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Ecosystem Degradation Due to Change in Vegetation Cover and Land Productivity in the Upper Huaura River Basin Lima - Peru

[1]María Herlinda Veliz Garagatti, [2]William Augusto Llactayo León, [3]Doris Esenarro Vargas, [4]Mabel Eliana Nolasco Chuco, [5]Pedro Raúl Tinoco Rodríguez

[1,2,3,4,5] *National University Federico Villarreal UNFV -EUPG Lima, Perú.*
E-mail: mveliz@unfv.edu.pe, wllactayo@unfv.edu.pe, desenarro@unfv.edu.pe, mnolascoch@gmail.com, tinoco.r@gmail.com.

Abstract

This research aims to identify degraded areas due to changes in vegetation cover and land productivity in high Andean terrestrial ecosystems in a prioritized area of the upper watershed of the Huaura River, Department of Lima, which allows its categorization as a starting point to seek the appropriate recovery of these ecosystems, For this purpose, satellite information was used to recognize degraded areas in high Andean terrestrial ecosystems, which are reliable and applicable to our national territory. To identify degraded areas, pixels with a negative trend in the time series with a confidence value of 95% and a P-value lower than 0 were considered. 05, as results were 7 the ecosystems analyzed and a degradation was generated until the moment of 8,916.7 has that corresponds to the 5.01% of the area occupied by these spaces of life; in addition the studied degradation corresponded to the 3.19% of the territory of the high basin of river Huaura.

Keywords: degraded areas, vegetation cover, productivity, ecosystems,Land

1 Introduction

There are 53 basins in the Western Slope of the national territory [1], many of which have been altered by natural effects and more frequently by anthropic actions such as : mining, unsustainable agricultural practices,

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overgrazing, pollution from industrial and non-industrial sources, as well as landscape modification; the upper basin of the Huaura River begins in the central zone of the Andes Mountains at more than 5,000 meters above sea level, and runs westward to flow into the Pacific Ocean, covering an area of 4,770 km [2], but its territory is formed by different ecosystems that determine different characteristics in their ecological structure, in which if alterations are found, the conditions of analysis must be differentiated[3]. Considering the similar characteristics of the Upper Huaura River Basin, with the 53 that exist in the Western Slope of the national territory, it is of interest to know the feasibility of making a study of the degradation in the different ecosystems that this basin presents, through the use of satellite images and the analysis of biophysical indicators that these provide when they are processed by analysis platforms such as Google Earth Engine (GEE). The identification and characterization of degraded areas in the upper Huara River basin is a strategic step to seek a solution to the degradation processes and to adequately manage these spaces with actions that allow the recovery of ecosystem services, reduce or stop the decrease in species diversity, improve the nutritional value of crops, reduce or stop soil erosion and reduce the incidence of natural hazards (landslides and mudslides) that ultimately impact the quality of life of the population and their livelihoods [4].

Peru has degraded natural areas that are located throughout the country, according to MINAM degraded areas nationwide reach 14% of the territory and include coastal ecosystems, Andean and Amazon, these areas are characterized by having suffered total or partial loss of their essential factors such as soil, vegetation or water [5,6]. Given that the identification of degradation in ecosystems is complex, international organizations such as the United Nations Convention to Combat Desertification (UNCCD) recommend using key indicators such as the change in vegetation cover, changes in land productivity (measured as a reduction in the net primary productivity of ecosystems) and changes in soil carbon stocks, in this case, the degradation resulting from the measurement of the first two is specifically obtained in the upper basin of the Huaura River, Department of Lima[7,8].. The generation of these indicators is only possible using a time series of biophysical data that is extracted from satellite images, so it is necessary and technologically feasible to use images with a high time series, in this case 31 years, to analyze changes in land use and loss of productivity, which allows to establish with greater specificity the degradation conditions of the different ecosystems of the upper Huaura River Basin, in order to support the recovery of affected ecosystems. [9,10].

The NDT conceptual framework has been designed to be applicable to all land uses - i.e. land managed for production (such as agriculture or forestry), for conservation (such as protected areas) and land occupied by human settlements and infrastructure - and to all types of land degradation, in a wide variety of circumstances in each country, so that it can be implemented in a harmonized way by all countries that choose to achieve the NDT[11,12].

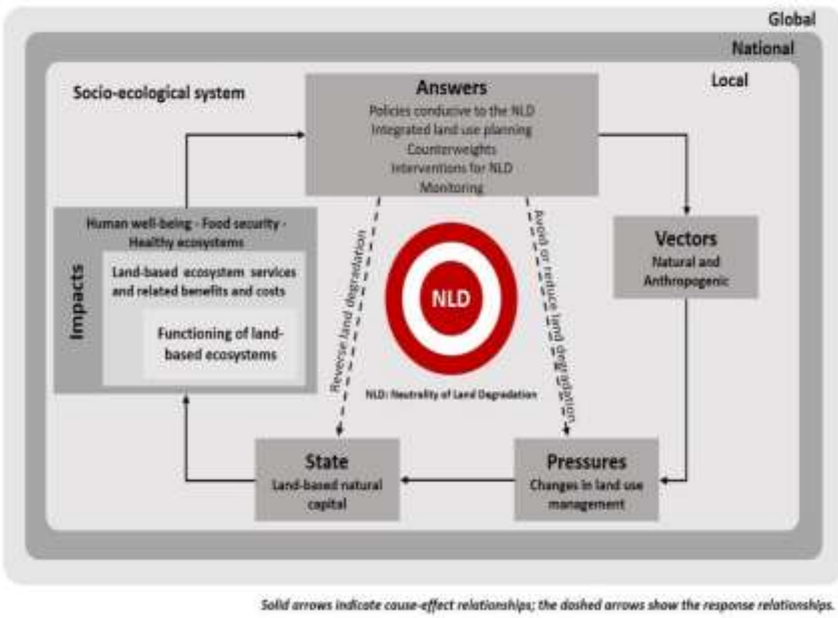

Figure 1 Conceptualizing the NDT According to the Cause-Effect Model along a Socioeconomic System

The causal framework depicted in Figure 1 relies on natural and biophysical human-influenced processes that cause and impact the provision of ecosystem services emanating from land-based natural capital that contribute to human well-being [13]. Figure 2 presents these complex interrelationships within a structure that seeks to simplify complexity while emphasizing a wide variety of relevant linkages and processes modified from [14].

2 Method

Universe: Upper basin of the Huaura River, Sample: The entire upper basin of the Huaura River : AD = (Δ PPN) U (ΔCUS).

The time series analysis of the Primary Vegetation Productivity (PPN) trend was executed using the Normalized Difference Vegetation Index (NDVI), as an approximation to the PPN. This implies the processing of LANDSAT satellite images for a period of 31 years depending on availability. Annual mosaics were built, choosing the best pixels found by using the average of the data per year.

For the study area, the following indicators were analyzed, following the analysis model presented: a) Dynamic of change in vegetation cover and b) Dynamic of change in net primary productivity of vegetation (NPP). From this, information from satellite images is collected and analyzed through the use of the GEE (Google Earth Engine) and Terra I platform respectively. [5,6,15].

Mann-Kendall's non-parametric statistical test has been used to evaluate and detect time series trends. The purpose of the Mann-Kendall test [14,15,16]. is to statistically evaluate whether there is a monotonic upward (positive) or downward (negative) trend of the variable of interest over time. A monotonic upward (or downward) trend means that the variable increases (or decreases) steadily over time, but the trend may or may not be linear. For the identification of degraded areas, we have considered those pixels that have a negative trend, in the time series, with a confidence value of 95% and a P-value less than 0.05.

Likewise, changes in land cover and use (CUS) were evaluated using information from MODIS image analysis (MDVI) and TRMM (Precipitation) that detects changes in vegetation cover due to anthropic interventions, which is provided by Terra-i. The system is based on the premise that, from one date to the next, natural vegetation follows a predictable pattern of changes in its greenery. This is done by using a computerized neural network that is "trained" to understand the normal pattern of changes in vegetation greenery in relation to the terrain and rainfall of a site and then mark areas of change where the greenery suddenly changes by normal limits[7,8]

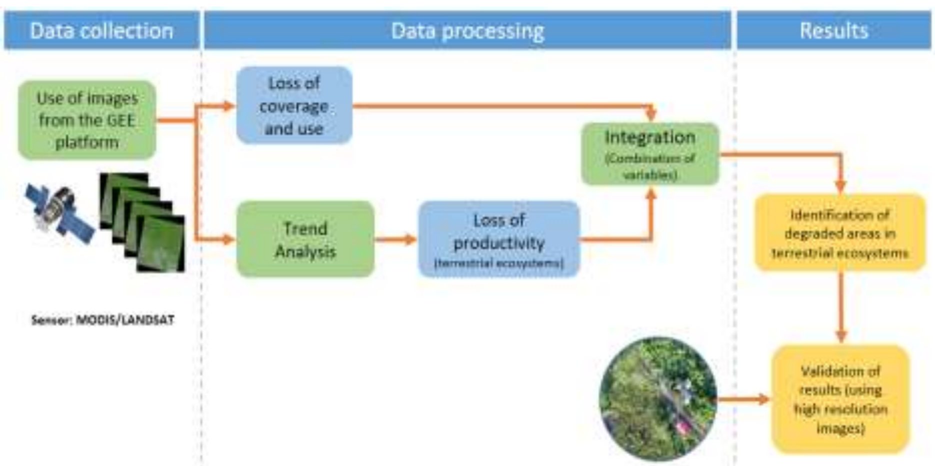

Figure 2 Outline of the Data Collection and Analysis Instrument

Figure 2 shows the outline of the data collection and analysis instrument for the determination of degraded areas in the research area. Figure 3 shows Reduced Productivity of the Wetland Ecosystem.

Figure 3 Reduced Productivity of the Wetland Ecosystem

3 Results

Evaluation of the thematic accuracy of the results obtained through the use of high-resolution images.

Mann-Kendall's non-parametric statistical test was used to evaluate and detect time series trends. The purpose of this test is to statistically evaluate whether there is a monotonic upward (positive) or downward (negative) trend of the variable of interest over time. A monotonic upward (or downward) trend means that the variable increases (or decreases) steadily over time, but the trend may or may not be linear. [9].

Table 1 Statistical Test Results

Mann-Kendall confidence leve	Total number of elements	No. of elements that passed the test	% of elements that passed the test
95%	3102391	272675	8.8

The confidence of the Man Kendall test is defined at 95%, which was analyzed for each element (pixel) of the entire universe of the study area (3102391 pixels). As a result of the statistical test, 8.8% of the elements

(272675 pixels) have time series, with negative trends, that passed the test with the established confidence level [17].

For the identification of degraded areas, those pixels that have a negative trend, in the time series, with a confidence level of 95% and a P-value lower than 0.05 have been considered. Table 1 provides Statistical Test Results.

3.1 Evaluation of Thematic Accuracy

For the validation of the thematic accuracy, it was done with an esterified random sampling design, considering the degraded and non-degraded classes as the strata. The number of sampling points was calculated based on the formula of [10,18].

$$n = \frac{Z^2 pqN}{e^2(N-1) + Z^2 pq}$$

Where:

Z: 1.96 according to the 95% confidence level

p: percentage of the population that has the desired attribute: 70

q: percentage of the population that does not have the desired attribute: 30

N: size of the universe: 279 215 pixels

e: maximum accepted estimation error: 10%

n: sample size: 80

With the formula, 80 points were determined for the study area. These points were evaluated in cabinet by means of the multi-temporal interpretation of high-resolution images from the Google Earth Pro web platform and the Sentinel 2 satellite. The results of this evaluation were taken to the analysis in a confusion matrix, to obtain the global precision data and the Kappa index. Table 2 provides Confusion Matrix.

Table 2 Confusion Matrix

	REFERENCE RESULTS (validation)					
Identification Map	**Class**	**Degraded**	**No degraded**	**Total**	**User accuracy**	**Commission error**
	Degraded	31	9	40	0.5	0.5
	Not degraded	9	31	40	0.5	0.5
	Total	40	40	80		
	Accuracy Producer	0.5	0.5			
	Error Omission	0.5	0.5			

After this calculation it can be said that the map of degraded areas has an overall accuracy of 78%, i.e. the proportion of "degraded areas" and "non-degraded areas" are correctly classified at 78%.

The kappa index presents a value of 0.55, which indicates that the information has a moderate degree of agreement with respect to the evaluation in cabinet. Table 3 provides Concordance Levels According to the Kappa Index.

Table 3 Concordance Levels According to the Kappa Index

Kappa	Degree of agreement
< 0,00	without agreement
>0,00 - 0,20	insignificant
0,21 - 0,40	discreet
>0,41 - 0,60	moderated
0,61 - 0,80	substantial
0,81 - 1,00	Almost perfect

3.2 Categorization of Degraded Areas

Table 4 Categorization of Degraded Areas

Code	Ecosystem Approach	Origin Criteria	Intensity Criterion	Symbol	Surface Area (Ha)
1	natural ecosystems	direct	Low density	I-b	1328.04
2			medium intensity	I-m	242.55
3			high intensity	I-a	55.89
4			critical intensity	I-c	16.11
5		indirect	low intensity	D-b	2764.98
6			medium intensity	D-m	498.06
7			high intensity	D-a	112.77
8			critical intensity	D-c	25.02
9	intervened ecosystems		intervention areas	Ad-ZI	991.98
	Total degraded areas categorized				6035.4
	Total uncategorized areas				2870.13
	Total degraded areas				8905.53

Considering the ecosystems (ecosystem criterion) the degraded areas have been categorized according to whether they are under the influence of anthropogenic factors (direct factors) or natural factors (indirect factors). Among the direct factors we used the human footprint index, extractive activities, the index of roads (open street map), mining concessions, etc.; among the information that defines natural aspects we considered the slope, water occurrence, temperature variation, mass removal movements. Table 4 shows the results of this categorization. [19].

Identify areas degraded due to changes in vegetation cover and land productivity in high Andean terrestrial ecosystems show table 4, The high Andean ecosystems found in the upper basin of the Huaura River are:

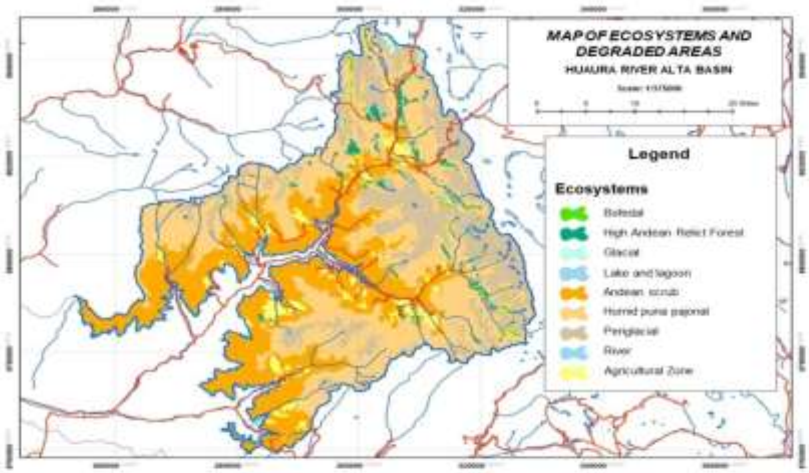

Figure 4 Map of Ecosystems present in the Upper Huaura River Basin

Figure 4 shows the Upper Huaura River Basin with the ecosystems, which present different colors for their identification, they are: the Bofedal of light green color, the High Andean Relict Forest, of dark green color; the Andean Matorral of light brown color, the Puna Húmeda Grass, of light orange color; the Periglacial identified by the light brown color; the Glacial ecosystem with the light blue color. The Agricultural area has been considered a space of the basin because it is millenary, developed by the ancient inhabitants of that area and is identified with the color yellow. The red lines are the transportation routes, the blue lines are the rivers and the lentic water mirrors such as the dark blue lakes and lagoons can also be seen [20].

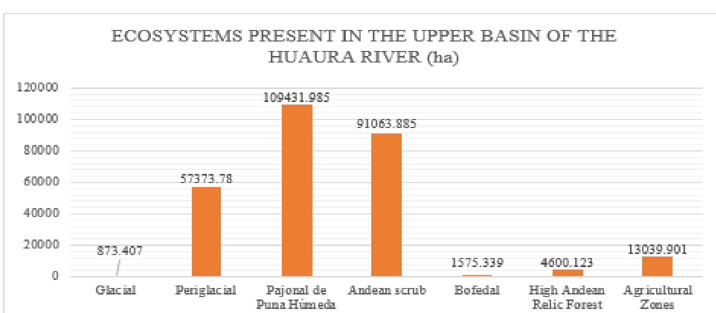

Figure 5 Total areas by Ecosystem of the Upper Watershed of tio Huaura (Ha)

Figure 5 shows the total number of hectares present for each ecosystem, noting that the most dominant are the Puna grasslands with 109431.985 hectares, followed by the Andean shrublands with 91063.885 hectares and the next most dominant is the Periglacial with 57373.78 hectares. The other ecosystems have less than 15,000 hectares each.

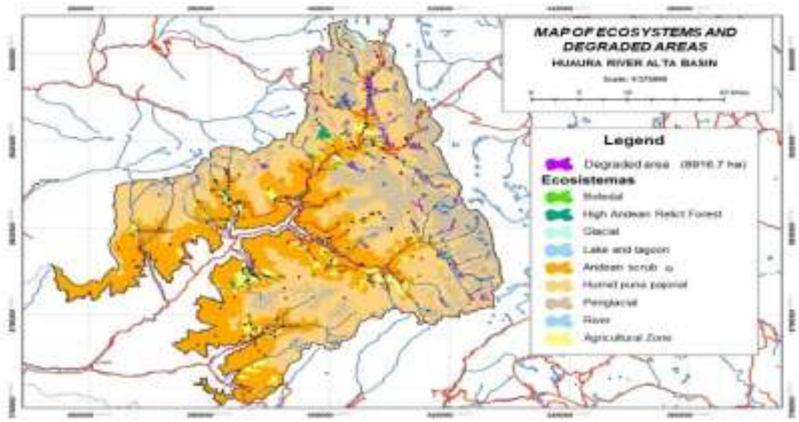

Figure 6 Location Map of the Ecosystems of the Upper Huaura River Basin, Incorporating the Area Degraded By Changes in Vegetation Cover and Land Productivity.

Figure 6 shows the areas degraded by changes in vegetation cover and land productivity, these are represented by the color purple and indicates that 8,916.7 hectares have been degraded, which is 5.01% of the total hectares of the sum of the ecosystems and 3.19% of the territory of the Upper Huaura River Basin. [18]

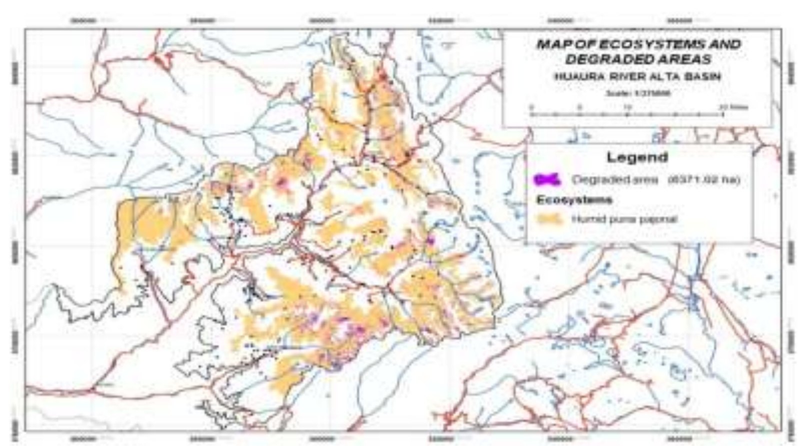

Figure 7 Location map of the Puna Húmeda Puna Ecosystem in the Upper Basin of the Huaura River, incorporating the area degraded by Changes in Vegetation Cover and Land Productivity.

Figure 7 shows the ecosystem present in a dispersed form, especially at the edges of the basin. There are 51 human populations, which are represented with black dots; the degraded areas that affect this ecosystem are also shown, those identified by the color purple and are found in a dispersed manner in this ecosystem and correspond to 6371.02 has, as shown in figure 10.

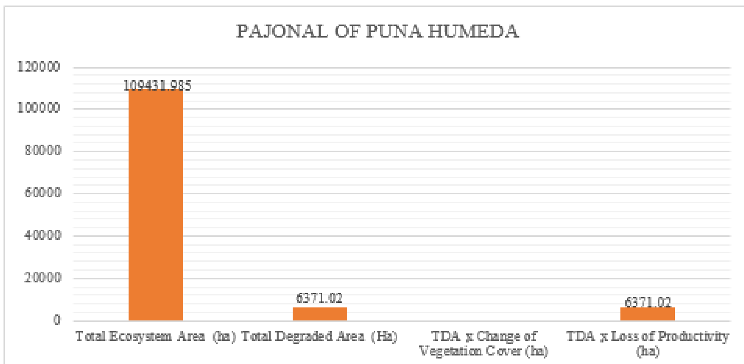

Figure 8 Total Area of the Puna Grassland Ecosystem and the Total Number of Hectares of Degraded Areas

Figure 8 shows the total number of hectares of the Puna grassland ecosystem with 109431.985 hectares and the degraded space adds up to 6371.02 hectares, which corresponds to the degradation by land productivity that is equivalent to 5. 8% of the total space of the Puna grassland ecosystem in the study area [21].

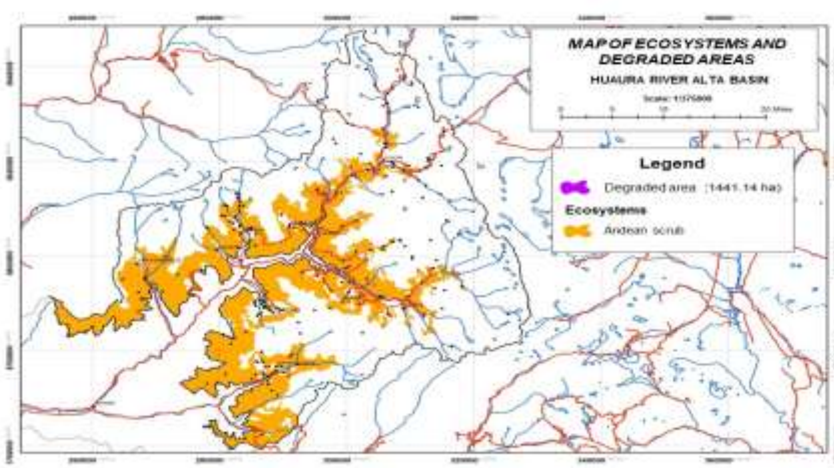

Figure 9 Location Map of the Andean Scrubland Ecosystem in the Upper Huaura River Basin, Incorporating the Area Degraded By Vegetation Cover Change and Primary Land Productivity.

Figure 9 shows this ecosystem in the central part of the Basin and very close to the roads that can be seen on the map in red lines. It presents a degraded space that can be seen as purple spots that add up to 1441.14 ha. It presents 77 human populated areas in its territory, which are expressed in black points present in the map [22].

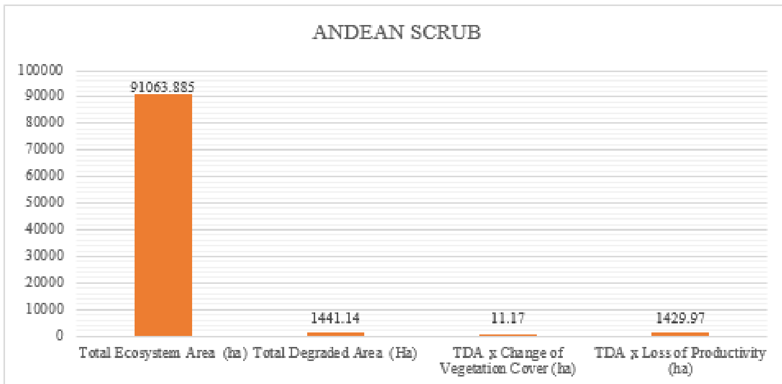

Figure 10 Total Area of the Andean Scrub Ecosystem and Total Has of Degraded Areas.

Figure 10 shows the total of 91063,885 has. of the Andean Scrubland ecosystem present in the studied basin; it also indicates the total area degraded by land use change which is 11.17 has. and 1429.97 has. of area degraded by loss of Primary Productivity, both summed up to present a total of 1441.14 which corresponds to 1.8% of the Andean Scrubland ecosystem. [22,23].

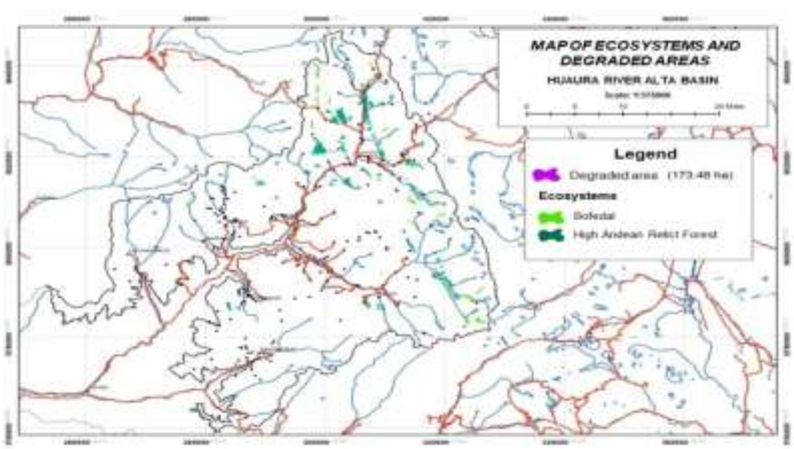

Figure 11 Location of the Bofedal ecosystem and High Andean Relict Forest in the Upper Huaura River Basin, Incorporating the Area Degraded by Change in Vegetation cover and Primary Land Productivity.

Figure 11 shows the Bofedal, an ecosystem that is quite related to the High Andean Relict Forest. This ecosystem is identified with a light green color and is distributed in a vertical strip that crosses the Upper Huaura River Basin from north to south. It presents degraded spaces in the form of purple spots incorporated over the Bofedal area and corresponds to 92.49 has. In this ecosystem there are 2 villages. The figure for the degraded area in the legend in Figure 13 corresponds to the sum of the area degraded by the Bofedal and the High Andean Relict Forest ecosystems. [24].

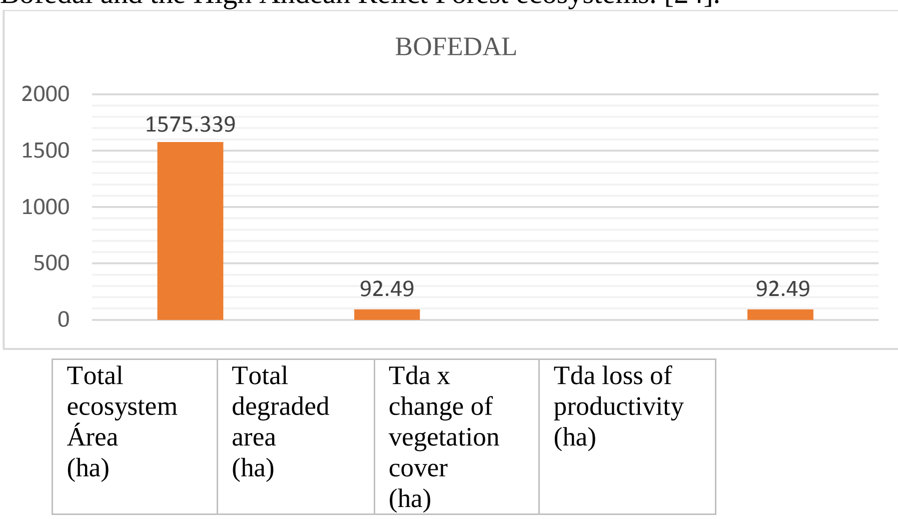

Figure 12 Total Area of the Bofedal Ecosystem and Has of Degraded Areas.

Figure 12 shows the total area of the Bofedal ecosystem present in the studied basin;[25-27] it also shows the total degraded area, which in this case belongs to degraded areas due to the loss of Primary Productivity, with 92.49 hectares, which corresponds to 5.9% of the Bofedal ecosystem.

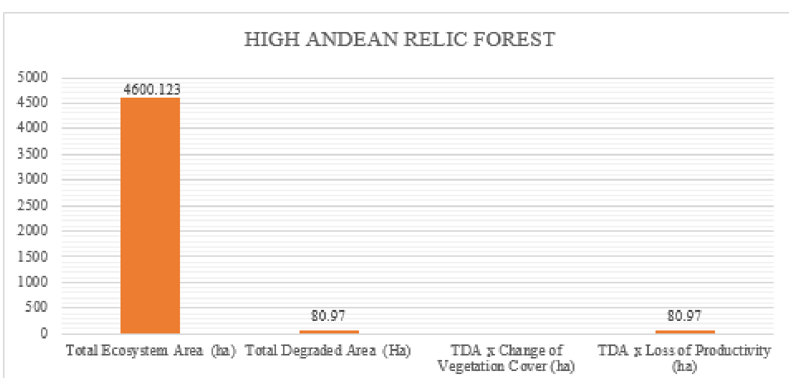

Figure 13 Total Area of the High Andean Relict Forest Ecosystem, and the Total Number of Hectares of Degraded Areas.

Figure 13 shows the total area of 4600,123 hectares of the High Andean Relict Forest ecosystem, found in the basin studied, and presents a total of degraded area that in this case belong entirely to areas degraded by loss of Primary Productivity, with 80.97 hectares that corresponds to 1.8% of this ecosystem.

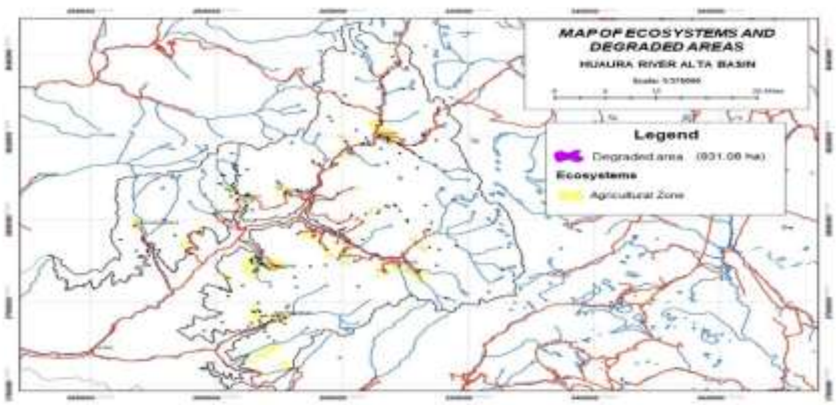

Figure 14 Location Map of the Agricultural Zone in the Upper Huaura River Basin, Incorporating the Area Degraded by Changes in Vegetation Cover and Primary Land Productivity.

Figure 14 shows the Agricultural Zone as a living space present in the Upper Huaura River Basin, which is located very close to the rivers and of course directly related to human settlements, which in turn are located along the roads; it is represented on the map by the color yellow. The degraded area in this space is 931.08 hectares and is expressed on the map in the form of purple spots. The human settlements present are 64 and are represented as black dots. [28,29].

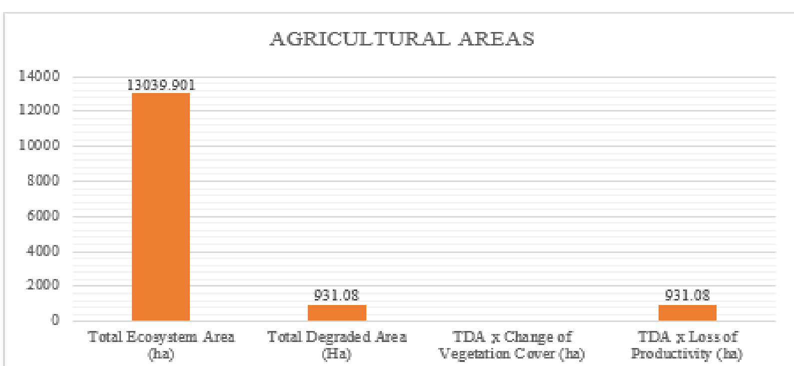

Figure 15 Total life area known as Agricultural Zone and the Total Number of has. of Degraded Spaces.

Figure 15 shows the total area of the Life Zone known as the Agricultural Zone, which has a total of 13039,901 hectares. It also shows the total degraded area, which in this case belongs entirely to areas degraded by loss of Primary Productivity, with 931.08 hectares, which corresponds to 7.1% of this life zone.

4 Discussion

The evaluation of the thematic accuracy of the results obtained through the high resolution images makes it possible to determine the degree of concordance between the results produced from degraded areas with what can be observed in the field for the upper Huaura River Basin. This accuracy is of the order of 78%, with a Kappa value of 0.55, which indicates that the information has a moderate degree of agreement with respect to the evaluation in the office.

The results allowed us to determine nine ecosystems in the study area, of which seven have been analyzed, the two not examined correspond to water mirrors, considering that the ecosystems of lakes, lagoons and rivers, are not affected by the change in land cover and land productivity.

The ecosystems analyzed were: Bofedal, 1575,339 hectares; High Andean Relict Forest, 4600,123 hectares; Andean Scrub, 91063,885 hectares; Puna Húmeda grassland, 109431,985 hectares; Periglacial, 57373,78 hectares; Glacial, 873,407 hectares; and Agricultural Zone, 13039,901 hectares.

The resulting analysis shows that the degradation of the ecosystems is almost exclusively due to the decrease in land productivity, which in total is 8,916.7 hectares and corresponds to 5.01% of the total area occupied by the seven ecosystems analyzed, and 3.19% of the territory of the Upper Huaura River Basin. Although the degraded territory in terms of surface area is not extensive, it has special significance given that the degraded surface area represents a decrease in ecosystem services linked to water regulation and erosion control.

The glacial and periglacial ecosystems are those found in the highest area of the basin under study, located between 4,500 and 5,000 meters above sea level, both have no degradation detected, influenced by the little or no vegetation, however, we must consider that the glaciers in Peru, from 1955 to 2016 has decreased by 53. 56% [25].and we can observe the anthropic influence on the periglacial ecosystem expressed in the presence of 6 towns in its territorial space which, if they do not develop under a conservationist form of life, can affect this fragile ecosystem that presents cryotubes vegetation, by the successional dynamics .

The Puna Húmeda is the dominant ecosystem in the High Basin of the Huaura River, with 109431.985 hectares and a degraded space of 6371.02 hectares, which is generated by the loss of primary productivity and is influenced by the presence of 51 villages that generate diverse anthropogenic activities producing 5.8% of degradation of this high Andean environment. This ecosystem occupies flat, undulating or hilly lands with moderate slopes whose spaces are protected by herbaceous vegetation made up of low grasses [25]. which allows it to maintain the humidity that characterizes it by allowing the formation of shrubby vegetation that generates greater protection; therefore, it is important to maintain this ecosystem in its best natural conditions considering that it is the dominant environment in the Huaura River basin

The Andean Scrubland is the second largest ecosystem in the Upper Huaura River Basin, with 91063,885 ha, The communication routes have affected its territory and it presents a degraded space of 1441.14 has. which corresponds to 1.8% of the ecosystem, however, in this case 11.17 has. are affected by land cover change which is 0.7% of the degraded space; and the loss of productivity is 1429.97 has. which corresponds to 93% of the degraded space; in this ecosystem there are 77 towns whose anthropic influence produces the deterioration of 1.8% of this ecosystem. The altitudinal range of this ecosystem is wide from 1500 to 4500 meters above sea level, which generates a high fragility if its soil is not covered by woody and shrubby vegetation [26].

The Bofedal is one of the least represented ecosystems in the study basin, with 1575,339 hectares; the degraded zone is 92.49 hectares, an area that corresponds entirely to the loss of primary productivity and affects 5.9% of this ecosystem. The bofedal is considered a high Andean wetland, with limited spaces, present only in the Central Andes, located from 3800 masl to more, present in plains where they store water from rainfall, glacial melt and some from subway outcrops and by the present climate change; therefore, the Bofedales that are presented in the territory of the High Basin of the Huaura River, must be cared for to maintain this environment of great ecosystemic importance.

The High Andean Relict Forest ecosystem is the third one with less hectares present in the High Basin of the Huaura River, with 4600.123 has., it presents a degraded zone of 80.97 has. that corresponds to the loss of Primary Productivity being 1.8% of this ecosystem. The High Andean Relict Forest, is present between 3600 and 4900 meters above sea level, they are called Relict because of their small area and steep slopes with little accessibility. They are forests of Polylepis associated with Gynoxis. sp., of shrub character that reach 3 meters in height and present the substrate covered with puna vegetation [26]. Therefore, the High Andean Relict Forest is a highly fragile ecosystem that may disappear if it is not supported by the other ecosystems that surround it, due to its reduced surface area, preventing the influence of the climate change present on the planet.

Of the total degraded areas identified, 68% have been categorized according to their origin and intensity. Of the total of categorized degraded areas, 1642.59 hectares have a primarily anthropic origin, meaning that some human factor such as the influence of roads, human settlements, agricultural activity is related to this degradation. In this sense, these areas are the objective of implementing measures to recover ecosystems and ecosystem services, mainly those of water regulation, applying natural infrastructure measures implemented through public or private investment projects.

5 Conclusions

This research work has allowed a deep analysis of the High Basin of the Huaura River, showing its different ecosystems and the degradation that each one of them presents due to the change in the vegetation cover and land productivity, locating the amount of settlements and construction of transportation routes that have influenced the alteration of their ecosystems.

Seven were the ecosystems analyzed and a degradation of 8,916.7 hectares was generated until now, which corresponds to 5.01% of the area occupied by these life spaces; in addition, the degradation studied corresponded to 3.19% of the territory of the upper basin of the Huaura River. Even though the percentage of deterioration due to vegetable coverage and land productivity is considered low, the geographical characteristics of the basin present a wide range of altitude and important slopes that generate several ecological floors or life zones that make them fragile and sensitive to the changes that occur in it; for this reason, it is necessary to orient the activities that take place in this high basin, to offer quality of life to its inhabitants causing the minimum deterioration of its territory.

Both the Puna Húmeda and the Matorral Andino, the two ecosystems with the greatest presence in the upper basin, need their natural eco-systemic conditions to remain in force and although their spaces have been affected by the construction of communication routes, which has allowed human migration generating unplanned human settlements, the environmental conditions so far are not highly harmful and nature-friendly activities can be oriented for the development of human populations.

The Bofedal and the High Andean Relict Forest are not very extensive environments in the Basin under study, because they are spaces with eco-systemic characteristics of narrow ranges in their geographical and abiotic conditions, which make them highly vulnerable and of important need to conserve them because they can easily disappear from the planet, therefore, it is necessary that the habitats of their surroundings are kept healthy; both environments are little degraded in the high Basin, so we are in the opportunity to keep them in balance.

The ancestral agricultural zone considered as a life zone of the upper basin under study, presents less than 10% of deterioration, so it can be preserved for posterity by proposing organic crops.

Of the 7 ecosystem analyzed, 5 present degraded surfaces on which recovery measures should be implemented, considering the type of ecosystem, prioritizing those that have water and biological importance. These measures should be implemented in the logic of investment projects or recurrent actions of state entities, as well as private initiatives of companies or civil society organizations, to restore ecosystems and ecosystem services such as water regulation or erosion control, articulating to the mitigation or adaptation measures against climate change and environmental land management processes.

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Biographies

María Herlinda Veliz Garagatti Professor at the Faculty of Environmental Engineering and Graduate School of the National University Federico Villarreal, biology.

William Augusto Llactayo León Geographical Engineer, specializing in Environment and Natural Resources, graduated from the Universidad Nacional Mayor de San Marcos. He currently works in the Ministry of the Environment of Peru, in the General Directorate of Environmental Territorial Planning

Doris Esenarro Vargas Professor at the Faculty of Environmental Engineering and Graduate School of the National University Federico Villarreal, with studies in System Engineering, Architecture, and Environmental Engineering.

Mabel Eliana Nolasco Chuco University student of the Environmental Engineering, of the national university Federico Villarreal, teaching assistant

Pedro Raúl Tinoco Rodríguez University student of the Environmental Engineering, of the national university Federico Villarreal, teaching assistant.