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Tesis

Climate Controversy under the Subjection of Forest Depopulation in the Jungle Eyebrow of Huanuco and Ucayali-Peru

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Climate controversy under the subjection of forest depopulation in the jungle eyebrow of Huanuco and Ucayali - Peru

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Abstract. Anthropogenic activities uneven climate balance. Deforestation is an environmental problem resulting from human activities that affect the climate and its variables. Huanuco and Ucayali are provinces of Peru located in the upper jungle of the Amazon and have high rates of deforestation with 347,583.96 and 267,899.76 hectares of forests lost in the last 21 years due to activities such as oil palm planting, and others. In the present investigation, it is investigaded the existence of a statical correlation between climate variability and deforestation. Likewise, the state of the forests.

In 2009, the temperature presented high peaks, with 31.43°C indicating a direct relationship with deforestation since in previous years it was deforested on a large scale. Likewise, in 2014 the study area reached the peak of deforestation in the 21 years analyzed with a total of 149,217.70 hectares of forests, which caused that in 2015 the temperature reached high figures again. 2020 is the second year with the highest deforestation, losing 146,743.83 hectares of forests and consequently presented a minimum temperature of 26°C, unlike previous years with 21.17°C, which in the long term would cause alterations in the ecosystems of the investigated areas. Similarly, precipitation and relative humidity show similar behaviours. Finally, the statistical analysis analyzed the existence of a 95% confidence correlation between climate variability and deforestation.

Key words: Deforestation, Climate, Climatic Variables, Forests, Correlation, Temperature.

1 Introduction

The climate is the result of all the atmospheric and meteorological conditions that have been recorded over many decades [1]. The climate crisis continues to be a matter of discussion and controversy around the world and recently the population has made

efforts to adapt and meet their long-term needs [2]. Likewise, it has deteriorated the vitality of the planet, leading to big consequences, from the melting of the poles, droughts, forest fires, and mass extinction of various species of flora and fauna [3]; [4]. Climate change is a global concern due to the increase in temperature and CO_2 emissions [5]. Deforestation in tropical areas brings with it the beginning of a global temperature variation of +0.4°C and a deviation of 60 ppm of CO_2, as a result of the fact the lost forests do not fulfill the function of sequestering and storing carbon in the atmosphere [6]. A close relationship between climate and deforestation has been evidenced. In addition, it is indicated that in approximately 40% of deforestation, the temperature increases from 3 to 4°C [7]–[14]. Therefore, forests can regulate temperature at a local and regional level, arguing the effect they have on the climate. Also, they increase resistance to climate change in impacted ecosystems [15].

From the local and universal hierarchy, humanity has intervened in the reduction of immense primary forests, causing an imbalance, and endangering the regulation ecosystem services provided by nature, such as: regulation of climate, water, air quality, erosion, pollination, and pests [16]–[18]. According to the FAO, the planet is made up of 31% of forests equivalent to 4,060 million hectares, but between the years 1990 and 2020, approximately more than 420 million hectares of primary and secondary forests have been destroyed due to deforestation. Of equal importance, forests are home to more than 80% of amphibians, birds, mammals, and 60% of varieties of vascular flora [19].

In Peru, the humid forests of the Amazon represent 94.2% of the territory, the Andean coastal dry forests 4.7%, and the Andean relict humid forests 1.1%. This data symbolizes approximately 60% of the national territory, covering 82 million hectares throughout the Peruvian territory [20], [21]. Due to deforestation, Peru had a huge suppression of its forests between 2001 and 2019, which led to almost 2.4 million hectares of primary and secondary forests being felled, having a proportion of 128 thousand hectares per year [22]. Therefore, native communities, biodiversity, ecosystems, and the acceleration of climate change have been threatened by the social, environmental, and economic impacts generated by environmental problems. According to reports made by Peruvian entities Programa de Bosques, Ministerio del Ambiente (MINAM), Servicio Nacional Forestal y de Fauna Silvestre (SERFOR) and the Ministerio de Agricultura y Riego (MIDAGRI), The Ucayali and Huanuco regions presented a very high concentration of forest loss from 2001 to 2008 and extremely high from 2009 to the present [23]. Being of big concern to the authorities is the impact of deforestation on the climate and the sources of heat that are being generated as a result of extractive activities in the forests. The ecosystems lost due to deforestation in Peru represent 90% of products of activities to open farms, causing serious environmental impacts such as contamination of water, soil, and air, the depravity of biodiversity, decrease in the capacity to generate food, medicines, landscape, the protection that it offers to native and indigenous communities, preventing them from assuring the quality of life.

The main activities that encourage deforestation are agriculture, livestock, illegal logging and mining, illicit crops, and land trafficking. Due to the high demand for inputs such as oil palm, the Amazon forests have been affected by deforestation, with

the Ucayali region having the greatest average increase of 10,500 hectares of primary and secondary forests [24]. Despite the commitment to achieve zero net deforestation by 2020, between 2000 and 2015 Peru evidenced an average of 40,000 hectares of forest cleared for, oil palm planting [25].

In 2012, the investigation began into alleged criminal organizations that would be linked to land trafficking and deforestation, whose criminal leaders would be 42 officials who work in the Regional Government. The cases of investigations are called Zanja Seca, Tibecocha, and Cocha Ania, which belong to the Ucayali region, where the directors of the Ucayali Regional Directorate of Agriculture would have given titles to large tracts of forest land and granted forest concessions to the foreign companies dedicated to oil palm planting: Pucallpa S.A.C and Ucayali S.A.C, later years they joined and changed their name in 2016 to Ocho Sur S.A.C now they are divided to Ocho Sur P S.A.C and Ocho Sur U S.A.C. Before the possession of Ocho Sur S.A.C the companies of Pucallpa S.A.C and Ucayali S.A.C caused environmental damage by logging indiscriminately, degrading ecosystems and killing a large number of species of wild fauna and flora that used to live in the areas of Zanja Seca, Tibecocha, accumulating between both areas approximately 10,000 hectares, and Cocha Ania, 3,600 hectares of deforested Amazon forest.; likewise, the companies did not have authorizations or environmental permits to felling and planting oil palm. The cases are still under investigation by the Peruvian authorities [26].

Corruption in Peru would be aggravating the vulnerability of ecosystems of indigenous communities, mass extinction of species of wild flora and fauna, and loss of primary forests; consequently, generating the loss of the green lung of the country due to deforestation that decreases climate stability and makes the fight against climate change difficult. Considering the above, this research study has as its main objective to describe the state of the forests and analyze the relationship between climate variability (meteorological variables) and deforestation (deforested forests) in the regions of Ucayali and Huanuco in Peru. We will describe the delimitation of the study area, the database for the collection of meteorological information and deforestation, the methodology applied for the analysis of the data obtained and processed, the presentation of the results in time 2001 to 2021, and finally the conclusions.

2 Data Repertoire and Methodology

2.1 Delimitation of the study area

The study area was determined based on the accelerated growth of deforestation in Peru. Of its 24 departments studied, Huanuco and Ucayali are the areas of the Amazon jungle with the highest deforestation rate in the last 21 years. They have the highest concentration of deforestation alerts [23], [27].

Huanuco is a province of Peru located between 160 and 3,580 meters above sea level. belonging to the Sierra and Selva Central natural regions; Likewise, there is the Tingo María National Park which has a big variety of flora and wild fauna [28]. On the other hand, Ucayali is located in the central and eastern part of Peru, it has 3 latitudinal levels: jungle, high jungle, and low jungle; In addition, it is home to indigenous

communities, Protected Natural Areas such as National Parks of Alto Purus, Cordillera Azul and Sierra Divisor [29].

The total surface of the study area is 2,306,096.2 hectares that have to all the districts of the province of Puerto Inca (Huanuco), all the districts of the province of Padre Abad (Ucayali), and two districts, Nueva Requena and Campoverde belonging to the province of Coronel Portillo (Ucayali), The following map shows the districts that are covered by each region in the study area.

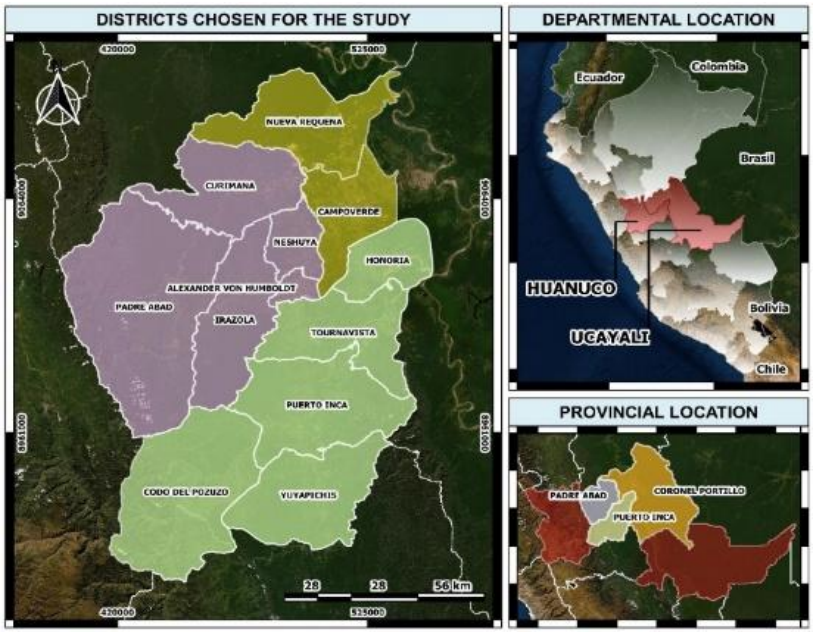

Fig 1: Delimitation map of the study area

2.2 Meteorological and forest data

For the collection of data on forest loss, two public domain databases were used, which allows everyone to freely access the data through their virtual platforms, which are: GEOSERFOR y GEOBOSQUES.

- GEOSERFOR, is a free access technological medium that gathers spatial data from the forestry sector within the framework of the Spatial Data Infrastructure under Executive Directorate Resolution No. 005-2017-SERFOR/DE; Likewise, it has geographic and geotelematic information on the modality of access to the forest, forest management, monitoring and control, forestry issues, forest fires, forest zoning, inventory and valuation of forests through national environmental authorities such as the Ministerio de Desarrollo Agrario y Riego (MIDAGRI) and Servicio Nacional Forestal y de Fauna Silvestre (SERFOR) [30], [31].
- GEOBOSQUES, includes reports, reports, maps and viewers within its open information platform of occurrence in forests, forest monitoring was carried out

with the support of the Ministerio del Ambiente (MINAM) and Servicio Nacional Forestal y de Fauna Silvestre (SERFOR) under the National Forest Conservation Program for Climate Change Mitigation. The Forest Cover Monitoring module includes: Forests and forest loss, early warning, degradation, reference levels, land use and land use change [23].

For the collection of meteorological data, two public domain databases were used, which allows everyone to freely access the data through their virtual platforms, which are: SENAMHI and POWER Data Access Viewer v2.0.0.

- SENAMHI, The National Service of Meteorology and Hydrology of Peru is a public institution in charge of providing information of a meteorological, hydrological and climatic nature. Likewise, it offers within its platform data on weather, climate, hydrology, agrometeorology and general spatial data [32].
- POWER, Data Access Viewer v2.0.0 (NASA) gathers weather-related data derived from the model Global Modeling and Assimilation Office (GMAO) [33], which provides high reliability data; since, they are based on daily comparison methodologies according to the reports of their monitoring stations scattered around the planet, which are: Global Downloads, List of layers, Reports on climate data [34].

2.3 Location of Weather Stations

The data extracted from the SENAMHI platform are hydrometeorological data from automatic stations, conventional stations in real and deferred time, which are presented in the following table.

Table 1: Location of SENAMHI weather stations

Province	Station name	Station type	Altitude (m.a.s.l)	Latitude (S)	Length (W)
Puerto Inca	Puerto Inca	Automatic	212	9°23'6.36"	74°57'49.54"
Puerto Inca	Tournavista	Conventional	196	8°55'38.98"	74°42'31.74"
Padre Abad	Aguaytia	Conventional	316	9°2'32.11"	75°30'22.46"
Padre Abad	San Alejandro	Conventional	216	8°50'4"	75°12'59.01"
Padre Abad	El Boquerón	Conventional	206	8°34'57"	74°51'58"
Padre Abad	El Maronal	Conventional	178	8°27'0"	75°5'48.5"
Padre Abad	Santa Ana	Automatic	235	8°29'51.47"	75°33'45.86"

Note: Compilation of the location of meteorological stations. Source of information:[32].

The location points chosen for downloading meteorological data within the Prediction Of Worldwide Energy Resources (POWER) viewer were carefully located, due to the coincidence between the SENAMHI meteorological stations and areas for data collection, in order to guarantee greater precision during data collection. The coordinates of the data collection points are mentioned below:

Table 2: Location of meteorological data sampling points POWER viewer

Reference of the station in Peru	Station name POWER	Latitude (S)	Length (W)
Puerto Inca	POWER-H-01	-9.3843°	-74.9636°
Tournavista	POWER-H-02	-8.9288°	-74.7075°
Aguaytia	POWER-U-01	-9.0419°	-75.5057°
San Alejandro	POWER-U-02	-8.8345°	-75.2164°
El Boquerón	POWER-U-03	-8.5717°	-74.8560°
El Maronal	POWER-U-04	-8.4496°	-75.0962°
Santa Ana	POWER-U-05	-8.4980°	-75.5626°

Note: Compilation of the location of meteorological data collection points. The coding of the data points collected from the POWER viewer was defined according to criteria. Source of information: [34].

2.4 Research strategy

In view of meeting the objectives set within this research to describe the state of the forests and analyze the existence of a relationship between climate variations and deforestation; likewise, expose the serious consequences for the climate that the reduction of the tree population has been generating over the last 21 years in the study area described in Table 1. Starting from deforestation, an inferential statistical analysis was proposed where the normality of the collected data is evaluated and it seeks to analyze the existence of influence of forest loss with respect to the variation of climatic variables such as temperature, relative humidity and the precipitation. First, the SENAMHI weather stations were analyzed, which provide incomplete data and very little prior data; therefore, confidence is limited during statistical analysis. Therefore, after data collection, an average was made between the SENAMHI sources together with the data collected from NASA, in order to guarantee the statistical process and reduce the margins of error. Then the Pearson coefficient was used.

$$r = \frac{\sum z_x z_y}{N},$$

Where “x” represents the number of trees deforested per hectare and “y” comes from the increase or decrease of the climatic variables analyzed during the last 21 years. This statistical analysis was used to find some type of statistical relationship between deforestation and the variation of the meteorological variables that determine the climate of the area. Likewise, estimates of the total deforested area and a report on the current state of the forests in the study area were made, calculating the total areas in hectares. The development of the research focuses on answering the following questions: What are the climatic conditions of the study area? What is the diagnosis of forests in the last 21 years? Does deforestation influence the climate?

3 Results

3.1 What are the climatic conditions of the study area?

Temperature. Studies carried out indicate that because of deforestation the temperature increases [35]–[38]. The following shows the distribution and behaviour of temperature in the last 20 years.

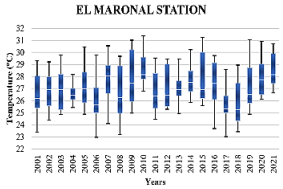

Fig 1: Temperature whisker box (°C) – El Maronal Station

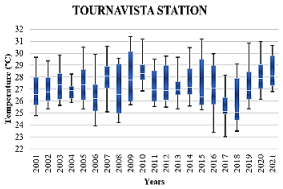

Fig 2: Temperature whisker box (°C) –Tournavista Station

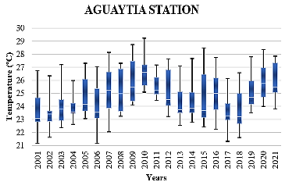

Fig 3: Temperature whisker box (°C) – Aguaytia Station

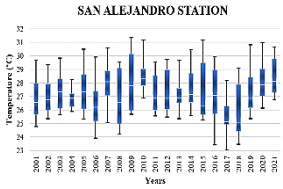

Fig 4 Temperature whisker box (°C) – San Alejandro Station

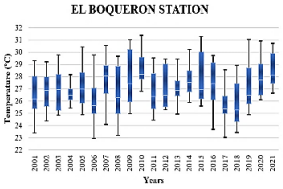

Fig 5: Temperature whisker box (°C) – El Boquerón Station

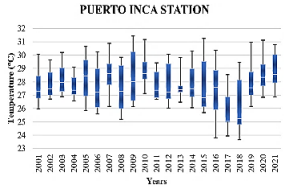

Fig 6: Temperature whisker box (°C) – Puerto Inca Station

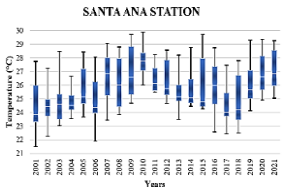

Fig 7: Temperature whisker box (°C) – Santa Ana Station

The temperature data analyzed was based on the average of both POWER and SENAMHI viewer information platforms. Likewise, temperature data was collected from the year 2001 to 2021. The maximum temperatures were recorded by the meteorological stations and the sampling points: Puerto Inca 31.43°C in 2009 as it is shown in Fig 6, Tournavista 31.39°C in 2009 as it is shown in Fig 2 and San Alejandro 31.42°C in 2009 as it is shown in Fig 4. The most predominant average temperatures

were recorded by the meteorological stations and the sampling points: San Alejandro 28.30°C in 2010 as it is shown in Fig 4, Puerto Inca 28.63°C in 2007 as it is shown in Fig 6 and Tournavista 28.35°C in 2010 as it is shown in Fig 2. Also, the minimum temperatures were recorded by the meteorological stations and the sampling points: Santa Ana 21.51°C in 2001 as it is shown in Fig 7, Aguaytia 21.17°C in 2006 as it is shown in Fig 3 and El Boqueron 22.96° C in 2006 as it is shown in Fig 5.

Precipitation. One of the most fundamental climatic variables in the climatological and hydrological manifestations in the environment is precipitation [39], [40]. The importance of precipitation is because it is the element of the climate that transports the most fresh water through the earth's crust, favoring life on the planet.

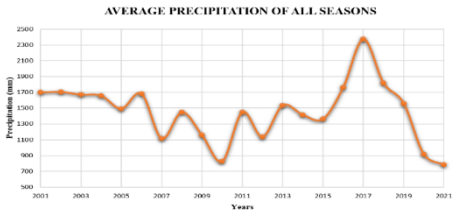

Fig. 8: Average annual precipitation for all seasons

The annual precipitation analyzed was based on the information data from the POWER viewer platform, since the data from the SENAMHI stations did not contain the information of the years necessary to give reliability to the analysis process; In addition, in compared data from both platforms the difference is big. Precipitation data was collected from 2001 to 2021 and an annual average was made for each sampling point, obtaining the following result: the maximum annual precipitation was recorded in 2017 with 2,373.02 mm/year and the minimum annual precipitation was recorded in the year 2021 with 784.23 mm/year as shown in Fig. 8.

Relative humidity. Regarding the relative humidity, it can be indicated that it is directly proportional to the temperature; therefore, it is very susceptible to sudden changes if the temperature increases. Likewise, if the temperature increases, the water vapor present in the environment will also do so; therefore, the weather will get warmer and the humidity levels will be higher.

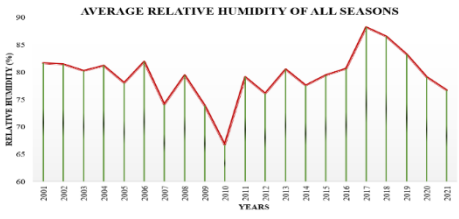

Fig. 9: Average Annual Relative Humidity of all seasons

The relative humidity data analyzed was based on the average of both POWER and SENAMHI viewer information platforms. Likewise, relative humidity data was collected from 2001 to 2021, the average maximum relative humidity is 88.12% recorded in 2017 and the average minimum relative humidity is 66.72% recorded in 2010.

3.2 What is the diagnosis of forests in the last 21 years?

Map of forest loss and current state of forest. After the process of collected data, the incidence of forest loss and current state of the forests in the study area are represented in the following graphs:

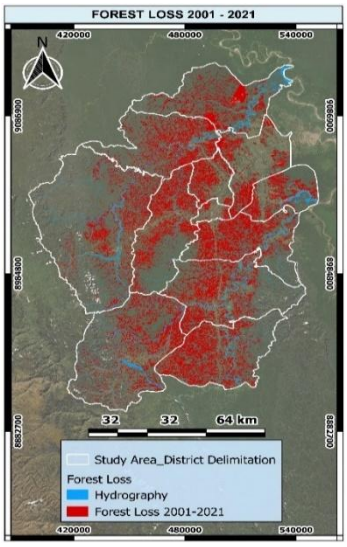

Fig. 10: Forest loss 2001-2021

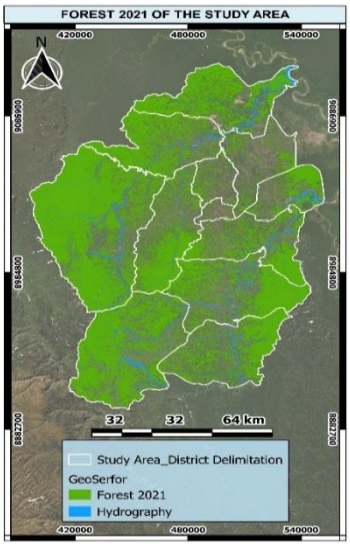

Fig. 11: Current Forest

In Fig. 10 the amount of forest deforested in the period of the last 21 years is observed, which is represented in red lines that covers a total of 542,374.02 hectares of deforested forests, representing approximately 41% of the current forest area. present in the study area.

In Fig. 11 the remaining forests that are in constant threat of deforestation due to extractive and monoculture activities that are carried out in the regions covered by the study area are observed. Likewise, the population calls for alerts against invaders who want to depredate the forest, but many times they are constantly threatened and harassed by the forest concessions that grow oil palm and other crops. In the study area there is a portion of the Cordillera Azul National Park that is under constant monitoring and supervision by the Servicio Nacional de Areas Naturales Protegidas por el Estado (SERNANP); Therefore, the National Forest Conservation Program for the Mitigation of Climate Change seeks to conserve the forest that has not yet been deforested, with the support of the Ministry of the Environment.

Deforested areas. From the symbolization seen in Fig. 10, we have the following data that shows the total deforested forest in hectares:

Table 3: List of hectares of deforested forests in the study area in the period 2001 - 2021

Department	Province	District	Total deforested forest (ha)
Huanuco	Puerto Inca	Yuyapichis	68,848.92
Huanuco	Puerto Inca	Codo del Pozuzo	63,940.41
Huanuco	Puerto Inca	Puerto Inca	60,179.31
Huanuco	Puerto Inca	Tournavista	58,146.12
Huanuco	Puerto Inca	Honoria	23,359.50
Ucayali	Padre Abad	Irazola	57,169.35
Ucayali	Padre Abad	Padre Abad	56,192.04
Ucayali	Padre Abad	Curimana	52,021.71
Ucayali	Padre Abad	Neshuya	23,458.77
Ucayali	Padre Abad	Alexander Von Humboldt	4,591.26
Ucayali	Coronel Portillo	Nueva Requena	42,894.45
Ucayali	Coronel Portillo	Campo Verde	31,572.18

Note: Other tables. Compilation of forest loss 2001-2021. Source of information: [23], [31].

According to an inventory made of the deforested areas in the study area, calculations were made of the total hectares of current forest in the area with a total of 1,326,158.64 ha of forests present in the study area. On the other hand, for the area of forests lost in the study area during the last 21 years, a total of 542,374.02 ha of deforested forests is estimated, which represents approximately 41% of the current area of forests present in the area.

Table 4: Areas deforested by years.

N°	Year	Deforestation (ha)	N°	Year	Deforestation (ha)
1	2014	149217.66	12	2019	109793.70
2	2020	146743.83	13	2011	106299.54
3	2016	133198.20	14	2021	104386.68
4	2009	130241.61	15	2008	91712.25
5	2015	129196.26	16	2007	90992.79
6	2005	128139.84	17	2004	78260.31
7	2012	126189.09	18	2002	67085.19
8	2013	125952.39	19	2001	67077.99
9	2010	121757.22	20	2003	60173.28
10	2018	119447.19	21	2006	59440.86
11	2017	113119.56			

Note: Other tables. Compilation by years of the largest forest losses.

3.3 Does deforestation influence the climate?

After the statistical analysis carried out on the meteorological variables of the 7 stations and the sampling points in the deforested areas in the study area, the following results were obtained. The temperature presented a normal distribution of its data, which contributed to the statistical analysis in which, with a bilateral analysis of correlation between the variables, the following was obtained: for the study point called "Aguaytia" there is a significant correlation at 0.01 with P value of 0.003, evaluation zones “El Boquerón”, “El Maronal” and “Santa Ana” presented a significant correlation at 0.05 with a P value of 0.030, 0.038 and 0.014 respectively; Finally, the remaining points "Puerto Inca", "San Alejandro" and "Torunavista" do not present a correlation. Likewise, after a unilateral correlation test for the same variables, 2 correlations with significance at 0.01 were obtained in the points of "Aguaytia" and "Santa Ana" and for the areas "El Boquerón", "El Maronal" and "San Alejandro" 3 correlations at 0.05 of significance were obtained, making a total of 5 points, which present a direct correlation between variables; In addition, the areas called "Puerto Inca" and "Tournavista" are those that do not show the existence of a probabilistic relationship between both variables; that is to say, that the zones that presented a correlation are those in which the greatest loss of forests was evidenced over the years, thus concluding that the reduction of forests presents a direct probabilistic relationship with the behavior of temperature. The precipitation analyzed in the study area presents 2 stations that indicate a statistical correlation at 0.05 of significance with respect to the amount of forest loss. El Boqueron and El Maronal have a P value of 0.040 and 0.038 respectively, which indicates the existence of a statistical relationship between both variables; on the other hand, the remaining 5 points yielded negative results, exposing the limited data that is not found to evaluate precipitation with greater confidence.

4 Conclusions

The departments of Huanuco and Ucayali are the ones with the highest rates of massive deforestation registered in recent years. Under this criterion, the probabilistic relationship analysis carried out in this study shows the influence generated by deforestation on temperature, precipitation and relative humidity, the which showed their highest peaks or behaviors inconsistent with previous records, after dates of massive or large-scale deforestation. So it can be affirmed that the changes in the climate are not immediately after having lost the forest, but that the changes occur up to 4 years after the environmental impact. As a result of deforestation in the years 2016 (third place in deforestation) and 2020 (second place in deforestation) the behavior of the temperature has changed drastically, that is, if in previous years the minimum temperature was 21.17°C, in the today is 26°C, then these changes would cause long-term alterations in the ecosystems of the provinces of Padre Abad, Puerto Inca and Coronel Portillo. On the other hand, precipitation and relative humidity also show a behavior similar to that of temperature, due to the increase in deforestation, a precipitation and humidity deficit is not characteristic of the Peruvian jungle area. In addition, the damage generated by the massive deforestation produced during these 21

years represents approximately 41% of the tree area currently present in the research area; with which it can be inferred that large portions of deforested land were replaced by oil palm plantations as mentioned in various sources of information; In this way, variations in the variables are observed, indicating an influence on the ecosystems of the study area. Once the statistical correlation analysis was carried out, it was identified that 5 of the 7 stations and points selected for the evaluation of the meteorological data present a statistically significant relationship with more than 95% confidence with respect to the forest depopulation present in the study area over the course of the study over the years; likewise, the stations that presented direct correlation and with a higher value of significance are located in areas where deforestation is more evident; exposing the influence that deforestation has on climate variation.

5 Limitations

It is very important to consider for future research the El Niño phenomenon in the Central Pacific, which presented four events: two weak level (2004 to 2007) and two moderate levels (2002-2003 and 2009-2010); in the same way, to the phenomenon "La Niña" that occurred in 2007. It is also important to consider the introduction of oil palm plantations in the study area; since, it is possible that its phenological process and its extraction have an influence on the meteorological behavior evaluated in the study area.

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