 5,14 | 0,09 | 3,61 | 50,27 |
| Tacna | 0,07 | 34,08 | 8,94 | 2,61 | 0,07 | 0,86 | 46,63 |
| Tumbes | 0,49 | 2,33 | 49,05 | 4,37 | 0,09 | 0,79 | 57,12 |
| Amazonas | 0,00 | 7,87 | 41,21 | 6,64 | 0,04 | 0,17 | 55,93 |
| Apurímac | 0,01 | 14,99 | 28,91 | 10,01 | 0,10 | 0,27 | 54,29 |
| Ayacucho | 0,00 | 16,80 | 27,20 | 9,17 | 0,08 | 0,26 | 53,51 |
| Huánuco | 0,00 | 8,88 | 35,97 | 11,47 | 0,05 | 0,21 | 56,58 |
| Loreto | 0,00 | 23,25 | 25,92 | 0,25 | 0,00 | 0,04 | 49,46 |

Source: Authors

The four (4) Departments with the highest Hemeroby in Peru are San Martín (57.93), Lambayeque (57.65), Puno (57.64) and Madre de Dios (57.29). On the contrary, the four (4) with the lowest Hemeroby are Moquegua (44.07), Ica (45.24), Tacna (46.63) and Arequipa (46.84). The other 16 Departments are between the range of 49.44 (Ancash) and 57.20 (Ucayali). The mean of Hemeroby in Peru is 53.28 with a calculated error deviation of 0.878; in turn, for a 99% confidence interval for the mean, we have that, in the lower limit, Hemeroby has been calculated at 50,815; and, for the upper limit, at 55,745. Also. the interquartile range for Hemeroby in Peru is 7.32 with an asymmetry of -0.854. In Table VII, shows the descriptions for the anthropometric influence in Peru.

TABLE VII
DESCRIPTIVES FOR ANTHROPOMETRIC INFLUENCE - HEMEROBY - *M*

| | | | **Statistical** | **Dev. Error** |
|---|---|---|---|---|
| Hemeroby (*M*) | Mean | | 53,2801 | 0,87810 |
| | 99% onfidence interval for the mean | Lower limit | 50,8150 | |
| | | Upper limit | 55,7453 | |
| | Average trimmed to 5% | | 53,5253 | |
| | Median | | 54,7777 | |
| | Variance | | 18,505 | |
| | Dev. Deviation | | 4,30178 | |
| | Minimum | | 44,07 | |
| | Maximum | | 57,93 | |
| | Rank | | 13,86 | |
| | Interquartile range | | 7,32 | |
| | Asymmetry | | -0,854 | 0,472 |
| | Kurtosis | | -0,496 | 0,918 |

Source: Authors

Figure 3 shows the frequency of the dependent variable: Anthropic Influence - Hemeroby (M) in Peru.

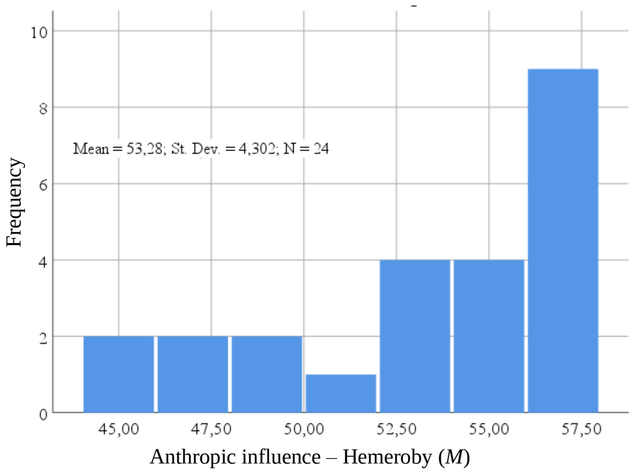


Fig. 3. Frequency of the dependent variable: Anthropic Influence - Hemeroby (*M*). Source: Authors

Figure 4 shows the graph of stems and leaves of the dependent variable Anthropic Influence - Hemeroby (*M*); also. Figure 5 shows the map with the calculation of the area for each degree of Hemeroby in Peru expressed in millions of hectares. Figure 6 shows the 6 thematic grid surface maps for each grade of Hemeroby in Peru.

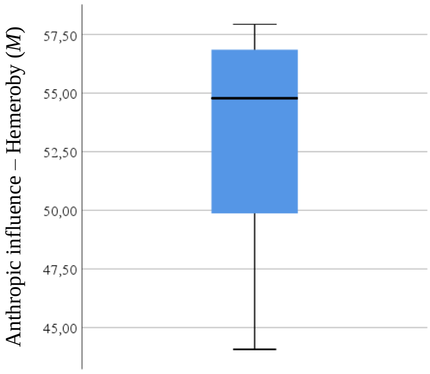


Fig. 4. Stems and leaves graph for the variable Anthropic Influence - Hemeroby (*M*). Source: Authors

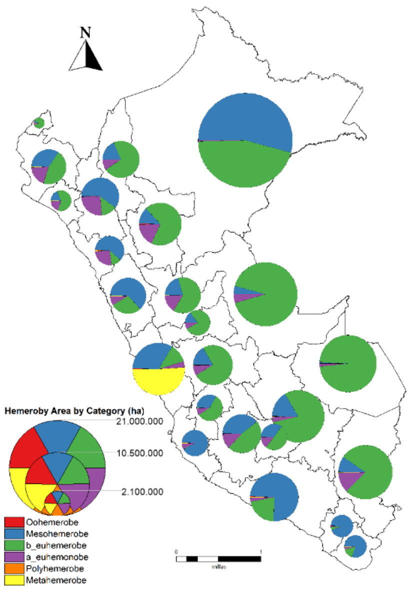


Fig. 5. Map with the calculation of area for each degree of Hemeroby in Peru expressed in millions of hectares. Source: Authors

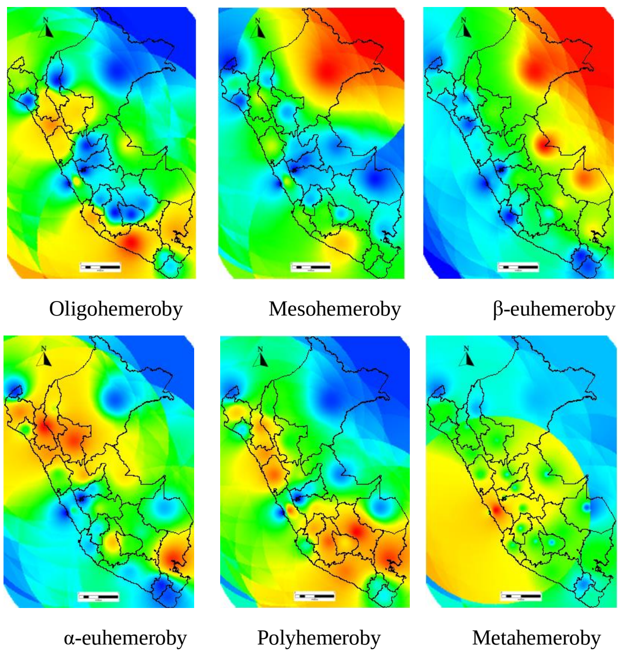


Fig. 6. Grid surface thematic maps for each grade of Hemeroby in Peru. Source: Authors

The reduction of the ANOVA prediction error is almost 76% (R squared) with respect to the 16 predictors. Table VIII shows the summary of the proposed model.

TABLE VIII
SUMMARY OF THE MODEL FOR HEMEROBY IN PERU

| Model | R | R square | R square adjusted | Standard error of the estimate |
|---|---|---|---|---|
| 1 | ,871[a] | 0,759 | -0,383 | 5,05909 |

a. Predictors: (Constant), DAP, AU, AAscAD, RIO1000, PETC, AUHab, IDHajD, VAAcc, ViVe, RSG, IDE, UADI, APNAD, PROT, ALTcd, VAAT, AATAD, PITC, IDH
b. Dependent variable: Hemeroby – *M*

Table IX shows the ANOVA of the proposed model.

TABLE IX
ANOVA FOR THE PREDICTIVE VARIABLES

| Model | | Sum of squares | Gl | Quadratic mean | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 323,245 | 19 | 17,013 | 0,665 | ,759[b] |
| | Residue | 102,378 | 4 | 25,594 | | |
| | Total | 425,623 | 23 | | | |

a. Dependent variable: Hemeroby - *M*
b. Predictors: (Constant), DAP, AU, AAscAD, RIO1000, PETC, AUHab, IDHajD, VAAcc, ViVe, RSG, IDE, UADI, APNAD, PROT, ALTcd, VAAT, AATAD, PITC, IDH
Source: Authors

Due to the ANOVA, applied to the regression, it is reported whether the relationship between the variables is significant or not. As the value of F, is significant ($F = 0.665$; $p < 0.05$) showing that there is a relationship between the departmental factors and naturalness of human intervention and Hemeroby in Peru. Furthermore, the regression coefficients are significantly different from zero (see t-test values) in Table X.

TABLE X
REGRESSION COEFFICIENTS OF THE INDEPENDENT VARIABLES WITH RESPECT TO HEMEROBY IN PERU

| Variable | Non-standardized coefficients | | Standardized coefficients | t | Sig. |
|---|---|---|---|---|---|
| | B | Dev. Error | Beta | | |
| (Constant) | 76,195 | 82,328 | | 0,926 | 0,407 |
| APNAD | 26,176 | 33,224 | 1,088 | 0,788 | 0,475 |
| AATAD | 123,448 | 123,049 | 2,145 | 1,003 | 0,373 |
| VAAcc | 0,000 | 0,000 | -0,945 | -0,705 | 0,519 |
| VAAT | 7,292E-05 | 0,000 | 0,436 | 0,306 | 0,775 |
| IDE | -69,297 | 159,504 | -0,858 | -0,434 | 0,686 |
| IDH | 39,259 | 131,490 | 0,839 | 0,299 | 0,780 |
| IDHajD | 7,485 | 74,677 | 0,061 | 0,100 | 0,925 |
| UADI | -0,022 | 0,036 | -0,438 | -0,622 | 0,568 |
| RSG | 0,023 | 0,037 | 0,419 | 0,627 | 0,565 |
| RIO1000 | -0,007 | 0,006 | -0,417 | -1,154 | 0,313 |
| PROT | 4,195 | 56,865 | 0,118 | 0,074 | 0,945 |
| AU | 6,864E-05 | 0,000 | 0,385 | 0,523 | 0,628 |
| AAscAD | -162,496 | 187,933 | -1,810 | -0,865 | 0,436 |
| AUHab | -1,542E-05 | 0,000 | -0,234 | -0,380 | 0,723 |
| PETC | 0,183 | 0,610 | 0,540 | 0,300 | 0,779 |
| PITC | -0,122 | 0,242 | -1,186 | -0,502 | 0,642 |
| ViVe | 1,630E-05 | 0,001 | 0,009 | 0,014 | 0,990 |
| ALTcd | 0,004 | 0,005 | 1,273 | 0,709 | 0,518 |
| DAP | 1,017 | 1,248 | 1,561 | 0,815 | 0,461 |

a. Dependent variable: Hemeroby – *M*.
Source: Authors

Figure 7, the histogram of the dependent variable: Anthropic Influence - Hemeroby (M) in Peru was calculated.

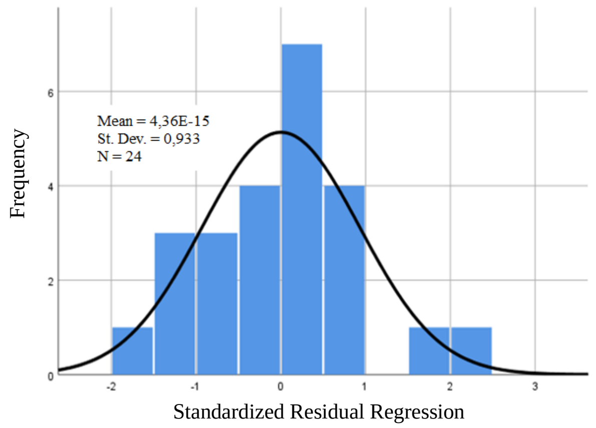


Fig. 7. Histogram of the dependent variable: Anthropometric influence - Hemeroby. Source: Authors

In figure 8, the regression of the values of the variables of the "Departmental Factors and Regional Naturalness of Human Intervention" with respect to the dimension "Anthropic Influence - Hemeroby" in the biophysical environment of the Regions of Peru was calculated.

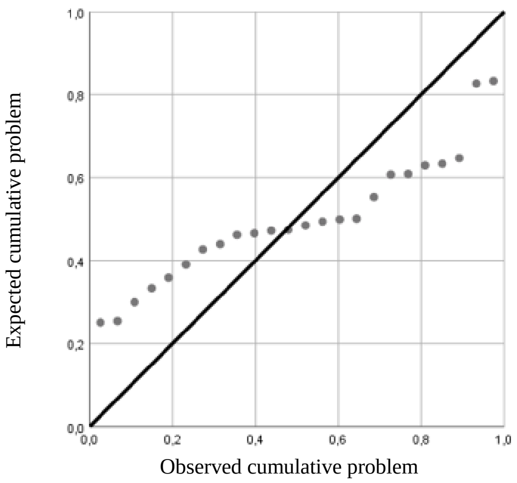


Fig. 8. Regression normal for the Human Development Index with respect to its predictors. Source: Authors

In figure 9, the dispersion of the dependent variable: Anthropometric influence – Hemeroby was calculated.

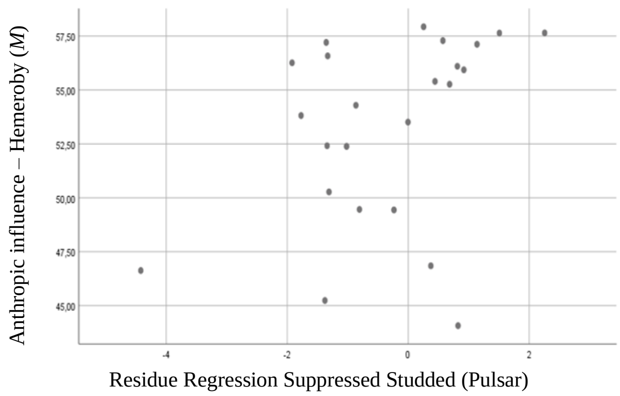


Fig. 9. Dispersion of Hemeroby in Peru. Source: Authors

The bilateral correlations related to the independent variables "Departmental Factors and Regional Naturality of Human Intervention" have been calculated with: (i) the Hemeroby, (ii) the Altitude of the capital of the Department; and, (iii) the Differential of the Psychometric Fan (Table XI).

TABLE XI
PEARSON BILATERAL CORRELATION BETWEEN PREDICTORS AND LHEMEROBY, DEPATAMENT CAPITAL ALTITUDE AND PSYCHOMETRIC FAN DIFFERENTIAL

| Variable | $M^{1/}$ | ALTcd$^{2/}$ | DAP$^{3/}$ |
|---|---|---|---|
| APNAD | -0,031 | ,818** | -,838** |
| AATAD | 0,324 | 0,034 | -0,155 |
| VAAcc | ,428* | -0,092 | 0,192 |
| VAAT | 653** | 0,058 | 0,173 |
| M | 1,000 | 0,020 | 0,138 |
| M2012 | 0,091 | -0,311 | 0,182 |
| IA | -0,037 | 0,122 | -0,125 |
| IDE | -,504* | -0,259 | -0,013 |
| IDH | -0,318 | -,526** | 0,346 |
| IDHajD | -0,217 | -0,342 | 0,250 |
| EHDP | 0,253 | 0,202 | 0,040 |
| UADI | 0,131 | 0,147 | -0,236 |
| RSG | -0,308 | -0,296 | 0,321 |
| RIO1000 | -0,033 | 0,187 | 0,018 |
| PROT | 0,356 | -0,160 | 0,340 |
| AU | -0,142 | -0,048 | -0,173 |
| AAscAD | 0,045 | -0,022 | -0,077 |
| AUHab | 0,117 | 0,046 | 0,061 |
| PETC | -,597** | 0,111 | -0,310 |
| PITC | -,653** | -0,058 | -0,173 |
| ViVe | 0,136 | -0,398 | 0,363 |
| ALTcd | 0,020 | 1,000 | -,877** |
| DAP | 0,138 | -,877** | 1,000 |

1/ Hemeroby
2/ Department Capital Altitude
3/ Psychometric Fan Differential
**. The correlation is significant at the 0.01 level (bilateral).
*. The correlation is significant at the 0.05 level (bilateral).
Source: Authors

The data obtained confirm the hypotheses raised in this research, which indicates the Hemeroby of the Departments of Peru, the variable "roads / total agricultural area" (CC = .653, p < .001) does increase the probability of increasing Hemeroby in Peru (Table XI). In turn, the variable "internal charge potential" has a positive significance with Hemeroby (CC = .653, p <.001).

Table XI also, shows a strong positive correlation between the variable "Natural pasture area / departmental area" and the variable " Altitude of the capital of the Department" (CC = .818, p <.001); and, with the variable "Differential of the psychometric fan" (CC = .838, p <.001). We also found a positive correlation between the variable "Altitude of the capital of the Department" and the variable "Differential of the psychometric range" (CC = .877, p <.001).

## IV. Discussion

On the one hand, this research has been able to generate a tool to make visible the different forms of transformation of the Peruvian territory because of the variety of human activities [4-5]. To achieve this, the Hemeroby degree has been determined as an integrating measure of the impacts generated by all human activities [11], thus finding the naturalness index in Peruvian ecosystems [12-15]. It is in this way that it has been possible to analyze natural and anthropogenically influenced environments on a large scale through the use of variables that are related to human activities [19-21]. This is extremely important in terms of understanding the contradictions that arise between the aspects of ecosystem protection and economic development in Peru, since it covers both the productive human action of the country and its territory.

On the other hand, this research serves as a platform to identify critical points of increasing anthropogenic influence in rapidly developing regions in Peru [22-24]. In the same way, the identification of the Hemeroby provides a tool associated with the adaptive response capacity to the modification of the landscape [25, 28-30] applicable in the practice of conservation and monitoring of ecosystems [31-35]. Likewise, it contributes to the establishment of a complete "interference index" based on remote sensing data and data on socioeconomic aspects [40-44], being able to monitor large areas of the Peruvian territory [45-48]. With the aforementioned, territorial planning capacity of the identification of the Hemeroby in Peru is highlighted, which entails a benefit closely related to ecological sustainability.

## V. Conclusion

The influence of disturbances from human activity on the biophysical environment has been determined by calculating the distribution of Hemeroby in Peru. With this, it has been possible to identify the main characteristics of the landscape pattern and how human disturbance has influenced the change in landscape patterns in Peru. Likewise, it has been possible to establish a Hemeroby ranking for the Departments of Peru. This shows that the four departments with the highest Hemeroby in Peru are: San Martín (57.93), Lambayeque (57.65), Puno (57.64) and Madre de Dios (57.29). At the other extreme, the four departments with the lowest Hemeroby are: Moquegua (44.07), Ica (45.24), Tacna (46.63) and Arequipa (46.84). In addition, it has been calculated that the other 16 Departments are between the range of 49.44 (Ancash) and 57.20 (Ucayali).

The Hemeroby mean in Peru is 53.28 with a deviation of the calculated error of 0.878; in turn, for a confidence interval of 99% for the mean, we have that, in the lower limit, Hemeroby has been calculated at 50.815; and, for the upper limit, at 55,745. Also, the Hemeroby interquartile range in Peru is 7.32 with a skewness of -0.854.

The variable "roads/total agricultural area" (CC = .653, p <.001) does increase the probability of an increase in Hemeroby in Peru. In turn, the variable "internal load potential" is also correlated with Hemeroby (CC = .653, p <.001).

There is a strong positive correlation between the variable "Area of natural pastures / departmental area" and the variable "Altitude of the capital of the Department" (CC = .818, p <.001) and with the variable "Differential of the psychometric range" (CC = .838, p < .001). In the same way, a positive correlation was found between the variable "Altitude of the capital of the Department" and the variable "Differential of the psychometric range" (CC = .877, p <.001).

Finally, the importance of the identification of the Hemeroby is pointed out since it helps to point out the inconsistencies between the protection of the ecosystems of the Peruvian territory and the economic development of the country. The methodology presented in this research work allows detecting anthropic disturbances, as well as landscape characteristics and their variation patterns. This is how it is useful for territorial planning, ecological sustainability. Also, it is useful for understanding fragmentation structures and methodological refinements.

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