USE OF NEUTROSOPHIC STATISTICS FOR THE STUDY OF THE IMPACT ON THE FORESTRY EXPLOITATION OF A PRODUCTIVE FOREST

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ABSTRACT
This paper is dedicated to study the forest and the impact of its use in the native community of Chamiriari in the province of Satipo, Peru. The adequate forestry use of the forests in the area would allow the efficiency in the timber industry and therefore mean an economic improvement, in addition to reducing ecological damages and preserving the cultural wealth of the native Chamiriari people who inhabit the area. That is why the statistical study of how timber resources are exploited in this area of Peru was necessary. For this, plots that serve as a sample were randomly selected to study the trees distribution in Satipo. One drawback found is that due to the number of plots studied and the extension of them it is difficult to count exactly how many trees exist, even on how much land is not planted, that is why the technicians who carried out the data collection were asked to express the data in the form of intervals, where imprecision is included, but the accuracy is preserved. This way of representing the data needs to be processed with the use of Neutrosophic Statistics, which is the extension of the theory of classical statistics to cases where data or parameters are available in interval forms. The results obtained will make it possible to increase the efficiency of timber industry with a minimum of ecological damage and respecting the way of life of the Chamiriari community. It is the first time to the authors' knowledge that a study of this kind has been carried out in the province of Satipo. We concluded that the studied plots which are "non-intervened" or with few of cut out trees, have more variety in tree quality and economical interest in comparison with the "intervened" plots.

KEYWORDS: Forest harvesting, floristic composition, Tukey's mean comparison test, statistical inference.

MSC: 62P12, 62P30.

RESUMEN
Este artículo está dedicado a estudiar el bosque y el impacto de su uso en la comunidad nativa de Chamiriari en la provincia de Satipo, Perú. El aprovechamiento forestal adecuado de los bosques de la zona permitiría la eficiencia en la industria maderera y por ende significaría una mejora económica, además de reducir los daños ecológicos y preservar la riqueza cultural del pueblo nativo Chamiriari que habita la zona. Es por ello que se hizo necesario el estudio estadístico de cómo se explotan los recursos madereros en esta zona del Perú. Para ello, se seleccionaron aleatoriamente parcelas que sirvieran de muestra para estudiar la distribución de los árboles en Satipo. Un inconveniente encontrado es que por la cantidad de parcelas estudiadas y la extensión de las mismas es difícil contar con exactitud cuántos árboles existen, incluso en cuánto terreno no se planta, por lo que se consultó a los técnicos que realizaron la toma de datos para expresar los datos en forma de intervalos, donde se incluye la imprecisión, pero se preserva la exactitud. Esta forma de representar los datos necesita ser procesada con el uso de la Estadística Neutrosófica, que es la extensión de la teoría de la estadística clásica a los casos donde los datos o parámetros están disponibles en formas de intervalo. Los resultados obtenidos permitirán aumentar la eficiencia de la industria maderera con un mínimo de daño ecológico y respetando el modo de vida de la comunidad Chamiriari. Es la primera vez, según conocimiento de los autores, que se realiza un estudio de este tipo en la provincia de Satipo. Se concluyó que las parcelas estudiadas "no intervenidas" o con poca tala presentan la mayor variedad en calidad de los árboles y en interés económico en comparación con los espacios "intervenidos".

PALABRAS CLAVES: Aprovechamiento forestal, composición florística, prueba de comparación de medias de Tukey, inferencia estadística.

1. INTRODUCTION

The native community of Chamiriari located in the province of Satipo-Junín, has an area of 8,283.30 ha with a diversity of natural resources distributed in four life zones ([18]), more than 2000 ha of forests in Territorial Lot "B" harvested through forest exists ([18]) it has a timber volume of 36,363 m^3 corresponding to 25 forest species. The harvesting operations were carried out in compliance with the Forest Management Plan approved in 2002 by SERFOR, in 2002 the first annual operating program (POA I in Spanish) began, continuing in 2003 POA II and in 2004 POA III; later, activities were suspended due to non-compliance with the forest use plan; because road impacts were observed, as well as timber extraction without respecting the POA, damage to natural regeneration and non-compliance with the silvicultural plan. The forest extraction activities are

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renewed in 2008 with POA IV, continuing in 2009 with POA V and finally POA VI according to the terms of reference of Chief Resolution No. 232-AG, [6].
In the operational programs of Block B, 2002, 2003 and 2004, the forestry extraction of valuable species such as mahogany (*Swietenia macrophylla*), ishpingo (*Amburana cearensis*) and screw (*Cedrelinga catenaeformis*) was projected with volumes that exceeded 9,000 to 10,000 m^3 per POA. However, due to illegal extraction, valuable species were disappearing and the extraction of species of lower commercial value increased, such as the so-called "oaks" that comprise several unidentified species of lower commercial value ([18]).
There are no evaluations after forest harvesting on the structure and tree composition of the native Chamiriari community; there are three ([6]) studies evaluating the natural regeneration of three important species such as *Myroxylom balsamum*, *Clarisia racemosa* ([5]), and *Brosimun alicastrum* ([16]) in different areas of the POAs of Territorial Lot B that report minimal and worrying existence of whip oils and remnants. Likewise, in it is assessed forest resources determining the existence of more than ([6]) 32 timber species and 28 native species.
Although various studies have been carried out in other countries on the ecological consequences of forest harvesting, they have received very little attention in Peru. For some authors (see [4]) there are few investigations that have measured the effects of forest use, highlighting the urgency of documenting these effects on the structure and composition of the forest. Different forest harvesting operations cause various effects on the remaining forest, serious or minor, depending on the intensity of harvesting. These effects may include changes in edaphic conditions, loss of seed trees, opening of the canopy or clearings, alterations in the floristic structure and composition, damage to remaining trees, soil erosion, decrease in forest cover, river pollution, decrease in wildlife and habitat alteration and even the socioeconomic impact on the local indigenous population that is unaware of alterations by logging companies. Wagner ([23]) states that there is practically no research on the long-term development of forests under selective cutting. Additionally, the effects of harvesting on the floristic composition and biodiversity of forests are almost unexplored.
The province of Satipo has more than 210 native communities, most of them with productive forests and with current forest which permits for timber harvesting. However, there are no research works on the evaluation of the impacts of forest use of productive forests, mainly in the variables of diversity and floristic composition. The Chamiriari community is one of them, where timber harvesting has had obvious impacts and there is an urgent need to evaluate them. In this sense, the research problem has been raised with the following question: What are the impacts of forest use on the structure and floristic composition of the productive forest of the native Chamiriari-Satipo community?
In this sense, within the framework of forest planning, and with the recovery of the intervened forest in danger, it is of utmost importance to evaluate the impacts of forest use on the structure and floristic composition of the productive forest of the native Chamiriari community, in order to contribute information on the situation of forest use that allows sustainable forest management, ([22]), and thus contribute to decision-making in the development of efficient forest management techniques with the participation of the local population.
For the aforementioned reasons, the research work was carried out in the timber harvesting forest of the Chamiriari native community-Lot B, with the following objectives: to evaluate the impacts of timber harvesting on the abundance, frequency and dominance of trees larger than 10 cm diameter of the 2004 and to analyze the structure and composition of the arboreal vegetation smaller than 9.9 cm in diameter after forest use, in relation to the formation of clearings or disturbances.
This paper uses a random sample of forest plots where the exploitation of these plots by workers in the timber industry is analyzed. For this, it is necessary to collect data consisting of the number of trees in each plot. This counting process is imprecise due to the number of trees that varies per lot, which is why the technicians who carried out the counting were instructed to give an interval on the number of trees they estimate to be in each plot. This introduces imprecision within the final results, however maintains more accuracy. The data obtained are given in the form of intervals instead of numerical values, therefore the data processing cannot be carried out using classical statistical methods, but Neutrosophic Statistics must be used. The data represented in this way was determined to be sufficiently accurate for the study to be successful.
Neutrosophic Statistics generalize the methods and theories of classical statistics to problems where there are data, parameters, inferences in the form of intervals instead of numerical values, ([20]). Due to the form of data collection in this analysis, which are represented in the form of intervals, it was necessary to use the theory of Neutrosophic Statistics, especially for adapting the Tukey mean comparison test, [1]. Many examples of applications of neutrosophy can be read in [9], especially one issue on neutrosophic statistics can be consulted in [2].This article is the first to the knowledge of the authors which is dedicated to studying forest use in this area. It is of great economic importance, since the efficiency of the timber industry is studied, ecological because it allows measures to be taken to preserve the tree species of this forest, and social, since this is an area where native peoples live.
This paper is divided into the following sections; section 2 of Preliminaries contains the basic concepts on the impact of forest use and Neutrosophic Statistics. Section 2 also contains the results of studies obtained in similar contexts. Section 3 contains details of the study we carried out. Section 4 summarizes the results. Discussion and Conclusions are offered in the last section.

2. PRELIMINARIES

This section is divided into two subsections, where the main concepts underlying the results given in this article are explained. Subsection 2.1 contains the preceding works on the topic of forest harvesting impact and subsection 2.2 explains the fundamental concepts of Neutrosophic Statistics.

2.1 Some previous studies on forest development

Few studies have measured the effects of forest harvesting, which underscores the urgency of documenting these effects on the structure and composition of the forest, in order to recommend more adequate harvesting intensities that allow sustainable forest management. Likewise, Wagner ([23]) sustains the need for comparative studies between harvested forests and non-intervened forests that facilitate the documentation and evaluation of the effects of the current management system. As there are no long-term studies on forests harvested by selective felling, the development of vegetation is observed in forests harvested only once, in plots of different post-harvest ages in sites with comparable ecological conditions.

Toledo et al. ([22]) analyzed the structure and floristic composition of the understory after forest harvesting, in relation to the formation of gaps. They randomly established 100 permanent plots (50mx20m), divided into five categories of subplots, in an area of 400 ha of forest destined for forest use. In order to analyze the structure and floristic composition of the understory after forest use, they recorded information in 1998 on plants and the effects of disturbances in three of five categories of subplots. The results of the plots of category C (species between 5–9.9 cm Diameter to the Height of the Chest or DBH for short) were disturbances in 3.8% of them, in category D (<5 cm DBH and > 2 m height) in 32%, and in the category E (<5 cm DBH and <2 m height) 42% of the plots showed disturbances. Some species were more abundant in disturbed sites; some are woody, others herbaceous and other climbers.

Marcelo et al. ([12]) in an area of 1.25 ha, installed rectangular plots and measured the regeneration <10cm DBH (saplings, pole stands, stems) in the treatments: herds, clearings, skidding tracks and control area. The results of the intervened areas and the control show disturbances that stimulate natural regeneration. The greatest abundance of sapling and pole stand species occurs in areas caused by harvesting, especially in herds (larger gaps) where most are durable heliophytes. In stem, the highest abundance occurred in the control since, due to the short time of use, the species have not been able to reach these dimensions. The most abundant species was *A. colubrina* for the three regeneration sizes in almost all treatments.

Toledo et al. ([22]), in tropical forests of Bolivia determined 44 trees damaged by extracted tree, of them, 22 residual trees were seriously damaged and six corresponded to commercial species; the stem is the part of the residual trees most affected, it presents from superficial damage to the bark, to its detachment and exposure of the cambium. On the other hand, in [14] it is evaluated a forest in the eastern Amazon, resulting in that unplanned forest supply operations damaged 16 more trees than the planned activities and that the residual tree canopy was affected by 4.5 trees in the planned operation, against 7.4 trees in the unplanned one, per tree felled.

Wagner ([23]), according to his research, demonstrated the decisive effect of selective felling, he identified a change in the floristic composition: sciophytic and tolerant species were replaced by pioneer species and heliophytic species. Likewise, he states that these changes also included commercial species: while heliophytic species and species of potential commercial value regenerated much better, the sciophytic species, which comprised most of the currently commercial species, decreased much in abundance. Therefore, he remarks that under the current form of management of the humid forests of the Atlantic slope of Costa Rica, a change occurs in the floristic composition.

Finally, they concluded the effectiveness of the demolition of 80%, with a higher incidence in the residual trees, 3.5 damaged trees were calculated for each felled individual, the most affected species were those of the *Genus Pinus*, with 42% of the total. Moderate to strong alterations occurred in 24% of the harvested areas and 0.481 m^3 of soil and organic matter are removed per cubic meter of wood carried away. Likewise, they argue that there are various methodologies to evaluate the effects of harvesting that have to be implemented once they have concluded or during the progress of operations. They claim that they carried out the aforementioned research work, given the scant up-to-date information regarding the level of damage caused by the demolition and dragging activities to the residual trees and the forest floor.

2.2. Notions on neutrosophic statistics

Definition 1: ([21]) Let X be a universe of discourse. A *Neutrosophic Set* (NS) is characterized by three membership functions, $u_A(x), r_A(x), v_A(x) : X \rightarrow]-0, 1^+[$, which satisfy the condition $-0 \leq inf\ u_A(x) + inf\ r_A(x) + inf\ v_A(x) \leq sup\ u_A(x) + sup\ r_A(x) + sup\ v_A(x) \leq 3^+$ for all $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ are the membership functions of truthfulness, indeterminacy and falseness of x in A, respectively, and their images are standard or non-standard subsets of $]-0, 1^+[$.

Definition 2: ([21]). Let X be a universe of discourse. A *Single-Valued Neutrosophic Set* (SVNS) A on X is a set of the form:

$$A = \{\langle x, u_A(x), r_A(x), v_A(x)\rangle : x \in X\} \quad (1)$$

Where $u_A, r_A, v_A : X \rightarrow [0,1]$, satisfy the condition $0 \leq u_A(x) + r_A(x) + v_A(x) \leq 3$ for all $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ denote the membership functions of truthfulness, indeterminate and falseness of x in A, respectively. For convenience a *Single-Valued Neutrosophic Number* (SVNN) will be expressed as $A = (a, b, c)$, where a, b, c [0,1] and satisfy $0 \leq a + b + c \leq 3$.

Definition 3: ([21]) A *neutrosophic number* N is defined as a number as follows:

$$N = d + I \quad (2)$$

Where d is called *determinate part* and I is called *indeterminate part*.

Given $N_1 = a_1 + b_1 I$ and $N_2 = a_2 + b_2 I$ two neutrosophic numbers, some operations between them are defined as follows, [15]:

$N_1 + N_2 = a_1 + a_1 + (b_1 + b_2)I$ (Addition);

$N_1 - N_2 = a_1 - a_1 + (b_1 - b_2)I$ (Difference),

$N_1 \times N_2 = a_1 a_2 + (a_1 b_2 + b_1 a_2 + b_1 b_2)I$ (Product),

$\frac{N_1}{N_2} = \frac{a_1 + b_1 I}{a_2 + b_2 I} = \frac{a_1}{a_2} + \frac{a_2 b_1 - a_1 b_2}{a_2(a_2 + b_2)} I$ (Division).

Neutrosophic Statistics extends the classical statistics, such that we deal with set values rather than crisp values, [8][13][19][20]. Neutrosophic Statistics can be used as a quantitative research method in sociology for testing social hypotheses.

Neutrosophic Descriptive Statistics is comprised of all techniques to summarize and describe the neutrosophic numerical data characteristics.

Neustrosophic Inferential Statistics consists of methods that permit the generalization from a neutrosophic sampling to a population from which it was selected the sample.

Neutrosophic Data is the data that contains some indeterminacy. Similarly to the classical statistics it can be classified as:

- *Discrete neutrosophic data*, if the values are isolated points.
- *Continuous neutrosophic data*, if the values form one or more intervals.

Another classification is the following:

- *Quantitative (numerical) neutrosophic data*; for example: a number in the interval [2, 5] (we do not know exactly), 47, 52, 67 or 69 (we do not know exactly);
- *Qualitative (categorical) neutrosophic data*; for example: blue or red (we don't know exactly), white, black or green or yellow (not knowing exactly).

The *univariate neutrosophic data* is a neutrosophic data that consists of observations on a neutrosophic single attribute.

Multivariable neutrosophic data is neutrosophic data that consists of observations on two or more attributes.

A *Neutrosophical Statistical Number N* has the form $N = d + i$.

A *Neutrosophic Frequency Distribution* is a table displaying the categories, frequencies, and relative frequencies with some indeterminacies. Most often, indeterminacies occur due to imprecise, incomplete or unknown data related to frequency. As a consequence, relative frequency becomes imprecise, incomplete, or unknown too.

Neutrosophic Survey Results are survey results that contain some indeterminacy.

A *Neutrosophic Population* is a population not well determined at the level of membership (i.e. not sure if some individuals belong or do not belong to the population).

A *simple random neutrosophic sample* of size n from a classical or neutrosophic population is a sample of n individuals such that at least one of them has some indeterminacy.

A *stratified random neutrosophic sampling* of the pollster groups are the (classical or neutrosophic) population by a strata according to a classification; afterwards the pollster takes a random sample (of appropriate size according to a criterion) from each group. If there is some indeterminacy, we deal with neutrosophic sampling [3].

3. THE STATISTICAL STUDY

This section includes two subsections. Subsection 3.1 contains the details of the design of this study. Section 3.2 contains the final results of the study.

3.1. Design of the study

The study was carried out in the annual felling plot (PCA in Spanish) - 2004 that is part of the administrative division of the General Forest Management Plan, located in the native community of Chamiriari-Lot B that occupies the territory of the district of Satipo, with the following characteristics:

Department	Province	Districts	Lot	Percentage Distribution	Area per Lot (ha)	Perimeter in m.
Junín	Satipo	Río Tambo	A	64.00%	5066.30	35900.00
		Satipo	B	36.00%	3217.00	28850.00
Total				100.00%	8283.30	64750.00

Table 1. Political location, surface area by districts and territorial lots.

In order to carry out the research, in the first place, the collection of primary and secondary information was carried out. Then, for field data collection, the productive forest of the annual felling plot (PCA) 2004, which is part of the administrative division of the General Forest Management Plan of the native community of Chamiriari-Lot B, was previously stratified into two Altitudinal soils, low and high hill, corresponding to two life zones of the aforementioned PCA (transitional dry forest to tropical humid forest and tropical premontane humid forest). Two temporary sampling plots were established taking as a reference the methodology of Toledo et al. ([22]) and Phillips et al. ([17]); the data were taken through exploratory inventory with the following characteristics:

The population was 372.87 ha of forest with timber forest resources located in Block B–Chamiriari Sector (PCA2004).

Two samples of 100mx100m (1 ha) were selected by forest type, 2 ha of intervened forest plus 2 ha of non-intervened forest, each sample with 2 subplot of sampling of 50mx20m selected for the evaluation of tree species classified in 2 tree size categories, larger than 10 cm in diameter. For the evaluation of the disturbances, the subplots of rectangular shape and 10mx10m (0.10 hectare) were a total of 50; designed to evaluate trees less than 9.9 cm in diameter to less than 2 m in height, taking as a reference the methodology of Toledo et al. ([22]).

To evaluate the impacts of timber harvesting on abundance, frequency and dominance, the methodology of Toledo et al. ([22]), previously primary and secondary information was reviewed; then 100mx100m temporary sampling plots (PMT in Spanish) were selected, where subplots were installed which were categorized according to the size of the plants (A, B, C, D and E). For the first objective, the subplots of categories A and B were used and to evaluate the impact on the structure and composition of the arboreal understory of 9.9 cm DBH up to trees <5 cm DBH <2 m height, there were used the dimensioned subplots of categories C, D and E. The categories, dimensions and other characteristics are detailed in the following table:

Category	Subplot dimensions	Plant size	Sample number	Sample size
A	20mx50m	20 cm DBH	4	0.4 ha
B	20mx25m	10 – 19.9 cm DBH	4	0.2 ha
C	10mx1m	5 – 9.9 cm DBH	4	0.04 ha
D	10mx5m	< 5 cm DBH >2 m height	4	0.02 ha
E	4mx4m	< 5 cm DBH < 2 m height	4	64 m^2

Table 2. Categories, size of subplots and other characteristics.

The 2004 annual felling plot of an area of 372.86 ha was selected, partially exploited, based on secondary information from the POA such as reports of activities of the PCA, maps of the administrative division of the PCA, of species dispersal of community title, administrative division of the new Forest Management Plan and PCA-IC (year 2015), approved by the Forest and Wildlife Service-SERFOR and images of the Geographic Information System (GIS) version 2012.

The delimitation of the research plots consisted of dividing the area of the annual felling plot (PCA) 2004 into square plots of 100mx100m after stratification in altitudinal soil A and B – low and high hill respectively, considering the topographic characteristics, slope, intervened areas and ecological soils according to the ecological map, prepared by SERFOR, [6][18]. Then, four sampling plots of 1.0 ha (100mx100m) were randomly selected, two per altitudinal soil and type of forest (intervened and not intervened), one plot of "intervened forest" and another of "non-intervened forest" intervened with characteristics of the Temporal Sample Plots (PMT).

Then, in each PMT, 2 subplots of 20mx50m were demarcated and another two for the 4 additional categories of the study, taking as a reference the methodology of Toledo et al ([22]). We proceeded with the inventory of forest species of each selected subplot, the compilation of qualitative and quantitative information, such as species registration, quantity, diameter, commercial height and total. Data were taken from individuals of timber importance, from the category under 2m in height and under 5cm DBH to individuals > 20 cm DBH. In the 4mx4m square subplots, individuals less than 5cm DBH and less than 2m in height were evaluated.

Botanically known species and other unidentified tree species of the group known as "ordinary oak" were located. For this, we proceeded with the collection of samples, assembly and preservation of samples following the herborization methodology of Marcelo et al. [12]. The main characteristics were photographed to facilitate botanical identification. In the botanical determination of the largest number of species, support was received from the person in charge of the herbarium of the Faculty of Agrarian Sciences of the National University of the Center of Peru. Likewise, the other species were sent to the Herbarium of UNA – La Molina and Universidad Nacional Mayor de San Marcos.

To determine the effect of timber use on the structure and composition of the arboreal understory, we applied the second objective, the same steps of the Museum / CIMAE / Missouri Consortium methodology cited by Toledo et al. ([22]), in this case, 50 subplots of 10mx10m were established with the characteristics of categories C, D and E by type of forest: 25 subplots of the "intervened" forest and 25 subplots of the "no intervened ", chosen at random and delimited based on the mapping of the cartographic information of the GIS. The characteristics are detailed in the following table:

Category	Subplot dimensions	Plant size	Sample number	Sample size
C	10mx10m	5 – 9.9 cm DBH	25	0.250 ha
D	10mx5m	< 5 cm DBH >2 m height	25	0.125 ha
E	4mx4m	< 5 cm DBH <2 m height	25	0.040 ha

Table 3. Categories, size of subplots and characteristics of the plants

In the first place, the “opening of a clearing” or “clearings” in the harvesting forest, natural fall of trees and the clearings caused by forest harvesting activities such as: construction of roads, log yards, camping and logging was classified as a “disturbance”. Then, the evaluation was carried out in the three categories of subplots (C, D and E) of the five installed, in total 25 subplots of 10mx10m were evaluated for the "intervened forest" and 25 subplots of 10mx10m for "undisturbed forest" taking into account the main dasometric variables such as height and diameter. The subplots were selected according to the characteristics of distribution, topographic and forest extraction activities of the 2004 POA, after stratification by forest type. To analyze the effects of forest harvesting, the disturbances were classified into seven categories:

Category	Type of disturbance	Characteristics
I	No disturbances	No clear opening
II	Partial natural disturbance	Clear less than 50% of the forest due to natural fall of trees
III	Total natural disturbance	Clearance greater than 50% of the forest due to natural fall of trees
IV	Partial disturbance by road	Claire due to the construction of a forest use road, less than 50% of the forest area
V	Total disturbance by road	Claire due to the construction of a forest use road, greater than 50% of the forest area.
VI	Partial disturbance due to pruning	Clear due to tree felling, less than 50% of the forest area.
VII	Total disturbance due to pruning.	Clear due to tree felling, greater than 50% of the forest area.

Table 4. Category, type of disturbances and characteristics.

The results obtained for both specific objectives were compared with an “undisturbed forest” located in the same selected annual felling plot; likewise, the plots and subplots were evaluated in the same way as the intervened forest.

To evaluate the effects of timber harvesting on the abundance, frequency and dominance of trees greater than 10cm DBH of the productive forest of the native community of Chamiriari - PCA 2004 and less than 9.90 cm DBH, the dasonomic data by type of forest, “intervened” and “not interve.ned” were processed using the Microsoft Excel 2010 program and for the analysis of the variance of the treatments the SPSS23 and MINITAB programs were used. To determine the effect of forest use on the structure and composition of the arboreal understory, trees less than 9.9 cm DBH after forest use in relation to the formation of clearings or disturbances, was analyzed considering the seven types of disturbances and three plant size categories C, D and E that correspond to the vegetation of greatest interest for sustainable forest management.

In this article we worked with data values in the form of intervals, due to the difficulty of the exact count of the trees. That is why it was necessary to apply Tukey's test to interval data. Tukey's test is based on the difference between the J means. If the difference of the J(J-1)/2 possible comparisons exceeds a value called the Least Significant Difference LSD, then these means are considered to be significantly different, [1].

4. RESULTS OF THE STUDY

In Table 5 of the Tukey's mean comparison test of the effect of harvesting on dominance by forest type (intervened and not intervened), the highest mean was found for the non-intervened forest ([1.42023, 1.46298] m^2); which means a greater impact on the "intervened forest" due to harvesting; results that coincide with the greatest impacts of forest extraction in the tropics, as it is argued in [10]. They are related to the investigations of Gálvez [11], that affirms "the proportion of species of interest with respect to the total, in terms of abundance and AB is considerably reduced according to post-harvest studies".

The support for calculation was Minitab, which is a software containing statistical packages easy to use by any user with a minimum knowledge of statistics. Also, Excel and SPSS3 were used. SPSS is a statistical package very popular in social sciences' community.

Forest type	N	Mean	Cluster
Without intervention	[46, 52]	[1.42023, 1.46298]	A
With intervention	[48, 51]	[0.72245, 0.74958]	B

Table 5. Tukey's mean comparison test of the impact of timber harvesting on dominance (intervened and non-intervened forest)

In Table 6, from the test of comparison of means of the impact of timber harvesting on dominance (intervened and non-intervened forest), the non-intervened forest resulted with the highest average ([0.17955, 0.217711] m^2 AB/ha) due to the greater occupation in the plot, which means a greater impact on the intervened forest, which coincides with investigations and statements about the impact of forest extraction in the tropics, with mechanized operations, logging and other field operations that workers do in a careless and harmful way, which affects trees with smaller diameters, as argued in Camacho [7].

Forest type	N	Mean	Cluster
Without intervention	[54, 62]	[0.17955, 0.217711]	A
With intervention	[55, 63]	[0.123390, 0.17964]	B

Table 6. Tukey's mean comparison test of the impact of timber harvesting on dominance by forest type (intervened and not intervened), trees with 10 - 19.9 cm DBH.

In Table 7, it is observed that the altitudinal soil A, low hill, has a higher average dominance ([0.200449, 0.217242] m^2 AB/ha) with respect to the altitudinal soil B. There is a significant difference as a result of the type of forest extraction and the ecological characteristics of the two altitudinal soils located in life zones of transitional dry forest to tropical premontane humid forest (denoted by "bs-PT *") and the other tropical premontane humid forest (denoted by "bh- PMT"), which coincides with the life zones of the community, determined by SERFOR cited in [18]. The dominance differences coincide with investigations on the effect of forest extraction in the tropics of Toledo et al. ([22]) and FAO [10]. Equally, the lower dominance coincides with other primary or remnant forests.

Forest type	N	Mean	Cluster
Altitudinal soil A	[60, 64]	[0.200449, 0.217242]	A
Altitudinal soil B	[59, 61]	[0.153732, 0.153858]	B

Table 7. Tukey's mean comparison test for dominance by altitudinal soil A and B, trees with 10 – 19.9 cm. DBH.

5. DISCUSSION AND CONCLUSION

This article was dedicated to expose the results of statistically studying the productive forest of the native community Chamiriari, Peru. This study made it possible to identify possible inefficiencies in the felling of trees, ecological damage and unwanted intrusion in the community of this native people. Due to the difficulty involved in carrying out an accurate count of the plant specimens, the sample data are expressed in an interval way, which implies the need to use the Neutrosophic Statistics, in this case the Tukey's test adapted to intervals.

The conclusions we reached were the following:

1. The impacts on the abundance of species and families of trees greater than 20 cm DBH, in the 2004 annual felling plot, did not show significant differences between altitudinal soils (high hill: 900-1000 masl) and (low hill: 600 - 700 masl), types of forests (intervened and non-intervened forest) and in the interaction.
2. The abundance in trees greater than 20cm DBH, is represented by potential species, in high hills of the "intervened forest" and "not intervened" generally by *B. alicastrum*; in the lower hill of the "intervened forest" by *Pseuldomendialaevis* and in the "non-intervened forest" by both *Pseuldomendia rigida* and *P. amazonica*.
3. In both types of forest and altitudinal soils, the predominance of heliophytic species is evidenced rather than sciophytic and the loss of valuable species such as *Swietenia macrophyla* (mahogany) due to the intensity of the use that influenced the dominance (AB/ha) resulting in being statistically significant, with a higher average being the "undisturbed forest".
4. In trees with 10–19.9 cm DBH, the abundance of species did not show significant differences between altitudinal soils, forest types and in the interaction. There is no dependence on the frequency of species and forest type.

5. Impacts on trees less than 9.9 cm DBH by categories (“C” of 5.0 -9.9 cm DBH; “D” of <5.0 cm DBH and 2.0 m height and “E” of <5.0 cm DBH and <2.0 m height), with higher percentages were “partial clearing by felling” in “C” and lower in category“E”; therefore, the main cause was forest use (partial and total logging).
6. According to the type of disturbance in the “intervened forest”, the highest percentages were “partial clearing due to felling” followed by “natural clearing” and the lowest in “partial clearing by road or log yard”. On the contrary, in the “non-intervened forest”, 64.47% of the plots were “undisturbed”. There is no dependence between the types of clearings by size category of the tree forest coppice. Therefore, the magnitude of the damage is directly related to the intensity of harvesting and not to the type of disturbance.
7. We observed the abundance of trees of the smaller size categories C, D and E (<9.9 cm DBH), at the level of the two types of PCA choline, the little or minimum presence of valuable species.
8. It is the first time that such an exhaustive and rigorous study has been carried out in Peru, where statistical mathematical tools are used on the industry of timber trees in an area of the country.
9. This study is exclusively academic and scientific at the Universidad del Centro del Perú, we recommend to inform to the economical and political authorities of the region, about this results, to make the necessary decisions to improve this ecological framework.

These results corroborate the conclusions in Wagner ([23]); Toledo ([22]); Marcelo et al. ([12]), it is that there is not a rational exploitation of the forest, so, this is a universal behavior which must alarm authorities of countries which have a considerable forestry wealth. That is to say, always the non-intervened regions have logically better ecological results. The point is also, that regions should be intervened in a moderated and scientific way, such that to avoid an overexploitation, which damages considerably the ecological equilibrium, always maximizing the economical profits.

See that the comparison of our study with Gálvez’s yielded to the same conclusion ([11]), that is: “the proportion of species of interest with respect to the total, in terms of abundance and AB is considerably reduced according to post-harvest studies”, as we pointed out above.

Our trends in future works are twofold; one trend is to enhance the awareness of authorities about legal necessities to protect the forest without affecting the commerce and wood industry. The other trend is to generalize this study to other Peruvian regions by using this methodology. This study did not include some plots, thus it is a drawback, however we demonstrated the utility of Neutrosophic theory for making decision in environmental problems. This approach opens the door to an unexplored theoretical methodology to enrich the forestry framework.

The advantage of our approach over the other ones based on classical statistics is that the collected data are more accurate, because we took into account the imprecision of these data. Imprecision is intrinsic to real life phenomena. This is the main difference with respect to other studies like in Wagner ([23]); Toledo ([22]); Marcelo et al. ([12]).

RECEIVED: SEPTEMBER, 2022.
REVISED: JANUARY 1, 2023

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