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Editorial

Dear reader:

Scientific publishing production increases in the country both, in quality and organization, this year we celebrate the creation of Scielo-Ecuador, where quality scientific production gets more visible; and shows the interest of the state in its improvement and promotion. La Granja, Journal of Life Sciences, is part of this select collection and applauds this initiative aware of the importance of adequate transmission of the information born of scientific research.

In this way, and with pleasure we present the thirtieth number of our collection starting with the themes of biodiversity conservation, a topic of current concern. In this case, Leonardo Ordóñez-Delgado and his team of researchers from the Private Technical University of Loja analyze the state of knowledge of the Podocarpus National Park. Along the same lines, in an alliance between the Technological University Indoamerica and the Iberoamerican University, Patricio Yánez and his team analyze the state and conservation perspectives of the Spectacled bear.

From the point of view of sustainable agriculture, Víctor Sánchez and José Zambrano from INIAP, analyze the impact of modern technologies on agricultural yield and production. While, from the field of veterinary sciences applied to cattle, Orlando Quinteros and his team, in an alliance between IKIAM and the Universidad del Rosario in Argentina, analyze the crossing of different bovine breeds and their impacts on growth patterns. While Santiago Miranda and Cristian Albuja from the Universidad Nacional de Córdoba in Argentina and Central University in Ecuador, analyze the effects of subclinical mastitis in dairy herds. Next, in a variety of topics, we present an analysis of the aggressiveness of natural phenomena, Mercy Ilbay-Yupa leading the researchers of the Agrarian University La Molina of Peru, the Technical University of Cotopaxi of Ecuador and the Geophysical Institute of Peru presents a study of the rainy precipitation over the Guayas River Basin. On the other hand, and in the field of natural products, the analysis of Sacha Inchi seed oil, led by Luis Romero and researchers from the University of Guayaquil, is presented. In addition, in the water treatment topic, researchers from the Salesiana Polytechnic University-UPS and the University of Guayaquil, led by Lenin Ramírez, present innovative techniques for the detection of antibiotics in river bodies.

To close with a flourish, two articles on the theme of sustainable development are presented, the first analyzing the sustainability of small milk producers into the Andean zoner, led by Christian Franco and his team of researchers from the Technical University of Ambato , while from the UPS together with the Military Geographic Institute, Gustavo Navas and his team present us with a spatial analysis of the coverage in areas of poverty of the Millennium Education Units.

We are sure that this number will contribute to the scientific work of the country and will be useful in your studies and research.

Cordially,

Ph.D Ignacio de los Ríos Carmedano
Universidad Politécnica de Madrid
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Review / Reseña bibliográfica
CONSERVATION

Systematic review of the state about the knowledge of the Vertebrates of the Podocarpus National Park

Revisión sistemática del estado del conocimiento de los Vertebrados del Parque Nacional Podocarpus

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Resumen

El Parque Nacional Podocarpus es una de las áreas protegidas de mayor importancia y tamaño de los Andes Tropicales del sur de Ecuador. Desde hace mucho tiempo esta reserva ha sido el centro de atención de un importante número de investigadores que, entre otros elementos, han tratado de explicar diversos tópicos relacionados a la fauna que alberga. Sin embargo, hasta el año 2018 no se contaba con una sistematización adecuada de estas investigaciones. Con el objetivo de establecer el nivel de conocimiento alcanzado sobre los vertebrados del área protegida, se estructuró un proceso metodológico para la recopilación, sistematización y análisis de la información existente sobre esta temática. Se generó una base de datos de los estudios recopilados, con un total de 128 trabajos: 64 sobre aves, 26 de mamíferos, 22 sobre anfibios, 6 sobre reptiles, 2 sobre peces y 8 investigaciones que abarcan más de un grupo faunístico al mismo tiempo. El período con la mayor cantidad de publicaciones corresponde a la década del 2000. De las 16 localidades identificadas en donde se han efectuado trabajos sobre los vertebrados de esta área protegida, destacan con el mayor número de investigaciones Tapichalaca y Cajanuma, con 33 y 24 estudios, respectivamente. Esta información constituye la primera aproximación respecto del nivel de investigación alcanzado sobre los vertebrados que mantiene y protege este parque nacional.
Palabras clave: Fauna, aves, anfibios, reptiles, mamíferos, peces, Parque Nacional Podocarpus, Ecuador.

Abstract

The Podocarpus National Park is one of the most important and biggest protected areas of the Tropical Andes of southern Ecuador. This reserve has been the center of attention for a large number of researchers who, among other elements, have tried to elucidate various topics related to its fauna. However, there has not been adequate systematization of these investigations so far. In order to establish the level of knowledge reached on the vertebrates of the protected area, a methodological process was structured for the compilation, systematization and analysis of existing information on this subject. A database of the collected studies was generated with a total of 128 works: 64 on birds, 26 on mammals, 22 on amphibians, 6 on reptiles, 2 on fish and 8 research works involving more than one faunistic group at the same time. The period with the largest number of publications corresponds to the decade of the 2000. Among the 16 locations identified where work has been done on the vertebrates of this protected area stand out Tapichalaca and Cajanuma with the largest number of investigations, with 33 and 24 studies, respectively. This information constitutes the first approximation regarding the level of research achieved on vertebrates that maintains and protects this national park.
Keywords: Fauna, birds, amphibians, reptiles, mammals, fish, Podocarpus National Park, Ecuador.

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1 Introduction

Despite its small area (283561 km^2), Ecuador is considered a benchmark in the area of biodiversity, because its richness of species, ecosystems and high levels of endemism, among other factors, have made the country to be recognized as one of the megadiverse nations (Mittermeier, 1997). Ecuador is home to at least 4718 species of vertebrates, including 436 species of mammals (Tirira, 2018), 1626 bird species (Freile and Restall, 2018), 609 species of amphibians (Ron et al., 2019), 473 species of reptiles (Torres-Carvajal et al., 2018), 635 species of amphibian aquaculture fish, and 939 marine and estuarine (Jiménez-Prado, 2010). In addition, more than 17748 species of vascular plants have been reported in the national territory (Neill, 2012). Despite this remarkable reality, in 2014 36,25% of the country's species were threatened, placing Ecuador in the first place in terms of countries with threatened species in South America (UICN, 2014).

Among the strategies that the Ecuadorian State has used to address this problem is the creation and management of a network of public, private and community protected areas, covered by the Constitution of the Republic (Constituyente, 2008). Protected areas are defined as the preferred conservation strategy (Primack et al., 1998; Dudley and Stolton, 2010; Watson et al., 2014) and have evolved from an exclusive vision of biodiversity conservation to more diverse objectives, including the provision of social and economic benefits (Watson et al., 2014).

Podocarpus National Park (PNP), located between the provinces of Loja and Zamora Chinchipe, is one of these areas aimed at the conservation of biodiversity and maintenance of environmental services in the southern region of the country (Apolo, 2002; Calderón, 2002). This National Park is part of the "hotspot"Tropical Andes, the richest in biodiversity on the planet (Myers et al., 2000) and the main terrestrial ecoregion "Páramos de la Cordillera Central"(Dinerstein et al., 1995), present in Ecuador exclusively in the Southern Andes, and that is made up of a kind of small islands of High-Andean ecosystems, confined to the peaks of the central and internode mountains of the Andes at 3000 masl (Cuesta et al., 2005).

In addition, this protected area is located in the Huancabamba depression, the most important biogeographic barrier of the Andes for the distribution of species in the north-south (Duellman, 1979; Cuesta et al., 2005; Ordóñez-Delgado, 2011). Hence, this area is considered as a center of plant endemism called Huancabamba Region (Davis et al., 1997). Cuesta et al. (2005) state that the low similarity in the composition of flora and fauna of this area, with respect to the moors of the Andes located to the north can be attributed to this geographical element.

On the other hand, the area where the PNP is located overlaps the centers of endemism of the North Andes and Tumbes (Terborgh and Winter, 1983) and two bioclimatic currents converge, one coming from the Amazon with large amounts of humidity, and the other from the Pacifics, with the influence of dry winds coming from northern Peru (Ordóñez-Delgado, 2011). All these conditions along with their irregular orography have influenced the occurrence of various microclimates, habitats and niches, resulting in a great diversity of flora and fauna, as well as significant levels of endemism (Cuesta et al., 2005; Ordóñez-Delgado, 2011). This protected area, among others, is the focus of conservation efforts in the Southern Andes of the country for the contribution in environmental services to the region (Apolo, 2002). Three binational watersheds originate from the interior of the protected area: Catamayo-Chira, Mayo-Chinchipe and Zamora; inside is located the Lagunas del Compadre lake system, recognized as a Ramsar site (International important wetland) (Ordóñez-Delgado, 2011) and is constituted in the largest core area of the Podocarpus Biosphere Reserve El Condor, recognized in 2007 by UNESCO (Serrano, 2008).

All these elements have influenced the national and international scientific community to shown interest in the development of studies in this territory (Aguirre et al., 2002; Serrano, 2008). However, research carried out in the protected area has not had so far an adequate process of analysis and systematization to the extent that they do not know the level reached to the present day or the dynamics experienced throughout history. One of the initial steps to define what is known or unknown about a given topic is what is defined as the "state of knowledge analysis", which is conceptualized as "systematic analysis and the assessment of the knowledge generated around a field of research for a defined period"(Rueda, 2003). This work is based on this concept and is aimed at establishing the "state of knowledge.existing so far on the vertebrates that this protected area has, the topics that have been investigated around this group of fauna, the geographical location of the studies, existing information gaps and priority research lines in the future.

2 Materials and methods

2.1 Area of research

Podocarpus National Park (PNP) is located between Numbala and el Nudo de Sabanilla, on the border of the provinces of Loja and Zamora Chinchipe in southern Ecuador (Ordóñez-Delgado, 2011). It covers an area of 146280 ha and was officially declared on December 15, 1982 (Ministerial Agreement *No*. 0398, Official Journal.

No,404, January 5th 1983) (Ministerio de Agricultura, Ganadería y Pesca de Ecuador, 1983). Approximately 83 % of the territory of this protected area is part of the province of Zamora Chinchipe and 17 % is part of Loja. Its altitude range is distributed between 900 and 3650 masl (Aguirre et al., 2002). The temperature of the sector fluctuates between 20 and 25 °*C* in the lower (Amazon) zone and from 8 to 15°*C* in the Andean high zone (Maldonado and Numa, 2002) (Figure 1a).

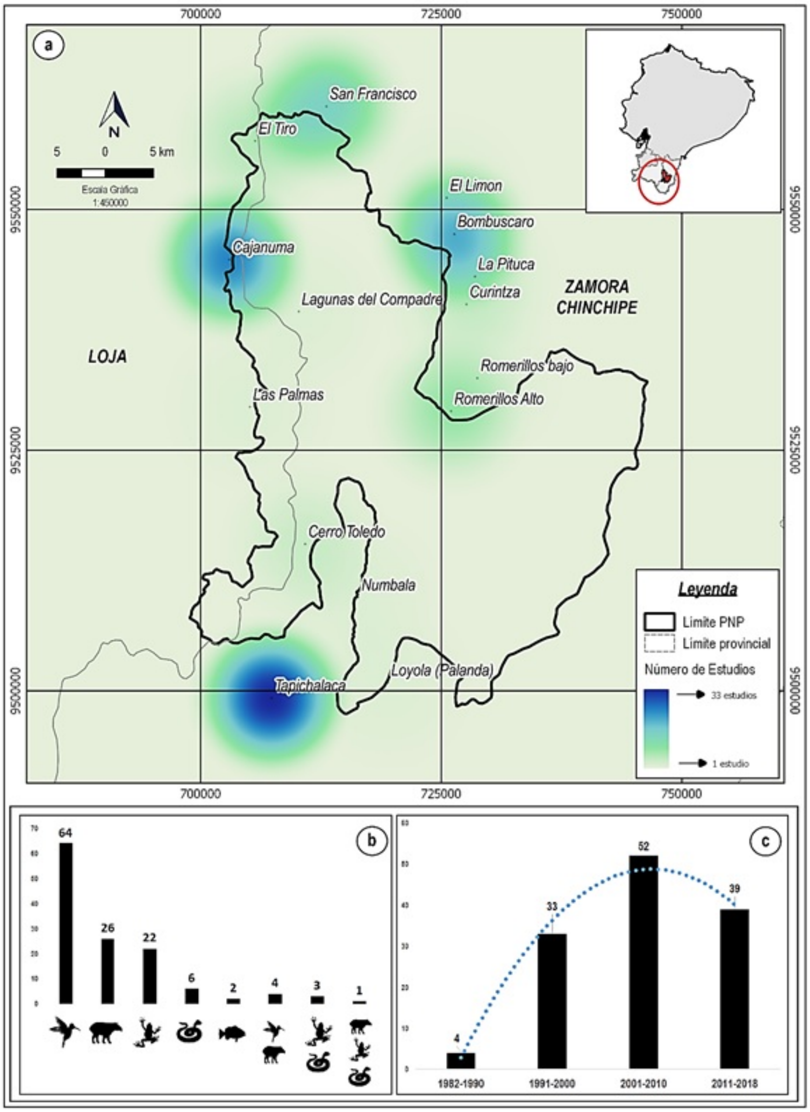

Figure 1. a) Graphical representation of geographical influence level of the vertebrate studies of the Podocarpus National Park. b) Number of studies per taxa. c) Number of studies by time range from the declaration of the protected area.

2.2 Methods

The process of collecting, analyzing and systematizing information included the following steps: The working area for the analysis included the entire national park, considering for this its official limits. However, because several investigated locations are immediately outside the boundaries of the site, it was considered to extend the analysis to the most immediate influential area. Search, collection, analysis and systematization of information on vertebrates was carried out in primary and secondary sources. As primary sources, scientific literature was used, among these, indexed or peer-reviewed publications, as well as books with ISBNs; grey literature as books or documents without ISBN but with scientific support (i.e., documents of recognized researchers in the field of work of the protected area and the subject matter covered in this document), in addition to undergraduate and postgraduate thesis of universities with online repositories.

As sources of secondary information, interviews conducted with researchers and entities linked to the protected area were included, among these: Universidad Técnica Particular de Loja, Universidad Nacional de Loja and/or researchers from NGOs and research entities who have carried out studies on the Podocarpus National Park and its surroundings. Finally, access was obtained to the database of scientific research managed by Coordination 7 of the Ministry of the Environment of Ecuador for this protected area. For the search of information in scientific databases, as well as in bibliographic repositories and indexed journals, a set of keywords were established in Spanish and English. After setting the keywords, other search optimization parameters were used, such as:

- Enclose the search keywords in quotation marks to search for an exact phrase.
- Use the plus sign (+) before the words of the topic to be investigated, so that all of these are taken into account in the web search.
- Use the 'OR' and 'AND' operators in uppercase between two keywords to find pages that contain any of these in their text.
- Use the 'Allintitle' command followed by the keywords which allowed to find documents with these words in their title.
- Use the 'Allintext' command before keywords to find investigations that include the words specified for the search.

The words used to search for information were: Podocarpus National Park. Fauna of Podocarpus National Park. Birds (mammals, amphibians, reptiles, fish) of the Podocarpus National Park. Vertebrates of the Podocarpus National Park. Name of the localities: Cajanuma, Tapichalaca, Bombuscaro, San Francisco, Cerro Toledo, Numbala, Vilcabamba, alone or added to the name of the protected area: Podocarpus National Park. Birds (or the name of each fauna group), the name of the localities described in the previous paragraph, and the name of the protected area.

These names were used because they are the most important access sectors to the protected area. All these phrases or words (except proper names) were translated into English to expand the search to that language. The above parameters were searched in databases and scientific repositories such as: Academia.edu, BioOne, Biodiversity Heritage Library, BirdLife International, Fauna Web Ecuador, Google Schoolar, ResearchGate, SciELO, Science Direct, Scopus, Semantic Scholar, Web of Science. On the other hand, the databases of undergraduate and postgraduate thesis of these universities were also used: Universidad Técnica Particular de Loja, Universidad Nacional de Loja, Pontificia Universidad Católica del Ecuador, Universidad Central del Ecuador and Universidad del Azuay.

An additional method of searching for information used was to take bibliographic references from the collected documents as a starting point to search for documents. If any of these references referred to studies carried out on vertebrates in the PNP and its immediate area of influence, the entire document was searched on the website or other source of information. A matrix was developed in Excel with the information obtained, which served as a database for the analysis of the information. This matrix consisted on the following items: Study number, family group, author, title, publication date, document type (article, thesis, book, report), area of knowledge (ecology, diversity, biogeography, conservation, taxonomy), location, coordinates and reference altitudes. For documents omitting the latter information, reference coordinates of localities near the study location were defined through a detailed review of the information mentioned in materials and methods of each document or by consulting experts. The information collected quantified the total number of studies, number of studies per family group, publications per year, geographical distribution and zoogeographic floors. Studies that considered more than one family group in the research, or two or more study locations were counted separately; i.e., whether a study covered birds and bats, it is counted as a separate multitaxa study, not as a bird study and one of bats, this in order to prevent the result of the number of investigations from being oversized.

The temporal analysis of the studies was carried out for decades, from the creation of the protected area (1983) until December 2018. The proposal of Albuja et al. (2012) was used for the distribution of studies with respect to the zoogeographic ecosystems of Ecuador, which correspond to a general classification of the fauna of the country according to its altitude distribution. Hence, according to the altitude range present in the protected area, the following zoogeographic ecosystems were included: subtropical or tropical (1000 to 2000 masl), temperate (2000 to 3000 masl) and High-Andean (>3000 masl). The "heat map"symbolization style was applied to the georeferenced locations using the QGIS software (QGIS, 2018), where the PNP wildlife studies were conducted, using the point weight containing the number of studies conducted at each site to determine the intensity of the map. Colors ranging from green (lower intensity) to blue (higher intensity) was used. It should be emphasized that the distinction of the taxa studied was not taken into account for the generation of this map.

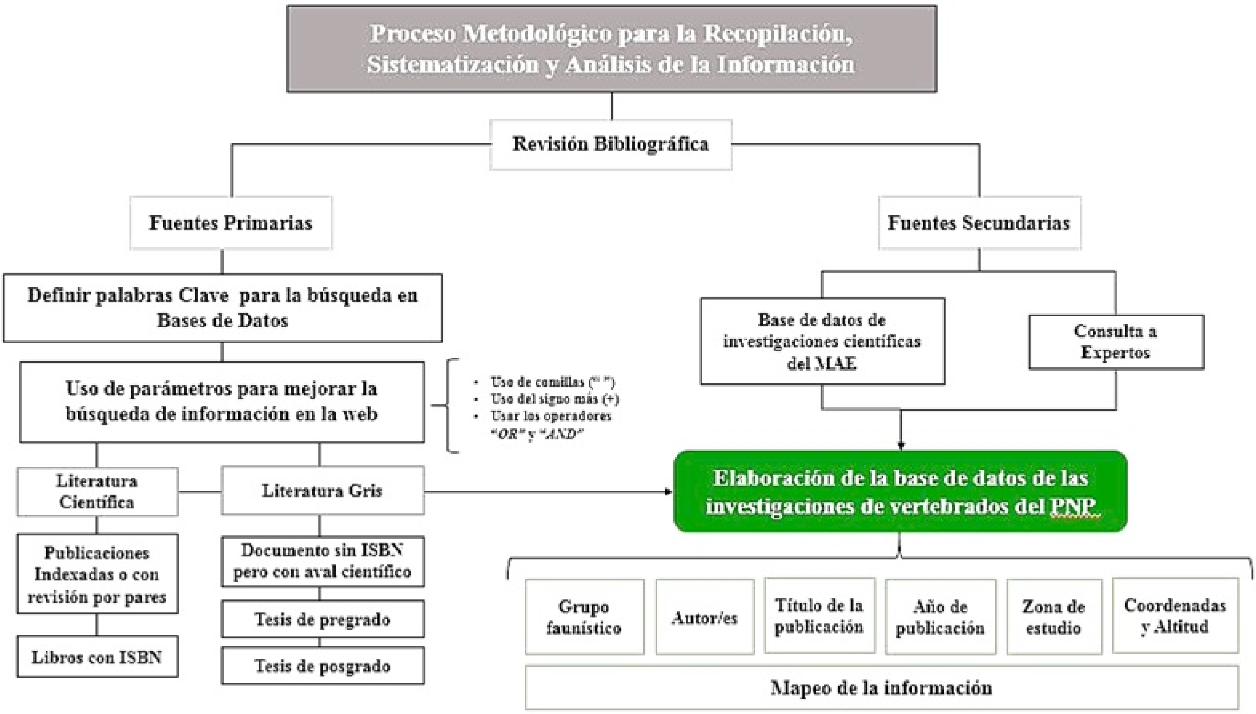

Figure 2. Scheme of the methodological process developed for the systematic analysis of the knowledge of the vertebrates of the Podocarpus National Park.

3 Results

3.1 Methodological scheme developed

The first result of this work is the methodological proposal for the collection, analysis and systematization of information. The resulting graphical schema of the developed process is proposed (Figure 2).

3.2 Number of studies

128 publications on vertebrates from Podocarpus National Park and its areas were collected. Out of these, 84 (66 %) correspond to scientific publications and 44 (34 %) to gray literature. From the total, 64 correspond to birds (50 %), 26 mammals (20 %), 22 amphibians (17 %), 6 to reptiles (5 %) and 2 to fish (2 %). Eight multi-tax studies were found: four on birds and mammals (3 %), three on amphibians and reptiles (2 %); and one study of mammals, amphibians and reptiles (1 %) (Figure 1b).

3.3 Number of publications per time range

Regarding the time range, the initial decade of creation of the protected area (1982-1990) constitutes the period with the lowest number of publications, which in the following decades increased significantly. However, in the current decade there is a decrease of at least 25 % in the number of research carried out in this region on vertebrates (Figure 1c).

3.4 Geographical distribution of the studies

Based on the analysis of the information collected, 16 locations studied for the protected area were identified, 15 correspond to individual areas and one assigned to studies covering the entire protected area. Out of the 128 publications identified, 89 (69 %) publications cover a single study location, 10 (8 %) cover two locations, 10 (8 %) studies with three locations (8 %); and 19 (15 %) researches covering the entire PNP (Figure 1a). However, if considering the number of researches in the area would stand out

Tapichalaca (n = 33) and Cajanuma (n = 24) as the areas with the greatest number of investigations conducted. It is followed by studies that cover the entire protected area PNP (n = 19), Bombuscaro (n = 18), San Francisco (n = 14) and Romerillos Alto (n = 7). While the rest of the localities have been studied in five research process or less.

3.5 Number of publications per zoogeographic floor

Regarding the distribution of studies based on the classification of the zoogeographic floors of Ecuador, it can be mentioned that the temperate climate (2000 to 3000 masl) constitutes the most studied altitude of the protected area, having 60 investigations in total. It is followed by the eastern subtropical floor (1000 to 2000 masl) with 35 investigations, and 21 investigations that cover the three zoogeographic floors present in the park (temperate, subtropical eastern and High Andean). Meanwhile, the highest floors have 12 investigations in total, 10 covering the eastern, temperate and sub-tempered floor, and two covering the tempered and High Andean floor (Figure 3).

3.6 Topics

Analyzing the studies by the area of research it was observed that the topics of ecology (n=51) and diversity (n=30) dominate over the rest, followed by publications on distribution (unusual registers and distribution range extensions) (n=18), conservation (n=15) and taxonomy (n=13), and finally a single study on bioacoustics conducted in the protected area (Flanagan, 1998) (Figure 4).

4 Discussion

Systematic information analyses have been widely used in medical-related fields (Urrútia and Bonfill, 2010; Manterola et al., 2013); however, as shown in this manuscript, this type of process presents the ease of being shaped and applied to other branches of knowledge by contemplating schematic lines of work. The method developed is similar to other existing methodological proposals, for example: Medina-López et al. (2010) or Manterola et al. (2013). This systematization is the first effort of its kind developed for a protected area of the country and proposes methodological guidelines (Figure 2) that can be easily replicated in other protected areas, or even in other processes or types of research.

On the other hand, it is indisputable the importance currently possessed by geographic information systems, since these tools allow to represent graphically the results of various investigations (Greene and Pick, 2012), reason for which the mapping of the information was generated for the purpose of demonstrating the degree of territorial influence of the research collected as well as the geographical and thematic gaps in the knowledge of existing vertebrates in the protected area. On the taxonomic groups studied, it can be noted that the reality found is similar to that of other latitudes. It is well known that birds and mammals are considered the best known taxonomic groups on the planet (Stotz et al., 1996; Larsen et al., 2012), fact that is also proposed for Ecuador (Albuja et al., 2012). This study corroborates this trend and shows that the most studied group of vertebrates of the PNP corresponds to birds (50 % of studies in the protected area), followed by mammals (20 %) (Figure 1a).

The interest in the existing fauna biodiversity in the territory corresponding to the PNP has a long data, this is evidenced by the visit of a significant number of researchers to this region from the American Museum of Natural History between 1854 and 1920 (Chapman et al., 1926; Anthony, 1922). However, after these works the research in this area was sporadic, being resumed from the seventies with the expeditions of Louisiana State University Museum of Zoology (LSUMZ); and increased from the late 1980s by the Zoological Museum of Copenhagen (ZMUC) (Bloch et al., 1991). These works based the interest in the area in the years following the declaration of the protected area. One of the most influential factors for this interest, mainly by the ornithological community, relies on the discovery of two bird species in this region in less than a decade (1992, 1997) (Krabbe et al., 1999; Coopmans and Krabbe, 2000). Elaenia Tropandina (*Myiopagis olallai*) was discovered in the Bombuscaro sector in 1992 (Coopmans and Krabbe, 2000) and Grallaria Jocotoco (*Grallarialy ridgei*) was discovered in 1997 in the Tapichalaca sector, in the south of the PNP (Krabbe et al., 1999). In addition, species such as Cotinga Ventricastaña (*Doliornis remseni*) were first registered in the country in the Cajanuma sector in 1989 (Robbins et al., 1994), all in a territory not exceeding 147 000 ha.

Among others, the importance on the biodiversity of the sector that influenced the NGO Nature Culture International in the late 1990s to establish a scientific station on the northern edge of the protected area, in which, with funding from the German Foundation for Scientific Research, a number of research actions are conducted (Kiss and Bräuning, 2008), which are maintained to this day. The factors exposed contributed to the number of research published for the protected area from the 1990s to increase significantly. Although, currently (2011-2018), there has been a decrease of at least 25 % in this type of work (Figure 1c). Much of the eastern site of the study area is forests and pristine moors, a state attributed to the wild and the difficult access to them (Remache et al., 2004; Kiss and Bräuning, 2008); hence, there are still important areas without information about the biological wealth in the protected area (Figure 1a).

Albuja et al. (2012) propose that information on Ecuador's fauna be dispersed and presents difficulties in its access. This work takes place after 35 years of the official declaration of this protected area and shows that there is a significant number of publications around the object of study, but these are mostly scattered and are not available to institutional actors linked to the management of the area, mainly for the decision-makers of the Environment Ministry of Ecuador.

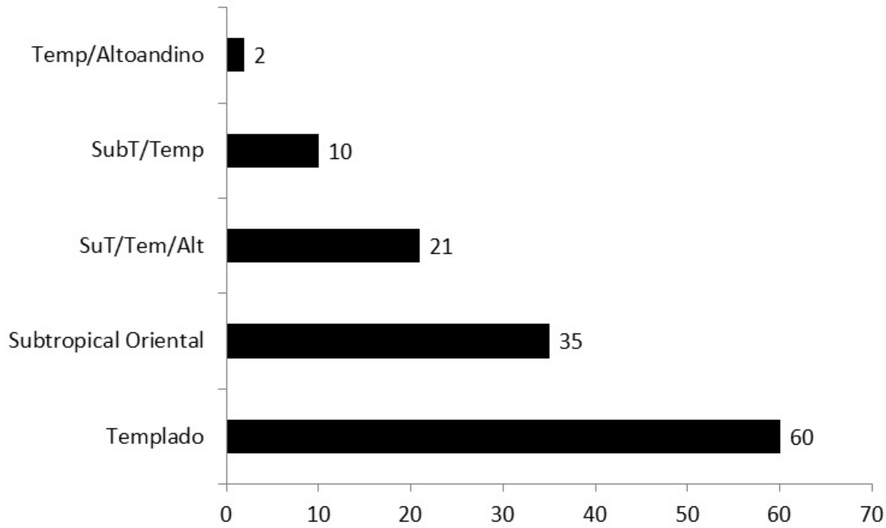

Figure 3. Number of publications per zoogeographic floor. Codes: Temp/High Andean: Temperate/ High Andean, SubT/Temp: Subtropical Western/Temperate, SubT/Tem/Alt: Subtropical Western/Temperate/ High Andean.

This analysis allows to define some geographically and thematically research priorities for the protected area. PNP fish and reptiles require priority attention, as they have few studies so far. In addition, it is necessary to increase knowledge about the biodiversity and ecology of the fauna in the center and southeast of the park. The results show that most of the studies carried out on vertebrates in the sector have been developed on their edges or their immediate area of influence, being the Lagunas del Compadre lake system the one that has a study on amphibians in the sector. Extensive internal territories of the park show lack of research, mainly in the center and southeast of the area. However, it is worth noting that access to these sites is difficult, hence significant work efforts will be required to fill these gaps of information. On the other hand, topics with significant development potential on the site, such as bioacoustics, should have new efforts of work or systematization. This is because there are currently online platforms (e.g. Xeno-Canto, Internet Bird Collection) that host an important collection of records (photographic and auditory) of birds of this protected area; however, this material has not been systematized or analyzed in the context.

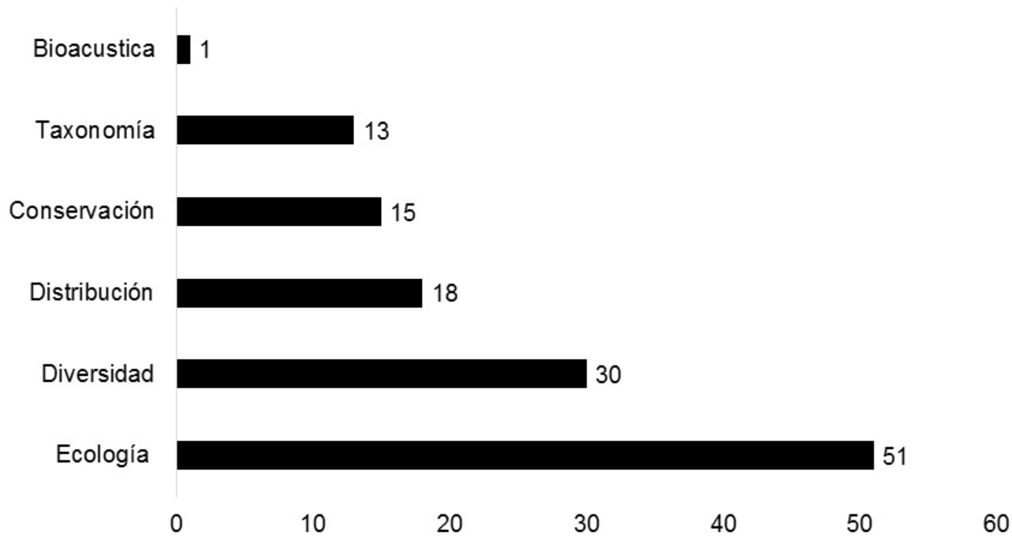

Figure 4. Number of publications by topics on the vertebrates of the Podocarpus National Park.

5 Conclusions

This work is a baseline on vertebrate research carried out in this National Park, which will allow to prioritize and monitor future efforts in this area. While systematic information analyses the collection and systematization of existing literature in scientific databases, this paper highlights the importance of including local gray references. 34 % (n=44) of the studies that make up the results of this work correspond to gray literature, hence, the importance in the collection and inclusion of this information in this type of revisions.

The proposed methodology is a valuable opportunity for entities in charge of one or more protected areas, its application is simple, wwith minimal cost, and adaptable to various themes and realities. It can be developed by state entities such as the Ministry of the Environment, Decentralized Autonomous Governments or by community or private protected areas. It is clear that knowledge of the research processes carried out in a given sector will strengthen the management of the area.

References

Aguirre, Z., Madsen, J., Cotton, E., and Balslev, H. (2002). Botánica austroecuatoriana: Estudios sobre los recursos vegetales en las provincias de el oro, loja y zamora chinchipe. *Ediciones Abya Yala, Quito. EC*, pages 1–28. Online:https://bit.ly/2Ywe5wd.

Albuja, L., Almendiariz, C., Montalvo, L., Cáceres, F., Román, C., and Luisauthor, J. (2012). *Fauna de vertebrados del Ecuador*. Escuela Politécnica Nacional. Online:https://bit.ly/2ZGLK2J.

Anthony, H. (1922). Preliminary report on ecuadorean mammals. no. 2. *American Museum Novitates*, (32):9. Online:https://bit.ly/2yKLxzE.

Apolo, W. (2002). *Botánica Austroecuatoriana. Estudios sobre los recursos vegetales en las provincias de El Oro, Loja y Zamora Chinchipe*, chapter El Parque Nacional Podocarpus: Perspectivas de conservación y desarrollo, pages 411–431. Editorial Abya Yala, Quito.

Bloch, H., Poulsen, M., Rahbek, C., and Rasmussen, J. (1991). A survey of the montane forest avifauna of the loja province, southern ecuador. *ICBP Study Reports*, (49):Online:https://bit.ly/2ZGMtRv.

Calderón, S. (2002). *Botánica Austroecuatoriana Estudios sobre los recursos vegetales en las provincias de El Oro, Loja y Zamora-Chinchipe.*, chapter El Parque Nacional Podocarpus y fundamentos legales que lo respaldan, pages 433–451. Abya-Yala, Quito.

Chapman, F., Cherrie, G., Gill, G., , O'Connell, G., Tate, G., Murphy, R., and Anthony, H. (1926). *The distribution of bird-life in Ecuador: A contribution to a study of the origin of Andean bird-life*. Order of the Trustees, American Museum of Natural History. Online:https://bit.ly/2KlLDo0.

Constituyente, A. N., editor (2008). *Constitución Política de la República del Ecuador.* Tribunal Constitucional de Ecuador. Online:https://bit.ly/2yOeU3L.

Coopmans, P. and Krabbe, N. (2000). A new species of flycatcher (tyrannidae: Myiopagis) from eastern ecuador and eastern peru. *The Wilson Bulletin*, 112(3):305–313. Online:https://bit.ly/2YSQv84.

Cuesta, F., Baquero, F., Ganzenmuller, A., Rivera, B., Sáenz, M., Riofrío, G., Larrea, M.and Cisneros, R., and Beltrán, K. (2005). Evaluación ecorregional de los páramos y bosques montanos de la cordillera real oriental: componente terrestre. ecociencia. *The Nature Conservancy. Quito, Ecuador*, page Online:https://bit.ly/2TvhNiP.

Davis, S., Heywood, V., Herrera-MacBryde, O., Villa-Lobos, J., and Hamilton, A. (1997). *Centres of Plant Diversity: A Guide and Strategy for Their Conservation*, volume 3: The Americas of *Cambridge. Onlne: https://bit.ly/2YUdVu2*. IUCN Publications Unit.

Dinerstein, E., Olson, D., Graham, D., Webster, L., Primm, A., Bookbinder, M., and Ledec, G. (1995). *A conservation assessment of the terrestrial ecoregions of Latin America and the Caribbean*. The World Bank. Online:https://bit.ly/2TvBYwU.

Dudley, N. and Stolton, S. (2010). *Arguments for protected areas: multiple benefits for conservation and use*. Routledge. Online:https://bit.ly/2GSW0xK.

Duellman, W. (1979). The herpetofauna of the andes: patterns of distribution, origin, differentiation, and present communities. *The South American herpetofauna: its origin, evolution, and dispersal*, 7:371–459. Online:https://bit.ly/2M4Mn3f.

Flanagan, J., editor (1998). *Aves de Cajanuma: Parque Nacional Podocarpus. Vocalizaciones de algunas especies del bosque nublado montañoso tropical*. Fundación Ecológica Arcoíris, Loja-Ecuador. Online: https://bit.ly/2M7Rboy .

Freile, J. F. and Restall, R. (2018). *Birds of Ecuador*. Helm, Bloomsbury Publishing Plc. Online:https://bit.ly/2OOoBum.

Greene, R. and Pick, J. (2012). *Exploring the urban community: A GIS approach*. Prentice Hall. Online:https://bit.ly/2yM1XrI.

Jiménez-Prado, P. (2010). *Fauna de Vertebrados del Ecuador*, chapter Peces de Ecuador, pages 17–94. Universidad Técnica Particular de Loja, Loja-Ecuador.

Kiss, K. and Bräuning, A. (2008). *El bosque húmedo de montaña: investigaciones sobre la diversidad de un ecosistema de montaña en el Sur del Ecuador*. Deutsche Forschungsgemeinschaft. Online:https://bit.ly/2SGn1Z0.

Krabbe, N., Agro, D., Rice, N., Jacome, M., Navarrete, L., and M., S. (1999). A new species of antpitta (formicariidae: Grallaria) from the southern ecuadorian andes. *The Auk*, 116(4):882–890. Online:https://bit.ly/2GUqM9n.

Larsen, F., Bladt, J., Balmford, A., and Rahbek, C. (2012). Birds as biodiversity surrogates: will supplementing birds with other taxa improve effectiveness? *Journal of Applied Ecology*, 49(2):349–356. Online:https://bit.ly/2YRHQ63.

Maldonado, N. and Numa, P. (2002). Clima y vegetación de la región sur del ecuador. *Aguirre J, Madsen JE, Cotton E, Balslev, editores. Botánica Austroecuatoriana. Quito: Ediciones Abya Ayala*, pages 1–28.

Manterola, C., Astudillo, P., and Arias, E. (2013). Revisiones sistemáticas de la literatura. qué se debe saber acerca de ellas. *Cirugía Española*, 91(3):149–155. Online:https://bit.ly/2TqxA3L.

Medina-López, C., Marín-García, J., and Alfalla-Luque, R. (2010). Una propuesta metodológica para la realización de búsquedas sistemáticas de bibliografía (a methodological proposal for the systematic literature review). *WPOM-Working Papers on Operations Management*, 1(2):13–30. Online:https://bit.ly/2M86Dkr.

Ministerio de Agricultura, Ganadería y Pesca de Ecuador (1983). Declaratoria del parque nacional podocarpus. acuerdo ministerial n° 0398, registro oficial. n_0 404, 5 de enero de 1983. In *Registro Oficial de Ecuador*, Quito.

Mittermeier, R. (1997). *Megadiversity: Earth's biologically wealthiest nations*. Agrupacion Sierra Madre. Online:https://bit.ly/2yMlZm4.

Myers, N., Mittermeier, R., Mittermeier, C., Da Fonseca, G., and Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 403(6772):853. Online:https://go.nature.com/2Gnztdw.

Neill, D. (2012). ¿ cuántas especies nativas de plantas vasculares hay en ecuador? *Revista Amazónica Ciencia y Tecnología*, 1(1):70–83. Online:https://bit.ly/2Rwi0VH.

Ordóñez-Delgado, L. (2011). Caracterización biofísica de los sistemas lacustres del parque nacional podocarpus y parque nacional yacuri, andes tropicales del sur del ecuador. Technical report, Ministerio del Ambiente de Ecuador (Zonal 7), Loja-Ecuador. Online:https://bit.ly/2MeoINV.

Primack, R., Rozzi, R.and Feinsinger, P., Dirzo, R., and Massardo, F. (1998). *Fundamentos de conservación biológica. Perspectivas latinoamericanas*. Fondo de Cultura Económica, México.

QGIS, D. T. (2018). Qgis geographic information system. Technical report, Open Source Geospatial Foundation Project.

Remache, G., Cuesta, F., Ordóñez Delgado, L., Sánchez, A., Aguilera, R., and Cisneros, R. (2004). Integridad ecológica del microcorredor de conservación yacuambi-podocarpus-sabanilla. Online: https://bit.ly/2MR7Agr.

Robbins, M., Rosenberg, G., and Molina, F. (1994). A new species of cotinga (cotingidae: Doliornis) from the ecuadorian andes, with comments on plumage sequences in doliornis and ampelion. *The Auk*, 111(1):1–7. Online:https://bit.ly/2R9P8mF.

Ron, S., Yanez-Muñoz, M., Merino-Viteri, A., , and Ortiz, D. (2019). Anfibios del ecuador. *Museo de Zoología, Pontificia Universidad Católica Del Ecuador*, page Online:https://bit.ly/2s6zWHu.

Rueda, M. (2003). Presentación de la colección. la investigación educativa en méxico, 1992-2002. *2003). Consejo Mexicano de Investigación Educativa A. C.*, pages 1992–2002. Online:https://bit.ly/2DX8GUn.

Serrano, F. (2008). Reserva de biósfera podocarpus-el condor: Reflexiones del primer año de gestión. *XXXII Jornadas Nacionales de Biología]. Universidad Técnica Particular de Loja.*, page Online:https://bit.ly/2yNwm8W.

Stotz, D., Fitzpatrick, J., Parker III, T., and Moskovits, D. (1996). *Neotropical birds: ecology and conservation*. University of Chicago Press. Online:https://bit.ly/2YBHxRF.

Terborgh, J. and Winter, B. (1983). A method for siting parks and reserves with special reference to columbia and ecuador. *Biological Conservation*, 27(1):45–58. Online:https://bit.ly/2GSXZlm.

Tirira, D. (2018). Mamíferos del ecuador: Lista actualizada de especies/mammals of ecuador: Updated checklist species. versión 2017.2. Technical report, Fundación Mamíferos y Conservación, Online: https://bit.ly/2VtvcJU.

Torres-Carvajal, O., Pazmiño-Otamendi, G., and Salazar-Valenzuela, D. (2018). Reptiles del ecuador. versión 2018.0. Online: https://bit.ly/2rSGmdj.

UICN (2014). Lista roja de especies amenazadas de la uicn. resumen para américa del sur. Online: https://bit.ly/2Cgx6VJ.

Urrútia, G. and Bonfill, X. (2010). Declaración prisma: una propuesta para mejorar la publicación de revisiones sistemáticas y metaanálisis. *Medicina clínica*, 135(11):507–511. Online:https://bit.ly/2GPIc75.

Watson, J., Dudley, N. Segan, D., and Hockings, M. (2014). The performance and potential of protected areas. *Nature*, 515(7525):67. Online:https://go.nature.com/2t9QDpu.

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Review / Reseña bibliográfica
conservation

Biological and ecological aspects of the spectacled bear (Tremarctos ornatus, Ursidae) in the Ecuadorean Andean zone and conservation perspectives under the Landscape Species approach

Aspectos biológicos y ecológicos del oso de anteojos (Tremarctos ornatus, Ursidae) en la zona andina de Ecuador y perspectivas para su conservación bajo el enfoque de especies paisaje

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Resumen

El oso andino u oso de anteojos (*Tremarctos ornatus*) ha habitado Sudamérica por más de cinco millones de años, y es el único representante viviente de los osos de nariz corta, un grupo que habitó solamente en el continente americano. Dentro de Ecuador es considerado en peligro de extinción, principalmente debido a la fragmentación y pérdida de hábitats naturales en la región andina, causada por actividades antrópicas productivas (ganadería y agricultura) y de extracción de recursos naturales. Este oso es un mamífero que necesita de grandes extensiones para poder alimentarse y buscar pareja. El oso andino es importante para las zonas que habita, principalmente el bosque andino y el páramo, debido a su eficiente rol como dispersor de semillas. En el presente trabajo se analizan aspectos de esta especie en Ecuador, utilizando el enfoque teórico de 'especies paisaje' para proponer actividades en pro de la conservación de este mamífero y de los hábitats en los que se desarrolla. Este enfoque permite evaluar de forma sistemática la calidad del paisaje en términos de los requerimientos biológicos de una especie de interés (en este caso, Tremarctos ornatus) y de los usos humanos del paisaje; de igual forma considera características del área de conservación como su variación.
Palabras clave: Conservación biológica, *Tremarctos Ornatus*, Andes ecuatorianos, especies.

Abstract

The Andean bear (*Tremarctos ornatus*) has inhabited South America for more than five million years, and he is the only living representative of the short-nosed bears, a group that only lived on the American continent. In Ecuador he is considered an endangered species, mainly because the loss of natural habitats in the Andes, due to the pressure of productive anthropic activities (mainly, livestock and agriculture) and extraction of natural resources. This bear is a mammal that needs large areas to eat and find a mate. The Andean bear is important for cloud forests and paramos due to his efficient role as seed scatter. In this work, the 'landscape species' theoretical approach is applied in order to propose activities to conserve the Andean bear and the places that inhabits. This approach also allows to evaluate in a systematic way the quality of the landscape in terms of biological requirements of the species (here, Tremarctos ornatus) and the landscape human uses; likewise, it also considers the size and limits of the conservation area and its internal variation.
Keywords: Biological conservation, *Tremarctos Ornatus*, Ecuadorian Andes, Landscape Species.

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1 Introduction

Several regions in Latin America have been proposed as 'hotspots' (areas with special concentration of biodiversity), 'threatspots' (areas with such diversity, but with clear threats on it) or as 'countries with high numbers of threatened species' (Cole et al., 1994; Ceballos and Brown, 1995; IUCN, 1996). In this context, it is worth mentioning that mammals and birds, as well-known and more studied groups, are often seen as emblematic animal organisms, around which are planned activities and execution of conservation of habitats and natural ecosystems.

The richness of species, biodiversity values and mammalian endemism ranges for each country have been used as measures to characterize habitat loss and human population growth, as well as to identify global anthropic threats on the biological diversity (Sisk et al., 1994). Despite this, there are still some gaps in the knowledge of this group of vertebrates in neotropical regions. Among the emblematic mammals of Andean areas, the Andean bear (Tremarctos ornatus) is known as a vulnerable species (VU) within the Red List of the International Union for the Conservation of the Nature (IUCN, 2018) and endangered in Ecuador (Cuesta et al., 2001).
La riqueza de especies, valores de biodiversidad y rangos de endemismo de mamíferos para cada país han sido utilizados de manera conjunta como medidas de caracterización de la pérdida de hábitat y crecimiento poblacional humano, así como para identificar las amenazas antrópicas globales sobre la diversidad biológica (Sisk et al., 1994). A pesar de ello, todavía existen algunos vacíos en el conocimiento de este grupo de vertebrados en regiones neotropicales. Entre los mamíferos emblemáticos de zonas andinas, el oso andino (*Tremarctos ornatus*) se encuentra catalogado como especie vulnerable (VU) dentro de la Lista Roja de la Unión Internacional para la Conservación de la Naturaleza (IUCN, 2018) y en peligro de extinción en Ecuador (Cuesta et al., 2001).

One of the most challenging problems in the biodiversity conservation in Ecuador's Andean area is to protect large species, such as the spectacled bear (Castellanos, 2010) or the mountain tapir (Álvarez and Yánez, 2017), and at the same time to meet the needs of people who share spaces with them. Large carnivores, for example, are particularly difficult to conserve because they compete directly or indirectly with humans for space and resources (Treves et al., 2006), carnivores have direct effects on the abundance of herbivores, scavengers, and indirect effects on the vegetation and food nets through trophic waterfalls (McFarland, 2009), making their conservation important and complex.
The conservation of the spectacled bear in Andean countries, where protected areas and wildlife habitats are embedded in a matrix of heterogeneous uses, usually with rapid changes in land use and/or tenure, is particularly difficult (Peyton et al., 1998; Ferraro, 2002; Himley, 2009).

1.1 The Andean region of Ecuador and neighboring countries as a natural habitat of the spectacled bear

The habitat is considered as all the resources and characteristics of a place, which allow the presence of an organism (Begon et al., 1999); therefore, an animal can use a habitat in different ways, according to the access, its availability, as well as its particular requirements (Cuesta et al., 2001). The availability and access to such habitat may vary over the time, depending on environmental factors such as the climate and biological factors of the species, as well as the communities that structure the local system (Begon et al., 1999).
In South American, the spectacled bear inhabits cloud forest and mooring environments in six countries: Colombia, Venezuela, Ecuador, Peru, Bolivia and northwestern Argentina (Castellanos, 2010). The presence of this species in its southernmost area, the northwestern of Argentina, is based on the encounter of DNA fragments, extracted from hair and feces (Teta et al., 2018).
In Ecuador, the presence of the bear is reported mainly in cloud forests and Andean moors, usually within protected areas, but possibly also outside them (Cuesta, 2000; Goldstein and Cancino, 2001; Bioweb, 2018) (Figure 1).

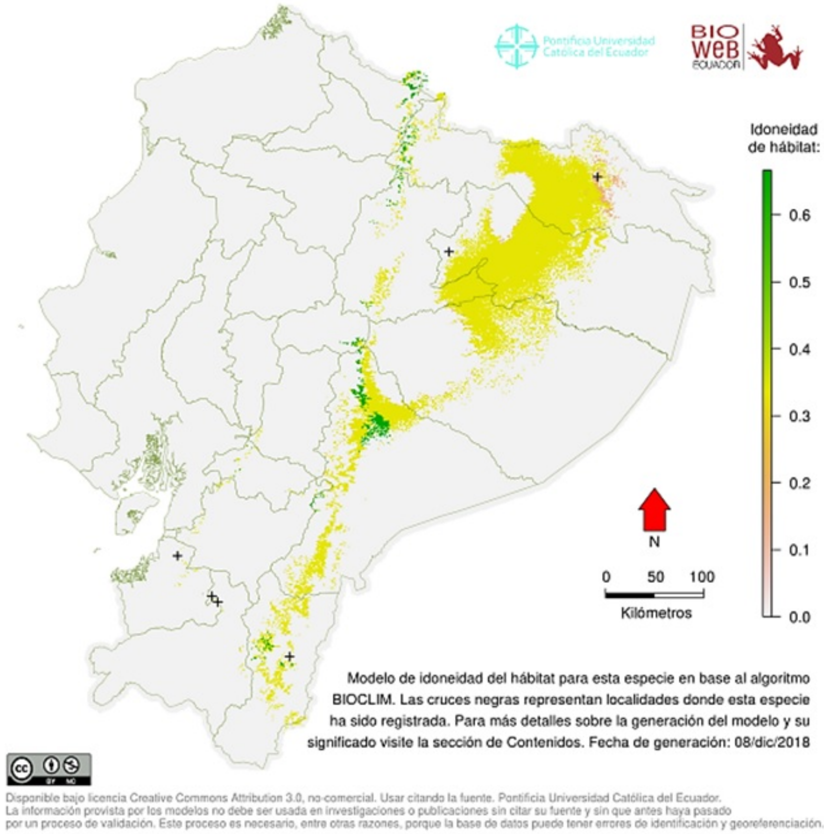

Figure 1. Potential distribution of the spectacled bear Source:Bioweb (2018).

Some records of its presence include cloud forest and moorland to adjoining subtropical forest regions. Its presence in these three ecosystems relates to records made in the provinces of Pastaza, Morona Santiago, Zamora Chinchipe, Sucumbíos, Napo, Chimborazo, Cañar, Azuay, Loja, Carchi, Imbabura, Pichincha, Cotopaxi, Bolívar, Tungurahua and El Oro (Tirira, 2007). Taking into a more standardized nomenclature of the natural regions, it can be mentioned that it is located in: Western Montane Forest, Moorland, Eastern Montane Forest (Castellanos and Boada, 2018).

1.2 Description of the species

The spectacled bear, also known as Andean bear, is a unique species of the Andes. It is large and robust in body, males are between 1.8-2.0 m tall, they weigh up to 175 kg, females are somewhat smaller (Tirira, 2007). Adult males and females have a muscular short neck, small ears and dark brown snout, their black fur is thick and abundant. They also have a combination of white or light brown spots around the eyes, which can extend to the jaw, throat and chest (Figure 2 and 3); the size, coloration and shape of these spots are usually different in each individual and are characteristics that are often used for their identification (Castellanos, 2010; Tirira, 2007).
He is a mammal of daytime and nocturnal habits, terrestrial, partially arboreal and solitary; he is also an omnivorous animal (he eats fruits, plant matter and meat, and can eat carrion if necessary). Generally, his diet includes ripe fruits, bromeliad buds, tender parts of palms, orchid bulbs or even tree bark (Castellanos, 2005). However, his eating habits may change according to where he is and the availability of the resources (Peralvo et al., 2005), and if food is scarce, he may even go so far as to hunt deer, rodents and sometimes calves (Goldstein, 2002; Castellanos, 2005). He usually builds nests on both the ground and tall trees for resting and for uninterrupted feeding (Goldstein, 2002).

1.3 Objectives and methodological aspects

This document aims to share with the national and regional academic society information of interest for the knowledge and conservation of the spectacled bear. It was based on a critical review of specific literature (considering technical and/or scientific publications published mainly in the last two decades around this species of mammal and his habitats), as well as authors' opinions on the ecological and conservation role, present and future of this species in Ecuador.

2 Reproductive biology

Figure 2. Physical appearance of a spectacled bear. Source:Tirira (2007).

Much of the mating behavior of this species remains unstudied. Males and females gather to mate between April and June. The couple remained together for 1 to 2 weeks, copulating several times during this period (International Association for Bear Research and Management, 1999). Molecular genetics studies conducted by Ruiz-García (2003) in bear populations in five Andean countries show an alarming reality: the genetic variability of the Andean bear is relatively low. The populations of Ecuador have the least variability, possibly because the fragmentation of their habitats is greater in Ecuador, which generates populations of bears more isolated and most at risk of disappearing (Kattan et al., 2004).

3 Ecological importance in cultural tourism and nature

The spectacled bear is the only living representative in South America of the entire Ursidae family, giving him a particular right to exist and the academic community a great ethical obligation to facilitate his conservation. Human beings, as the main transformative agent of the environment, have the obligation and responsibility to conserve not only the Andean bear but also the rest of the wild species.

However, despite this ethical need, little is known about the ecology of this bear in Ecuador and his role in the ecosystems he inhabits. Studies in Bolivia have shown that he is an active seed dispersing agent and that the passage of these through his digestive tract does not affect the viability(Rivadeneira, 2008).

Therefore, this mammal is very important for the areas he inhabits, mainly for some plant species of Andean forest and moorland, due to his effective role of depositing seeds with higher germination in suitable areas. Moreover, in most of the time the spectacled bear takes down complete trees to reach their fruits and eat (Troya, 2002). In this way, spaces open up within the forest where more sunlight enters and rainwater reaches directly into the ground. Thus, the bear helps to the renewal of the vegetation of the forest, since many plants need to have an open space above them (clear) to grow better. heir droppings also contribute to some extent to manure the forest floor. In addition, they feed many small organisms such as beetles, insect larvae, butterflies (Castellanos, 2003).

He is a great climber and when he climbs trees to feed or sleep he builds platforms folding and breaking some branches. Many of these branches or sticks that were accumulated in the forest canopy fall to the ground to decompose and become organic fertilizer. In this way, the bear helps to prevent too much organic matter from accumulating in the upper part of the trees and generates spaces in the canopy or subdosel where sunlight reaches directly to the forest floor (Suárez, 1985).

Figure 3. Spectacled Bear (*Tremarctos ornatus*). Source:Appleton (2017).

The Andean bear has also been an emblematic animal, involved in the development of many of the indigenous and peasant cultures in the Andean countries. For many he is sacred, for others he is the elder brother of the human being. In the oral traditions of people, the bear is found in legends, tales, songs and myths (Lameda and Del Moral, 2008).

The Andean bear appears in the common names of some plants, 'the bear's hand' (*Oreopanax bogotensis*) and 'bear grass' (*Xerophyllum tenax*). It is also very common to find places named after the Andean bear: Alto del Oso (Colombia), La cueva del Oso (Ecuador), Quebrada El Oso (Colombia, Peru, Venezuela), Vereda del Oso (Colombia), among others. In this way, the Andean bear is part of the cultural heritage and worldview of the countries of the Andean region.

4 Aspects around the current care and conservation of the Andean bear under the landscape species approach

4.1 The landscape species-based conservation model

The spectacled bear conflict - cattle is an element worthy of being analyzed and addressed under the conceptual scheme for landscape species conservation planning (Sanderson et al., 2002), due to the particular characteristics of the conflict, which include ecological, social and economic components. Effective planning in conservation or conflict management must clearly define the elements that are biologically, economically and socially relevant to the species or the conflict, so that the the conflicts can be planned on an appropriate scale (Poiani et al., 1998; Whited et al., 2000), preferably with an ecosystem approach and/or landscape ecology.

The landscape species approach focuses its efforts on an explicit spatial model that systematically evaluates the landscape in terms of the biological requirements of a species (in this case, Tremarctos ornatus) and the human uses of the landscape. This approach uses the requirements of the species to define the boundaries of the conservation area (the extent) and the variation within it (the point)(Sanderson et al., 2002). The conceptual model of conservation based on landscape species considers the identification of:

1. The biological landscape of the species.
2. The landscape of different human activities.
3. Spaces and moments in which human activities could endanger populations of the landscape species.
4. A potential focal landscape for the conservation of the species, based on the necessary local elements and the different interventions required for the conservation of the chosen biological population (Sanderson et al., 2002).

4.2 The choice of the species

Theoretically, any species could be considered as a candidate for landscape species, but in practice, considering many species as candidates would make the selection process very long. Therefore, organizations such as the WCS suggest that the initial group of candidate species for a given area consists of few species with a reasonable probability of being selected and that would meet one or more of the five following criteria (WCS: Wildlife Conservation Society, 2002):

- Area: the candidate species for landscape species should be widely distributed in natural habitats, so that if its life's area many other species of flora and fauna will be protected at the same time, this is known as the Umbrella Effect (Umbrella species (WCS: Wildlife Conservation Society, 2002)). In this sense the spectacled bear, for what has been mentioned above and for his distribution in Andean natural habitats of Colombia, Venezuela, Ecuador, Peru and northern Argentina, is a strong candidate for being considered landscape species.
- Heterogeneity: Some species require more than just large areas. In many cases, a wild species candidate for landscape species needs a variety of available natural habitats and different vegetation types for dispersion, fodder, reproduction and survival at favorable and unfavorable times (WCS: Wildlife Conservation Society, 2002). Again, the Andean bear meets these conditions.
- Vulnerability: another consideration in the selection of a landscape species is the number and severity of the threats that affect it. Threats can be classified according to the probability of their occurrence, how quickly they occur or may occur, their severity and the area they may affect in relation to the candidate species (WCS: Wildlife Conservation Society, 2002). The spectacled bear is currently listed as a vulnerable species by IUCN (2018), so his protection is necessary and urgent.
- Ecological functionality: some species have particularly strong effects on the structure and function of natural ecosystems: for example, beavers originate swampy areas by building dikes in rivers (WCS: Wildlife Conservation Society, 2002); tapirs and spectacled bears distribute seeds in the systems they visit and larger predators can control the abundance and composition of prey communities. Given these important effects on other species, maintaining healthy populations of landscape species and their habitats, such as the Andean bear, will help to conserve the ecosystems.
- Socioeconomic importance: the last criterion for the selection of a landscape species is its socioeconomic importance. Some examples show that the so-

cial environment in and around protected areas can drastically affect conservation outcomes. Since landscape species travel through large areas and find in this action a wide variety of habitats and types of land use, it is very likely that they will have contact with people and their activities (WCS: Wildlife Conservation Society, 2002). This is precisely what happens with the spectacled bear, in a negative sense for the human being, the bear can affect crops, annoy livestock, compete for space or resources; in a positive sense this bear has important benefits such as being a powerful cultural icon in Andean rurality by providing income, generating opportunities to local human communities through the development of ecotourism activities, such as those described for another species such as Andean tapir in similar studies (Álvarez et al., 2017).

4.3 Programs and plans for the conservation of the spectacled bear as an emblematic species in Ecuador

The Nature Foundation and the EcoScience Foundation in Ecuador have worked in recent decades (1980-2010) with the national government supporting the management of three protected areas where the spectacled bear is located (Podocarpus, Cotacachi-Cayapas, Cayambe-Coca). On the other hand, the Andean bear conservation program in the Northwestern Metropolitan District of Quito uses the bear as an umbrella species for the conservation of the environmental health of this region (Secretaría de Ambiente, 2014). The actions that are implemented to support the conservation of the bear support directly or indirectly the conservation and recovery of the remnants of natural vegetation. These conservation efforts must undoubtedly be expanded and supported by relevant management and research institutions.

5 Conclusions and recommendations

Since pre-Hispanic times, populations of Andean bear have been under a lot of pressure from humans. In Ecuador they were hunted out of fear, for sport, for obtaining products from their bodies or because they were eventually considered pests for crops and/or farm animals.

Currently, the main threats the bear faces are poaching and the destruction of his natural habitat, isolating the few remaining populations of spectacled bears in Ecuador. Additionally, the main habitat of the Andean bear is located in one of the areas of greatest growth and economic and social development in Ecuador: the Andean provinces.

Some measures must be considered to collaborate with the preservation of this species in its natural habitats; in addition, the spectacled bear must be taken into account officially as a landscape species for Ecuador and possibly also for the other Andean countries where he is located.

The relevant measure and action is to avoid the hunting of the bear; the law currently prohibits hunting and selling; however, it would need a little more control so that the norm would be fully complied with. It should be emphasized that these animals are shy and frightened; they try to avoid the presence of the human being and are not any threat to humans. If there were problems with an Andean bear in an area, the local environmental entity should be informed; they will indicate what to do. Hunting is not the solution and this practice only contributes to increase the risk of extinction of this species.

Do not cut down the Andean forest or the subtropical forest, nor modify the moors. In addition to being home to the Andean bear, these environments protect watersheds and ensure the supply of water in the region for the benefit of people. On the other hand, the forest and the moor are home to many other species of animals and plants beneficial to the ecosystem and for humans, some of them are not found in any other region of the planet. In this way, protecting the Andean bear's home also preserves the home of several plants and animals that share his habitat.

Campaigns to recover and protect Andean forests and moors are necessary. The deterioration of these systems implies the loss of water sources, indispensable for crops or human consumption. Attempts should be made to reforest areas where forest with native species once existed, as those that remain are discontinuously and fragmented. Forest restoration plans can be developed to connect those fragments to help the Andean bear have a wider area to live in.

Governments (national, provincial, municipal) must take effective control actions to illegal trafficking of spectacled bear. Consideration should also be given to applying stimuli for those who promote in some way the protection of this species and/or the habitats in which he is located or on which he depends. Non-governmental organizations interested in the conservation of this species must have the capacity, facilitated by the National Government, to channel national and international resources for the acquisition and/or management of land to ensure the conservation of the Andean bear's natural habitats.

Private and public Universities and research centers carrying out activities and programs in life and environmental sciences should be able to provide technical and scientific advice to rural communities and governmental and non-governmental entities for the conservation and recovery of Andean bear populations and the habitats they occupy.

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References

Álvarez, P., Abrigo, P., Vite, F., Trelles, D., Espinoza, A., and Yánez, P. (2017). El tapir de montaña (tapirus pinchaque), como especie bandera en los andes del sur del ecuador. *INNOVA Research Journal*, 2(8):86–103. Online: https://bit.ly/2ZnuZN7.

Álvarez, P. and Yánez, P. (2017). Actividades de conservación y de educación ambiental en torno a una especie emblemática, el tapir de montaña (tapirus pinchaque), en sectores andinos del sur de ecuador. *INNOVA Research Journal*, 2(8):1–9. Online: https://bit.ly/2N0tr5h.

Appleton, R. (2017). Spectacled bear. tremarctos ornatus. Online: https://bit.ly/33vReQm.

Begon, M., Harper, J., and Townsend, C., editors (1999). *Ecología*. Omega, Online: https://bit.ly/2ZdR4yx.

Bioweb, editor (2018). *Mapa de distribución potencial del oso de anteojos*, Quito. Pontificia Universidad Católica del Ecuador.

Castellanos, A. (2003). Datos ecológicos del oso andino tremarctos ornatus en la reserva alto chocó, ecuador. In del Ecuador, U. C., editor, *Memorias de las XXVII Jornadas Ecuatorianas de Biología*, Quito-Ecuador.

Castellanos, A. (2010). *Guía para la rehabilitación, liberación y seguimiento de osos andinos*. Imprenta Anyma., Quito.

Castellanos, A. and Boada, C. (2018). *Mamíferos del Ecuador. Version 2018.0.*, chapter Tremarctos ornatus. Pontificia Universidad Católica del Ecuador, Museo de Zoología., Quito.

Castellanos, A., A. M. . T. G. (2005). Ecología y comportamiento de osos andinos reintroducidos en la reserva biológica maquipucuna, ecuador: implicaciones en conservación. *Revista Politécnica*, 26:54–82.

Ceballos, G. and Brown, J. (1995). Global patterns of mammalian diversity, endemism, and endangerment. *Conservation Biology*, 9(3):559–568. Online: https://bit.ly/2U5eWOR.

Cole, F., Reeder, D., and Wilson, D. (1994). A synopsis of distribution patterns and the conservation of mammal species. *Journal of Mammalogy*, 75:266–277.

Cuesta, F., editor (2000). *La distribución del oso andino en el Ecuador*. Fundación EcoCiencia., Quito.

Cuesta, F., Peralvo, M., and Sánchez, D. (2001). Métodos para investigar la disponibilidad del hábitat del oso andino: el caso de la cuenca del río oyacachi, ecuador. Serie Biorreserva del Cóndor 1, Fundación EcoCiencia., Quito.

Ferraro, P. (2002). Global habitat protection: limitations of development interventions and a role for conservation performance payments. *Conservation Biology*, 15(4):990–1000. Online:https://bit.ly/2ZiPdbO.

Goldstein, I. (2002). Spectacled bear-cattle interactions and tree nest use in bolivia and venezuela. *Ursus*, 13:153–156. Online: https://bit.ly/2zjyJkn.

Goldstein, I. and Cancino, L. (2001). Distribución y status del oso andino: una iniciativa regional de conservación a largo plazo. mérida: Andean bear program-wcs northern andes. d. Online: http://wcsfrontino.ula.ve.

Himley, M. (2009). Nature conservation, rural livelihoods, and territorial control in andean ecuador. *Geoforum*, 40(5):832–842. Online: https://bit.ly/2HpVYO2.

International Association for Bear Research and Management (1999). Bear species descriptions. Online: https://www.bearbiology.org/.

IUCN (1996). Guidelines for re-introductions. gland: Iucn/ssc rsg. Technical report, International Union for the Conservation of Nature, Reintroduction Specialist Group.

IUCN (2018). The iucn red list of threatened species. Online: https://www.iucnredlist.org/, International Union for the Conservation of Nature, Reintroduction Specialist Group.

Kattan, G., Hernández, O., Goldstein, I., Rojas, V., Murillo, O., Gómez, C., Restrepo, H., and Cuesta, F. (2004). Range fragmentation of the spectacled bear tremarctos ornatus in the northern andes. *Oryx*, 38(2):1–10. Online: https://bit.ly/2KTjxB0.

Lameda, I. and Del Moral, F. (2008). The andean bear in the world: view of the south american andes. i. *nternational Bear News*, 17(4):14–15. Online: https://bit.ly/2ZqVGk3.

McFarland, D. (2009). Population estimation, habitat associations and range expansion of black bears in the upper midwest. Master's thesis, University of Wisconsin, Madison.

Peralvo, M., Cuesta, F., and van Manen, F. (2005). Delineating priority habitat areas for the conservation of andean bears in northern ecuador. *Ursus*, 16(2):222–233. Online: https://bit.ly/2zk3gOG.

Peyton, B., Yerena, E., Rumiz, D., Jorgenson, J., and Orejuela, J. (1998). Status of wild andean bears and policies for their management. *Ursus*, 10:87–100. Online: https://bit.ly/2ZcLIn8.

Poiani, K., Richter, B., M., A., and Richter, H. (1998). Biodiversity conservation at multiple scales: functional sites, landscapes, and networks. *BioScience*, 50(2):133–146. Online:https://bit.ly/2NwrgXu.

Rivadeneira, C. (2008). Study of the andean bear (tremarctos ornatus) as a legitimate seed disperser and elements of its diet in the region of apolobamba-bolivia. *Ecología en Bolivia*, 43(1):29–40.

Ruiz-García, M. (2003). Molecular population genetic analysis of the spectacled bear (tremarctos ornatus) in the northern andean area. *Hereditas*, 138:81–93.

Sanderson, E., Redford, K., Vedder, A., Coppolillo, P., and Ward, S. (2002). A conceptual model for conservation planning based on landscape species requirements. *Landscape and Urban Planning*, 58(1):41–56. Online: https://bit.ly/33UZMQW.

Secretaría de Ambiente (2014). Programa de conservación del oso andino en el nor-occidente del distrito metropolitano de quito. Technical report, Municipio del Distrito Metropolitano de Quito, Quito.

Sisk, T., Launer, A., Switky, K., and Ehrlich, P. (1994). Identifying extinction threats: global analyses of the distribution of biodiversity and the expansion of the human enterprise. *Bioscience*, 44(9):592–604. Online: https://bit.ly/33Vi2JW.

Suárez, L. (1985). Hábitos y distribución estacional del oso de anteojos, tremarctos ornatus, en el páramo suroriental del volcán antisana, ecuador. Tesis de grado, Pontifica Universidad Católica, Departamento de Ciencias Biológicas, Quito.

Teta, P., Abba, A., Cassini, G., Flores, D., Galliari, C., Lucero, S., and Ramírez, M. (2018). Lista revisada de los mamíferos de argentina. *Mastozoología Neotropical*, 25(1):163–198. Online: https://bit.ly/2PdZlxU.

Tirira (2007). *Nombres de los Mamíferos del Ecuador*. Number 5 in Publicación Especial de los Mamíferos del Ecuador. Ediciones Murciéélago Blanco y Museo Ecuatoriano de Ciencias Naturales, Quito.

Treves, A., Wallace, R., Naughton, L., and Morales, A. (2006). Co-managing human-wildlife conflicts: a review. *Human Dimensions of Wildlife*, 11(6):383–396. Online: https://bit.ly/2zmEXzS.

Troya, V. (2002). *Food habits of the Andean bear in different vegetation types in the Oyacachi river basin*. Fundación EcoCiencia, Quito.

WCS: Wildlife Conservation Society (2002). La selección de especies paisaje. Online: https://bit.ly/2SymCH2.

Whited, D., Galatowitsch, S., Tester, J., Schik, K., Lehtinen, R., and Husveth, J. (2000). The importance of local and regional factors in predicting effective conservation: Planning strategies for wetland bird communities in agricultural and urban landscapes. *Landscape and Urban Planning*, 49(1):49–65. Online: https://bit.ly/33X5zWf.

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Review / Reseña bibliográfica
SUITABLE AGRICULTURE

ADOPTION AND IMPACT OF AGRICULTURAL TECHNOLOGIES DEVELOPED IN ECUADOR

ADOPCIÓN E IMPACTO DE LAS TECNOLOGÍAS AGROPECUARIAS GENERADAS EN EL ECUADOR

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Resumen

El conocimiento de los efectos que tienen las tecnologías en la sociedad es el instrumento esencial para motivar el desarrollo de la investigación, ya que brinda insumos a los tomadores de decisiones y generadores de políticas que permiten proyectar el impacto de futuras inversiones. En Ecuador, el principal centro público encargado de la investigación y desarrollo de tecnologías en el sector agropecuario es el Instituto Nacional de Investigaciones Agropecuarias (INIAP), que desarrolla material genético, alternativas de manejo para incrementar y agregar valor a la producción, alternativas para el manejo del suelo y agua y la conservación de los recursos genéticos. Con el objetivo de estimar la adopción e impacto de las tecnologías agropecuarias que se generan en el país, se analizaron 37 estudios de adopción, impacto y rentabilidad económica de tecnologías generadas por el INIAP, publicados en el período 2007-2017. La tasa de adopción promedio a nivel nacional de las variedades desarrolladas por el INIAP fue del 37 %, con una tasa interna de retorno promedio del 33 %. Los impactos fueron positivos a nivel económico, ambiental y productivo para los agricultores que adoptaron las tecnologías. Estos resultados sirven de apoyo a los políticos y tomadores de decisiones en el país para el direccionamiento y planificación estratégica de la investigación, que permitan el desarrollo de una agricultura sostenible y de referencia para la región.
Palabras clave: Agricultura sustentable, economía agrícola, innovación, política agropecuaria.

Abstract

Knowing the effects that technologies have on society is the essential input to motivate the development of science, since it provides inputs to policy makers to project the impact of future investments. In Ecuador, the main public center in charge of research and development of technologies in the agricultural sector is the National Institute of Agricultural Research (INIAP), which develops genetic material (seeds) and crop management recommendations to

increase and add value to farmer's production, alternatives for the soil and water management and the conservation of genetic resources. In order to estimate the adoption and impact of agricultural technologies generated in the country, 37 studies of adoption, impact and economic profitability of technologies generated by the INIAP were analyzed. These studies were published in the period 2007-2017. The average adoption rate of the varieties developed by INIAP at the national level was 37 %, with an average internal rate of return of 33 %. The overall impacts of agricultural technologies developed in Ecuador were positive at an economic, environmental and productive level for the farmers who adopted these technologies. These results support the politicians and decision makers in the country for the direction and strategic planning of the research to invest more in science and technology, which will allow the development of a sustainable agriculture for Ecuador and the region.
Keywords: Sustainable agriculture, agricultural economy, innovation, agricultural policy.

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1 Introduction

Assessing the effects of the technologies is crucial for institutions committed to Research and Development (R+D), as it allows to demonstrate the effectiveness of the developed products and justify the investments done (Feinstein, 2012). Additionally, because technology generation, especially that which uses a proportion of public funds, has a high opportunity cost in less developed countries, i.e., government funding for science and technology is limited because it must address other social priorities (López, 2017; Rivas et al., 1992). This latter statement would explain the low investment in R+D in Ecuador, which by 2014 accounted for 0,44 % of Gross Domestic Product; and less than 0,03 % of Gross Domestic Product for the agricultural sector in particular (SENESCYT e INEC. n.d, 2014).

In Ecuador's agricultural sector, the efforts made by research organizations have focused on achieving the highest crop productivity. Therefore, much of the technological offer has been based on the provision of genetic material (seed) and recommendations of cultivation practices. The National Agricultural Research Institute (INIAP) is Ecuador's main research center, accounting for 73 % of agricultural researchers engaged in the country's full-time research, followed by education entities (universities) and private institutions or non-profit research centers, 14 % and 13 % of the country's full-time researchers, respectively (Stads et al., 2016). INIAP has developed improved plant genetic material with characteristics of yield, pest resistance and other environmental factors. It has also released technologies for crop management, such as: good practices for the use of supplies, natural resources, crop rotation and integrated pest management. From 2007 to 2013, INIAP released 38 improved varieties and around 198 technological alternatives in areas such as: beans, maize, potatoes, cocoa, rice, wheat, among others (Stads et al., 2016).

The effect or impact of several of these technologies released by INIAP have been evaluated and published in an isolated way by several research projects of different institutions (Barrera et al., 2017; Clements et al., 2016; Barrowclough and Dominguez, 2016). Consequently, it is necessary to consolidate and quantify the impact of technologies, in such a way as to serve as a tool for politicians and decision-makers for the analysis and strategic direction of the research for the country's agricultural technological development. This review aims to synthesize and analyze the results obtained in these studies, to provide more knowledge about the benefits of technologies developed in Ecuador with public resources, taking as a reference the results obtained by the country's most important research center.

Table 1. Internal Rate of Return (TIR) of the investment done in 12 items of Research and Development of INIAP

Topic	Periods (years)	Internal rate of return (%)	Reference
Rice	2000-2008	52	Mendoza2010
Cocoa	2000-2010	28	Sotomayor2011
Barley	2000-2012	0	Suquillo2014
Bean	1991-2010	35	Reyes2012
Lemon	2000-2012	13	Salgado2013
Hard maize	2009-2010	42	Racines2011
Naranjilla	2004-2021*	43	Guayasamin2015
African palm	2000-2011	46	Cordova2013
Potato	2000-2010	27	Mora2012
Piñón	2015	17	Rade2017
Soy	2000-2012	68	Alava2014
Cassava	2000-2012	21	Molina2014
Average		33	

*Analysis.

2 Materials and methods

The available information on adoption studies and impact on Google Academics was used as well as the bibliographic repository of INIAP (http://repositorio.iniap.gob.ec), which has 4660 documents to date to estimate the impact of public investment in research and technological development of the results generated by INIAP. The search focused on publications made in: scientific articles, technical publications, post-graduate thesis and pregraduate thesis, which were published from 2007 to 2017. To facilitate the analysis, the available information was grouped according to three criteria: (i) research profitability studies (indicator: Internal rate of return - TIR); (ii) technological adoption studies, either of improved genetic material or agronomic management practices (indicator: percentage of technology adoption); and, (iii) impact studies (productive indicators, conservation of natural resources and social indicators). Once the indicators were identified, they were systematized into tables and described statistics (minimum, maximum, average and median) were used to analyze and discuss the information.

3 Results

3.1 Profitability of the R+D

The bibliographic research identified 12 studies that evaluated the profitability of the technologies generated by INIAP. Most of these studies used the economic surplus method (Mendoza et al., 2010; Racines et al., 2011) and in some cases it was combined with descriptive methods (Guayasamín, 2015; Reyes, 2012). Nine of these studies were conducted nationally on: rice (Mendoza et al., 2010), cocoa (Sotomayor, 2011), barley (Suquillo, 2014), lemon (Salgado, 2013), hard maize (Racines et al., 2011), African palm (Córdova, 2013), potato (Mora, 2012), soybeans (Álava, 2014) and cassava (Molina Loor, 2014); and the rest in specific geographical areas: beans evaluated in Sierra Norte (Reyes, 2012); Naranjilla (*Solanum quitoense*) in the provinces of Napo, Pichincha and Tungurahua (Guayasamín, 2015); and, piñón (*Jatropha curcas*) conducted in the province of Manabí (Rade et al., 2017). The average TIR for the 12 studies conducted was 33 %, while the median was 32 % (Table 1). The development of technology for soy and rice report the best return rates with 68 % and 52 %, respectively. The lowest value corresponds to the study carried out in Barley, with a TIR of 0 %, result indicated that this crop is intended basically for self-consumption; and therefore will not generate surpluses for marketing (Suquillo, 2014).

3.2 Use of technologies

Table 2 shows the adoption rates of INIAP-generated technologies obtained in 30 studies found in the analyzed databases. On average, genetic material and other management technologies or practices developed by INIAP have been adopted in 37 %. The genetic material or seed, developed by INIAP had an average adoption rate of 38 %, while culture management technologies had an adoption of 35 %. The medians were 33 % and 38 % for genetics and management practices, respectively.

Rice and potato are the crops with more adoption studies conducted (Table 2). The area with the highest adoption percentage at the national level was rice (Moreno, 2014; Monteros and Salvador, 2015) and the one with the lowest adoption was barley (Suquillo, 2014). The adoption level of technologies developed by INIAP varies a lot, from 0 % in the case of management practices for the cultivation of hard maize in the provinces of Los Ríos and Guayas (Chicaiza, 2010), up to 90 % adoption of rice seed in the province of Guayas (Mendoza et al., 2011). The reasons for this great variation were diverse. In the case of Mauceri et al. (2007), adoption rates of technological practices were in agreement with the relationship of farmers with extensionists: (i) participants in field schools: 23,3 % to 83,3 %, averaging 56,5 %; (ii) producers who had contact with participants in field schools: 3,6 % to 85,7 %, averaging 41,4 %; and, (iii) producers who had no contact with field school participants: 2 % to 52,9 %, averaging 21,9 %.

In the case of technological practices for the conservation of natural resources developed for the Upper Andean region, the adoption rate depended on the locality and the type of technology (Barrera et al., 2012). In this study, the most adopted technologies were: crop rotation (locality 1: 59,41 % and locality 2: 92,5 %), living barriers (locality 1: 24,69 % and locality 2: 63,75 %) reduction of tillage (26,36 % and 76,25 %). Carrión Yaguana et al. (2015) also found differences in the adoption of technological practices in the Andean area of Ecuador, with a range of 5.5 to 68,1 %. The most adopted technologies were: rotation of low toxicity pesticides (68,1 %), crop rotation (68,1 %) and management of plant waste in cultivation (37,1 %). The same study showed that the determining factors for the adoption of technologies were: education, health and the training method. Other authors also reported different levels of adoption depending on the type of technology under evaluation, which will depend much on the field studied (Sowell and Shively, 2012; Fernández Pérez and Mendoza Coronel, 2011; Cedeño, 2013; Bazurto, 2014).

3.3 Impact assessment

Ten impact assessment studies of technologies developed by INIAP have been published between 2007 and 2017 (Table 3). Impact assessments have been mostly ex post, using quasi-experimental econometric methods, which generally consisted of determining what would have happened to project beneficiaries if the project had not existed (Khandker et al., 2010).

The studies have been mostly conducted in naranjilla and potato. In the case of naranjilla, the impact of grafted plants was evaluated, while training programs and conservation practices were studied for potato. The

Table 2. Adoption studies of the technology developed by INIAP.

Topic	Level	Adoption technology rate	Reference
Rice	National	Genetics: 74 %	Mendoza2010
Rice	Guayas	Handling practices: 11 % a 89 % Average: 41 % Genetics: 90 %	Mendoza2011
Rice	National	Genetics: 45 %	Moreno2014
Rice	National	Genetics: 70 %	Moreno2014
Rice	National	Genetics: 50 %	Moreno2015
Rice	National	Genetics: 70 %	Monteros2015
Rice	National	Genetics: 45 %	Castro2016a
Rice	National	Genetics: 50 %	Castro2016b
Rice	National	Genetics: 23 %	Castro2016c
Cocoa	National	Genetics: 10 %	Sotomayor2011
Cocoa	Manabí	Handling practices: 1 a 100 % Average: 36 % Genetics: 6 a 7 %	Fernandez2011
Barley	National	Genetics: 1 %	Suquillo2014
Preservation of the natural resources	Bolívar	Handling practices: 7 a 68 % Average: 31 %	Barrowclough2016
Bean	Carchi Imbabura	Genetics: 50 %	Reyes2012
Cattle farming	Manabí Guayas Los Ríos	Handling practices: 36 % Genetics: 27 %	Bazurto2014
Lemon	National	Genetics: 40 %	Salgado2013
Hard maize	Los Ríos Guayas	Handling practices: 0 % Genetics: 63 %	Chicaiza2010
Hard maize	National	Genetics: 23 %	Racines2011
Hard maize duro	National	Genetics: 3 %	Lusero-Sumba2014
Naranjilla	Pichincha Napo Morona Santiago Pastaza	Handling practices: 11 a 100 % Avergae: 43 %	Sowell2012
African palm	National	Genetics: 33 %	Cordova2013
Potato	Carchi	Handling practices: 40 %	Mauceri2007
Potato	National	Genetics: 33 %	Mora2012
Potato	Carchi	Handling practices: to the 2012 year: 6 a 68 % Average: 28 %	Carrion2016
Plantain	Manabí Santo Domingo	Handling practices: 19 a 61 % Average: 39 %	Cedeno2013
Quinoa and chocho (Andean grain)	Cañar Chimborazo Cotopaxi	Genetics: 23 %	Mazon2016
Natural resources	Bolívar	Handling practices: 57 %	Barrera2012
Soya	National	Genetics: 3 %	Alava2014
Cassava	National	Genetics: 22 %	Molina2014
Cassava	Manabí	Genetics: 85 %	Nevarez2011
Average		Handling practices: 35 % Genetics: 38 %	

results of the evaluations show positive effects in economic, production (performance) and environmental variables (Table 3). In the economics, the use of integrated pest management technologies in potato cultivation increased farmers' incomes from $250 to $560 per hectare (Mauceri et al., 2007). Integrated management of natural resources in the Upper Andean region of Ecuador with INIAP technology increased farmers' net income from 65 % to 81 %. The proper handling and application of pesticides increased the benefit in potato cultivation by 50 %, while the use of grafted Naranjilla increased economic benefit by 40 % to 60 % (Sowell and Shively, 2012).

Conservation technologies evaluated by INIAP increased milk production by 122 % (Barrera et al., 2012), and in potato the production increased by 1.9 tons per hectare (Cavatassi et al., 2011). In environmental terms, the development of the INIAP quitoense naranjilla released in 2009, will prevent deforestation of 17 300 hectares in 20 years (Clements et al., 2016); this high-yielding variety allows to increase production without affecting the agriculture. In bean farming, conservation tillage technologies increased production by 10 %. The incorporation of green fodder (oats) into the soil increased 20 % of barley production and 40 % of bean (Nguema et al., 2013).

The modernization impact of technologies on the cultivation of mulberry on the market price has also been a topic of study (Barrera et al., 2017). The results indicate the importance of implementing high quality standards during the production process. A single additional modernization activity during production - such as harvesting in ready-to-market containers, the use of improved varieties, among others-increases the price by 34 %. Sophisticated marketing-organic certifications, associativity, specific knowledge of the buyer, among others- and modernization in sales- the placement of the product in appropriate markets, sale to buyers with better prices, among others- also increase the price by 19 % and 27 %, respectively.

4 Discussion

The cost-effectiveness analysis of the 12 studies presented indicates that the results of INIAP's R+D, seen in improved genetic material and new agronomic practices allow produce more with a favorable economic return. The TIR generally represents or means the interest rate or return on an investment. TIR of public investment for the generation of technologies in INIAP has an average of 33 %. The profitability distribution in the 12 studies was wide, with values from 0 % to 68 %. Although each study was conducted independently in various areas and different regions of the country, the analysis of the results showed a uniform data distribution, with average values of 33 % and a median of 32 % (Table 1).

The economic surplus method was the most used to find the TIR. This method analyzes the surpluses generated by the displacement of a curve of a calculated offer, due to the effect of the increases caused by the increment in a planted area and yields, assigning a weight attributable to R+D (Alston et al., 1998). In other words, this method is based on the use of improved technologies to produce more with the same level of input. This technological development will allow the producer and consumer to benefit to some degree. The estimate of the economic surplus generated by the technological change considers the displacement of a supply curve due to increases in yields and in the cultivated area.

The study conducted by Reyes (2012) evaluated the productivity of bean varieties developed for the replacement of ancient varieties in Central America, Honduras and northern Ecuador, using experimental productivity data. The productivity gains observed in Ecuador, particularly on speckled red varieties, are 1,68 % per year. The same author found that the economic income of researches at the regional level showed a value of $358 million and a TIR of 32 %, and in Ecuador it reached a TIR of 35 %, and a VAN of 10.9 million dollars.

The TIR obtained in 11 out of the 12 studies identified was higher than the opportunity cost of the investment offered by the active benchmark rate for the public investment (9,33 %), published by the Central Bank of Ecuador in October 2018 (Banco Central del Ecuador, 2018). These results corroborate Timmer (1992), stating that agricultural productivity can grow faster than in other sectors due to the investment in scientific and technological development.

Technological adoption in the agricultural sector is a complex process that can cover a significant period of time, since it not only requires that the technology to be transferred is good, but that the actors involved have the resources and tools and destine them to the final users (Cadena Iñiguez et al., 2018). 37 % adoption average of technologies released by INIAP is below the average (40 %) obtained from thirteen adoption studies described by Barrientos-Fuentes and Berg (2013); work that collected information from assessments carried out in several countries around the world on agricultural technologies such as: genetic material, conservation agriculture, cultivation techniques, pest and disease management, among others.

Technology transfer in Ecuador is not the exclusi-

Table 3. Impact assessment studies of technologies developed by INIAP.

Topic	Period	Level	**Economic and environmental impact indicators**	**Reference**
Potato	1998-2003	Carchi	*E: the use of Integrated Pest Management increased income by $310 per hectare.	Mauceri2007
Naranjilla	2004-2013	National	A: 17 300 ha of deforestation avoided by the adoption of INIAP Quitoense.	Clements2017
Handle and preservation of natural resources	2006-2010	Bolívar	E: increased 65 % to 81 % in net income. Proper management of pesticides in potatoes increased the profit by 50 %. P: the use of better fodder increased milk production by 122 %.	Barrera2012
Potato	2007	Tungurahua Chimborazo	P: Increased of the potato production in 1.9 t/ha.	Cavatassi2011
Potato	2009-2012	Carchi	E: Decrease in expenditure due to the pesticide use by 60 %.	Carrion2016
Banana and other musaceae	2009	Manabí Cotopaxi	A: Biodiversity, banana and musaceae in an area decreases 2.56 times the possibility of damage caused by black stinging.	Marcillo2012
Naranjilla	2010	Pichincha, Napo, Morona Santiago, Pastaza	E: The economic benefit increases from 40 % to 60 %.	Sowell2012
Handle and preservation of natural resources	2010-2011	Bolívar	A: Zero tillage in bean increases yield by 10 %. The incorporation of oats into the soil increases barley production in 20 %, and 40 % in beans.	Nguema2013
Mulberry	2015-2016	National	E: The modernization of technologies: production, and commercialization determine the price between 19 and 34 %.	Barrera2017
Handle and preservation of natural resources	2011-2014	Bolívar	P: Farmers were willing to inves 2 % more in conservation techniques to achieve a 1 % increase in yield.	Barrowclough2016

*A= Environmental; E= Economic; P= Productive

ve competence of INIAP, but is part of other actors in a national public system and non-existent technical assistance for the Ecuadorian agro. The success of the American agro-industrial sector is dueto its high technological adoption, among other factors (Vieira Filho and Fornazier, 2016).

Studies with economic, productive and conservation indicators of natural (environmental) resources were observed in the results of impact assessments (Table 3). The works have been published in indexed journals, most are expost, and explain a causal relationship by solving the counterfactual problem by using quasi-experimental econometric methods. The main challenge of an impact assessment is to identify what would have happened to the beneficiaries of a program if the project had not existed (Khandker et al., 2010).

The impact of research investment has also been assessed at the regional level, where it was estimated that the potential economic value caused by technologies developed by INIAP and other public institutes in the Andean region for late blight control in potato reached $298 million over 20 years (González, 1998). A more recent study in Brazil reported that the increase in the land productivity in recent years is mainly due to increased investment in research, especially in the National Research Agricultural Institute-Embrapa (Gasques et al., 2010). These results support the information presented in Table 3, by stating that the investment in R+D has a positive impact in the agricultural sector in the medium and long term. However, these impacts do not reach all farmers and have not solved all the needs of Ecuadorian agribusiness. Although investment in agricultural R+D recorded a growth of 9 % during the period 2009–2014 (SENESCYT e INEC. n.d, 2014), Ecuador has one of the lowest investment rates in R+D activities in South America, with an expenditure of 0,18 % of its Agricultural GDP - GDPA (Stads et al., 2016), a value below the recommended by the World Bank (2 % of GDPA) or the Interamerican Cooperation Institute for the Agriculture (1 % of GDPA) (UNCTAD, 2007; IICA, OEA, 1999).

5 Conclusions

In the period 2007-2017, 37 socioeconomic studies have been published on the impact, profitability or adoption of technologies developed by INIAP, conducted by thirteen institutions, such as: Virginia Tech, University Purdue, Escuela Politécnica del Ejército, INIAP, among others. The results show that the technologies developed by INIAP, as Ecuador's main agricultural R+D center, have generated an internal rate of return of 33 % with a 37 % of adoption, positive results that justify the public investment in science and technology in Ecuador's agricultural sector. However, it is clear that many more studies are required to have better statistics in a greater number of research items and topics carried out by the institute, for example in coffee, cocoa, agrobiodiversity conservation and value (agribusiness). In addition, it is necessary to increase investment in science and technology, and to consolidate a national system and technical assistance for Ecuadorian farmers to increase the adoption of the technologies generated and to contribute to the sustainable and reference agriculture of the region.

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References

Álava, G. (2014). Estimación del impacto económico de las inversiones realizadas por el iniap en gneración y transferencia de tecnologías, en el cultivo de soya, durante el periodo 2000-2012. B.S. thesis.

Alston, J., Norton, G., and Pardey, P. (1998). *Science under scarcity: principles and practice for agricultural research evaluation and priority setting*. Cornell University Press. Online:https://bit.ly/2yJiaOh.

Banco Central del Ecuador, editor (2018). *Tasas Interés Efectivas: Octubre 2018*, Quito. Online:https://bit.ly/2Law9oD.

Barrera, V., Alwang, J., Andrango, G., A., D., Escudero, L., Martínez, A., Jácome, R., and Arévalo, J. (2017). La cadena de valor de la mora y sus impactos en la región andina del ecuador. Technical Report 171, Instituto Nacional de Investigaciones Agropecuarias, Unidad de Economía Agrícola., Quito-Ecuador. Online: https://bit.ly/2OGoEZ9.

Barrera, V., Escudero, L., Alwang, J., and Andrade, R. (2012). Integrated management of natural resources in the ecuador highlands. page Online:https://bit.ly/2yFRQES.

Barrientos-Fuentes, J. C. and Berg, E. (2013). Impact assessment of agricultural innovations: a review. *Agronomía Colombiana*, 31(1):120–130. Online:https://bit.ly/2GTlU4j.

Barrowclough, M.; Stehouwer, R. A. J. G. R. M. V. B. V. and Dominguez, J. (2016). Conservation agriculture on steep slopes in the andes: Promise and obstacles. *Journal of Soil and Water Conservation*, 71(2):91–102. Online:https://bit.ly/2yJ6Bqr.

Bazurto, D. (2014). Incidencia productiva y socioeconómica en productores de ganado bovino doble propósito en cuatro cantones del litoral, como consecuencia del grado de apoderamiento de tecnologías promovidas por el iniap. Tesis de pregrado. online: https://bit.ly/2YSsF0k, Universidad Técnica Estatal de Quevedo, Quevedo.

Cadena Iñiguez, P., Guevara-Hernández, F., Argüello-Aguilar, R., and Rendón Medel, R. (2018). Proceso de comunicación, extensionismo y adopción de tecnologías. *Revista mexicana de ciencias agrícolas*, 9(4):851–864. Online:https://bit.ly/2yHCX4H.

Carrión Yaguana, V., Alwang, J., Norton, G., and Barrera, V. (2015). Does ipm have staying power? revisiting a potato-producing area years after formal training ended. *Journal of agricultural economics*, 67(2):308–323. Online:https://bit.ly/2YMVPxR.

Cavatassi, R., Salazar, L., González-Flores, M., and Winters, P. (2011). How do agricultural programmes alter crop production? evidence from ecuador. *Journal of Agricultural Economics*, 62(2):403–428. Online:https://bit.ly/2Kz2qmu.

Cedeño, M. I. (2013). Factores agrosocioeconómicos que inciden en la adopción de tecnologías generadas por el iniap para el cultivo de plátano en la zona el carmen-santo domingo año 2013. Tesis de pregrado. online:https://bit.ly/2Kn0jmZ, Universidad Técnica Estatal de Quevedo, Quevedo.

Chicaiza, G. (2010). Determinación del nivel de adopción del híbrido del maíz duro iniap h-551 y sus componentes tecnológicos. Tesis de pregrado. online:https://bit.ly/31qX0ka, Universidad de las Fuerzas Armadas ESPE, Sangolquí-Ecuador.

Clements, C., Alwang, J., Barrera, V., and Dominguez, J. (2016). Graft is good: the economic and environmental benefits of grafted naranjilla in the andean region. *Renewable Agriculture and Food Systems*, 32(4):306–318. Online:https://bit.ly/33aTADY.

Córdova, J. (2013). Impacto económico de las inversiones realizadas por el iniap en investigación y transferencia de tecnología en palma africana (*Elaeis guineensis Jacq*). ecuador. 2000-2011. Tesis de pregrado. online: https://bit.ly/2KAHyv1, Universidad Central del Ecuador, Quito-Ecuador.

Feinstein, O. (2012). La institucionalización de la evaluación de políticas públicas en américa latina. *Presupuesto y gasto público*, (68):41–52. Online:https://bit.ly/33hBq3B.

Fernández Pérez, M. Á. and Mendoza Coronel, L. (2011). Determinación de la adopción de genotipos de cacao y sus componentes tecnológicos generados por iniap, en zonas cacaoteras representativas de manabí. Tesis de pregrado. online: https://bit.ly/2ZQdxOc, Universidad de las Fuerzas Armadas, Sangolquí.

Gasques, J., Vieira Filho, J., and Navarro, Z. (2010). A agricultura brasileira: desempenho, desafios e perspectivas. page Online:: https://bit.ly/2MM05rk.

González, J. (1998). *Evaluación económico-ecológica de temas de investigación agropecuarioa en los países andinos*, volume 5. Iica.

Guayasamín, M. (2015). Evaluación ex ante del impacto socio-económico del manejo convencional y mejorado del cultivo de naranjilla (solanum quitoense) en el ecuador. Tesis de pregrado. online: https://bit.ly/33kXFFC, Universidad Central del Ecuador, Quito.

IICA, OEA (1999). *Balance del estado general y la evolución de la agricultura y el Medio Rural de América: retos y oportunidades en el Siglo XXI*. OEA, San José.

Khandker, S., B. Koolwal, G., and Samad, H. (2010). *Handbook on impact evaluation: quantitative methods and practices*. The World Bank.

López, C., S. L. y. D. S. C. (2017). Gasto público, evaluaciones de impacto y productividad agrícola: Resumen de evidencias de américa latina y el caribe. Technical report, Banco Interamericano de Desarrollo, División del Medio Ambiente, Desarrollo Rural y Administración de Riesgos por Desastres. Online:https://bit.ly/2yFGnFl.

Mauceri, M., Alwang, J., Norton, G., and Barrera, V. (2007). Effectiveness of integrated pest management dissemination techniques: a case study of potato farmers in carchi, ecuador. *Journal of Agricultural and Applied Economics*, 39(3):765–780. Online:https://bit.ly/2YygkiI.

Mendoza, L., Racines, M., and Chávez, J. (2010). Retornos económicos de la investigación y transferencia de tecnologías generadas por iniap-ecuador: El caso arroz. Technical Report 141, Instituto Nacional de Investigaciones Agropecuarias, Dirección de Planificación y Economía Agrícola. Online:https://bit.ly/2yJp1Y7.

Mendoza, L., Racines, M., and Espín, O. (2011). Adopción de la variedad de arroz iniap-14 y sus componentes tecnológicos, en el proyecto de riego américa lomas, cantón daule, provincia del guayas. Technical report, Instituto Nacional de Investigaciones Agropecuarias, Dirección de Planificación y Economía Agrícola. Online:https://bit.ly/2MKkhJP.

Molina Loor, J. J. (2014). Determinación del impacto económico de las inversiones realizadas por el iniap en la generación y transferencia de tecnologías en el rubro yuca (*Manihot esculenta Crantz*). Tesis de pregrado. online: https://bit.ly/2KzhS1Y, Universidad Técnica de Manabí, Portoviejo.

Monteros, A. and Salvador, S. (2015). Rendimientos del arroz en cáscara segundo cuatrimestre del 2015. Technical report, Ministerio de Agricultura, Ganadería, Acualcultura y Pesca, Dirección de Análisis y Procesamiento de la Información, Quito-Ecuador. Online: https://bit.ly/31n1Uij.

Mora, J. (2012). Estimación del retorno económico de la investigación y transferencia de tecnologías generadas por el iniap en el rubro papa, ecuador. período 2000-2010. Tesis de pregrado. online:https://bit.ly/2OTLDAe, Universidad de las Fuerzas Armadas ESPE, Sangolquí.

Moreno, B. (2014). Rendimientos del arroz en cáscara en el ecuador, primer cuatrimestre de 2014. Technical report, Ministerio de Agricultura, Ganadería, Acuacultura y Pesca, Dirección de Análisis y Procesamiento de la Información, Coordinación General del Sistema de Información Nacional. Online:https://bit.ly/2yJ2Ot0.

Nguema, A., Norton, G. W., Alwang, J., Taylor, D. B., Barrera, V., and Bertelsen, M. (2013). Farm-level economic impacts of conservation agriculture in ecuador. *Experimental Agriculture*, 49(1):134–147. Online:https://bit.ly/2ZQAy3y.

Racines, M., Mendoza, L., and Yánez, F. (2011). Retorno económico de la investigación y transferencia de tecnología generada por iniap: caso maíz duro. Technical Report 143, Instituto Nacional de Investigaciones Agropecuarias, Dirección de Planificación y Economía Agrícola, Quito-Ecuador. Online: https://bit.ly/31n1Uij.

Rade, D., Cañadas, Á., Zambrano, C., Molina, C., Ormaza, A., and Wehenkel, C. (2017). Silvopastoral system economical and financial feasibility with jatropha curcas l. in manabí, ecuador. *Revista MVZ Córdoba*, 22(3):6241–6255. Online:https://bit.ly/33lcMyQ.

Reyes, B. (2012). *The Economic Impact of Improved Bean Varieties and Determinants of Market Participation: Evidence from Latin America and Angola*. Michigan State University. Agricultural, Food and Resource Economics.

Rivas, L., García, J., Seré, C., Jarvis, L., and Sanint, L. (1992). Modelo de análisis de excedentes económicos. Technical Report 107, Centro Internacional de Agricultura Tropical CIAT, Online:https://bit.ly/2OLD4az .

Salgado, J. (2013). Estimación del impacto económico de las inversiones realizadas por el iniap en investigaciones y trasferencia de tecnología en "limón sutil" (*Citrus aurantifolia Swingle*). Tesis de pregrado. online:https://bit.ly/2YQVAxG, Universidad Técnica de Manabí, Potoviejo.

SENESCYT e INEC. n.d, editor (2014). *Indicadores de Actividades de Ciencia, Tecnología e Innovación (ACTI) del Ecuador, Período 2009-2014.*, Quito. Online: https://bit.ly/2ON21Cm. Editogram-Medios Públicos.

Sotomayor, D. (2011). Estimación de los retornos de las inversiones realizadas por iniap en investigación y transferencia de tecnologías en cacao, ecuador (2000-2010). Tesis de pregrado. online: https://bit.ly/2M4MGek, scuela Politécnica del Ejército, Quito-Ecuador.

Sowell, A. and Shively, G. (2012). Economic and environmental impacts of grafted naranjilla. *Forests, Trees and Livelihoods*, 21(1):30–43. Online:https://bit.ly/2ZEnFJT.

Stads, G., Perez, S., Iglesias, C., and Beinterma, N. (2016). Ecuador: Ficha técnica - indicadores de i+d agropecuario. Technical report, International Food Policy Research Institute (IFPRI) and National Institute for Agricultural Research. Online:https://bit.ly/2yJ19Ui.

Suquillo, F. (2014). Estimación del impacto económico de las inversiones realizadas por el iniap, en la generación y transferencia de tecnologías en cebada (*Hordeum vulgare L.*). Tesis de pregrado. online:https://bit.ly/2OGWwF7, Universidad de las Fuerzas Armadas, Sangolquí.

Timmer, C. P. (1992). Agriculture and economic development revisited. *Agricultural Systems*, 40(1-3):21–58. Online:https://bit.ly/33f2UGV.

UNCTAD (2007). Los paises menos adelantados: el conocimiento, el aprendizaje tecnológico y la innovación para el desarrollo. informe 2007. Technical report, Naciones Unidas, New York y Ginebra.

Vieira Filho, J. E. R. and Fornazier, A. (2016). Productividad agropecuaria: reducción de la brecha productiva entre el brasil y los estados unidos de américa. *Revista Cepal*, page Online:https://bit.ly/2TbxY5S.

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GROWTH PATTERN DURING THE FIRST GESTATION OF HEIFERS CROSSES WITH BRAHMAN FATHER AND DIFFERENT MATERNAL GENOTYPE

PATRÓN DE CRECIMIENTO DURANTE LA PRIMERA GESTACIÓN DE VAQUILLONAS CRUZA CON PADRE BRAHMAN Y DIFERENTE GENOTIPO MATERNO

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Resumen

El objetivo del presente trabajo fue evaluar el patrón de crecimiento durante la primera gestación de vaquillonas cruza con padre Brahman y diferente genotipo materno, en la Amazonía Ecuatoriana. Se utilizaron datos retrospectivos de 2304 pesos individuales de 48 vacas cruzas lecheras. Con ello, se evaluó el comportamiento dinámico del peso corporal de cuatro genotipos: Brahman x Gyr (Gyr) (n=12), Brahman x Brown Swiss (BS) (n=12), Brahman x Jersey (J) (n=12) y Brahman x Sahiwal (S) (n=12), pertenecientes al rodeo lechero del Centro de Investigación, Posgrado y Conservación de la Biodiversidad Amazónica (CIPCA) – Ecuador. Las diferencias entre genotipos en el peso corporal a la preñez y al primer parto no fueron estadísticamente significativas. Se observaron diferencias en la edad a la primera preñez correspondiendo la mayor precocidad a la cruza con madre Brown Swiss y la menor precocidad a las cruzas con Gyr y Sahiwal. Las hembras producto del cruzamiento con Jersey presentaron un comportamiento intermedio. Se observó que, durante su primera gestación, las vaquillonas F1 con padre Brahman y diferente genotipo materno, presentan similar patrón de crecimiento en las condiciones limitantes de la Amazonía Ecuatoriana, respuesta interpretable en términos de interacción genotipo-ambiente negativa.
Palabras clave: Biogás, metano, relleno sanitario, estimación teórica.

Abstract

The objective of the present work was to evaluate the growth pattern during the first gestation of heifers crossed with Brahman father and different maternal genotype in the Ecuadorian Amazon. Retrospective data of 2304 individual weights of 48 dairy cows were used. The dynamic behavior of the body weight of four genotypes was evaluated: Brahman x Gyr (Gyr) (n=12), Brahman x Brown Swiss (BS) (n=12), Brahman x Jersey (J) (n=12) and Brahman x Sahiwal (S) (n=12) belonging to the dairy herd of the Research Center, Postgraduate studies and Preservation of the Amazonia Biodiversity (CIPCA) – Ecuador. The differences between genotypes in body weight at pregnancy and at first birth were not statistically significant. Differences in age at the first pregnancy were observed, with the highest precocity at crossing with Brown Swiss mother and the lower precocity at crosses with Gyr and Sahiwal. The females produced by crossing with Jersey showed intermediate behavior. It was observed that, during their first gestation, F1 heifers with Brahman father and different maternal genotype have a similar growth pattern under the conditions of the Ecuadorian Amazon, response in terms of negative genotype-environment interaction.
Keywords: Landfill gas, methane, landfill, theoretical estimation.

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1 Introduction

Calderón et al. (1993); Abeygunawardena and Dematawewa (2004), reported that females from crossbreeds between zebu and European breeds begin puberty at a younger age compared to pure breeds in wet tropic conditions, with values of 15 and 19 months, respectively. The genetic variability existing within and between breeds results in differences in age and body weight to the presentation of the first estrus, affecting subsequent reproductive events that end up being global productive (Navarrete, 1995; Nogueira, 2004). For this reason, it is important to have different breeds adapted to these particular conditions, able to overcome the productive limits that *Bos taurus* breeds present in these regions. In this sense, it has been observed that cows from Brahman x *Bos taurus* crosses have higher fertility, higher milk production and greater longevity than those of pure *Bos taurus* genotype (Grajales et al., 2006; Zambrano-Sepúlveda et al., 2014).

However, by increasing the proportion of indica genes, females tend to delay age at puberty and this impacts negatively their subsequent reproductive behavior. In this sense, it has been found (Rocha and Lobato, 2002; Zambrano and Contreras, 2014) the inability of cows to cross Brahman x *Bos taurus* to produce a replacing cow that maintains its same productivity characteristics, as a result of the loss of heterosis with respect to that expressed by F1. The live weight record of cattle is a strategy that allows to monitor the behavior in their natural environment, and this information is specifically used for a variety of purposes, including determining the appropriate feeding level and the nutritional status of animals, monitoring the growth rate and responses to the genetic selection (Marulanda, 1996; Lesosky et al., 2013; Lukuyu et al., 2016).

The assessment of the live weight of animals in livestock production systems is essential if wanting to implement good grassland management practices aimed at achieving sustainable production in the Amazon. In this context, the aim of this research is to evaluate the growth pattern during the first gestation of heifers crossed with Brahman father and different maternal genotype in the Ecuadorian Amazon.

Table 1. Age and body weight at the first pregnancy in four F1 heifer groups with Brahman father and different mother genotype.

Variable	Mother genotype				Contrastes
	Gyr	Brown Swiss	Jersey	Sahiwal	
Age (days)	$1148^{c} \pm 57{,}7$	$852^{a,b} \pm 38{,}3$	$994^{b,c} \pm 49{,}5$	$1135^{c} \pm 54{,}4$	F = 7,619 p = 0,0003
Pregnancy weight (kg)	319 ± 17,3	350± 9,5	308± 13,6	324± 8,6	F = 1,239p = 0,307
Calving weight (kg)	392± 15,8	414± 18,8	399± 14,0	399± 11,0	F = 1,239p = 0,307

All values correspond to an arithmetic mean ± standard error.
Sample size: n = 12 individuals per group.
a, b, c Values with different letters differ in at least 0.05.

2 Materials and methods

Retrospective data were used from 2304 individual body weight records of 48 dairy cross cows belonging to four genotypes: Brahman x Gyr (Gyr) (n=12), Brahman x Brown Swiss (BS) (n=12), Brahman x Jersey (J) (n=12) and Brahman x Sahiwal (S) (n=12) belonging to the Research Center, Postgraduate studies and Preservation of the Amazonia Biodiversity (CIPCA). This center is located in Carlos Julio Arosemena Tola, Napo province (Ecuador), at kilometer 44 of Puyo-Tena (coordinates: S 01° 14.325; W077° 53.134) and has 42 ha of pasture for breeding. Heifers came from the same establishment and had been bred under the same environmental, nutritional and management conditions, and entered in CIPCA at 15-17 months of age and with body weights (average EE) of 204 x 7.7 kg (G); 276 x 11.0 kg (BS); 204 x 8.7 kg (J) and 186 x 6.0 kg (S). In order to assess the dynamic behavior of the body weight, all animals were weighed individually between December 2012 and December 2016, every 30 days. The feeding of the bovine herd under study was free grazing, with grasslands based on Brachiaria decumbens (17 585 kg MS/ha/year, Protein: 10.6 % Phosphorus: 0.18 %; DIV: 44.4 %), Brachiaria brizantha (26 970 kg MS/ha/year; Protein: 10.1 %; Phosphorus: 0.18 %; DIV: 44.1 %), Arachis pintoi (6 212 kg MS/ha/year; Protein: 19.4 %; Phosphorus: 0.21 %; DIV: 59.2 %), Desmodium ovalifolium (5 890 kg MS/ha/year; Protein: 16.3 %; Phosphorus: 0.16 %; DIV: 39.6 %) and Stylosanthes guianensis (15 237 kg MS/ha/year; Protein: 21.4 %; Phosphorus: 0.4 %; DIV: 48.7 %) (Leonard, 2015).

The health management applied was commonly used for CIPCA, which includes deworming, claw stools and flies, vaccinations for foot-and-mouth disease, bovine rabies and vesicular stomatitis and the injectable application of vitamins and minerals. The body weight (kg) was recorded individually at the first pregnancy, the age (days) to the first pregnancy and the body weight (kg) at the first calve. The normal distribution of each of these variables was evaluated with the D'Agostino Pearson test (D'Agostino and Pearson, 1973) and the homogeneity of its variances with Brown-Forsythe test (Brown and Forsythe, 1974). For each genotype, the average body weight during the first gestation was calculated at monthly intervals. The average data calculated were organized according to the months of gestation, in all cases identifying behavior similar to a linear model found with a cycle test. The effect of the genetic group on the values of the estimators of linear function parameters was assessed with a covariance analysis.

3 Results

Table 1 shows the effect of the genetic group on the three response variables, all of them presenting normal distribution and homogeneous variations. The observed differences between genotypes in body weight at pregnancy and early calving were not statistically significant. Differences in age to the first pregnancy were observed, being the highest precocity the crosses with Mother Brown Swiss and the lowest precocity the crosses with Gyr and Sahiwal. Females with Jersey crossing presented intermediate behavior.

On adjusting the average body weight vs gestation months, a non-significant deviation from linearity was observed for the four genetic groups [Mother Gyr (p = 0.833), Mother Brown Swiss (p = 0.283), Mother Jersey (p = 0.881) and Mother Sahiwal (p = 0.405)]. The values of the linear determination coefficient (R^2) and the residual variances (S_{yx}) showed an adequate goodness of the adjustments [mother Gyr (R^2 = 0.773; S_{yx} = 9.88), mother Brown Swiss (R^2 = 0.958; S_{yx} = 6.00), Mother Jersey (R^2 x 0.967; S_{yx} = 5.54) and Sahiwal mother (R^2 = 0.975; S_{yx} = 3.85)]. Regression equations corresponding to the different groups are listed in Table 2.

Table 2. Regression of the different groups of different mother genotype.

Mother Gyr	Y= 5,676 * X + 321,2
Mother Pardo suizo	Y= 8,884 * X + 342,5
Mother Jersey	Y= 9,347 * X + 307,5
Mother Sahiwal	Y= 7,488 * X + 321,7

Table 3. Ordinates of regressions of groups of different mother genotype.

Genotype	Ordinate	Registered weight
Mother Gyr	a= 321,2 Kg	319Kg
Mother Pardo suizo	a=342,5 Kg	350 Kg
Mother Jersey	a=307,5 Kg	308 Kg
Mother Sahiwal	a=321,7 Kg	324 Kg

Ordinate values at origin (body weight estimators at the beginning of gestation) showed no differences (p >0.05) with the observed values (Table 3). All the slopes were statistically different to zero (Table 4).

The analysis of covariance revealed a statistically significant difference in the value of the slopes (F = 5.018; p = 0.0058) of the different genetic groups, which prevented the comparison of the differences in height. Since the slopes are estimators of the daily weight gain rate throughout gestation, the observed difference between them highlighted a particular behavior of females resulting from Brahman x Gyr crossbreeding, showing lower weight gain in the period. When excluding this group from the analysis, the differences between the slopes of the three remaining genotypes were statistically non-significant (F = 2.845; p = 0.078), which allowed to calcu-

Table 4. Slopes of regressions of groups of different mother genotype.

Genotype	Regression	Significance
Mother Gyr	b ± S_b = 5,676 ± 1,088 kg/mes	F = 27, 2 p = 0,0008
Mother Pardo suizo	b ± S_b = 8,884 ± 0,661 kg/mes	F = 181 p <0,0001
Mother Jersey	b ± S_b = 9,347 ± 0,610 kg/mes	F = 235 p <0,0001
Mother Sahiwal	b ± S_b = 7,488 ± 0,423 kg/mes	F = 313 p <0,0001

late a slope common to all of them (bc = 8.573 kg/month) and compare the heights, which are statistically different (F = 99.4; p <0.0001).

4 Discussion

In Ecuador, as in other countries of the tropics and subtropics of Latin America, there has been a strong tendency to replace local breeds with exotic breeds in order to increase milk production levels. These breeds introduced in the area for breeding purposes come from regions where climatic and nutritional conditions are generally more favorable compared to those prevailing in the destination area, so their productive performance is negatively affected. Because of this, a genetic management strategy that local producers have resorted to is the use of crossbreeding between zebu breeds (*Bos indicus*) and European breeds (*Bos taurus*) in an attempt to minimize the adaptation problems (Tewolde, 1993; Madalena, 2012).

Despite their differences in the body size, all the genotypes evaluated in this work showed similar behavior in terms of growth pattern during their first gestation. This result agrees with the fact that weight increases during the breeding to the first milking of the four cross dairy genotypes analyzed were 0.201 kg/day, according to the region under study. None of the dairy crossings stood out above the other, all were similar (Quinteros et al., 2015).

The fact that the heifers under study do not differ in their weight gains during the first gestation regardless their genetic formation can be interpreted in terms of a negative genotype-environment correlation. According to this, the best genotype in terms of potential growth rate-crosses with Brown Swiss-receives the worst environment. This claim is based on the fact that, if the weight to pregnancy accounted for 65 % of the adult weight of each maternal genotype, the calve weight should be 90 % of the adult weight, with theoretical values for Brahman x Gyr of 441 kg, for Brahman x Brown Swiss of 538 kg, for Brahman x Jersey of 473 kg and for Brahman x Sahiwal of 498 kg.

This prediction differs from the results reported in this work, with observed body weights lower than the expected under this hypothesis (Table 1), and is in line with the limited atmosphere of the area. The high relative humidity and the high temperatures typical of the Ecuadorian Amazon are factors that negatively impact the cows, and according to Sánchez (2010); Arias et al. (2008), animals will produce to the extent that environmental conditions allow them to show their productive potential. The low yield value reflects the values resulting from the assessment of productive and reproductive variables used as indicators of their rate or level of economic profit and adaptation of animals, expressed as averages of age at first calve, interval between calves and postpartum estrum and milk production (Morales, 2009; Motta et al., 2012; Quinteros-Pozo and Marini, 2017).

The genotype with maternal Brown Swiss begins pregnancy at an earlier age (higher precocity), and these are maintained throughout pregnancy although the differences did not reach statistical significance with higher body weight. Most likely, an improvement in quality and in the amount of diet offered could increase the average daily weight gain. The reality indicates that this option is not always possible, hence, alternatives of using the elements available in the Amazon should be thought. In this regard, there are findings that show that weight gain values ranging from 600 to 750 grams per day would be optimal for future dairy cows, while lower values could cause a delay in puberty (Wathes et al., 2014; González-Stagnaro et al., 2007). However, these are works that have not been carried out in environments such as the Amazon, so the transfer of the results derived from them is not always possible.

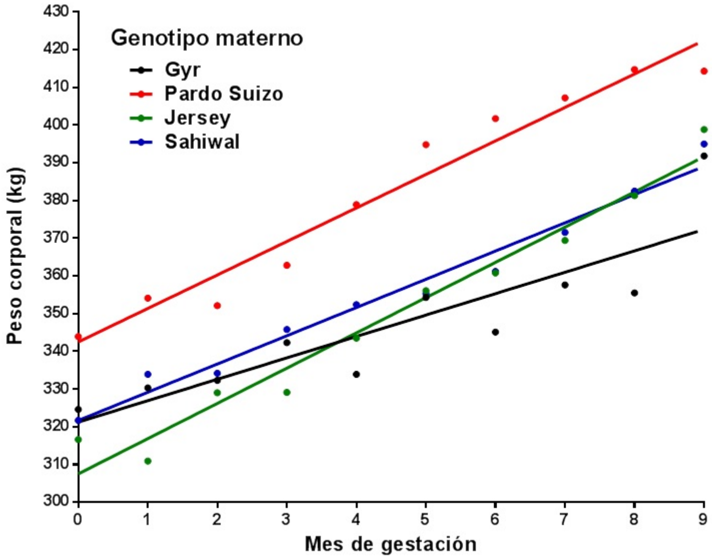

Figure 1. Linear growth pattern during the first gestation of cows crossed with Brahman paternal genotype and different maternal genotype in grazing conditions in the Ecuadorian Amazon.

5 Conclusion

The results confirm that the limiting environmental conditions in the Ecuadorian Amazon prevent the expression of the different genetic potentials of F1 heifers with Brahman father and different maternal genotype during their first gestation, resulting in a similar growth pattern in all of them. Considering that what is measured in animals is a phenotype resulting from the action of its genetic composition in the environment in which it is to express itself, the choice of a particular cross will be determined by the feasibility of offering an ambition nutritional status more in line with the requirements. The presence of a negative-genotype environment interaction indicates that it makes no sense to generate a population by crossbreeding whose growth potential and its correlation at the reproductive level cannot be expressed by limitations attributable to the environment.

References

Abeygunawardena, H. and Dematawewa, C. (2004). Prepubertal and postpartum anestrus in tropical zebu cattle. *Animal Reproduction Science*, 82:373–387. Online: https://bit.ly/2YJcZbE.

Arias, R., Mader, T., and Escobar, P. (2008). Factores climáticos que afectan el desempeño productivo del ganado bovino de carne y leche. *Archivos de medicina veterinaria*, 40(1):7–22. Online: https://bit.ly/2yBzbtB.

Brown, M. B. and Forsythe, A. B. (1974). The small sample behavior of some statistics which test the equality of several means. *Technometrics*, 16(1):129–132. Online: https://bit.ly/2Ko6ENK.

Calderón, R., Villa-Godoy, A., Zapata, S., and Lagunes, L. (1993). Actividad ovárica en becerras suizo pardo y cebú en clima tropical af (c). i. inicio de la pubertad y su correlación con la primera ovulación. *Memorias Reunión Nacional de Investigación Pecuaria, INIFAP, Jalisco*.

D'Agostino, R. and Pearson, E. S. (1973). Tests for departure from normality. empirical results for the distributions of b_2 and $\sqrt{b_1}$. *Biometrika*, 60(3):613–622. Online: https://bit.ly/2YJcZbE.

González-Stagnaro, C., Madrid-Bury, N., Goicochea-Llaque, J., González-Villalobos, D., and Rodríguez-Urbina, M. A. (2007). Primer servicio en novillas de doble propósito. *Revista Científica*, 17(1):39–46. Online: https://bit.ly/2YGerzx.

Grajales, H., Hernández, A., and Prieto, E. (2006). Edad y peso a la pubertad y su relación con la eficiencia reproductiva de grupos raciales bovinos en el trópico colombiano. *Livestock Research for Rural Development*, 18(10):1–25. Online:https://bit.ly/2U7wVmS.

Leonard, I. (2015). *Recursos forrajeros autóctonos y promisorios para la ganadería en la provincia de Pastaza. Retos y posibilidades para una ganadería sostenible en la provincia de Pastaza de la Amazonia Ecuatoriana.*, chapter IV, pages 46–69. Universidad Estatal Amazónica.

Lesosky, M., Dumas, S., Conradie, I., Handel, I. G., Jennings, A., Thumbi, S., Toye, P., and de Clare Bronsvoort, B. M. (2013). A live weight–heart girth relationship for accurate dosing of east african shorthorn zebu cattle. *Tropical Animal Health and Production*, 45(1):311–316. Online:https://bit.ly/2Kgv9O9.

Lukuyu, M. N., Gibson, J. P., Savage, D., Duncan, A. J., Mujibi, F., and Okeyo, A. (2016). Use of body linear measurements to estimate liveweight of crossbred dairy cattle in smallholder farms in kenya. *SpringerPlus*, 5(1):63. Online: https://bit.ly/2ZuwQwF.

Madalena, F. E. (2012). Animal breeding and development–south american perspective. *Journal of Animal Breeding and Genetics*, 129(3):171–172. Online: https://bit.ly/2ODeFDP.

Marulanda, E. (1996). Evaluación de la edad al primer servicio y su incidencia en la productividad y reproducción de novillas cebú. *Revista El Cebú*, 287. Online:https://bit.ly/2Kgvqk2.

Morales, D., P. B. B. R. (2009). Parámetros productivos y reproductivos de importancia económica en ganadería bovina tropical. En líneaÑ http://goo.gl/VEM5Gr.

Motta, D., Rivera, C., Mariño, A., Lizcano, P., et al. (2012). Productive and reproductive performance of f1 gyr× holstein cows in colombian warm climate. *Veterinaria y Zootecnia*, 6(1):17–23.

Navarrete, M. (1995). Análisis de productividad de diferentes cruzamientos en doble propósito. experiencias en la costa norte colombiana. In *Estrategias de mejoramiento genético en la producción bovina tropical*, Memorias seminario internacional. Medellín. Colombia, pages 159–170.

Nogueira, G. P. (2004). Puberty in south american bos indicus (zebu) cattle. *Animal reproduction science*, 82:361–372. Online: https://bit.ly/2yG9vMF.

Quinteros, O. R., Vargas, J. C., Barbona, I., and Marini, P. R. (2015). Live body weight evaluation of four genotypes of dairy heifers under free grazing conditions in ecuador. *Asian Journal of Agriculture and Food Sciences*, 3(3):273 – 281.

Quinteros-Pozo, R. and Marini, P. (2017). Evaluación productiva y reproductiva de cuatro genotipos lecheros en pastoreo libre en la amazonía ecuatoriana. *Revista veterinaria*, 28(1):9–13. Online: https://bit.ly/2yCt7ky.

Rocha, M. G. d. and Lobato, J. F. P. (2002). Avaliação do desempenho reprodutivo de novilhas de corte primíparas aos dois anos de idade. *Revista brasileira de zootecnia.*, 31(3):1388–1395. online: https://bit.ly/2Kgwnc6.

Sánchez, T. (2010). Análisis técnico económico del intervalo entre partos de bovinos. Technical report, AFAGRO LTDA. Online: https://bit.ly/2T5r0iX, Medellín, Colombia.

Tewolde, A. (1993). El estado actual de los recursos genéticos animales en américa latina. In *Memoria Simposio sobre los Recursos Genéticos animales en América Latina*, pages 11–18.

Wathes, D. C., Pollott, G. E., Johnson, K. F., Richardson, H., and Cooke, J. S. (2014). Heifer fertility and carry over consequences for life time production in dairy and beef cattle. *Animal*, 8(1):91–104. Online: https://bit.ly/2ZuCZJf.

Zambrano, R. and Contreras, R. (2014). Descarte, vida productiva y selección en rebaños doble propósito. *Logros Desafíos de la Ganadería Doble Propósito. C. González-Stagnaro, N. Madrid-Bury, E. Soto-Belloso (Eds.). Fundación GIRARZ. Ediciones Astro Data SA Maracaibo, Venezuela.*, 16:157–164.

Zambrano-Sepúlveda, R. A., Chirinos, Z., Bracho, B., and Yáñez-Cuellar, L. F. (2014). Evaluación de la vida productiva de un rebaño bovino mestizo doble propósito, utilizando análisis de supervivencia. *Revista Científica*, 24(6):535–542. Online: https://bit.ly/2yzS3cG.

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ASSOCIATION BETWEEN SUBCLINICAL MASTITIS WITH EARLY LOSS OF GESTATION IN A DAIRY COW HERD

ASOCIACIÓN ENTRE LA MASTITIS SUBCLÍNICA CON LA PÉRDIDA TEMPRANA DE GESTACIÓN EN UN HATO DE VACAS LECHERAS

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Resumen

El objetivo del presente estudio fue evaluar la asociación entre los diferentes grados de mastitis subclínica con la pérdida temprana de gestación durante los primeros 90 días posteriores al servicio en vacas lecheras Holstein. La investigación se realizó en una explotación lechera ubicada en Ecuador, provincia de Pichincha, cantón Mejía. Para el estudio se analizaron los datos de 619 vacas durante el período de octubre de 2015 hasta octubre de 2016. Se utilizaron tres grupos experimentales clasificados por la severidad de mastitis subclínica diagnosticada por California Mastitis Test (CMT). El Grupo control (CMT 0) vacas que no presentaron mastitis subclínica hasta los 90 días posteriores a la inseminación artificial (IA). El grupo CMT T-1, vacas diagnosticadas con mastitis subclínica grado trazas y grado 1 hasta los 90 días posteriores a la IA y el grupo CMT 2-3, vacas que presentaron mastitis subclínica grado 2 y 3 hasta los 90 días posteriores a la IA. El diagnóstico de gestación se realizó por ultrasonografía transrectal entre los 28 y 35 días posteriores a la IA y se realizó un seguimiento ecográfico a los 60 y 90 días de gestación. Se encontró una pérdida de gestación entre los 30 a 60 días del 12 % y entre los 60 a 90 días del 5 %. Con este resultado se evidenció una asociación entre mastitis subclínica grado 2 y 3 con la pérdida temprana de gestación (OR 2,6; p <0,01). Se postula que un proceso infeccioso en la ubre posterior a la IA desencadenaría la liberación de mediadores inflamatorios como la prostaglandina $F2\alpha$ que ocasionaría lisis del cuerpo lúteo y pérdida de la gestación. En conclusión, las vacas que tienen mastitis subclínica de grado 2 y 3 tienen mayor riesgo de pérdida de gestación durante los primeros 90 días posteriores al servicio.

Palabras clave: Bovinos, gestación, luteólisis, mastitis, subclínica.

Abstract

The objective of this research was to evaluate the relationship between different levels of subclinical mastitis with the early gestation lost during the first 90 post-insemination days in Holstein dairy cattle. The research was made on a dairy farm located in Mejía, Pichincha Province, Ecuador. This research analyzed data from a sample of 619 cows during one year since October 2015 until 2016. Three experimental groups graded by the severity of subclinical mastitis and diagnosed by California Mastitis Test (CMT) were used. The control group (CMT 0), formed by cows that did not present any subclinical mastitis until 90 post-insemination days. The CMT T-1 group, formed by cows diagnosed with subclinical mastitis grade 1 up to 90 post-insemination days and the CMT 2-3 group, cows that presented subclinical mastitis grade 2 and 3 up to 90 post-insemination days. The pregnancy diagnosis was made by transrectal ultrasonography between 28 and 35 post-insemination days and a follow up ultrasound was performed at 60 and 90 days of gestation. A pregnancy loss of 12% was found between 30 to 60 and 5% between 60 to 90 days. With this result a relationship between subclinical mastitis grade 2 and 3 with early pregnancy loss was evidenced (OR 2.6, p <0.01). It is postulated that an infectious process in the udder after the insemination can induce the release of inflammatory mediators such as prostaglandin $F2\alpha$ that would cause lysis of the corpus luteum and loss of gestation. In conclusion, dairy cattle presenting subclinical mastitis grade 2 and 3 have a higher risk of pregnancy loss during the first 90 post-insemination days.
Keywords: Cattle, gestation, luteolysis, mastitis, subclinical.

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1 Introduction

Mastitis in cattle is a contagious infected disease of the udder, in which an inflammatory process by invasion occurs through the nipple channel of different types of bacteria, mycoplasmas, fungi, yeasts and some viruses. Bacteria of the genera *Streptococcus, Staphylococcus, Corynebacterium* and some Gram - germs are responsible for more than 90% of clinical and subclinical infections. It is the most common and expensive disease affecting dairy cattle; there are numerous studies indicating the importance of the disease, mainly for causing economic losses and risks in public health (Philpot and Nickerson, 2002).

Its impact is mainly on the volume and quality of production, animal welfare and herd reproduction (Hillerton and Berry, 2005). The profitability in the dairy industry depends on several factors of reproductive efficiency. The conception rate, the rate of estrus detection and gestation loss are among the main factors that determine reproductive efficiency in dairy herds. However, the loss of gestation can have detrimental effects on the economic success of dairy herds. It is estimated that there is an average loss of USD $640 for each gestation loss (Thurmond et al., 1990).

The costs of mastitis are mainly associated with milk loss, increased discard rates and treatment costs. However, this disease also indirectly affects reproductive performance in dairy cows by altering interstellar intervals, shortening the lutetium phase (premature luteolysis) and gestation losses (Moore et al., 1991).

Several studies have found that bacterial multiplication, the release of endotoxins and exotoxins are involved in the release of inflammatory mediators, which could lead to luteolysis (Riollet et al., 2001). Inflammatory mediators such as prostaglandins, histamine leukotriene and serotonin have been shown to increase cases of experimentally induced mastitis through intravenous infusions of lipopolysaccharides endotoxins (LPS) or intramammary infusions of endotoxin of *Escherichia coli* or *Salmonella typhimurium* (Blum et al., 2000; Waller et al., 2003). In addition, there are studies that have shown the synthesis of luteolytic prostaglandin concentrations after an infusion of endotoxins or septicaemia by gram-negative. *Salmonella enteritidis* intravenous endotoxin causes abortion in mice. Risco et al. (1999) concluded that the use of bacterial endotoxins causes dose-dependent clinical signs, ranging from transient fevers to abortions 24 to 48 hours after the intravenous injection.

Mastitis caused by Gram negative bacteria can cause bacteremia in more than 30% of cases in affected cows (Wenz et al., 2001). With regard to Gram positive bacteria, their cell wall is composed of many layers of peptidoglycan mucopeptide, these do not have endotoxin, but their presence in the mammary gland cause an inflammatory response that is identical to that caused by the endotoxins of Gram negative bacteria (Salyers and Whitt, 1994). Therefore, it is clear the information that shows the influence of mastitis on the rates of conception, early embryonic mortality and abortions (Risco et al., 1999; Barker et al., 1988).

2 Materials and methods

The experiments were conducted in a private livestock farming that is committed to the production of milk under a semi-intensive production system. It is located in Ecuador, in the province of Pichincha, Canton Mejía, Tambillo Parish; the farm is at an altitude of 2827 masl, there is an average temperature between 10 and 25 $^{\circ}C$ and a rainfall of 1157 mm per year.

2.1 Factors under study

The livestock farm has an average of 500 Holstein milking cows, with an average production of 24 liters cow/day. Data on 619 cows were analyzed for the test. The study period was carried out during the months of October 2015 to December 2016. Lactating cows and cattle that passed the 60-day voluntary waiting period and were in a position to be inseminated were considered. Cows that had clinical mastitis through the CMT test were not considered in this study because they received anti-inflammatory and antibiotic treatment to control udder infection.

The diagnosis of subclinical mastitis was made by the Veterinary Physician of the livestock farm, using the field test CMT to the group of cows in production once a month during the lenght of the research. The protocol for applying the test was as follows:

To avoid false positives, the first milk jets of each nipple were discarded, then milked in the 2 ml milk palette, an equivalent amount of reagent was added, stirred to mix the milk with the reagent and the reading was made: negative, trace, one, two, three (Zurita, 1982). The CMT test is a diagnostic field tool based on the detergent breaking down cells (lysator) and letting their DNA out of the cell membrane, these DNA filaments tend to form gel-like structures when they bind with others (Philpot and Nickerson, 2002). The highest degree of inflammation is characterized by releasing a higher concentration of DNA; therefore, the result and interpretation will be a gelatin reaction (Smith, 1990; Saran and Chaffer, 2000; Medina and Montaldo, 2003).

The classification made by Ruíz (1996) was used for the interpretation of the degree of subclinical mastitis:

- Negative: There is no precipitate, therefore there is no infection.
- Traces (T): There is slight precipitation that disappears when shaking, a veil forms in the well of the paddle.
- Grade 1: There is a slight agitation with some lumpy filaments, when moving the paddle for about 20 seconds the lumps tend to disappear, it has a light gelatin appearance.
- Grade 2: It has the appearance of an egg white, it takes mucus consistency and drops the precipitate into the well slowly, this grade corresponds to a serious infection.
- Grade 3: The reaction has a consistency of clot that sticks to the paddle, falls very slowly and it does not lose its shape despite the agitation, this degree corresponds to a serious infection.

2.2 Diagnosis of gestation

The diagnosis of gestation was made by a gynecologist veterinary doctor using transrectal ultrasound (Mindray DP-10 VET with 8.5 mHZ transducer) between 28 and 35 days post-insemination. The gestation was monitored twice during 60 and 90 days gestation.

2.3 Experimental groups

2.3.1 Control group

Cows that were diagnosed as pregnant within 30 days of service and did not have mastitis by testing CMT until 90 days after artificial insemination (AI).

2.3.2 Group 1

Cows that were diagnosed as pregnant within 30 days of service and who had trace-grade subclinical mastitis and grade 1 subclinical mastitis through the CMT test up to 90 days after AI.

2.3.3 Group 2

Cows that were diagnosed as pregnant within 30 days of service and who had grade 2 subclinical mastitis and grade 3 subclinical mastitis through the CMT test up to 90 days after AI.

Table 1. Odds Ratio (OR) and p value of the different degress of subclinical mastitis.

Degree of mastitis	N	Cows with gestation loss	Pregnant cows	OR	p value
0	309	44	265	reference	
T	130	14	116	0,72	>0,01
1	77	14	63	1,38	>0,01
2	48	13	35	2,24	<0,05
3	55	18	37	2,93	<0,01

The degrees of mastitis are indicated by 0: Negative, T: Traces, 1: Subclinical mastitis degree 1, 2: Subclinical mastitis degree 2, 3: Subclinical mastitis degree 3. OR Represents the reproductive rate.

2.4 Statistical analysis

To determine the association between the embryonic and fetal loss variable in Holstein dairy cows during the first 90 days of gestation with the exposure factor presence of subclinical mastitis, the Odds Ratio (OR) test was performed in group 1 and group 2, and the significance level was analyzed using the Square Chi test. The reason for opportunities or probability ratio is a statistical measure used in cross-sectional epidemiological studies, case and control studies, as well as meta-analysis. It is defined as the possibility of one health condition or disease occurring in one animal population group versus the risk of it occurring in another animal.

3 Results

The OR for group 1 was 0.94, and the test of Chi square concluded that there was no significant association between the presence of trace-grade subclinical mastitis and grade 1 with gestation loss. The OR for group 2 was 2.6 and the test of Chi square concluded that there was a highly significant association between the presence of grade 2 and grade 3 subclinical mastitis with the gestation loss (P <0.01).

Table 1 shows the score results of the different degrees of subclinical mastitis with the results of the OR and Chi square test, which concludes that cows with grade 2 mastitis have a risk of 2.24 times more of having a loss of gestation compared to cows that do not have mastitis during the first 90 days following insemination; while cows with grade 3 mastitis have a 2.93 times higher risk of having a loss of gestation compared to cows that do not have mastitis during the first 90 days post insemination.

3.1 Rate of gestation loss

Embryonic mortality in cattle refers to losses that occur during the first 45 days of gestation that agrees with the end of the embryo differentiation period. Embryonic losses in turn can be classified as early embryo mortality when occurring within 25 days, and late embryo mortality between 25 and 45 days (Humblot, 2001). The terms stillbirth or abortion refer to losses that occur between 45 and 260 days of gestation. Table 2 shows the results of the number of cows who lost gestation and who had subclinical mastitis during the first 90 days post-insemination. Out of a total of 103 cows that lost gestation, 31 cows had some degree of udder infection, possibly causing embryonic and fetal death. The highest percentage of gestation loss was present in cows with grade 3 subclinical mastitis.

The highest number of embryonic and fetal deaths occurred between day 30 and 60 post-insemination with a percentage of 12 %, while between days 61 and 90 days, 5 % stillbirth was recorded. There is a total embryonic and fetal loss of 17 % during the first 90 days post-insemination, as shown in Figure 1.

Within the group of cows who lost gestation caused by subclinical mastitis grade 2 between 30 and 60 days, 89 % of cows lost gestation in this period, while cows that had grade 2 subclinical mastitis between 61 and 90 days, 50 % of cows lost gestation. In the group of cows who lost gestation caused by grade 3 subclinical mastitis between 30 and 60 days, 67 % of cows lost gestation in this period, while cows that had grade 3 subclinical mastitis between 61 and 90 days, 17 % of cows lost on gestation.

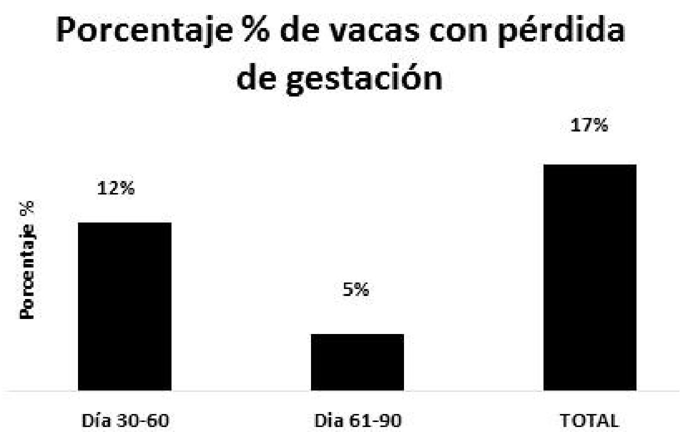

Figure 1. Percentage (%) of embryonic and fetal losses between days 30-60 and 61-90 post-insemination in Holstein dairy cows.

4 Discussion

The results obtained in this research confirm the hypothesis raised, i.e., that there is an association between grade 2 and 3 subclinical mastitis with early gestation loss during the first 90 days of gestation in Holstein dairy cows.

In the CMT 2-3 group, an association with gestation loss was found during the first 90 days (OR = 2.6). The gestation loss shown in this group could be caused by the luteal regression induced by the release of cytokines such as prostaglandin $F2\alpha$, TNF-α, INF-γ and/or the effect of endotoxins, such as LPS (lipopolysaccharide) and bacterial exotoxins on the ovary, uterus and/or embryo (Hansen et al., 2004; Hertl et al., 2014). Embryonic mortality is considered the leading cause of the increase in the interval between deliveries in cattle (Thatcher et al., 1994; Vanroose et al., 2000; Sreenan et al., 2001).

The association results of cows of the CMT 2-3 group with gestation loss agree with the Moore et al. (2005), in which the association between subclinical mastitis and gestation maintenance was analyzed. Cows that experienced subclinical mastitis immediately (LSCC >4.5) before AI had 2.4 times higher risk of losing gestation

Table 2. Percentage (%) of cows with gestation loss according to mastitis grades in Holstein dairy cows during the first 90 days post insemination.

Degree of mastitis	N	Cows with gestation losses
0	309	44 (14%)
T	130	14 (11%)
1	77	14(18%)
2	48	13 (27%)
3	55	18 (33%)
Total	**619**	**103 (17 %)**

The degrees of mastitis are indicated by 0: Negative, T: Traces, 1: Subclinical mastitis degree 1, 2: Subclinical mastitis degree 2, 3: Subclinical mastitis degree 3. OR represents the base reproductive rate.

between 28 and 35 days after AI, compared to cows that had a linear somatic cell count less than 4.5 (LSCC <4.5, (Moore et al., 2005)).

In this study, the overall loss of gestation between 30 and 60 days was 12% and between 61 and 90 days was 5%. Reproductive losses in lactating dairy cows have increased in recent years (Lucy, 2001). Several researchers have been able to characterize the timing and extent of late embryonic losses in livestock through ultrasonography and other methods for early diagnosis of pregnancy. Humblot (2001) assessed embryonic losses on Holstein cows in 44 herds in France and noted that early and late embryonic death after the first AI was 31.6 and 14,7%, respectively. Late embryonic death after day 27 of gestation ranged from 3,2% in dairy cows, producing 6000-8000 kg of milk per year in Ireland (Silke et al., 2002) to 42,7% in high-production cows under heat stress (Cartmill et al., 2001).

These results agree with the conducted by McDougall et al. (2005), which showed the preponderance and risk factors related to gestation losses in lactating dairy cows fed with pasture in New Zealand. A total of 2004 pregnant cows participated in the study and 128 animals (6,4%) lost their pregnancy. The rate of pregnancy loss was higher between weeks 6 to 10 of gestation than between weeks 10 to 14. Likewise, Santos et al. (2004) summarized information from several studies and concluded that the risk of pregnancy loss was much higher at the beginning of pregnancy than towards the end.

Table 3. Number of cows losing gestation between days 30-60 and 61-90 post-insemination with varying degrees of subclinical mastitis and absence of mastitis in dairy cows.

Degree of mastitis	Day 30-60	Percentage	Day 61-90	Percentage
0	34/309	11.00%	10/275	4.00%
T	11/130	9.00%	3/119	3.00%
1	Nov-77	14.00%	March-66	5.00%
2	Sept-48	19.00%	April-39	10.00%
3	Dec-55	22.00%	June-43	14.00%

The degrees of mastitis are indicated by 0: Negative, T: Traces, 1: Subclinical mastitis degree 1, 2: Subclinical mastitis degree 2, 3: Subclinical mastitis degree 3. OR represents the base reproductive rate.

5 Conclusions

The results of the experiments confirm the association between grade 2 and grade 3 subclinical mastitis with early gestation loss during the first 90 days of gestation in Holstein lactating dairy cows. Gestation loss was greater between 30 and 60 days than between 61 and 90 days of gestation.

Cows with grade 2 and 3 subclinical mastitis were found to be 2.24 and 2.93, respectively, more likely to lose gestation during the first 90 days post-insemination. Overall gestation loss between 30 and 60 days was 12 % and 5 % between 61 and 90 days.

References

Barker, A., Schrick, F. N., Lewis, M. J., Dowlen, H., and Oliver, S. (1988). Influence of clinical mastitis during early lactation on reproductive performance of jersey cows. *Journal of Dairy Science*, 81(5):1285–1290. Online: https://bit.ly/301SPLv.

Blum, J. W., Dosogne, H., Hoeben, D., Vangroenweghe, F., Hammon, H. M., Bruckmaier, R. M., and Burvenich, C. (2000). Tumor necrosis factor-a and nitrite/nitrate responses during acure mastitis induced by escherichia coli infection and endotoxin in dairy cows. *Domestic Animal Endocrinology*, 19(4):223–235.Online: https://bit.ly/2N0ua6h.

Cartmill, J. A., El-Zarkouny, S. Z., Hensley, B. A., Lamb, G., and Stevenson, J. (2001). Stage of cycle, incidence and timing of ovulation, and pregnancy rates in dairy cattle after three timed breeding protocols. *Journal of Dairy Science*, 84(5):1051–1059. Online: https://bit.ly/2Z1U0xi.

Hansen, P. J., Paolete, S., and Natzke, R. P. (2004). Mastitis and fertility in cattle – possible involvement of inflammation or immune activation in embryonic mortality. *American Journal of Reproductive Immunology*, 51:294–301. Online: https://bit.ly/2MgGGPz.

Hertl, J. A., Schukken, Y. H., Welcome, F. L., Tauer, L. W., and Gröhn, Y. T. (2014). Effects of pathogen-specific clinical mastitis on probability of conception in holstein dairy cows. *Dairy Science*, 97(11):6942–6954. Online: https://bit.ly/2H7yjBL.

Hillerton, J. and Berry, E. (2005). Treating mastitis in the cow a tradition or an archaism. *Journal of Applied Microbiology*, 98:1250 –1255. Online: https://bit.ly/33ukR4u.

Humblot, P. (2001). Use of pregnancy specific proteins and progesterone assays to monitor pregnancy and determine the timing, frequencies and sources of embryonic mortality in ruminants. *Theriogenology*, 56(9):1417–1433. Online: https://bit.ly/2ZYUuSd.

Lucy, M. C. (2001). Reproductive loss in high-producing dairy cattle: where will it end? *Journal of Dairy Science*, 84(6):1277–1293. Online: https://bit.ly/2MdBnjX.

McDougall, S., Rhodes, F., and Verkerk, G. (2005). Pregnancy loss in dairy catlle in the waikato region of new zealand. *New Zealand Veterinary Journal*, 53(5):279–287. Online:https://bit.ly/2OVUG3r .

Medina, C. M. and Montaldo, V. (2003). El uso de la prueba de conductividad eléctrica y su relación con la prueba de california para mastitis. In CNM, editor, *V Congreso Nacional de Control de Mastitis*, Aguascalientes-México.

Moore, D. A., Cullor, J., Bondurant, R., and Sischo, W. (1991). Preliminary field evidence for the association of clinical mastitis with altered interestrus intervals in dairy cattle. *Theriogenology*, 36(2):257–265. Online: https://bit.ly/2H5oXqd.

Moore, D. A., Overton, M. W., Chebel, R., Truscott, M. L., and BonDurant, R. (2005). Evaluation of factors that affect embryonic loss in dairy cattle. *Journal of the American Veterinary Medical Association*, 226(7):1112–1118. Online: https://bit.ly/2N0DMy4.

Philpot, W. and Nickerson, S. (2002). *Vencendo a Luta Contra a Mastite*. Westfalia Surge Inc. e Westfalia Landtechnik do Brasil Ltda. pp 6-9, 15-17, 22-27, 38-43.

Riollet, C., Rainard, P., and Poutrel, B. (2001). Cell subpopulations and cytokine expression in cowmilk in response to chronic staphylococcus aureus infection. *Journal of Dairy Science*, 84(5):1077–1084. Online: https://bit.ly/2Ky3VCH.

Risco, C., Donovan, G., and Hernandez, J. (1999). Clinical mastitis associated with abortion in dairy cows. *Journal of Dairy Science*, 82(8):1684–1689. Online: https://bit.ly/2yVAvHV.

Ruíz, S. (1996). Presencia de mastitis subclínica en ocho hatos de la periferia de uruapán, michoacán, en bovinos productores de leche. Master's thesis, Universidad Michoacana de San Nicolás de Hidalgo, Facultad de Medicina Veterinaria y Zootecnia, Michoacán, México. pp 35-38.

Salyers, A. A. and Whitt, D. D. (1994). *Bacterial Pathogenesis A Molecular Approach*. ASM Press, Washington D.C. Pages 56 and 341.

Santos, J. E. P., Cerri, R. L. A., Ballou, M. A., Higginbotham, G. E., and Kirk, J. H. (2004). Effect of timing of first clinical mastitis occurrence on lactational and reproductive performance of holstein dairy cows. *Animal Reproduction Science*, 80(1):31–45. Online: https://bit.ly/2Z6bBQC.

Saran, A. and Chaffer, M. (2000). Mastitis y calidad de leche. Technical report, Inter-Médica, Buenos Aires-Argentina. 194 pp.

Silke, V., Diskin, M. G., Kenny, D. A., Boland, M. P., Dillon, P., Mee, J. F., and Sreenan, J. M. (2002). Extent, pattern and factors associated with late embryonic losses in dairy cows. *Animal Reproduction Science*, 71(1):1–12. Online: https://bit.ly/33xDFju.

Smith, B. P. (1990). *Large Animal Internal Medicine The C. V.* The C. V. Mosby Co., St Louis, Missouri. Online: https://amzn.to/2Kzqgjr.

Sreenan, J. M., Diskin, M. G., and Morris, D. G. (2001). Embryo survival rate in cattle: a major limitation to the achievement of high fertility. in: Fertility in the high producing dairy cow. *BSAP Occasional Publication*, 26(1):93–104.Online: https://bit.ly/2H4qbCb.

Thatcher, W. W., Staples, C. R., Danet-Desnoyers, G., Oldick, B., and Schmitt, E. P. (1994). Embryo health and mortality in sheep and cattle. *Journal of Animal Science*, 72(suppl 3):16–30. Online: https://bit.ly/2OQT2jw .

Thurmond, M. C., Picanso, J. P., and Jameson, C. M. (1990). Considerations for use of descriptive epidemiology to investigate fetal losses in dairy cows. *Journal of the American Veterinary Medical Association*, 197(10):1305–1312. Online: https://bit.ly/33ukdny.

Vanroose, G., de Kruif, A., and Van Soom, A. (2000). Embryonic mortality and embryo-pathogen interactions. *Animal Reproduction Science*, 60:131–143. Online: https://bit.ly/300BNNN.

Waller, K. P., Colditz, I. G., and Östensson, K. (2003). Cytokines in mammary lymph and milk during endotoxin-induced bovine mastitis. *Research in Veterinary Science*, 74(1):31–36. Online: https://bit.ly/2KzAOPA.

Wenz, J. R., Barrington, G. M., Garry, F. B., McSweeney, K. D., Dinsmore, R. P., Goodell, G., and Callan, R. J. (2001). Bacteremia associated with naturally occurring acute coliform mastitis dairy cows. *Journal of the American Veterinary Medical Association*, 219(7):976–981. Online: https://bit.ly/2OSSaeg.

Zurita, L. (1982). Mastitis bovina con especial énfasis en la realidad nacional. Master's thesis, Facultad de Ciencias Agrarias, Veterinarias y Forestales Universidad de Chile.

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NATURAL RISKS

REGIONALIZATION OF PRECIPITATION, ITS AGGRESSIVENESS AND CONCENTRATION IN THE GUAYAS RIVER BASIN, ECUADOR

REGIONALIZACIÓN DE LA PRECIPITACIÓN, SU AGRESIVIDAD Y CONCENTRACIÓN EN LA CUENCA DEL RÍO GUAYAS, ECUADOR

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Resumen

La agresividad de la lluvia contribuye a la erosividad del suelo en regiones de alta montaña, y por ende a la sedimentación en la parte baja de la cuenca. El conocimiento acerca de la agresividad de la lluvia en regiones costeras y andinas contribuye a la formulación de medidas de mitigación que influyen en la reducción de erosión y pérdida de nutrientes. Los índices Fournier, Fournier modificado y de concentración de precipitación proveen la capacidad de estimar la distribución espacial y temporal de la agresividad de la lluvia. Este estudio presenta un análisis de la lluvia mediante estos índices de agresividad en la cuenca del río Guayas ubicada en la costa y Andes ecuatoriales. Se seleccionaron datos mensuales registrados de 30 estaciones pluviométricas para el período 1968-2014. Se determinaron zonas homogéneas de precipitación mediante el método k-means. Los resultados indicaron dos regiones homogeneas predominantes, la primera ubicada al oeste en la zona costera y andina (85,2% del área de la cuenca), con un índice de agresividad alto y muy alto; mientras que la distribución de la precipitación en la segunda región (Alta montaña) resultó de muy baja a baja agresividad. La mayor agresividad potencial de la lluvia le corresponde una mayor acumulación de precipitación promedio anual, lo que indica una alta influencia estacional de las lluvias, es decir, una mayor cantidad de lluvia puede precipitar en un número reducido de meses consecutivos. Los valores de concentración revelan un gradiente regional en dirección este-oeste que va de moderadamente a fuertemente estacional. El análisis de tendencias de la concentración de lluvia mensual no muestra cambios significativos en el período de estudio. No obstante, los hallazgos del presente estudio explican el porqué la región oeste y sur de la cuenca del río Guayas está expuesta a problemas de sedimentación en la parte baja, producto de la capacidad erosiva de la lluvia en la parte alta y media de la cuenca.

Palabras clave: Guayas, concentración, precipitación, agresividad, erosividad, Ecuador.

Abstract

The aggressiveness of rain contributes to the erosion of the soil in high mountain regions, and therefore to the sedimentation in the lower part of the watershed. To know about the aggressiveness of rain in coastal and Andean regions contributes to the formulation of mitigation measures that help to the reduction of erosion and loss of nutrients. Fournier indices, Modified Fournier and precipitation concentration provide the ability to estimate the spatial and temporal distribution of the aggressiveness of the rain. This study presents a spatial and temporal analysis of climatic aggressiveness in the Guayas river watershed located on the coast and the equatorial Andes. Registered monthly data of 30 rainfall stations for the period 1968-2014 was selected. Homogeneous precipitation zones were determined by the k-means method. The results indicated two predominant homogenous regions, the first located to the west in the coastal and Andean zone (85,2 % of the area of the Watershed), with a high and very high aggressiveness index, while the distribution of precipitation in the second region (High mountain) resulted from very low to low aggressiveness. The greater potential aggressiveness of rain corresponds to a greater accumulation of average annual rainfall, which indicates a high seasonal influence of rainfall, i.e., a greater amount of rainfall can precipitate in a reduced number of consecutive months. The concentration values reveal a regional gradient in the east-west direction, which goes from moderately to strongly seasonal. The trend analysis of the monthly rainfall concentration shows no significant changes in the study period. However, these findings explain why the western and southern region of the Guayas river watershed is exposed to sedimentation problems in the lower part, due to the erosive capacity of rain in the higher and middle part of the watershed.
Keywords: Guayas, concentration, precipitation, aggressiveness, erosivity, Ecuador.

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1 Introduction

The erosion of precipitation causes loss of fertile soil, damage to infrastructure, agriculture and water pollution, which is influenced by changes in precipitation patterns (Martín-Fernández and Martínez-Núñez, 2011; Sanchez-Moreno et al., 2014). This is caused since large amounts of seasonal rain can precipitate in high mountain regions such as the Andes in a few days or weeks (Sarricolea et al., 2014; Zubieta et al., 2016; Sarricolea et al., 2019), or Amazonian regions (Zubieta et al., 2019). Precipitation is an important variable for climate studies, whose spatial and temporal variability can impact human activities during extreme hydroclimatic events such as droughts and floods (Parracho et al., 2016). It also plays a key role in water resource planning and management, directly linked to agriculture and disaster mitigation (Prakash et al., 2015). Accurate precipitation quantification is a challenge for many hydrological applications, especially in regions with complex topography due to orographic and small-scale slope effects (Prakash et al., 2015)

The aggressiveness of rain can cause environmental impacts and is a key factor in the occurrence of soil erosion, landslides or flooding. Therefore, parameters that evaluate the aggressiveness of rain can be considered as an appropriate environmental indicator ((Gregori et al., 2006; García-Barrón et al., 2018). Estimating this variable over long periods is useful for the soil conservation, agricultural planning and environmental policy development. The R-factor, or rainfall erosivity, is an accepted instrument for measuring local erosion and it depends on the kinetic energy of each rain episode ((Panagos et al., 2015). This model is the most widely used and was developed on a detailed scale in the agricultural sector; however, its application at the regional level presents limitations (Terranova et al., 2009). The soil erosion estimates do not conform to empirical sedimentation measures and do not incorporate direct water runoff (Kinnell, 2010).

The R-factor overestimates erosion at the regional or watershed level (Hernando and Romana, 2016) and is not recommended in areas where a validation process is not performed. In addition, it is advisable to use high-frequency precipitation records of weather stations for a period of more than twenty years for its estimation (Angulo-Martínez et al., 2009). Therefore, models that measure the effects of rainfall aggressiveness can be used by considering hourly rainfall records (intensity models) or monthly precipitation records (volume models). The latter model refers to the different partial accumulations of rain, regardless of the number, duration and amount of rain of each episode, so it is based exclusively on monthly precipitation records available in most countries. Thus, the aggressiveness index can be used in environmental studies (Fournier, 1960; Arnoldus, 1978; Oliver, 1980). These indices have been widely used in climate studies to identify spatial rainfall concentration patterns in regions of Europe, Asia, Africa and South America such as Spain (De Luis et al., 2011), Iberian Peninsula (García-Barrón et al., 2018), India (Ballari et al., 2018), Bangladesh (Rasel et al., 2016), Nigeria (Ezenwaji et al., 2017), Argentina (Besteiro and Delgado, 2011), Venezuela (Rey et al., 2012) and Chile (Sarricolea et al., 2014; Valdés-Pineda et al., 2016). Changes in the temporal patterns of these parameters have also been identified in Andean regions of Chile (Sarricolea et al., 2019).

The intense soil erosion resulting from increased rainfall intensity is a critical problem in many basins around the world (Vrieling et al., 2014; Mondal et al., 2016). The Guayas River Basin (CRG - acronym in Spanish), is Ecuador's most fertile agricultural area (Buckalew et al., 1998), and the main production center for agricultural goods. Seasonal distribution and annual rainfall totals are extremely irregular, causing CRG to be affected by flood events and droughts, causing economic losses. This was the case for 1982 and 1983, which produced estimated losses of 3,18% and 28,63% of PIB, respectively ($520 million) (Egas, 1985). While in 1997-98 5664 km^2 of agricultural production ($616,5 million) was lost (Corporación Andina de Fomento, 1998), caused by the marked influence of El Niño phenomenon on the basin (Cadier et al., 1996). But the area of greatest affectation is the low basin, because it is periodically subjected to flooding that can have catastrophic consequences, aggravated by human actions such as deforestation and erosion in the headwaters of the rivers (Rossel et al., 1996). The Guayas River presents sedimentation problems due to soil erosion in the basin (Gobierno Provincial del Guayas, 2016), which has resulted in the formation of islets at the junction of the Babahoyo and Daule River (Figure 1) (Soledispa, 2002). Measures such as dredging have been used in the face of sediment accumulation amounting to 250 thousand tons per year (Gobierno Provincial del Guayas, 2018). However, rain has not been studied as an erosion factor in Ecuadorian regions such as the CRG. The aim of this research is (a) to regionalize precipitation for a prolonged period of monthly precipitation data (1968-2014) and (b) to estimate the aggressiveness and concentration of precipitation in the CRG.

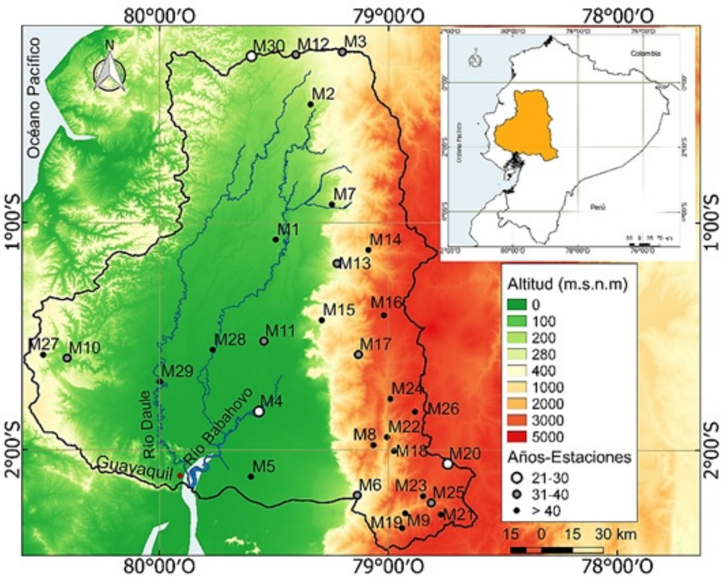

Figure 1. Location of the Guayas River basin, altitude, distribution of the 30 rainfall stations and years of study. The name of the stations is shown in Table 1.

2 Materials and methods

2.1 Study area

The CRG is located in the central western of Ecuador (0°14′ a 2°27′ S y 78°36′ a 80°36′ O) (Figure 1). The area is characterized by a significant altitude gradient up to 4000 masl with an area of 32890km^2, corresponding to 13 % of Ecuador area. It concentrates approx 40 % of the country's population (**?**). CRG drains into the Gulf of Guayaquil, the main rivers are the Daule and Babahoyo (Figure 1) that join near Guayaquil, the country's largest city Damanik-Ambarita2016. The Guayas River, the largest on the western coast of South America, with an average annual run of 1350m^3/s (Twilley et al., 2001), has a straight main channel forking into a network of river channels that run through 30 km of mangroves and tidal plains (Reynaud et al., 2018). The main economic activities in the CRG are: agriculture, fishing and hydroelectric power generation. The main environmental pressures on freshwater ecosystems are wastewater pollution, agriculture, land use changes and two hydroelectric dams (Thi Nguyen et al., 2015). In recent years, river sedimentation problems have increased in the lower part of the basin, considered to be one of the contributing factors to the risk of flooding from extreme rains. This sedimentation is perceived locally as a consequence of interventions carried out in the upper basin and natural events such as El Niño (Barrera-Crespo et al., 2018). The impacts of El Niño on this basin have caused flooding (rain erosion, slippage and landslides), pollution of drinking water, damage to infrastructure and the agricultural sector (Corporación Andina de Fomento, 1998).

2.2 Data

Precipitation records were collected from 250 weather stations from the National Institute of Meteorology and Hydrology (INAMHI), each with different periods between 1962 and 2016. In order to guarentee the highest availability of monthly data, 30 stations with a period of 47 years (1968-2014) were selected, which had the lowest amount (< 13 %) of missing data (Table 1). Out of the 30 stations, 63 % of them have more than 40 years of continuous records, and 10 % from 21 to 30 years.

2.3 Methodology

The methodology consists of three summarized steps in Figure 2: the first is the evaluation of the precipitation data, its homogenization and the completion of monthly data by the regional vector (MVR) method. The second corresponds to the process of regionalization by grouping stations using k-means and interpolation using cokriging, and the last stage corresponds to the determination of the aggressiveness and concentration of precipitation through different indices.

Table 1. Characteristics of 30 stations in the Guayas River basin: name, geographical location and missing data.

Code	Name	Latitude (°S)	Lenght (°O)	Altitude (msnm)	% missing data	Period
M1	Pichilingue	-1.07	-79.49	81	0	1968-2014
M2	Puerto Ila	-0.48	-79.34	319	2	1968-2014
M3	Sto. Domingo Aeropuerto	-0.25	-79.20	554	6	1968-1998
M4	Isabel María	-1.83	-79.56	4	8	1968-1988
M5	Milagro (Ingenio Valdez)	-2.12	-79.60	23	0.2	1968-2014
M6	Bucay	-2.20	-79.13	480	4	1969-2000
M6	San Juan La Mana	-0.92	-79.25	215	9	1968-2014
M8	Chillanes	-1.98	-79.06	2330	4	1968-2014
M9	Chunchi	-2.28	-78.92	2177	3	1968-2014
M10	Camposano #2	-1.59	-80.40	113	1	1977-2014
M11	Pueblo Viejo	-1.52	-79.54	19	13	1976-2014
M12	Las Delicias-Pichincha	-0.26	-79.40	340	8	1968-2002
M13	Moraspungo-Cotopaxi	-1.18	-79.22	409	8	1968-87; 96-2014
M14	Ramón Campaña	-1.12	-79.09	1462	7	1968-2014
M15	Echeandia	-1.43	-79.29	308	9	1968-2014
M16	Salinas-Bolívar	-1.40	-79.02	3600	10	1969-2014
M17	Río San Antonio-Monjas	-1.58	-79.13	2200	2	1980-2014
M18	Pallatanga	-2.00	-78.97	1523	9	1968-2014
M19	Compud	-2.34	-78.94	2402	8	1968-2014
M20	Palmira INAMHI	-2.06	-78.74	3180	4	1968-1991
M21	Achupallas-Chimborazo	-2.28	-78,77	3178	1	1968-2014
M22	Chimbo Pj Pangor	-1.94	-79.00	1452	10	1968-2014
M23	Alausi	-2.20	-78.85	2267	12	1968-2014
M24	Cañi-limbe	-1.77	-78.99	2800	6	1969-2014
M25	Guasuntos	-2.23	-78.81	2438	2	1975-2014
M26	Pangor-J.de Velasco	-1.83	-78.88	3109	11	1970-2014
M27	Colimes de Pajan	-1.58	-80.51	200	2	1970-2014
M28	Vinces INAMHI	-1.56	-79.77	14	8	1968-2014
M29	La Capilla INAMHI	-1,70	-80,00	7	5	1968-2014
M30	Palmeras Unidas (Palmar)	-0.26	-79.60	460	10	1987-2012

Figure 2. Methodological scheme for the regionalization, aggressiveness and concentration of the rain time series.

2.3.1 Method of regional vector

MVR was used to evaluate the quality and estimation of the missing data. This method is oriented to the criticism, homogenization and completion-extension of the precipitation data (Hiez, 1977; Brunet-Moret, 1979). The MVR is based on the creation of a station .ªverage species"type "Vector". This concept refers to the calculation of a weighted average rainfall anomalies for each season, overcoming the effects of seasons with extreme and low rainfall values. Then, there are Z_i annual interposition techniques and P_j's rainfall, which are extended by the least squares technique. This could be achieved by minimizing the sum of the following equation (Espinoza Villar et al., 2009).

$$\sum_{i=1}^{N}\sum_{j=1}^{M}\left(\frac{P_{ij}}{P_j}-Z_i\right) \quad (1)$$

Where i is the year index, j the station index, N the number of years and M the number of stations. P_{ij} represents annual rainfall in the station j, year i; P_j is the extended average rainy period of N years; and finally, Z_i is the regional rainfall index of the year i. The full set of Z_i values throughout the period is known as the annual vector of regional rainfall indices, and by being an iterative process, this method allows to calculate the vector of each of the vector of of the predefined regions, then it provides a comparison of year-on-year variability of stations -vector, to finally discard those that are not consistent with the regional vector (VR). This process is repeated as much as necessary and was performed using the HYDRACCESS software (Vauchel, 2005).

2.3.2 Regionalization

This study used the k-means method, widely employed to regionalize homogeneous areas of precipitation (Golian et al., 2010; Gómez-Latorre, 2015; Shahana Shirin and Thomas, 2016; Rau et al., 2017). K-means is a grouping algorithm, the most commonly used to identify homogeneous groups of objects called clusters. The data within a cluster shares many features but is very different from the data that does not belong to that cluster (Yashwant and Sananse, 2015). The data in this study are summarized in a 30-row matrix for weather stations and 6 columns with information such as: station name, altitude, latitude, longitude and cumulative precipitation. A key part of the k-means application is to define an optimal number of groups, which can be done by estimating the silhouette coefficient (S) for each number of groups, the S coefficient has the advantage that it only considers the current partition and does not depend on the grouping algorithm, its value is obtained by Equation 2 (Rousseeuw, 1987):

$$S_{(i)}=\frac{b_i-a_i}{max\left[a_{(i)},b_{(i)}\right]} \quad (2)$$

Where $a_{(i)}$ corresponds to the average similarity between object i and other objects in the same group, and $b_{(i)}$ is the average similarity between object i and k-cluster members. The S coefficient varies between -1 and +1; the partition will be better when it gets closer +1, a negative value means that there is no good correspondence between the members of the group, a value of zero means that the object could belong to any group (Kaufman and Rousseeuw, 2005). Also, the homogenization of precipitation was performed for extreme events such as El Niño from 1997-1998, considering the above methodology.

The interpolation of annual precipitation data was performed using a geostatistical approach, co-kriging method, which is a multivariate version of the kriging technique (Goovaerts, 1998), considering two variables (altitude and cumulative precipitation) transformed logarithmically due to the bias and the wide numerical range of precipitation values. This method was used for the interpolation and delimitation of precipitation zones (Rau et al., 2017) and for mapping the spatial distribution of indices.

2.3.3 Climatic aggressiveness analysis and concentration of precipitations

Climate aggressiveness was analyzed by interpreting the Fournier Index (FI) and Modified Fournier Index (MFI). Fournier (1960) proposes a climate aggressiveness index or IF, which has a high correlation with the amount of sediments carried by runoff. The IF estimates the erosive characteristics (aggressiveness) based on the rainiest month of each year within a given time period, and for the calculation of the IF the following expression (3) was used. Where FI: Fournier index for the year j, $p_{\text{máx}}$: average precipitation relative to the wettest month (mm) and P: Average annual precipitation (mm).

$$IF_j=\frac{p^2_{\text{máx}_j}}{P} \quad (3)$$

However, it is necessary to consider areas that have more than a monthly maximum or areas where rainfall values have high values due to seasonality (Jordán and Bellinfante, 2000). To correct these errors, a modification of the original FI was proposed using the accumulated precipitation, called MFI (Arnoldus, 1978). This index considers the rain of the twelve months and not only that of the wettest month, its calculation relates the monthly rainfall with those Equation (4). Where: MFI_j: rainfall aggressiveness idex, for year j, p_{ij}: monthly precipitation of the month i (mm) of the year j and P_m: average annual precipitation.

$$MFI_j=\frac{\sum_{i=1}^{12}\left(p_{ij}\right)^2}{P_m} \quad (4)$$

The seasonality of precipitation was estimated by the Precipitation Concentration Index (PCI) proposed by Oliver (1980), being a distribution indicator of temporal precipitation and used as an estimator of the extreme behavior of the precipitation (Sarricolea et al., 2014). It has traditionally been applied on an annual scale and it describes whether annual precipitation is temporarily concentrated in a single month or distributed evenly throughout the year. The PCI was calculated on an annual scale from the following Equation:

$$PCI_j = 100\frac{\sum_{i=j}^{12} p_{ij}^2}{P_j^2} \quad (5)$$

The PCI was also analyzed on a seasonal scale considering the periods of increased precipitation (December-May) and lower precipitation (June-November), according to Equation (6):

$$PCI_{\text{seasonal}} = 1000\frac{\sum_{i=j}^{6} p_{ij}^2}{\left(\sum_{i=j} P_{ij}\right)^2} \quad (6)$$

Where PCI_j: annual rainfall concentration index (%), for year j; PCI_{estac}: seasonal concentration index (%); p_{ij}: precipitation of month i in year j, P_j: annual precipitation of the year j. The main difference between these indices is the ranges of rank values (Table 2).

Table 2. Indixes that determine aggressiveness and concentration of precipitation

Index	Clasification	
Fournier Index (FI)	<50	Very low
	50-100	low
	100-150	Moderate
	150-200	High
	>200	Very high
Mofidified Fournier Index (MFI)	<100	Very low
	100-200	Low
	200-300	Moderate
	300-400	High
	>400	Very high
Precipitation concentration index (PCI)	8,3%˜10%	Uniform
	10%˜15%	Partly seasonal
	15%˜20%	Seasonal
	20%˜50%	Strongly seasonal
	50%˜100%	Irregular

The classification of indices is performed based on (Fournier, 1960; Arnoldus, 1978) and (Oliver, 1980). The influence of climate change on the seasonal pattern of precipitation concentration was determined by Mann-Kendall's nonparametric statistical test (MK), at three levels of significance (90%, 95% y 99%). MK analysis was performed using TREND software (https://toolkit.ewater.org.au/trend). The MK test verifies the existence of positive/negative changes in a series of data, against a zero hypothesis of non-trends and where the data are random and independent (Mann, 1945; Kendall, 1975). MK trend analysis is a robust test when the data differ from "normality.ªnd less sensitive to outliers (Lanzante, 1996). MK analysis has been widely used for the detection analysis of meteorological and hydrological trends (Kumar et al., 2009; Gocic and Trajkovic, 2013; Hermida et al., 2015; Zeleňáková et al., 2016; Güçlü, 2018; Sarricolea et al., 2019).

3 Results and discussion

3.1 Homogenous regions

The optimal value for cluster numbers was determined by the overall average value of S and the number of negative S for each cluster group that varies from 2 to 10 (Table 3). The maximum value of S was obtained for cluster group 2 (0.51) and with a lower number of negative silhouette (1); it is the only group that is considered to be a reasonable structure, because its value of S is greater than 0.50 (Kononenko and Kukar, 2007). Internally cluster group 2 has a strong clustering structure (S=0.66) while cluster 1 reached a lower value, with a negative S (Figure 3b). This indicates that in cluster 1, grouping centers can be found, although there is considerable 'noise'. Cluster groups for extreme events such as El Niño 97-98 presented similar results (Table 3).

The spatial distributions of K-means (2) show an array of stations according to topographic variation and length (Figure 3). The cluster of two groups divides the CRG into two homogeneous regions of precipitation: lower and middle (red triangles) and upper part (black circles). The two regions are well defined, taking into account the rain interpolation map, as shown in Figure 3a.

Region One (R1) is located on the slopes of the western Andes mountain range and the great plains of the Ecuadorian coast ($78,9°$ a $80,59°$ O) (Figure 4a). The altitude varies between 3 to 2500 masl, occupying 85,2 % of the CRG area. The regime is unimodal, the rainy season runs from December to May (Figure 4b) and concentrates 89 % of the accumulated annual rain (Cadier et al., 1996; Rossel and Cadier, 2009; Fries et al., 2014) and a dry season (June-November) (Hastenrath, 1997). The precipitation range ranges from 850 to 3500 mm per year and a year-on-year CV of 0.38 (Figure 4a). The rain in this region is convection type and the distribution of dry and rainy season is due to the north-south movement of the Intertropical Convergence Zone (ZCIT) (Rollenbeck and Bendix, 2011).

Region two (R2) is located in the western range of the Andes, the altitude is higher than 1500 masl and less than 4000 masl. Rainfall totals (450 to 1500mm year-1) and year-on-year CV (0.34) were relatively low compared to R1 (Figure 4a). The precipitation distribution has a bimodal trend: the first peak occurs from January to May, followed from October to December, and the period May to August has the lowest average monthly precipitation (Figure 4c). The amount of rain that falls in this area is due to the influence of orographic rain and convection (Rollenbeck and Bendix, 2011). Precipitation formation is complex in the mountains due to the interaction between moisture transport, differential surface heating, synoptic wind field and local mountain breeze system (Daly et al., 2007; Foresti and Pozdnoukhov, 2012).

Table 3. Results of the MK analysis for the number of cluster groups.

Cluster group	2	3	4	5	6	7	8	9	10
Average silhouette	0.51	0.46	0.35	0.31	0.34	0.30	0.34	0.27	0.23
Number of negative silhouette	1	3	3	3	2	3	3	4	6
General average of extreme silhouette_events	0.52	0.40	0.26	0.29	0.29	0.26	0.26	0.26	0.26
Number of extreme negative silhouette_events	0	3	4	5	6	5	4	5	5

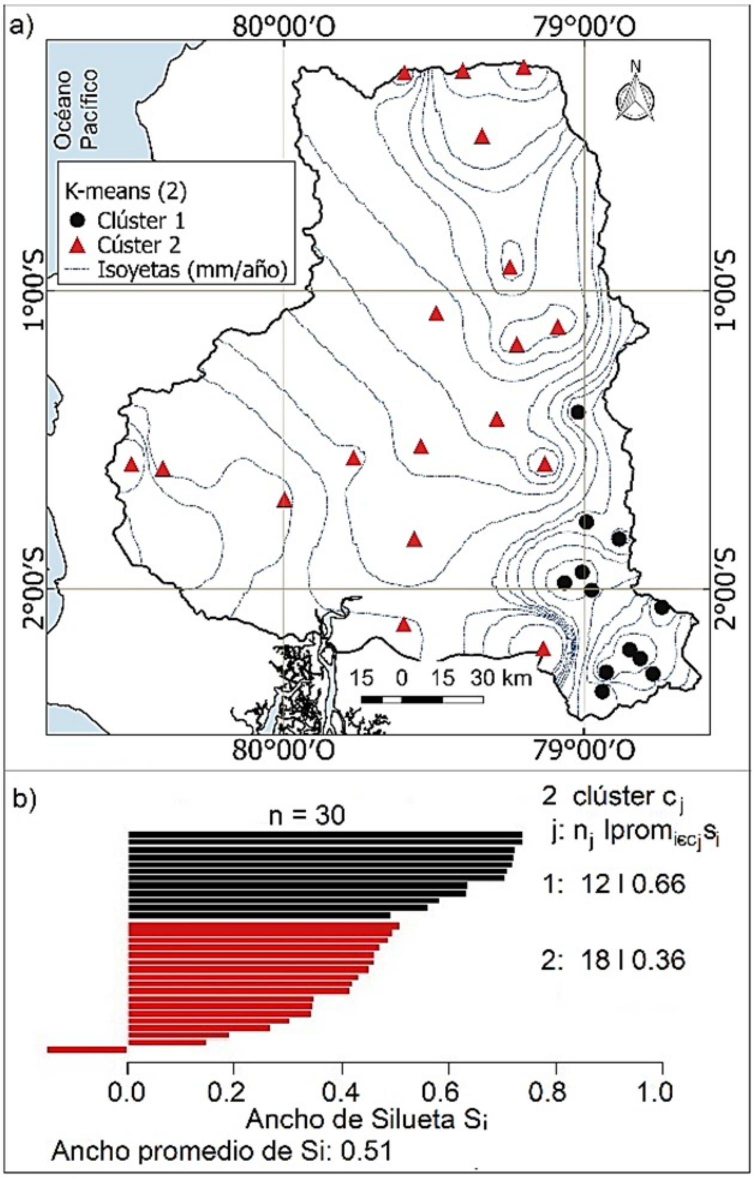

Figure 3. Spatial distribution of the cluster group (2) obtained with the k-means process and its silhouette value.

Two annual precipitation patterns can be identified within the study area: in R1, a well-differentiated annual cycle was found between periods of avenues and styling, characterized by peaks for the years 72-73; 75-76; 91-92; and extreme events for 82-83 and 97-98 (Figure 4d). Extreme rainfall in Ecuador is associated with El Niño events that caused severe flooding, economic losses and disease (Bendix and Bendix, 2006). In R1, the influence of El Niño is strongly linked to annual rainfall surpluses (Rossel et al., 1998). R2 has a weak seasonality, which is consistent with the estimated average variation coefficient (0.34), where a decrease in average annual precipitation is shown over most seasons compared to R1. Extreme events (82-83 and 97-98) are also observed in the R2 region, because the influence of El Niño in this area is variable (Cadier et al., 1996; Rossel et al., 1998).

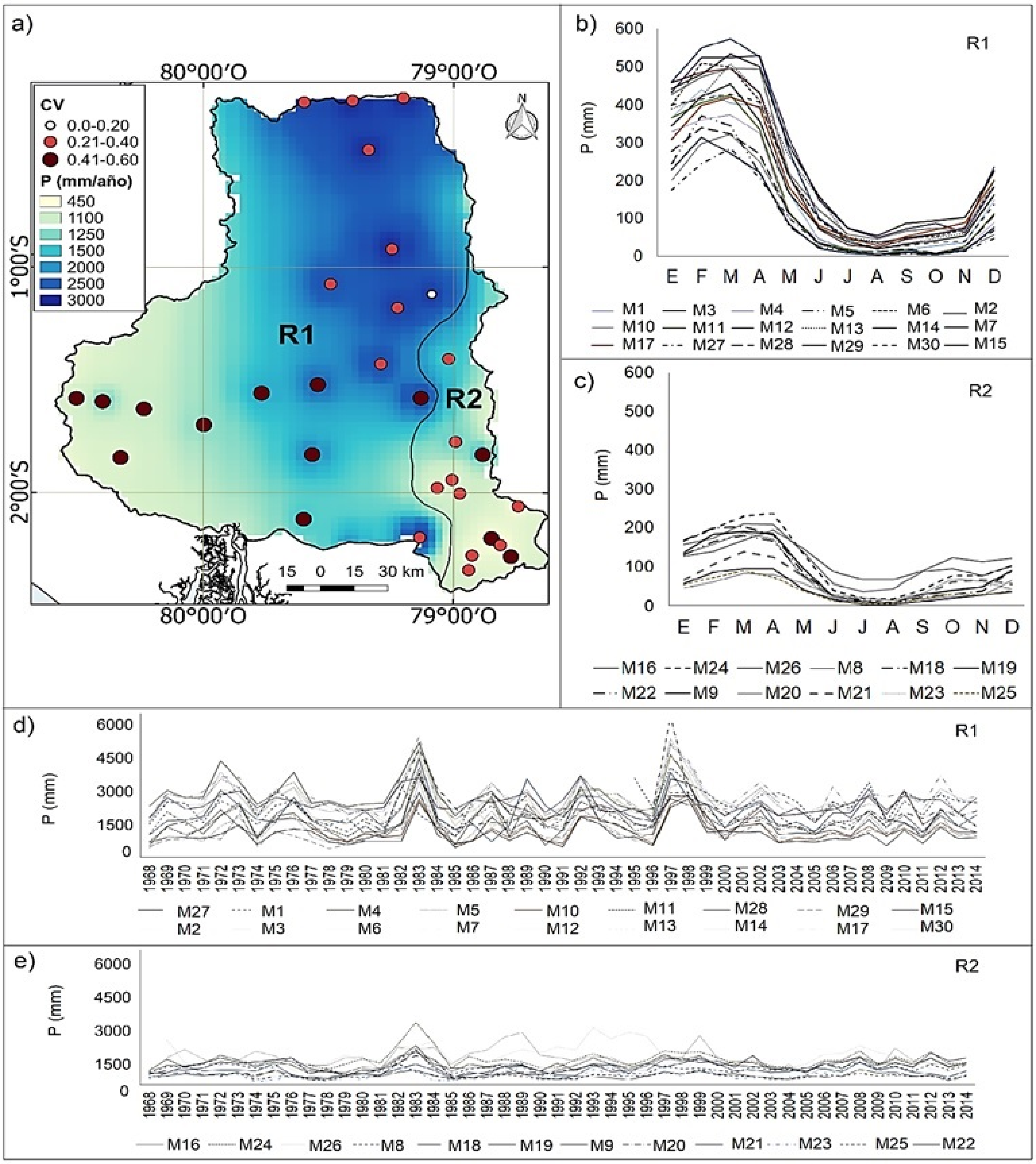

Figure 4. Spatial distribution of the two regions (R1-R2) of homogeneous rain after the regionalization process by k-means. a) Year-on-year variation coefficient (CV) range for the 30 rainfall stations. b) and c) Monthly precipitation regime of R1 and R2. (d) and (e) Annual precipitation distribution (1968–2014) for regions R1 and R2.

3.2 Climatic aggressiveness

In region R1, 45 % of the seasons had annual average of FI values greater than 150; this suggests the occurrence of very high erosion rain (Figure 5a). The FI for R2 shows that 50 % of the annual average values are less than 50 and remaining values were greater than 50 and less than 100, considered as very low and low erosion rain, respectively (Figure 5a). Results from MFI suggest a spatial pattern similar to FI (Figure 5b). In fact, in the R1 region, values greater than 300 are values associated with high erosion. While the R2 region has values of approximately 100, indicating low or very low levels of erosion. The difference in estimated rates for regions R1 and R2 may be associated with the spatial distribution of average annual rainfall (Figure 4a), suggesting a high influence on the seasonality of rainfall in both regions (Figure 4 d-e). Also, the seasonality of the basin is corroborated by the results of the PCI (Figure 5c), as these reach values around 20 %, which proposes a predominantly seasonal and strong seasonal classification. In addition, in the R1 region, the MFI manages to identify eight very high erosion seasons, this may be because the MFI considers the rain of all twelve months and not only that of the rainiest month of the year. Therefore, this methodology might be more appropriate to characterize the severity of the rains in the area under study (Castelan-Vega et al., 2015).

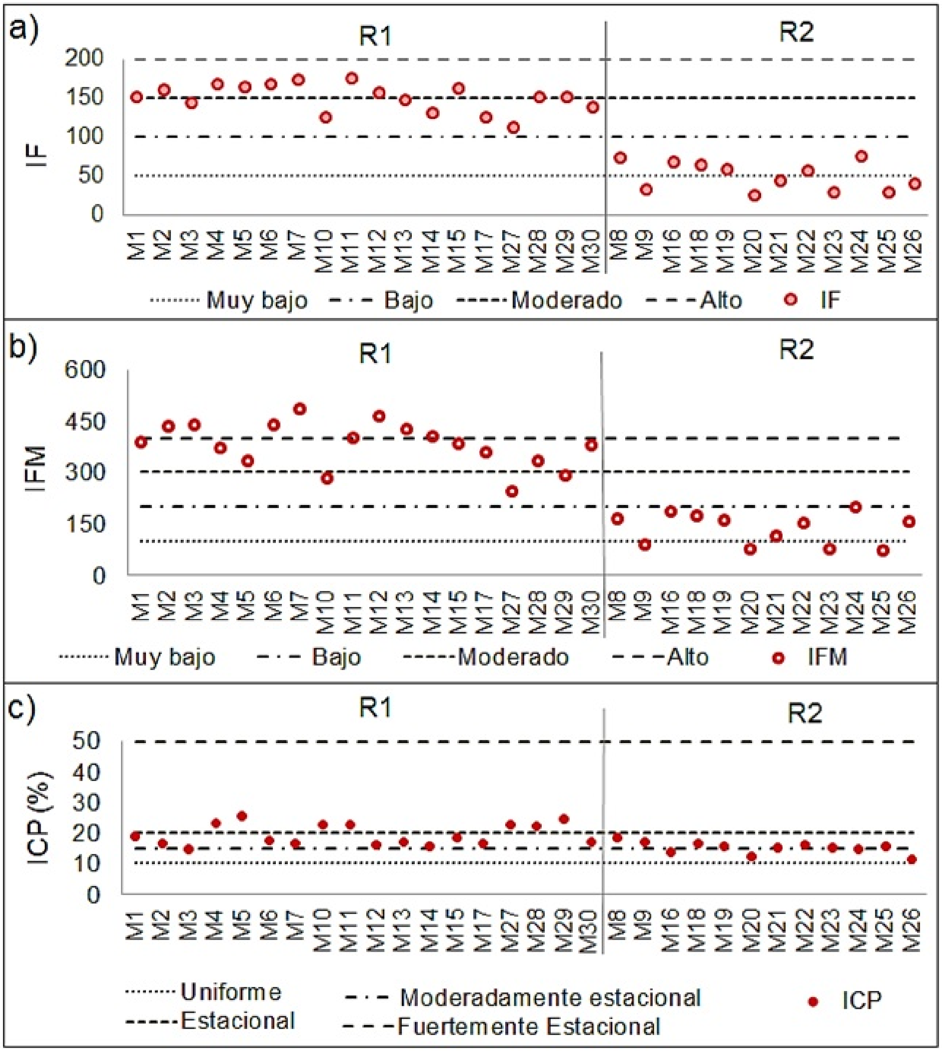

Figure 5. Aggressiveness rates: a) Fournier index (FI), b) Modified Fournier index (MFI) and c) annual mean precipitation concentration (PCI) of 30 stations in the study area.

It is important to mention that the aggressiveness results in region R2 are in agreement with the region with the highest annual precipitation, which has a good correlation and level of significance between the average annual precipitation pattern (mm) with the FI ($r = 0{,}77, p < 0{,}01$) and MFI ($r = 0{,}93, p < 0{,}01$) (Figure 6 d-e), which confirms that a higher annual accumulation (mm) would correspond to greater aggressiveness (Besteiro and Delgado, 2011) in areas where annual precipitation is greater than 900 mm (Jordán and Bellinfante, 2000; Rey et al., 2012). Also, a decrease in FI was observed with altitude ($r = 0{,}85, p < 0{,}01$), but not so for the MFI. No correlation was found between spatial patterns of climatic aggression for latitude and longitude.

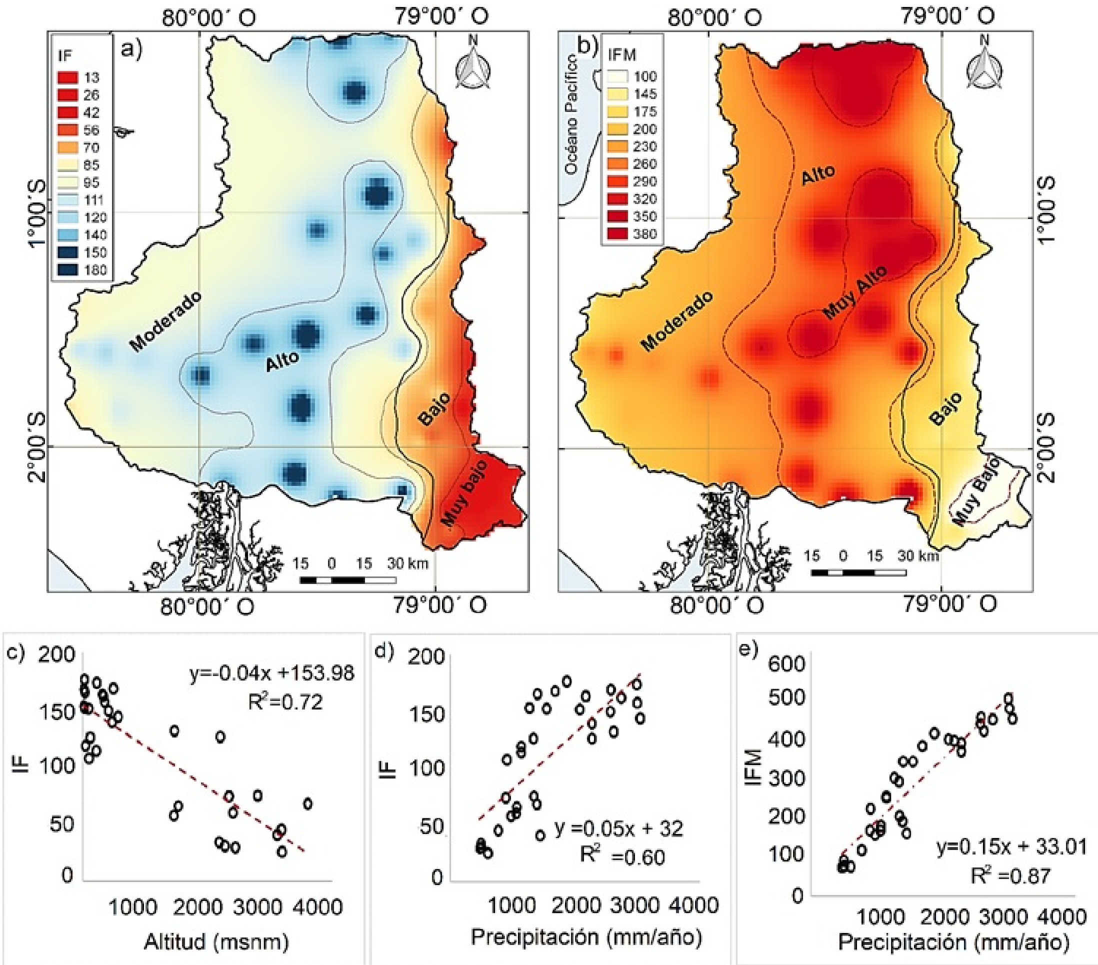

Figure 6. Spatial distribution: a) and b) Annual average aggressiveness (FI, MFI) for the period 1968-2014. Correlation: c) FI with altitude, d) and e) FI and MFI with cumulative precipitation.

3.3 Concentration of precipitations

The historical average annual concentration observed in R1 was distributed seasonally with values ranging from 15 − 19 %, followed by a strongly seasonal distribution (Figure 5c), i.e., precipitation is concentrated within a few months of the year. In region R2, the PCI registers values higher than 11 and lower than 18 %; nine seasons show a seasonal distribution and three moderately seasonal distributions throughout the year (Figure 5c). The historical average annual concentration observed in high mountain regions was predominantly a seasonal and moderately seasonal concentration, these results are consistent with Valdés-Pineda et al. (2016).

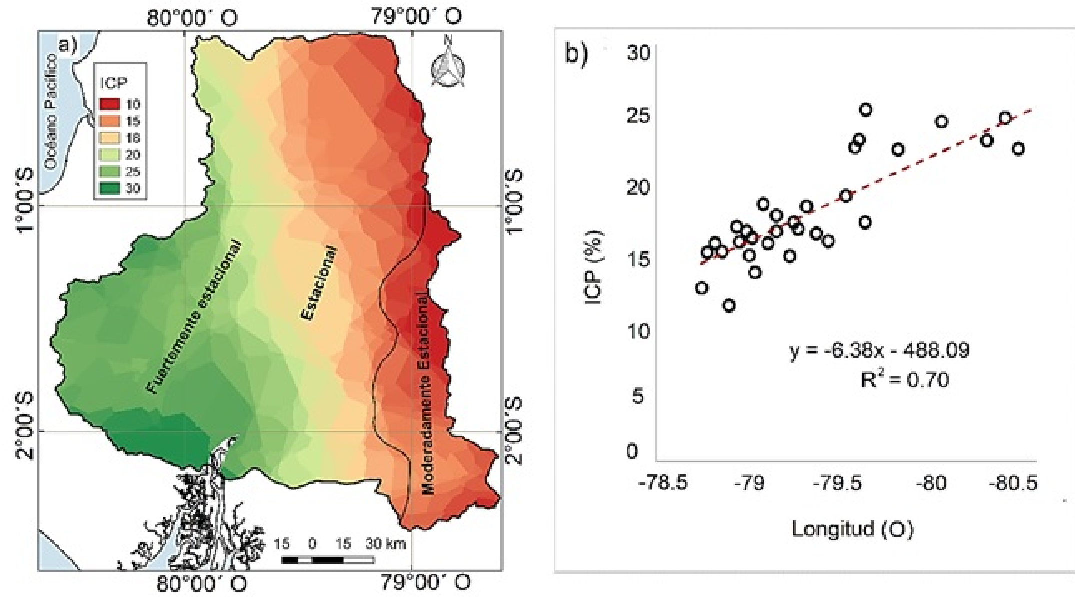

Figure 7. Spatial distribution: a) Annual average rainfall concentration (PCI) for the period 1968-2014 and b) Correlation of the PCI with the length.

The high mountain regions have a rain concentration between seasonal and moderately seasonal, and the central region between strongly seasonal and seasonal (Figure 7a). This suggests a strong association with the length (r=0.83, p<0.01) (Figure 7b). Along the longitudinal gradient, seasonality increases, leading to a more uniform concentration of annual precipitation. Changes in the PCI are complex, possibly related to global atmospheric characteristics and local and synoptic factors affecting precipitation. However, no correlation was found between PCI with latitude and average annual precipitation, suggesting that the years with the highest annual rainfall are not related to the precipitation concentration. These findings explain why R2 can be strongly affected by seasonal rain during the avenue period, where precipitation that is concentrated in a small number of months is relevant for the occurrence of soil erosion in the upper part, causing sedimentation in the urban area located in the lower part of the CRG.

To analyze changes in seasonal monthly rainfall concentration, the seasonal PCI series (period of highest and lowest precipitation) between 1968 and 2014 was estimated for regions R1 and R2 (Figure 8). Percentages of concentration values around 50% suggests irregularity of precipitation, i.e., a high amount of rain can precipitate in a small number of months, which is associated with flood events; on the other hand, a very low amount of precipitation may be falling in a greater number of months, causing periods of drought that can affect the rain-fed land. This irregularity of monthly rainfall is detected in some years in the dry period of the R1 region (Figure 8). This could affect rain-fed agriculture in the western region of the basin (≈ 1600 masl). Seasonal PCI results (≈ 20%) during the rainy period in R1 and R2 show no significant temporal changes and suggest marked seasonality.

The results of MK's trend analysis identified positive annual trends of the PCI_{estac} only for the dry season (June-November) and negative trends for both periods: dry and rainy. However, in most seasons it does not show a significant trend (Figure 9 a and b). Negative PCI_{estac} trends are concentrated for R1 and R2 in the northern and southeastern part of the CRG.

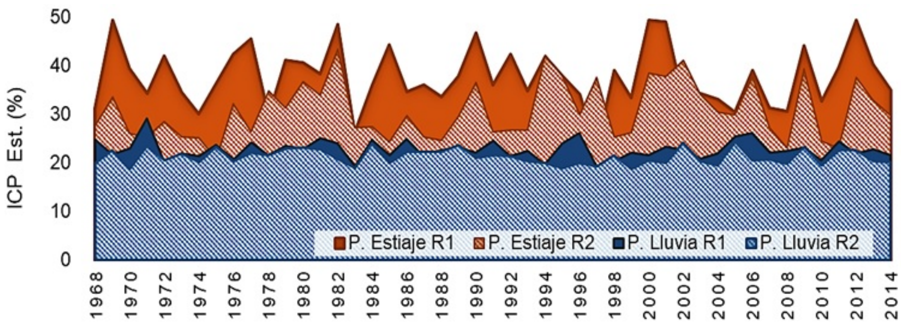

Figure 8. Annual series of seasonal precipitation concentration index (PCI_{estac}) for the period (*P.*) of the section (June to November) and rain (December-May), 1968-2014 for R1 and R2.

For the period of heavy rainfall (December-May), only two seasons show negative trend in R1 and R2, with significance levels of 90 % and 99 %, respectively (Figure 8a). In the dry period, two stations show significant negative trend at 90 and 95 % in the southern region of R1. Also, only one station located in high mountain region registers positive trend (Figure 8b). In general, the positive or negative trends identified in R1 and R2 indicate changes associated with irregularity of monthly rainfall in the temporal distribution of the concentration; however, this irregularity is identified in very few seasons.

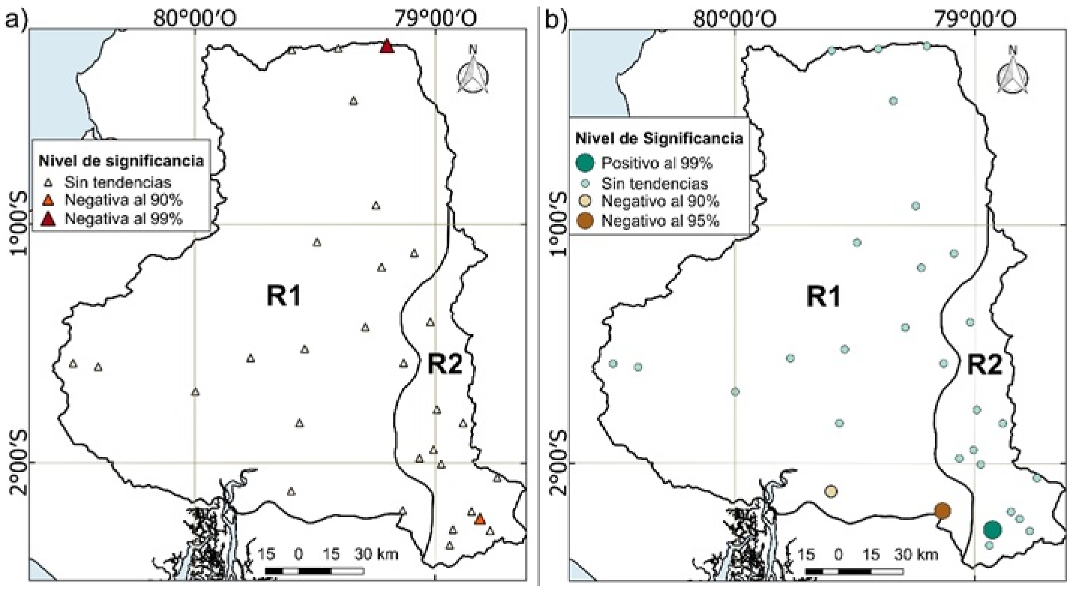

Figure 9. Seasonal distribution of PCI trends (1968–2014) in the Guayas River basin for different significance level ranges: (a) December - May, b) June - November.

4 Conclusions

The study of the aggressiveness of rainfall for the Basin of the Guayas-Ecuador River allowed to homogenize areas of precipitation, characterize the variability of rains in the period 1968 – 2014 and their potential erosive impact. The results suggest two regions 1) west of the basin in the coastal region up to 2500 masl and 2) east of the basin in the high mountain region between 1500 and 4000 masl. The basin was assessed annually using the Fournier Index (FI), Modified Fournier Index (MFI) and precipitation concentration index (PCI). These findings from IF and MFI indicate that the Guayas River basin in the coastal area is classified as a region of high to very high aggression in the coastal region, while the high mountain region is classified as low or very low erosion.

Areas of high agricultural activity located in the coastal region have greater erosive potential of rain compared to the high mountain region. The spatial distribution of precipitation concentration increases from east to west, showing moderate to strong seasonality levels. The results using the aggressiveness and concentration of precipitation rates allowed to assess qualitatively the possible impact of rain on the ground and identify aggressiveness patterns with precipitation accumulation and concentration of precipitation associated with the length. This may be associated with seasonal moisture flows from the Equatorial Amazon to the Andes (Espinoza Villar et al., 2009). These results also indicate that the monthly rainfall concentration does not have predominant changes or trends between 1968 and 2014. However, it is recommended to analyze the daily rainfall concentration in equatorial regions, as large percentages of seasonal or annual rain can precipitate in a few days.

References

Angulo-Martínez, M., López-Vicente, M., Vicente-Serrano, S., and Beguería, S. (2009). Mapping rainfall erosivity at a regional scale, a comparison of interpolation methods inthe ebro basin (ne spain). *Hydrol. Earth Syst. Sci.*, 13(10):1907–1920. Online: https://bit.ly/33ucq9c.

Arnoldus, H. (1978). *Assessment of erosion*, chapter An approximation of the rainfall factor in the Universal Soil Loss Equation. John Wiley and Sons, Inc., Chichester, England.

Ballari, D., Giraldo, R., Campozano, L., and Samaniego, E. (2018). Spatial functional data analysis for regionalizing precipitation seasonality and intensity in a sparsely monitored region: Unveiling the spatio-temporal dependencies of precipitation in ecuador. *International Journal of Climatology*, 38:3337–3354. Online: https://doi.org/10.1002/joc.5504.

Barrera-Crespo, P., Mosselman, E., Giardino, A., Becker, A., Ottevanger, W., Nabi, M., and Arias Hidalgo, M. (2018). Sediment budget analysis of the guayas river using a process-basedmodel. *Hydrol. Earth Syst. Sci.*, Discuss:1–21. Online: https://doi.org/10.5194/hess--2018--467.

Bendix, A. and Bendix, J. (2006). Heavy rainfall episodes in ecuador during el niño events and associated regional atmospheric circulation and sst patterns. *Adv. Geosci.*, 6:43–49. Online: https://bit.ly/2H3ejjB.

Besteiro, S. and Delgado, M. (2011). Evaluación de la agresividad de las precipitaciones en la cuenca del arroyo el pescado, provincia de buenos aires (argentina). *Revista de la Facultad de Agronomía, La Plata*, 110:82–90. Online: https://bit.ly/2MJ7Fnj.

Brunet-Moret, Y. (1979). Homogénéisation des precipitation. *Cahiers ORSTOM. Serie Hydrologie.*, 16(3-4):147–170. Online: https://bit.ly/2Lfg7Yg.

Buckalew, J., Scott, L., James, M., and Reed, P. (1998). Water resources assessment of ecuador. Technical report, US Army Corps of Engineers (USACE).

Cadier, E., Rossel, F., Sémiond, H., and Gomez, G. (1996). Las inundaciones en la zona costera ecuatoriana: mecanismos responsables, obras de proteccion existentes y previstas. Technical report, INESEQ 28.

Castelan-Vega, R., Tamariz Flores, V., Linares Fleites, G., and Cruz Montalvo, A. (2015). Agresividad de las precipitaciones en la subcuenca del río san marcos, puebla, méxico. *Investigaciones Geográficas*, 83:Online: https://doi.org/10.14350/rig.33480.

Corporación Andina de Fomento (1998). (1998) el fenómeno el niño 1997-1998. In *Memorias, Retos y Soluciones*, volume IV, pages 72–73, Ecuador.

Daly, C., Smith, J., and Smith, J.I., M. R. (2007). High-resolution spatial modeling of daily weather elements for a catchment in the oregon cascade mountains, united states. *Journal of Applied Meteorology and Climatology*, 46:1565–1586. Online: https://doi.org/10.1175/JAM2548.1.

De Luis, M., González-Hidalgo, J., Brunetti, M., and Longares, L. (2011). Precipitation concentration changes in spain 1946–2005. *Natural Hazards and Earth System Science*, 11:1259–1265. Online: https://doi.org/10.5194/nhess--11--1259--2011.

Egas, R. (1985). Ecuador, inundaciones 1982 – 1983 en la cuenca baja del guayas: Procesos de organizacion de los campesinos para hacer frente al desastre. In J. Hardoy, e. a., editor, *Desastres Naturales y Sociedad en América Latina*. Grupo Editora Latinoamericana.

Espinoza Villar, J., Ronchail, J., Guyot, J., Cochonneau, G., Naziano, F., Lavado, W., De Oliveira, E., Pombosa, R., and Vauchel, P. (2009). Spatio-temporal rainfall variability in the amazon basin countries (brazil, peru, bolivia, colombia, and ecuador). *International Journal of Climatology*, 29(11):1574–1594. Online: https://doi.org/10.1002/joc.1791.

Foresti, L. and Pozdnoukhov, A. (2012). Exploration of alpine orographic precipitation patterns with radar image processing and clustering techniques: Exploration of alpine orographic precipitation patterns. *Meteorological Applications*, 19:407–419. Online: https://doi.org/10.1002/met.272.

Fournier, F. (1960). *Climat et erosion; la relation entre l'erosion du sol par l'eau et les precipitations atmospheriques*. Presses universitaires de France, Paris, France. Online: https://bit.ly/2L0sM2j, 1 ed edition.

Fries, A., Rollenbeck, R., Bayer, F., Gonzalez, V., Oñate Valivieso, F., Peters, T., and Bendix, J. (2014). Meteorology and atmospheric physics. *Catchment precipitation processes in the San Francisco valley in southern Ecuador: combined approach using high-resolution radar images and in situ observations*, 126(1-2):13–29. Online: https://doi.org/10.1007/s00703--014--0335--3.

García-Barrón, L., Morales, J., and Sousa, A. (2018). A new methodology for estimating rainfall aggressiveness risk based on daily rainfall records for multi-decennial periods. *Science of The Total Environment*, 615(15):564–571. Online: https://doi.org/10.1016/j.scitotenv.2017.09.305.

Gobierno Provincial del Guayas (2016). Plan provincial de riego y drenaje del guayas. gaceta oficial del gobierno autónomo descentralizado provincial del guayas. año 1. Technical Report 90, Guayaquil.

Gobierno Provincial del Guayas (2018). Estudio de impacto ambiental del proyecto dragado de la ii fase y disposición de los sedimentos de los alrededores del islote el palmar en la provincia del guayas considerando como sitios de depósito isabel ana, lotización el tejar, caracoles y terrenos particulares del cantón durán. Technical report.

Gocic, M. and Trajkovic, S. (2013). Analysis of changes in meteorological variables using mann-kendall and sen's slope estimator statistical tests in serbia. *Global and Planetary Change*, 100:172–182. Online: https://doi.org/10.1016/j.gloplacha.2012.10.014.

Golian, S., Saghafian, B., Sheshangosht, S., and Ghalkhani, H. (2010). Comparison of classification and clustering methods in spatial rainfall pattern recognition at northern iran. *Theoretical and Applied Climatology*, 102:319–329. Online: https://doi.org/10.1007/s00704--010--0267--x.

Goovaerts, P. (1998). Geostatistics for natural resources evaluation. *Geological Magazine*, 135(6):819–842. Online: https://bit.ly/30Jsxho.

Gregori, E., Andrenelli, M., and Zorn, G. (2006). Assessment and classification of climatic aggressiveness with regard to slope instability phenomena connected to hydrological and morphological processes. *Journal of Hydrology*, 329:489–499. Online: https://doi.org/10.1016/j.jhydrol.2006.03.001.

Güçlü, Y. (2018). Multiple Şen-innovative trend analyses and partial mann-kendall test. *Journal of Hydrology*, 566:685–704. Online: https://doi.org/10.1016/j.jhydrol.2018.09.034.

Gómez-Latorre, D. (2015). Regionalización de patrones de precipitación para periodos multianuales secos y humedos en el altiplano cundiboyacense. page Online: https://bit.ly/327Z9BO.

Hastenrath, S. (1997). Annual cycle of upper air circulation and convective activity over the tropical americas. *Journal of Geophysical Research: Atmospheres*, 102:4267–4274. Online: https://doi.org/10.1029/96JD03122.

Hermida, L., López, L., Merino, A., Berthet, C., García-Ortega, E., Sánchez, J., and Dessens, J. (2015). Hailfall in southwest france: Relationship with precipitation, trends and wavelet analysis. *Atmospheric Research*, 156:174–188. Online:https://doi.org/10.1016/j.atmosres.2015.01.005.

Hernando, D. and Romana, M. (2016). Estimate of the (r) usle rainfall erosivity factor from monthly precipitation data in mainland spain. *J. Iber. Geol.*, 42:113–124. Online: https:// doi.org/10.5209/rev_JIGE. 2016.v42. n1. 49120.

Hiez, G. (1977). Lhomogénéité des données pluviométriques. *Cahiers ORSTOM. Serie Hydrologie*, 14(2):111–119.

Jordán, A. and Bellinfante, N. (2000). Cartografía de la erosividad de la lluvia estimada a partir de datos pluviométricos mensuales en el campo de gibraltar (cádiz). *Edafología*, 7(3):83–92.

Kaufman, L. and Rousseeuw, P. (2005). *Finding groups in data: an introduction to cluster analysis*. Wiley series in probability and mathematical statistics. Wiley, Hoboken, N.J.

Kendall, M. (1975). *Rank Correlation Methods*. Griffin, London, UK.

Kinnell, P. (2010). Event soil loss, runoff and the universal soil loss equation family of models: review. *J. Hydrol.*, 385.

Kononenko, I. and Kukar, M. (2007). *Machine Learning and Data Mining: Introduction to Principles and Algorithms*. Horwood Publishing, Chichester, UK. Online: https://bit.ly/2L0pL1Q.

Kumar, S., Merwade, V., Kam, J., and Thurner, K. (2009). Streamflow trends in indiana: Effects of long term persistence, precipitation and subsurface drains. *Journal of Hydrology*, 374:171–183. Online:https://doi.org/10.1016/j.jhydrol.2009.06.012.

Lanzante, J. (1996). Resistant, robust and non-parametric techniques for the analysis of climate data: Theory and examples, including applications to historical radiosonde station data. *International Journal of Climatology*, 16(11):1197–1226. Online: https://bit.ly/2OQzgok.

Mann, H. (1945). Nonparametric tests against trend. *Econometrica*, 13:245–259. Online: https://bit.ly/2ZvPQOj.

Martín-Fernández, L. and Martínez-Núñez, M. (2011). An empirical approach to estimate soil erosion risk in spain. *Science of The Total Environment*, 409:3114–3123. Online: https://doi.org/10.1016/j.scitotenv.2011.05.010.

Mondal, A., Khare, D., and Kundu, S. (2016). Change in rainfall erosivity in the past and future due to climate change in the central part of india. *International Soil and Water Conservation Research*, 4(3):186–194. Online: https://doi:10.1016/j.iswcr.2016.08.004.

Oliver, J. (1980). Monthly precipitation distribution: a comparative index. *The Professional Geographer*, 32(3):300–309. Online: https:// doi:10.1111/j.0033--0124.1980. 00300.x.

Panagos, P., Ballabio, C., Borrelli, P., Meusburger, K., Klik, A., Rousseva, S., Tadic, M., Michaelides, S., Hrabalíková, M., Olsen, P., Aalto, J., Lakatos, M., Rymszewicz, A., Dumitrescu, A., Beguería, S., and Alewell, C. (2015). Rainfall erosivity in europe. *Science of The Total Environment*, 511:801 – 814. Online: https://doi.org/10.1016/j.scitotenv.2015.01.008.

Parracho, A., Melo-Gonçalves, P., and Rocha, A. (2016). Regionalisation of precipitation for the iberian peninsula and climate change. *Physics and Chemistry of the Earth, Parts A/B/C*, 94:146–154. Online: https://doi.org/10.1016/j.pce.2015.07.004.

Prakash, S., Mitra, A., Agha Kouchak, A., and Pai, D. (2015). Error characterization of trmm multisatellite precipitation analysis (tmpa-3b42) products over india for different seasons. *Journal of Hydrology*, 529:1302–1312. Online: https://doi.org/10.1016/j.jhydrol.2015.08.062.

Rau, P., Bourrel, L., Labat, D., Melo, P., Dewitte, B., Frappart, F., Lavado, W., and Felipe, O. (2017). Regionalization of rainfall over the peruvian pacific slope and coast: Regionalization of rainfall (peruvian coast). *International Journal of Climatology*, 37:143–158. Online: https://doi.org/10.1002/joc.4693.

Rey, J., Rodríguez, M., Cortez, A., Lobo, D., Ovalles, F., and Gabriels, D. (2012). Análisis de la agresividad y concentración de las precipitaciones en venezuela. iv. región los andes. *BioAgro*, 24:115 – 120. Online:https://bit.ly/2MIEaSv.

Reynaud, J.-Y., Witt, C., Pazmiño, A., and Gilces, S. (2018). Tide-dominated deltas in active margin basins: Insights from the guayas estuary, gulf of guayaquil, ecuador. *Marine Geology*, 403:165–178. Online: https://doi.org/10.1016/j.margeo.2018.06.002.

Rollenbeck, R. and Bendix, J. (2011). Rainfall distribution in the andes of southern ecuador derived from blending weather radar data and meteorological field observations. *Atmospheric Research*, 99:277–289. Online: https://doi.org/10.1016/j.atmosres.2010.10.018.

Rossel, F., Caddier, E., and G., G. (1996). Las inundaciones en la zona costera ecuatoriana: causas; obras de protección existentes y previstas. *Bull. Inst. fr. études andines*, 25(3):399–420.

Rossel, F. and Cadier, E. (2009). El niño and prediction of anomalous monthly rainfalls in ecuador. *Hydrological Processes*, 23:3253–3260. Online: https://doi.org/10.1002/hyp.7401.

Rossel, F., Mejía, R., Ontaneda, G., Pombosa, R., Roura, J., Goulven, P., and Calvez, R. (1998). Régionalisation de l'influence du el nino sur les précipitations de l'equateur. *Bull. Inst. fr. études andines*, 27(3):643–654. Online: https://bit.ly/2zoRFOD.

Rousseeuw, P. (1987). Silhouettes: A graphical aid to the interpretation and validation of cluster analysis. *Journal of Computational and Applied Mathematics*, 20:53–65. Online: Online:https://doi.org/10.1016/0377--0427(87)90125--7.

Sanchez-Moreno, J., Mannaerts, C., and Jetten, V. (2014). Rainfall erosivity mapping for santiago island, cape verde. *Geoderma*, 217:74–82. Online: https://doi.org/10.1016/j.geoderma.2013.10.026.

Sarricolea, P., Araya, C., and Salazar, P. (2014). *Concentración de las precipitaciones en Chile central y su relación con los patrones de variabilidad de baja frecuencia, período 1965-2010*, pages 305–314. Online:https://bit.ly/30J8DmS.

Sarricolea, P., Meseguer-Ruiz, , Serrano-Notivoli, R., Soto, M., and Martin-Vide, J. (2019). Trends of daily precipitation concentration in central-southern chile. *Atmospheric Research*, 215:85–98. Online: https://doi.org/10.1016/j.atmosres.2018.09.005.

Shahana Shirin, A. and Thomas, R. (2016). Regionalization of rainfall in kerala state. *Procedia Technology*, 24:15–22. Online:https://doi.org/10.1016/j.protcy.2016.05.004.

Soledispa, B. (2002). Estudio de los sedimentos del sector donde convergen los ríos daule y babahoyo, y las posibles causan que están formando un nuevo islote en ese sector. *Acta oceanográfica del Pacífico*, 11(1):185–201.

Terranova, O., Antronico, L., Coscarelli, R., and Iaquinta, P. (2009). Soil erosion risk scenarios in the mediterranean environment using rusle and gis: an application model for calabria (southern italy). *Geomorphology*, 112:228–245. Online: https://doi.org/10.1016/j.geomorph.2009.06.009.

Thi Nguyen, T., Boets, P., Lock, K., Damanik Ambarita, M., Forio, M., Sasha, P., Dominguez-Granda, L., Thi Hoang, T., Everaert, G., and Goethals, P. (2015). Habitat suitability of the invasive water hyacinth and its relation to water quality and macroinvertebrate diversity in a tropical reservoir. *Limnologica*, 52:67–74. Online:https://doi.org/10.1016/j.limno.2015.03.006.

Twilley, R. R., Cárdenas, W., Rivera-Monroy, V. H., Espinoza, J., Suescum, R., Armijos, M. M., and Solórzano, L. (2001). *The Gulf of Guayaquil and the Guayas River Estuary, Ecuador*, pages 245–263. Online: https://doi.org/10.1007/978--3--662--04482--7_18. Springer Berlin Heidelberg, Berlin, Heidelberg.

Valdés-Pineda, R., Pizarro, R., Valdés, J., Carrasco, J., García-Chevesich, P., and Olivares, C. (2016). Spatio-temporal trends of precipitation, its aggressiveness and concentration, along the pacific coast of south america (36–49°s). *Hydrological Sciences Journal*, 61:2110–2132. Online:https://doi.org/10.1080/02626667.2015.1085989.

Vauchel, P. (2005). Hydraccess: Software for management and processing of hydro-meteorological data software, version 2.1.4. Free download. Online: https://www.mpl.ird.fr/hybam/utils/hydracces.html.

Vrieling, A., Hoedjes, J. C. B., and van der Velde, M. (2014). Towards large-scale monitoring of soil erosion in africa: Accounting for the dynamics of rainfall erosivity. *Global and Planetary Change*, 115:33–43. Online:https//doi:10.1016/j.gloplacha.2014.01.009.

Yashwant, S. and Sananse, S. (2015). Comparisons of different methods of cluster analysis with application to rainfall data. *International Journal of Innovative Research in Science, Engineering and Technology*, 4(11):10861–10872. online: https://bit.ly/347RXre.

Zeleňáková, M., Purcz, P., Poórová, Z., Alkhalaf, I., Hlavatá, H., and Portela, M. (2016). Monthly trends of precipitation in gauging stations in slovakia. *Procedia Engineering*, 162:106–111. Online: https://doi.org/10.1016/j.proeng.2016.11.023.

Zubieta, R., Saavedra, M., Espinoza, J., Ronchail, J., Sulca, J., Drapeau, G., and Martin-Vide, J. (2019). Assessing precipitation concentra-tion in the amazon basin from different satellite-based datasets. *Int. J. Climatol*, 39:3171– 3187. Online: https://doi.org/10.1002/joc.6009.

Zubieta, R., Saavedra, M., Silva, Y., and Giráldez, L. (2016). Spatial analysis and temporal trends of daily precipitation concentration in the mantaro river basin: central andes of peru. *Stochastic Environmental Research and Risk Assessment*, pages 1–14. Online: https// doi: 10.1007/s00477--016--1235--5.

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NATURAL PRODUCTS

Characterization of Sacha Inchi seed oil (Plukenetia Volubilis) from 'Canton San Vicente, Manabí, Ecuador', obtained by non-thermal extrusion processes

Caracterización del aceite de la semilla de Sacha Inchi (Plukenetia Volubilis) del cantón San Vicente, Manabí, Ecuador, obtenida mediante procesos no térmicos de extrusión

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Resumen

Sacha Inchi (*plukenetia Volubilis*) es una planta originaria de Perú. El fruto es una semilla oleaginosa la cual posee un alto contiene ácidos grasos polinsaturados, en la cual se destaca el omega 3 y 6. Para la extracción de este aceite se utilizó el método de compresión por extrusión, utilizando un tornillo sinfín, que aumenta la presión de la masa, separando así el aceite contenido dentro de la semilla. Para esto, se utilizó un extractor experimental el cual fue adaptado y puesto en marcha para la obtención de este aceite, extrayéndolo a temperatura ambiente. Con la finalidad de establecer las características fisicoquímicas de la semilla se realizaron análisis de humedad, fibra, ceniza, grasa y proteína. Una vez extraído el aceite se calcularon los rendimientos y se realizaron análisis de: índice de acidez, densidad relativa, índice de yodo, índice de peróxido y perfil de ácidos grasos. Estos resultados se compararon con los análisis realizados al aceite de la misma especie, pero de diferentes zonas de cultivo del Perú, aceite de pescado y oliva, conocidos por su alto contenido de ácidos grasos, dando como resultado que el aceite de Sacha Inchi presenta un alto contenido de ácidos grasos polinsaturados y que el método de extracción influye en la calidad del producto.
Palabras clave: Sacha Inchi, extrusión, índice de peróxido, ácido graso insaturado, índice de yodo.

Abstract

Sacha Inchi (*Plukenetia Volubilis*) (SI) is a plant native from Peru. The fruit of this plant is an oilseed than contains a high content of oil which is rich in unsaturated fatty acids (91.6 %), being one of the seeds that contain this type of fat in higher percentage. For the extraction of this oil, the extrusion method was used, using an endless screw that allows the pressure increase in the dough, separating the oil contained in the seed. For this, an experimental extractor was adapted and put into operation to obtain this oil, extracting it at room temperature. To analyze the physicochemical characteristics of the seed, moisture, fiber, ash, fat and protein analyzes were conducted. Once the oil was obtained, the yields were calculated, and the following analyzes were performed: acid index, relative density, iodine value, peroxide index and fatty acid profile. Those results were compared with the analysis made to olive and fish oil, known for their high content of fatty acids, resulting that Sacha Inchi oil is better in both quality indexes, as in percentage of unsaturated fatty acids.
Keywords: Sacha Inchi, extrusion, peroxide index, unsaturated fatty acid, iodine index.

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1 Introduction

Sacha inchi (SI) (*Plukenetia Volubilis Linnaeus*), also known as wild peanuts, sacha peanuts, mountain peanut is an oily plant that belongs to the Euphorceaebia family. It has been cultivated in the lowlands of the Peruvian Amazon, and has been planted for centuries by the indigenous population, becoming a diet component of several native groups of the region (Gutiérrez et al., 2011; Chirinos et al., 2013). According to Muangrat et al. (2018), the obtaining percentage of this pressed oil at 60 $^{\circ}C$ is 37.97 %, with an approximate percentage of 92 % of polyunsaturated fatty acids (GPA), such as alpha linolenic acid (18:3n-3, linolenic acid) and linoleic acid (18:2n-6, α linoleic acid) (Fanali et al., 2011; Cisneros et al., 2014). This type of fatty acids has one or more links between their carbons, and depending on their location they are called α-3, 6 or 9 BADUI. According to Araujo-Dairiki et al. (2018) these fatty acids have beneficial effects that include the ability to decrease glyceride levels, prevent cardiovascular disorders and have an antithrombotic action, in addition to certain experiments that have shown that this oil has a high antioxidant capacity that helps to reduce DNA damage due to oxidation (Takeyama and Fukushima, 2013). The interest in these nutrients has been due to a set of publications demonstrating that the intake of fat depends on its quality, i.e., the type of predominant fatty acid (Carrillo Fernández et al., 2011), Thus, the study of SI is a challenge both as oily material and also for the biological functionalities that could derive from its oil and/or its extracts (Castaño T. et al., 2012).

On the other hand, the consumption of olive oil (OO) has increased due to the benefits of vegetable oils, since the composition of OO has a large amount of monounsaturated fatty acids, particularly oleic acid. In addition, there are acid α-linolenic (α-3) and linoleic acid (α-6) required by the human body and which cannot synthesize (Piscopo et al., 2016).

Currently, fish oil in capsules is marketed globally because it is rich in polyunsaturated fatty acids α-3 [40.91 %, according to Paucar-Menacho et al. (2015)], eicosapentaenoic acid (EPA) (20: 5, n-3) and docosahexaenoic acid (DHA) (22: 6, n-3) (Van der Tempel et al., 1990). However, environmental pollution has caused the accumulation of heavy metals and dioxins in fish, hence, the benefits of obtaining unsaturated fatty acids from fish (Maurer et al., 2012).

People who cannot eat fish daily or do so infrequently, can supplement their intake of fatty acids α-3 with vegetable oils (Strobel et al., 2012). However, as these fatty acids are easily oxidized at high temperatures, their potential applications are limited. As such, the analysis of new sources of fatty acids α-3, would be extremely beneficial from the point of view of human health (Takeyama and Fukushima, 2013). The aim of this research is to extract the SI oil by a cold pressing and conduct its characterization to be able to compare between oils rich in unsaturated fatty acids, such as fish oil and olive oil.

2 Materials and methods

2.1 Process for obtaining the oil

The seeds of SI (Plukenetia volubilis Linnaeus) coming from San Vicente, Manabí, Ecuador, once cultivated were stored hermetically, then it was proceeded to extract manually the shell from the seed, and were ready for the analysis and extraction processes. Finally, to separate the non-lipid dry mass, a Dutch extruder "Piteba"brand was used from the oily part, in which its limitation lies in the use of seeds with total fat content of more than 25 % gross weight. According to Fanali et al. (2011), the presence of oil in SI seed was between 37 % and 47 %. This extraction was carried out at room temperature in order to generate the least possible impact on the unsaturated structures of fatty acids. Once the crude oil is extracted, which has suspended solids because during the extrusion process certain solid material particles were retained, it is left to rest for a few hours in a container that was properly sealed and without light in order to avoid accelerated oxidation. Once the two phases are separated (solid of the dry) it was proceeded to conduct the filtration of the first layer with a standard filter paper, thus leaving the oil ready for its storage as shown in Figure 1.

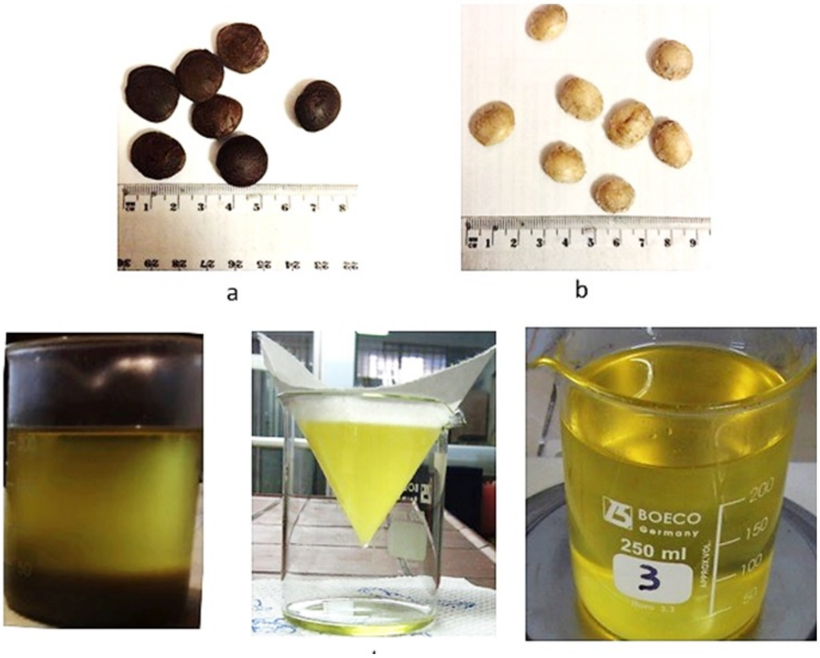

Figure 1. a) SI seed with shell. b) SI seed without shell. c) Product obtained after the extrusion. d) Oil filtration. d) Filtered oil.

2.2 Chemical-physical analysis of Sacha Inchi

Each test was performed following the parameters of the AOAC Official Methods of Analysis and the American Oil Chemists' Society (AOCS). In case of needing to weigh a sample, an AE Adam balance of 1000 grams was used, which was properly calibrated.

2.2.1 Percentage of humidity

Following the guidelines of the AOCS-94 Cde 13a-63 method, 5 grams approximately were weighed, then these were taken to a Thermo Fisher Scientific stove for approximately 5 hours at 110 °C and then were weighed again. The percentage of humidity in the sample was determined by using Equation (1).

$$\%\text{Humidity} = \left(1 - \frac{\text{Weight of dry sample}(g)}{\text{weight of humidity}(g)}\right) * 100 \quad (1)$$

2.2.2 Determination of fat

For this type of analysis, the AOAC 18th 922.06 method was followed by weighting 2 grams of the sample after the extraction of moisture, and the raw fat is separated from the sample by soxhlet and was weighted. The total fat percentage in the sample was determined by using Equation (2).

$$\%\text{fat} = \frac{\text{Sample weight of the fat obtained}(g)}{\text{weight of the sample seed}(g)} * 100 \quad (2)$$

2.2.3 Percentage of raw fiber and ash

The fiber determination was followed by the parameters of the AOAC method, 2005, 962.09 using 1.25% of diluted sulphuric acid, 1.25% of sodium hydroxide solution, 95% of ethyl alcohol and petroleum ether. The percentage of ash was determined by the AOCS-94 Ba 5-4 method, in which a Thermo scientific Lindbergh blue m flask was used.

2.2.4 Percentage of protein

A Thermo Fisher Scientific Brand Flash 2000 analyzer was used for this type of test, in which 1 milligram of the sample was weighed and carried to the instrument input, then combustion around 900°C and then it was heated in approximately 900 °C, and then a serpentine-shaped column is done and was finally detected by a Thermal Conductivity Detector (TCD) which automatically provides protein percentage data.

2.3 Chemical Physical Analysis of the Oil

The guidelines described in point 2.2 were also used for these analyses. In case of needing to weigh a sample, an AE Adam balance of 1000 grams was used, which was properly calibrated.

2.4 Free acidity index

A direct titration was conducted according to the AOCS-94 Cd 3a-63 method, 10 grams of the oil sample were weighed in an Erlenmeyer and 50 ml of ethyl alcohol was added, then about 3 drops of phenolphthalein indicator were added. It was then titrated with a 0.1 N sodium hydroxide (NaOH) solution until the color changed to pink. Finally, the calculation was performed with Equation (3). Where AI is the acidity index, V is the volume in ml of the valued NaOH solution used to neutralize the free fatty acids in the sample, N is the normal concentration of NaOH and W the weight in grams of the oil sample.

$$IA = \frac{V * N * 56,1}{W} \tag{3}$$

2.4.1 Relative Density Determination

Method AOAC-90 920-212 was used for this analysis. In a properly titrated specimen, 100 ml of the oil sample were placed and then this amount was weighed to obtain the result with the Equation (4), obtaining the same in the units of gr/ml.

$$\%\text{Relative density} = \frac{\text{weight of the oil}(g)}{100 \text{ ml}} \tag{4}$$

2.4.2 Peroxide index

Following the guidelines of the Method AOAC-90 965-33, first two grams of the oil sample were weighed, then 24 ml of 1:3 chloroform-acetic acid solutions were added, then 0.4 ml of potassium iodide solution and 24 ml of distilled water, the sodium thiosulphate solution with 0.01 N potassium permanganate was assessed and titration continued until the blue color disappeared. The peroxide index was calculated with Equation (5) and the result showed active oxygen mill equivalents per kilograms of fat. Simultaneously, a white sample is performed performing the same procedure with water. Where IP is the peroxide index, V the milliliters of sodium thiosulphate solution used in the test, V′ the milliliters of sodium thiosulphate solution consumed in the white, N is the normal sodium thiosulphate solution and P is the normal weight in grams of the sample.

$$IP = \frac{(V - V') * N * 1000}{P} \tag{5}$$

This test was carried out for 13 days with the aim to study the oxidation progression of this oil to the weather, environmental temperature and exposed to light. The analyses were carried out on days 1-4-6-8-11-13. Error bars were used as a method of statistical analysis.

2.4.3 Iodine Index

The measurement of this parameter was performed according to the parameters set out in method AOAC-90 920-159. First 0.1 g of SI oil was weighed in a 250 ml Erlenmeyer, the oil was dissolved in 10 ml of chloroform and 10 ml of the Wijs solution, then it was left to rest for 30 minutes in the darkness stirring occasionally; then 5 ml of potassium iodide solution at 15 % were added stirring vigorously, and 100 ml of freshly boiled and flared water were added, washing any residue of the existing solution in the edges. Finally, it was titrated with sodium thiosulphate 0.1 N, using starch as an indicator. At the same time, analysis of a white sample was performed. The calculation of the iodine index was done using Equation (6). In which V_s are the milliliters of sodium thiosulphate used in the white, V_m are the milliliters of sodium thiosulphate used in the sample and N is the normality of sodium thiosulphate.

$$\text{Iodine index} = \frac{(V_s - V_m) * N * 12{,}67}{\text{weight of the sample}} \tag{6}$$

2.5 Fatty Acid Profile

It was performed in accordance with the AOCS Ce 1B-89 procedure using a TRACE 1310 Mainframe gas chromatograph with a Trace TR-FAME 260M137P capillary column (25m x 0.32mm x 0.25um). The working conditions were performed as described by Wang and Kakuda (2018).

2.6 Statistical analysis

For the physicochemical seed and oil analyses, three replications of each were made, and the means were obtained with their corresponding standard deviations. In addition, a statistical analysis was performed using Tukey's ANOVA test and the Real Statistics program to determine potential significant differences at $p < 0{,}05$ level. For the elaboration of graphs, the software 'R' was used.

3 Results and Discussion

3.1 Yields on the extraction of Sacha Inchi seed oil

As observed in Table 1, it can be seen that taking 1000 grams of SI seed a lot of this total weight is lost in the shell, so the weight of the seed will be taken without shell as a calculation basis for the other parameters. The dry mass (extraction residue) obtained after the extraction (68.08 %) gives a very high value, so it represents a very important percentage as it can be used later. The percentage of oil yield shown in Table 1 is 26.92 %, which compared to the results provided by Muangrat et al. (2018) who obtained oil yields between 37.97 % and 40.63 %, it is evidenced that the performance in this study was lower, because during oil extraction in this investigation the temperature did not increase.

Table 1. Yields on obtaining SI seed oil.

Oil obtained (%p/p)	Sediments (%p/p)	Seed residue (%p/p)	Seeds without shell (g)	Shelled seed (g)	Semilla con cáscara (g)
26,93 $\pm 1,67$	3,8$\pm 0,18$	68,08 $\pm 7,46$	653,17 $\pm 13,83$	347,2 $\pm 14,4$	1000,3 $\pm 0,6$

3.2 Physicochemical analysis of Sacha Inchi seed

As can be seen in Table 2, this seed contains a high oil content: 42.0 % which according to Wang and Kakuda (2018) is in the estimated range (33.4 % - 54.3 %). The amount of protein: 29.78 %, suggests that this seed once extracted the oil will have a very high protein remnant. The ash percentage is 2.9 % which is slightly lower as reported by Gutiérrez et al. (2011) who obtained a percentage of 4 %. The amount of moisture is relatively low: 6.72 % as it is a dry fruit. According to James (1995) it is within the range 0-10 % for processing and storing without degradation of microorganisms to triacylglycerides. The amount of fiber obtained in this study was 18 % on a dry sample, which is higher than the one reported by Muangrat et al. (2018), who obtained a percentage of 13.86 % on a dry sample.

Table 2. Physicochemical characteristics of SI seed

Characteristics	SI Seeds
Moisture	6,72 $\pm 0,1$
Fat	42,03 $\pm 0,2$
Ash	2,9 $\pm 0,025$
Fiber	18,0 $\pm 0,095$
Protein	29,78 $\pm 1,6$

3.3 Physical-chemical analysis of Sacha Inchi seed oil

3.3.1 Acidity Index

As observed in Table 3, the acidity index of this oil is 0.38 mg KOH/g. According to FAO/OMS (2015), it should not be higher than 4 mgNaOH/g for cold-pressed vegetable oils. The low acidity of this acid reflects the low refining and good quality of SI oil. The good quality of this oil is corroborated compared to the olive oil that according to Paucar-Menacho et al. (2015) has a value of 1.14 mgNaOH/g, and the fish oil that according to Nascimento et al. (2015) has a value of 11.72 mgNaOH/g,

3.3.2 Relative density

In Table 3 is presented the result of this parameter with a value of 0.91, which reflects that this oil is light. According to Gutiérrez et al. (2011) this is due to the amount of unsaturated fatty acids present in it. Compared to the olive oil that according to Paucar-Menacho et al. (2015) gives a value of 0.9252, there is a similarity between these two oils due to the high unsaturation in both.

3.3.3 Iodine index

According to Muangrat et al. (2018) this characteristic of the oil is related to its unsaturation, which as can be seen in Table 3 it gives a value of 192.5 I_2/100g. Comparing it with the reported by Paucar-Menacho et al. (2015) for olive oil (56.15 g I2/100 g) and by Nascimento et al. (2015) for fish oil (93.92 g I_2/100 g), the SI oil shows very high value in the iodine index, reflecting that this oil has greater unsaturation compared to the other two oils.

Table 3. Physical-chemical characteristics of SI oil

Property	Oil type		
	Sacha Inchi	**Olive**	**Fish**[3]
Acidity index (mg KOH/g)	0,38 ± 0,02	1,14 ± 0,037 [1]	11,72 ± 0,1
Relative density	0,91	0,9252 ± 0,0014 [1]	N/D
Peroxide index (m-eq O_2/Kg)	5,81 ± 0,5	6,91 ± 3,44 [2]	7,22 ± 1,1
Iodine index (I_2/100g)	192,5 ± 0,7	56,15 ± 0,14 [1]	93,92 ± 0,7

[1] (Paucar-Menacho et al., 2015), [2] (Piscopo et al., 2016), [3] (Nascimento et al., 2015).

3.3.4 Peroxide index

As mentioned by Cebi et al. (2017) this test directly measures the concentration of hydroperoxide resulting from the primary oxidation in the oxidation of products, which according to FAO/OMS (2015) it must not exceed 10 mill equivalents of oxygen peroxide/kg in the case of vegetable oils and animal origin. The result obtained in this study was 5.81 m-eq O_2/Kg, which gives a lower value compared to olive oil with a value of 6.91 m-eq O_2/Kg according to Piscopo et al. (2016), and a value of 7.22 m-eq O_2/Kg in fish oil according to Nascimento et al. (2015).

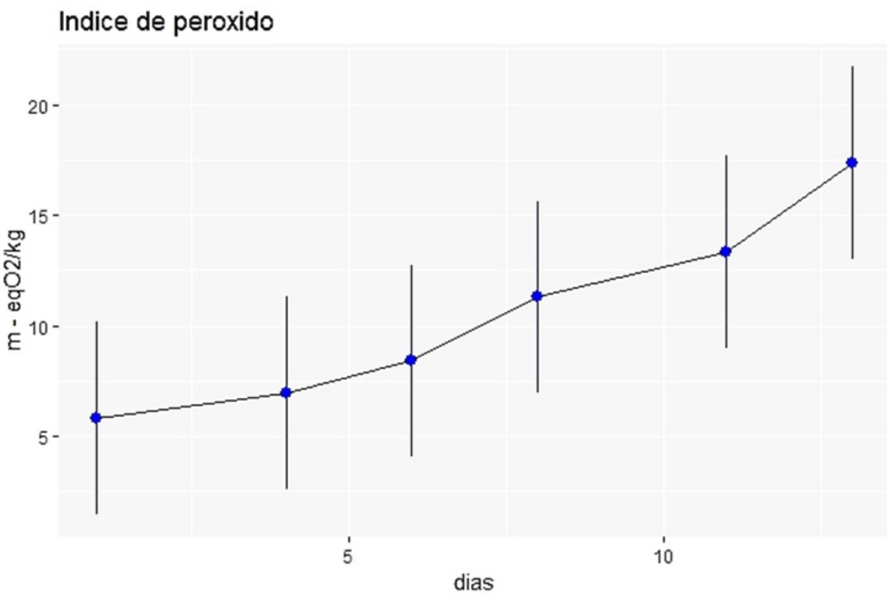

Figure 2. Oxidation index (m-eq O_2/Kg) vs time (days).

To find out how vulnerable SI oil is to oxidation, the procedures described in 2.2.3 at room temperature (25 °C) were performed, proving that this oil is sensitive to develop rancidity if it is exposed for a long time to light and the weather. As reported by Takeyama and Fukushima (2013) which exposed the oil to a certain UV radiation of 300 nm for 15 days and obtained an increase in the oxidation of the same, obtaining values of 250 m-eq O_2/Kg. As reported by Maurer et al. (2012), who obtained a value of 100 m-eq O_2/Kg at 65 °C for 15 days, which is very different compared to the analysis carried out in this research which was performed at 25 °C (16 m-eq O_2/kg for 15 days). All these results indicate that this oil has a high sensitivity to oxidation due to exposure to ultraviolet light and temperature.

3.4 Fatty acid profile

Table 4. Oil fatty acid profile.

Fatty acid profile				
Composition of fatty acid	**Sacha Inchi(%)**	**Sacha Inchi(%)[1]**	**Olive(%)[2]**	**Fish(%)[3]**
C14:0	N.D	N.D	N.D	10,22
C16:0	5,44	4,7	13,56	22,8
C16:1	N.D	N.D	1,43	10,54
C17:0	N.D	N.D	242	0,85
C18:0	3,94	3,3	1,86	4,4
C18:1	17,12	8,9	71,22	9,62
C18:2	34,67	34,1	10,13	1,51
C18:3	38,84	48,2	618	0,99
C20:0	N.D	N.D	356	N.D
C20:5n3	N.D	N.D	N.D	20,28
C22:6n3	N.D	N.D	N.D	19,64
C20:1	N.D	N.D	284	2,56
C20:2	N.D	N.D	102	N.D
C22:1	N.D	N.D	N.D	1,62
Total α-3	38,84	48,2	618	40,91
Total α-6	34,67	34,1	10,13	1,51
Total α-9	17,12	8,9	71,22	9,62
Total Saturated	9,38	8	15,88	37,42
Total Unsaturated	90,63	91,2	83,92	62,58
Total mono unsaturated	17,12	8,9	73,17	20,16
Total Poly unsaturated	73,51	82,3	10,75	42,42

[1] (Cisneros et al., 2014), [2] (Romero Aroca, 2011), [3] (Paucar-Menacho et al., 2015).

The fatty acid profile can be seen in Table 4. The high content of unsaturated fatty acids can be observed in all the three oils, the highest being SI (90.63%) similar to the one reported by Fanali et al. (2011) who obtained a value of 92%. Within them linolenic acid α-3 (38.84%) is the most present, which helps to reduce the risk of cardiovascular disease in humans (Araujo-Dairiki et al., 2018). The fatty linoleic acid α-6 is the second with the highest percentage within SI oil (34.67%) which contributes to the prevention of inflammatory diseases (Saiki et al., 2017) and decreases body fat in children (Racine et al., 2010). In addition, compared to the values obtained in this trial with those provided by Cisneros et al. (2014), it is observed that there is a small difference in the composition of fatty acids, reaching higher values in linolenic acid α-3 (48.2%) and decreasing in oleic acid α-9 (8.9%). There is no greater difference in the case of linoleic acid α-6.

According to Romero Aroca (2011) olive oil has a total saturated percentage of 15.88%, and a total unsaturated percentage of 83.92%, emphasizing that oleic acid α-9 is the most present in this type of oils, reaching a percentage of 71.22% , which is stable to oxidation because it is a fatty acid with only a double bond (Paucar-Menacho et al., 2015). According to Paucar-Menacho et al. (2015) the fatty acid profile of fish oil has a total saturated percentage of 37.42%, and total unsaturated percentage of 62.58%. It should be emphasized that linolenic acid α-3 is the most present in this type of oil, reaching 40.91%.

Comparing these three oils, it can be shown that SI oil provides a higher amount of unsaturated fatty acids, which differ in the amount between linolenic acid α-3, linoleic α-6 and oleic α-9, the first two being the ones with more presence. It can be said that SI oil has a beneficial health effect, reducing the amount of triglycerides in the blood. These can help in the control of certain diseases such as diabetes mellitus, obesity and also work as possible cytotoxic agents for certain tumor cells (Rodríguez-Cruz et al., 2005).

4 Conclusions

The oil extraction percentage by extrusion (26.92 %) compared to that obtained in physicochemical analyses (42.03 %) shows that this extraction method has a low yield, taking as an alternative other types of extraction to obtain more oil.

SI seed has a high oil content, and in this research it was determined to contain a high content of unsaturated fatty acids (90.63 %); and compared to the results obtained with seeds from Peru, it has a slight variance in the linolenic (9.36 % difference) and oleic fatty acids (8.22 % difference), concluding that the composition of polyunsaturated and monounsaturated fatty acids varies depending on the origin of the seed.

Compared to olive and fish oils which are commonly known for their high unsaturation level, it has a higher level of polyunsaturated fatty acids: 62.76 % compared to olive oil and 31.09 % compared to with fish oil. However, olive oil is rich in oleic acid α-9 and fish oil in linolenic acid α-3, which are beneficial depending on the consumer's need. By performing a physicochemical analysis of the three oils, it was possible to determine that the quality of SI oil is higher compared to the other two oils, being a less processed and lighter product.

Due to the high protein content present in SI oil, a subsequent study is recommended to obtain a possible product from the residue after the oil extraction.

References

Araujo-Dairiki, T., Chaves, F., and Dairiki, J. (2018). Seeds of sacha inchi (plukenetia volubilis, euphorbiaceae) as a feed ingredient for juvenile tambaqui, colossoma macropomum, and matrinxã, brycon amazonicus (characidae). *Acta Amazonica*, 48(1):32–37. Online:https://bit.ly/2YTCzL4.

Carrillo Fernández, L., Dalmau Serra, J., Martínez Álvarez, J., Solà Alberich, R., and Pérez Jimenéz, F. (2011). Grasas de la dieta y salud cardiovascular. *Clínica e Investigación en Arteriosclerosis*, 23:1–36. Online:https://bit.ly/2KnftZl.

Castaño T., D. L., Valencia G., M., Murillo P., E., Mendez A., J. J., and Joli E., J. (2012). Fatty acid composition of inca peanut (plukenetia volúbilis linneo) and its relationship with vegetal bioactivity. *Revista Chilena de Nutrición*, 39(1):45–52. Online:https://bit.ly/31rIJE8.

Cebi, N., Yilmaz, M., Sagdic, O., Yuce, H., and Yelboga, E. (2017). Prediction of peroxide value in omega-3 rich microalgae oil by atr-ftir spectroscopy combined with chemometrics. *Food chemistry*, 225:188–196. Online:https://bit.ly/2YzxyMG.

Chirinos, R., Zuloeta, G., Pedreschi, R., Mignolet, E., Larondelle, Y., and Campos, D. (2013). Sacha inchi (plukenetia volubilis): a seed source of polyunsaturated fatty acids, tocopherols, phytosterols, phenolic compounds and antioxidant capacity. *Food chemistry*, 141(3):1732–1739. Online:https://bit.ly/2ZLntsC.

Cisneros, F., Paredes, D., Arana, A., and Cisneros-Zevallos, L. (2014). Chemical composition, oxidative stability and antioxidant capacity of oil extracted from roasted seeds of sacha-inchi (plukenetia volubilis l.). *Journal of agricultural and food chemistry*, 62(22):5191–5197. Online:https://bit.ly/2ZHDkrV.

Fanali, C., Dugo, L., Cacciola, F., Beccaria, M., Grasso, S., Dacha, M., Dugo, P., and Mondello, L. (2011). Chemical characterization of sacha inchi (plukenetia volubilis l.) oil. *Journal of agricultural and food chemistry*, 59(24):13043–13049. Online:https://bit.ly/2KlW1Mw.

FAO/OMS (2015). Norma para aceites vegetales especificados, codex alimentarius. *Normas internacionales de los alimentos*, pages 1–14. Online:https://bit.ly/2M79PN9.

Gutiérrez, L., Rosada, L., and Jiménez, A. (2011). Chemical composition of sacha inchi (plukenetia volubilis l.) seeds and characteristics of their lipid fraction. *Grasas y aceites*, 62(1):76–83. Online:Online: https://bit.ly/2yKSWPs.

James, C. (1995). *Analytical Chemistry of Foods*, volume Online:https://bit.ly/2GVhR7E. New York: Chapman and Hall publishers.

Maurer, N., Hatta-Sakoda, B., Pascual-Chagman, G., and Rodriguez-Saona, L. (2012). Characterization and authentication of a novel vegetable source of omega-3 fatty acids, sacha inchi (plukenetia volubilis l.) oil. *Food chemistry*, 134(2):1173–1180. Online:https://bit.ly/2GT985G.

Muangrat, R., Veeraphong, P., and Chantee, N. (2018). Screw press extraction of sacha inchi seeds: Oil yield and its chemical composition and antioxidant properties. *Journal of food processing and preservation*, 42(6):1–10. Online:https://bit.ly/2GTgiqG.

Nascimento, V., Bermúdez V., M., Oliveira A., L., Kleinberg M., N., Ribeiro R., T.M. Abreu R., F., and Carioca J., O. (2015). Characterization of a hydrolyzed oil obtained from fish waste for nutraceutical application. *Food Science and Technology*, 35(2):321–325. Online:https://bit.ly/2GWTyWK.

Paucar-Menacho, L. M., Salvador-Reyes, R., Guillén-Sánchez, J., Capa-Robles, J., and Moreno-Rojo, C.

(2015). Comparative study of physical-chemical features of sacha inchi oil (plukenetia volubilis l.), olive oil (olea europaea) and fish oil. *Scientia agropecuaria*, 6(4):279–290. Online:https://bit.ly/2MOwYDw.

Piscopo, A., De Bruno, A., Zappia, A., Ventre, C., and Poiana, M. (2016). Characterization of monovarietal olive oils obtained from mills of calabria region (southern italy). *Food chemistry*, 213:313–318. Online:Online: https://bit.ly/2YULHPE.

Racine, N., Watras, A., Carrel, A., Allen, D., McVean, J., Clark, R., O'Brien, A., , O'Shea, M., Scott, C., and Schoeller, D. (2010). Effect of conjugated linoleic acid on body fat accretion in overweight or obese children. *The American journal of clinical nutrition*, 91(5):1157–1164. Online:https://bit.ly/2TemiPX.

Rodríguez-Cruz, M., Tovar, A. R., del Prado, M., and Torres, N. (2005). Mecanismos moleculares de acción de los ácidos grasos poliinsaturados y sus beneficios en la salud. *Revista de investigación clínica*, 57(3):457–472. Online:https://bit.ly/2MOjc40.

Romero Aroca, A. (2011). *Caracterización y diferenciación de los aceites vírgenes de oliva de la comarca del Priorat (Tarragona) dentro del mercado global de aceites de la variedad'Arbequina'*. PhD thesis, Universitat de Lleida, Online:https://bit.ly/2YwJqyV.

Saiki, P., Kawano, Y., Van Griensven, L., and Miyazaki, K. (2017). The anti-inflammatory effect of agaricus brasiliensis is partly due to its linoleic acid content. *Food & function*, 8(11):4150–4158. Online:https://rsc.li/2yNoXXb.

Strobel, C., Jahreis, G., and Kuhnt, K. (2012). Survey of n-3 and n-6 polyunsaturated fatty acids in fish and fish products. *Lipids in Health and Disease*, 11(1):144. Online:https://bit.ly/2YUifgN.

Takeyama, E. and Fukushima, M. (2013). Physicochemical properties of plukenetia volubilis l. seeds and oxidative stability of cold-pressed oil (green nut oil). *Food Science and Technology Research*, 19(5):875–882. Online:https://bit.ly/2KCNfJf.

Van der Tempel, H., Tulleken, J. E., Limburg, P. C., Muskiet, F. A., and van Rijswijk, M. H. (1990). Effects of fish oil supplementation in rheumatoid arthritis. *Annals of the rheumatic diseases*, 49(2):76–80. Online:https://bit.ly/2TgXW7X.

Wang, S.; Zhu, F. and Kakuda, Y. (2018). Sacha inchi (plukenetia volubilis l.): Nutritional composition, biological activity, and uses. *Food chemistry*, 265:316–328. Online:https://bit.ly/2GTbrpm.

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Scientific paper / Artículo científico
WATER TREATMENT

Detection of betalactamic antibiotics, tetracyclines and sulfamides as emerging pollutants in the rivers San Pedro and Pita of the canton Rumiñahui

Detección de antibióticos betalactámicos, tetraciclinas y sulfamidas como contaminantes emergentes en los ríos San Pedro y Pita del cantón Rumiñahui

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Resumen

Las actividades que se realizan en el diario vivir, como la higiene personal o el cuidado de la salud, pueden provocar efectos negativos en el ecosistema, generando alteraciones sobre el medio ambiente, dado que se consumen varias sustancias de diferente origen y composición química, de estas sustancias se conoce relativamente poco con respecto al impacto que tendrá en el ambiente y en el ser humano, sustancias que son reconocidas con el nombre de contaminantes emergentes. El presente trabajo experimental fue desarrollado en las parroquias de Uyumbicho, Amaguaña, dos localidades ubicadas a 1 Km de la orilla del río San Pedro y la parroquia de Sangolqui cerca al río Pita, se evaluó la probable existencia de residuos de antibióticos betalactámicos y sulfamidas, en los 13 puntos de muestreo distribuidos de la siguiente manera: 9 en el río San Pedro y 4 en el río Pita, se realizaron 6 muestreos de agua, para ser analizadas mediante la utilización de un kit de detección para antibióticos, las muestras fueron analizadas 2 veces cada mes, por 3 meses, se procesó las imágenes con técnica fotogramétricas y estadísticas para cuantificar los antibióticos, de manera rápida y sencilla. Los resultados obtenidos son claros con un total del 41 de 78 muestras que representa el 52 % de casos positivos con presencia de residuos de antibióticos betalactámicos y sulfamidas en los afluentes de los ríos San Pedro y Pita.

Palabras clave: Antibióticos, contaminantes emergentes, ambiente, betalactámicos, sulfamidas.

Abstract

The activities carried out in daily living, such as personal hygiene and health care, they may cause negative effects on the ecosystem, generating alterations on the environment given that consumed several substances of different origin and chemical composition, these substances are relatively little known regarding the impact that will have on the environment and human substances that are recognized under the name of polluting emerging. This experimental study was developed in the parishes of Uyumbicho, Amaguaña, two towns located 1 Km from the shore of the San Pedro river and the parish of Sangolqui near the Pita river, assessed the likely existence of residues of beta-lactam antibiotics and sulphonamides at the 13 sampling points distributed in the following manner: 9 in the San Pedro river and 4 in the Pita river 6 samples of water, were taken to be analyzed using a kit of detection for antibiotics samples were tested 2 times every month, for 3 months, antibiotics were estimated by photogrammetric and statistical analysis. The results are clear with a total of 41 of 78 samples representing 52 % of positive cases with the presence of residues of beta-lactam antibiotics and sulfonamides in the tributaries of the rivers San Pedro and Pita.
Keywords: Antibiotics, contaminants emerging, environment, beta-lactams, sulfonamides.

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1 Introducción

The deterioration in the environment is provoked by the accelerated increase of the population which implies the increase of production and in industrial, pharmaceutical, agricultural activities because the waters that each activity generates are directly poured to the bodies of water. These waters are not treated beforehand, consequently it is not possible to mitigate the impact that is being generated on the bodies of water (Elena et al., 2009; Ramírez Cando et al., 2017).

The announcement of the first sulfa antibiotic in 1935 initiated the modern era of antimicrobial therapy, characterized by a huge decrease in morbidity and mortality for many infectious diseases (Gimeno, 2001; Reig and Toldrá, 2008). In this group of pollutants, pharmaceuticals and byproducts are found, although they are not considered as persistent substances, their frequent use and disposal make them present in our environment. Therefore, antibiotics are part of the pharmacological agents used repeatedly, and in other cases these are used without any control as a nutritional supplement or to treat diseases in animals, being administered in many times in an unwise way and in inadequate doses (Talero Pérez et al., 2014).

The right of every citizen to live in a healthy and ecologically balanced environment, free of contamination (CIJUL, 2013; Mátyás et al., 2018; Ramírez Cando et al., 2017), is the basis for the project to detect antibiotics and their derivatives as emerging contaminants in the basin of the rivers Pita and San Pedro, so as to generate ideas for the subsequent treatment necessary for the decontamination of the rivers. The aim of this work is to identify, analyze, detect and quantify the types of antibiotics and their derivatives that are present in the rivers San Pedro and Pita considered as emerging contaminants, in this way, to generate data that facilitate the analysis of the behavior of these antibiotics, and also to determine damage levels both in the human health and the environment itself. This process will be analyzed by sampling in situ, and controlled processes in a laboratory for a post-result analysis to have a clear idea of the effect of antibiotics in the environment. One of the important characteristics that this group of pollutants has to cause a negative effect on the nature is that they do not necessarily need to be persistent, because, although there are systems that can remove them or transform them into simpler compounds or sub-composite, its continuous consumption and the waste generated leads to the permanent presence in the environment (Barceló, 2003; Guevara Granja and Ramirez Cando, 2015; Ramírez Cando et al., 2017). In the rivers San Pedro and Pita, the following emerging contaminants (antibiotics) are specifically studied and analyzed: Betalactamicos, tetracyclines, Sulfonamides (Barceló, 2003).

Antibiotics are substances originated from different types of microorganisms, such as bacteria, fungi or actinomyces, including certain species of insects and plants, which manage to intervene in the development of other microorganisms and can even eliminate them (Volfredo Camacho, 2010). These are made of organic molecules, which reveals to us that its degradation mechanism to which it is exposed in the environment is equal to any organic compound, but with the difference that all the reactions carried out are performed even if the concentrations of these compounds are very diluted (Henríquez Villa, 2012). It is necessary that the estimated time for the biodegradation of the antibiotics in the environment is of months or years, depending on the conditions in which it is found: quantity of oxygen, the light availability, water supply (Ferrer and Thurman, 2012; Alvarez Mendoza et al., 2019). Considering the above, the detection and quantification of these compounds in bodies of water is a need for the decision making and regulations.

2 Materials and methods

2.1 Study area

The detection of antibiotics occurs in the waters of the rivers San Pedro and Pita, located in the province of Pichincha, in the parishes Uyumbicho in Mejía and Amaguaña canton and Sangolquí in the Rumiñahui canton, by which the rivers under the study pass, as seen in Figure 1.

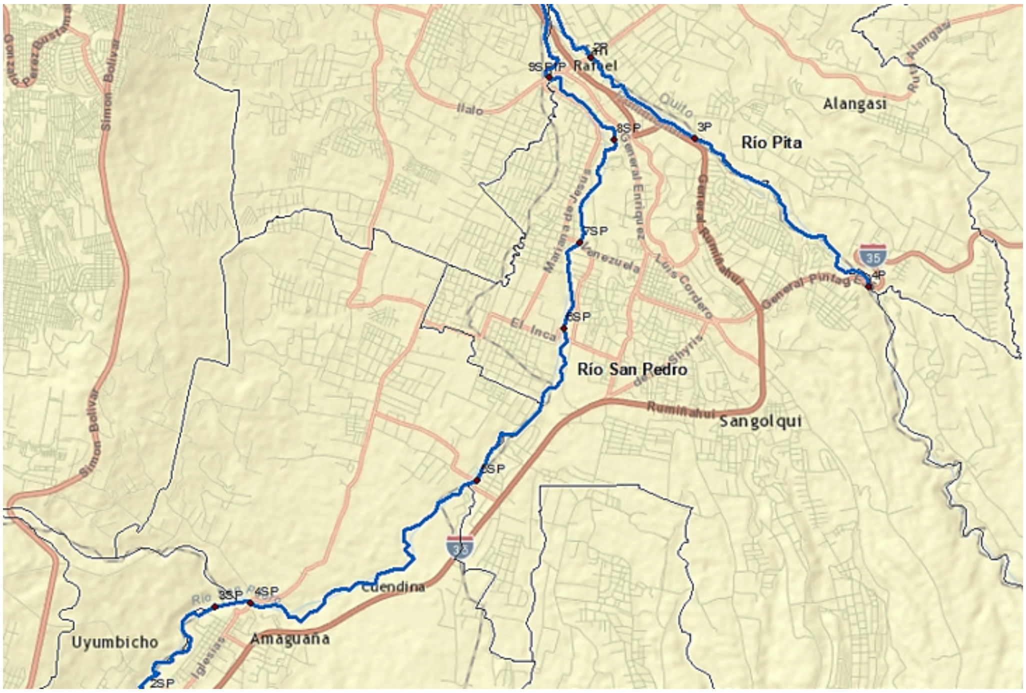

Figure 1. Location of the project from the parishes Uyumbicho, Amaguaña and Sangolquí.

Uyumbicho

The parish of Uyumbicho is located to the north of the Mejía Canton, 23 km from the center of Quito, and 1 Km from the left bank of the San Pedro River. It is between 2600 and 4600 masl, and it has a humid temperate climate, with an average temperature of 12°C to 27°C (Uyumbicho, 2014).

Amaguaña

The parish of Amaguaña belongs to the Metropolitan district of Quito located to the north of the Mejía canton, and San Pedro River crosses the parish. It is between 1740 and 4120 masl, and it has a temperate climate with an average temperature of 17°C and 18°C (Amaguaña, 2013).

Sangolquí

The parish of Sangolquí is located at Valle de los Chillos; it is the capital of the Rumiñahui canton and is part of the Hoya de Guayllabamba. It is located 1 Km from the right bank of the river Pita, between 2415 and 2512 masl. It has a climate temperate, with an average temperature of 16°C and 23°C (Rumiñahui, 2014).

2.2 Obtaining of the sample

In this process, a specialized team to georeference the sampling points was used. This equipment is called GPS, and it allows to locate on a map the points of reference for each of the rivers, so it was possible to obtain the coordinates and location maps for the sampling points of o Pita and San Pedro rivers. A total of 13 samples were used; 9 samples in the San Pedro River and 4 samples in Pita river, taking 1 liter of each of the samples for further use and analysis, this was done using an equipment such as pH-meter (FiveGo^{TM} , Meter Toledo) and a kit (AuroFlow^{TM} BTS Combo Strip Test Kit"by BIOO Scientific brand).

2.3 Field analysis

The field work was carried out following the steps for the collection of the samples according to the NTE INEN 2117:2013 on water, water quality, sampling management and specimen conservation (INEM, 2013); as for the analysis of these samples by using the kit .^{A}uroFlowTM BTS Combo Strip Test Kit"brand BIOO Scientific (Scientific, 2018), which is a kit for analysis and identification of antibiotics. For each sampling point, pH, conductivity and temperature measurement were carried out using the portable pH meter ph-Meter FiveGo^{TM} which is used for the measurement of pH, conductivity (MS) and temperature (°C), this equipment complies with the safety regulations recognized (Toledo, 2017). The identification of antibiotics was done with the reading strips for the comparison of results with the guide of the kit AuroFlow^{TM}, the validation reports are available and show the effectiveness of the tests at environment and other conditions (Scientific, 2018). The quick and simplified protocol or process for using the kit can be seen below:

- Add 200uL of cold water to the reaction vessel and mix by pipetting up and down 10 times.
- Incubate the mixture for 3 minutes at room temperature.
- Add the dipstick or measuring strip to the reaction container.
- Incubate the mixture for 4 minutes at room temperature.
- Visually interpret the result using the diagram or the reader.

2.4 Laboratory analysis

The samples were stored and refrigerated for a week. As a first step, materials for the preparation of the culture medium are prepared with nutritious Agar in both the MacConkey and PCA (DIFCO brand BBL microbiology, presentation of 500 grams), which are universal means for the determination of microorganisms and quite useful for the identification of CFU (colony forming units), 500ml of each agar type was prepared following the preparation procedures.

2.4.1 Preparation of the Agar

The preparation of the culture medium consists in weighing the desired quantity and dissolving it in distilled water following the manufacturer's instructions according to the label provided on the product container. This mixture, after being prepared, is sterilized in the autoclave; once the sterilization is finished, the means will be allowed to cool at room temperature, avoiding their solidification since these means must be poured into the Petri dishes for the sowing of the samples to show the corresponding results for each of them.

2.4.2 Preparation of samples for the sowing

Once the materials have been sterilized: Petri dishes, pipettes and test tubes are taken, and the molten and sterile medium is poured into them in an aseptic environment. It is advisable that a flame of a bunsen burner is in a radius of 20 to 30 cm depending on the intensity and the color of the flame (APHA, 1970) or PCA agar (Plate count agar). The samples are removed from the refrigeration and kept in environmental conditions, and once these samples were conditioned, 1 ml of each of the bottles for the respective sowing was taken. Once the aliquot was placed, the agar is poured into each of the Petri dishes, considering that for the dilutions process 10^{-1} and 10^{-2} were performed to help reduce the concentration of microorganisms (APHA, 1970) or PCA Agar.

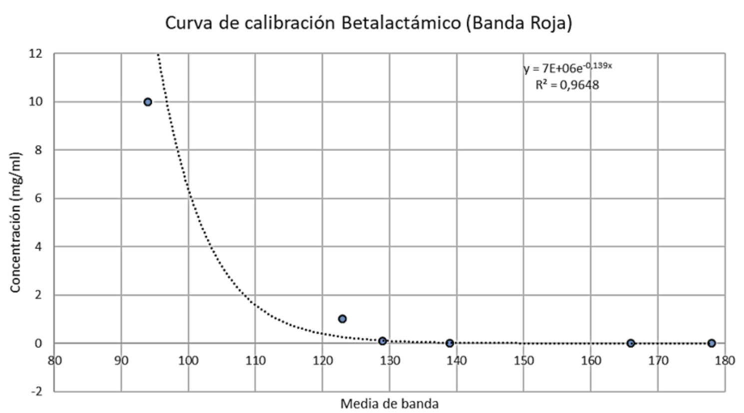

Figure 2. Calibration curve for beta-lactams with the data analyzed from the control images.

After placing a certain amount of the sample, the MacConkey and PCA agar were selected for each dilution and poured into each Petri dish, occupying a crop sowing technique called "poor box", in which one milliliter of each of the dilutions is placed. In each of the labeled Petri dishes, this milliliter is spread throughout the box and after this, in a sterile environment, the agar is poured with a maximum temperature of 40°C. The process was carried out using 26 petri dishes, 13 boxes for samples in MacConkey agar and 13 boxes for PCA. In order to check the functionality of the process, 28 petri dishes were used, counting on a target to differentiate the other samples.

Once the sowing process has been prepared and completed, the Petri dishes are put into an incubator which is maintained at a defined temperature of 37°*C*, preserved in a period of approximately 48 hours for optimal growth in both agar types: standard (APHA, 1970) or PCA Agar.

2.5 Preparation of the calibration Curves

For the calibration curves, an analysis was conducted considering the control that refers to water without the presence of antibiotics.

Table 1. Location of sampling points.

	COORDINATES		
POINTS	**RIVER**	**X**	**Y**
1	SAN PEDRO	776320.179	9957033.03
2	SAN PEDRO	776459.837	9957513.84
3	SAN PEDRO	777471.527	9958809.98
4	SAN PEDRO	777999.499	9958872.2
5	SAN PEDRO	781362.462	9960688.91
6	SAN PEDRO	782648.687	9962947.4
7	SAN PEDRO	782899.269	9964211.35
8	SAN PEDRO	783390.9	9965736.51
9	SAN PEDRO	782436.11	9966660.18
1	PITA	782436.11	9966660.18
2	PITA	783049.537	9966952.45
3	PITA	784595.582	9965756.81
4	PITA	787187.462	9963561.93

2.5.1 Elaboration of the calibration curves

The calibration curve is measured according to the concentration of an analyte. The calibration includes the selection of a model to evaluate parameters that allow to check the linearity of that curve and, as a result, the capacity of an analytical method to obtain results that are proportional to the concentration of a compound in that sample. The procedure compares a property of the analyte with that of known concentration standards of the same analyte (or another with similar properties) (Dosal and Villanueva, 2008). The analytical calibration phase is carried out using a straight line model based on finding the calibrated line that best fits a number of n experimental points, where each point is defined by a variable x (independent variable, usually concentration of the analyte of interest) and a variable y (dependent variable, usually instrumental response). The calibration line is defined by an ordinate to the origin (b) and a slope (m), by the equation $y = mx + b$ or any of its linear forms (Dosal and Villanueva, 2008).

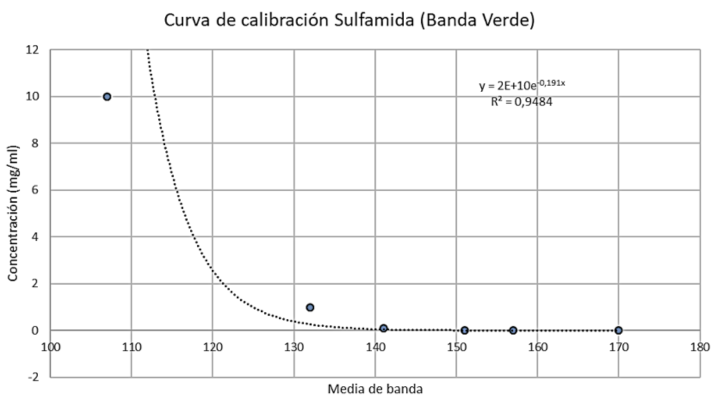

Figure 3. Calibration curve for sulfonamides with the data analyzed from the control images.

2.5.2 Preparation of the calibration curves

The control will allow to compare with the other results, and pure samples were needed for both -lactamic and sulfonamides. One gram of each was taken, and in this process 6 samples of each antibiotic were formed, a control (concentration 0) and a standard solution of 1g of antibiotic for every 100 mL, and five 5 dilutions were prepared with the help of the AuroFlow^{TM} kit: $10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}$ and 10^{-5} to evaluate and recognize the different concentrations. A raster image analysis technique was used with the R Studio software (RStudio, 2016), in which the bands can be related to the quantity of existing antibiotic, the bands are: red, green and blue (RGB). It should be considered for this evaluation to take accurate images of the measuring strips of the kit, at the same distance (height), to a light exposure equal for all the strips and avoiding the shadows in them, since any type of error in this process will significantly alter the value of the bands, as they pass through the computer analysis (Alvarez Mendoza et al., 2018).

Once the images corresponding to the control are analyzed, all the 78 strips obtained from the sampling which correspond to the calibration curve are performed (set of concentrations describing the interval in which the composed must be in order to be analyzed), and in order to ensure that the line found with the experimental points is correctly adjusted to the mathematical model of the equation, the values of the ordinate to the origin are calculated with the slope and determination coefficient (R^2) and model residue analysis (Dosal and Villanueva, 2008).

3 Results

3.1 Field and sampling

The results obtained are presented in Table 1 for the geographical location. The information from the spatial distribution of the sampling points indicate the variables such as PH, temperature and conductivity, and the presence of antibiotics in the different samples. In Table 2 can be seen that the presence of lactams-based antibiotics is higher than the presence of sulfonamides-based antibiotics in a ratio of at least 2:1; the PH values are maintained in a range of 7.14 to 8.51, the temperature is maintained between 14,15°C to 26,45°C and the conductivity in a range of 13,67mS to 82,00mS.

3.2 Microbiological tests

After obtaining the samples and once observed the presence or not of antibiotics in the samples in the culture media: Agar MacConkey and PCA agar, the following results were obtained taking into account dilutions made for all the samples, because the concentration of microorganisms should be reduced in order to be able to identify the colonies, also counting that only the positive samples are presented, with values of the CFU (colony forming units) once the respective conversion factor was used. Additionally, the data of the first sampling was eliminated because its concentration yielded countless results, as shown in Table 3.

3.3 Calibration curves

In the process, the control was also considered thanks to the antibiotic-indicating strips, which allowed to determine by programming and detection of bands corresponding to red, green and blue colors, the calibration curves that would help to estimate the concentration of each antibiotic found, in this case of lactams and sulfonamides, resulting in Table 4 for Beta-lactams and Table 5 for sulfonamide.

Determining that for the calculation of antibiotics with beta-lactams the red band will be occupied (Table 4), since this presents a correlation that satisfies the process, whereas, for the samples of sulfonamide antibiotics, the green band will be occupied (Table 5). With this data, the corresponding calibration curves were programmed and designed, which will then be used for the calculation of antibiotic concentrations of each sample. Getting the equation $y = 7 \cdot 10^6 e^{-0,139x}$ de ajuste $R^2 = 0,9648$ (Figure 2) para beta lactams and the equation $y = 2 \cdot 10^1 e^{-0,191x}$ with $R^2 = 0,9484$ (Figure 3) to sulfanamides. Considering that R^2 greater than 0,9 or the closest to 1, are values accepted as valid (Martínez Rodríguez, 2005).

Considering the analysis of residues where normal distribution was observed and complying with the homoscedasticity condition (White test), it was continued with the calculation of the antibiotic concentrations thanks to the equations elaborated from Figure 2 and Figure 3, with their corresponding values of R2 closer to veracity (Olea, 2016), for each sample in the same way that it was done with the control, eliminating the negative results. Thus, Table 6 shows the result of the calculation.

These results will be helpful for further analysis on illustrative maps of the situation of antibiotics and the

Table 2. Data of the sampling dates; the points that had the presence of antibiotics were presented, giving a positive value (1) and a negative value (0) to their presence.

Date	Points	River	pH	Conductivity	Temperature	Beta-lactams	Sulfonamide
7/11/2017	2	SAN PEDRO	8.43	76.67	18.7	1	1
	3	SAN PEDRO	8.5	80	18.45	0	1
	4	SAN PEDRO	8.47	78.67	20.05	0	1
	6	SAN PEDRO	8	53	24	1	1
	7	SAN PEDRO	8.37	74.33	19.89	1	0
	8	SAN PEDRO	8.36	73	23.55	0	1
	9	SAN PEDRO	8.29	21	22.5	0	1
	3	PITA	8.51	24.67	23.5	1	1
22/11/2017	3	SAN PEDRO	8.3	76.33	17.55	1	0
	8	SAN PEDRO	8.13	67	16.75	1	0
	2	PITA	7.44	28.67	19.8	1	0
	3	PITA	8.1	65.33	17.25	1	0
	4	PITA	8.25	73.33	16.85	1	0
4/12/2017	1	SAN PEDRO	7.91	64.67	15.95	1	0
	2	SAN PEDRO	7.85	61.67	17.6	1	0
	6	SAN PEDRO	7.56	45.67	21.1	0	1
	2	PITA	7.14	21.33	23.95	1	1
	4	PITA	7.83	60.67	18.7	1	1
18/12/2017	1	SAN PEDRO	7.84	60.67	16.8	1	0
	5	SAN PEDRO	7.96	67.67	17.95	1	0
	6	SAN PEDRO	7.71	54.33	21.3	1	0
	7	SAN PEDRO	7.73	54.67	19.9	1	0
	8	SAN PEDRO	7.71	54.33	20.35	1	0
	2	PITA	7.18	24	24.5	1	0
	4	PITA	7.61	48	20.95	1	0
2/1/2018	4	SAN PEDRO	7.72	54.33	16.35	1	0
	6	SAN PEDRO	7.42	37	21.1	1	0
	9	SAN PEDRO	7.48	40.67	17.8	1	0
	1	PITA	7.47	40	16.95	1	0
	2	PITA	7.32	31.67	17.15	1	0
	3	PITA	7.36	33.33	16.5	1	0
	4	PITA	7.36	33.33	17	1	0
17/1/2018	2	SAN PEDRO	7.99	69.67	16.45	1	0
	3	SAN PEDRO	7.99	69.33	19.3	1	0
	5	SAN PEDRO	7.94	67	17.2	1	0
	6	SAN PEDRO	7.56	45	19.1	1	1
	7	SAN PEDRO	7.92	65	15.5	1	0
	9	SAN PEDRO	7.87	62	15	1	1
	2	PITA	7.4	35.67	15.55	1	0
	3	PITA	7.69	52	14.4	1	1
	4	PITA	7.34	32	14.15	1	0

relationship of these concentrations with other variables considered in the study when taking into account that there are 13 samples in total along the rivers under study.

Table 3. Representation of the total values of CFU for each of the samples, in each of the sampling dates performed by counting in quadrants.

Date	Points	River	TOTAL (UFC/ml)
November 22th, 2017	3	SAN PEDRO	29400
	8	SAN PEDRO	44100
	2	PITA	60950
	3	PITA	38450
	4	PITA	24300
november 4th, 2017	2	SAN PEDRO	1700
	3	SAN PEDRO	400
	4	SAN PEDRO	500
	5	SAN PEDRO	250
	6	SAN PEDRO	500
	7	SAN PEDRO	350
	8	SAN PEDRO	100
	9	SAN PEDRO	300
	2	PITA	3250
	3	PITA	200
	4	PITA	300
December 18th, 2017	1	SAN PEDRO	14350
	2	SAN PEDRO	16500
	3	SAN PEDRO	7000
	4	SAN PEDRO	16950
	5	SAN PEDRO	12450
	6	SAN PEDRO	26750
	7	SAN PEDRO	17600
	8	SAN PEDRO	22000
	9	SAN PEDRO	37600
	1	PITA	14700
	2	PITA	14500
	3	PITA	16000
	4	PITA	12000
January 2nd, 2018	1	SAN PEDRO	14000
	2	SAN PEDRO	29300
	3	SAN PEDRO	25000
	4	SAN PEDRO	24500
	5	SAN PEDRO	25000
	6	SAN PEDRO	34900
	7	SAN PEDRO	72000
	8	SAN PEDRO	25700
	9	SAN PEDRO	24100
	1	PITA	27000
	2	PITA	33000
	3	PITA	12000
	4	PITA	2400
January 17th, 2018	1	SAN PEDRO	1000
	2	SAN PEDRO	3000
	3	SAN PEDRO	5000
	4	SAN PEDRO	8700
	5	SAN PEDRO	5900
	6	SAN PEDRO	18300
	7	SAN PEDRO	13950
	8	SAN PEDRO	18500
	9	SAN PEDRO	9500
	1	PITA	14650
	2	PITA	28500
	3	PITA	4450
	4	PITA	4000

3.4 Result of the study maps

With the data calculated above, Q maps can be developed to understand the location of the points and their specific characteristics as well as their assessment. The data even show the antibiotics around the area of study (Figure 4).

These charts help to determine: the pH variation in the area ranges from the value of 7.14 to 8.51 considering that the water of the rivers is maintained at a neutral to basic level; the conductivity was estimated in a range of 13,67 mS to 82,00 mS, having higher values in sectors adjacent to the river Pita. There is a variation between 14,15°C and 26,45°C with respect to the temperature. Regarding the antibiotics found, the lactams have higher concentration in points 7 in San Pedro river and 4 in Pita river, with concentration values between $1{,}37 \times 10^{-3}$ mg/ml and $1{,}57 \times 10^{-3}$ mg/ml. Whereas in relation to the sulfonamides, it was considered that the highest concentration point was the point 3 of the Pita river, with values between $2{,}05 \times 10^{-3}$ mg/ml and $2{,}35 \times 10^{-3}$ mg/ml.

4 Discusion

Table 4. Bands: Red, green and blue for beta-lactams with their corresponding concentrations in mg/mL.

Red		Green		Blue	
Average	Concentration	Average	Concentration	Average	Concentration
94	10	160	10	191	10
123	1	147	1	181	1
129	0.1	182	0.1	202	0.1
139	0.01	123	0.01	164	0.01
166	0.001	151	0.001	181	0.001
178	0.0001	164	0.0001	158	0.0001

Table 5. Bands: Red, green and blue for sulfonamides with their corresponding concentrations in mg/mL.

Red		Green		Blue	
Average	**Concentration**	**Average**	**Concentration**	**Average**	**Concentration**
124	10	107	10	169	10
136	1	132	1	174	1
117	0.1	141	0.1	160	0.1
148	0.01	151	0.01	172	0.01
170	0.001	157	0.001	165	0.001
103	0.0001	170	0.0001	118	0.0001

After having analyzed the results of each of the rivers, it was observed that in relation to the environmental conditions such as pH and temperature, both rivers presented similar conditions. However, there is a difference of 26,03 mS with conductivity, indicating higher conductivity the Pita River. The results showed that there are antibiotics in the water of San Pedro and Pita rivers, the results obtained are similar to the values of 36,5 and 50%, reported by other researchers in the detection of betalactams in raw and pasteurized milk which is related to the proximity of industries to the sampling zone.

The presence of industries near the rivers, which have as effluent the riverbed, contribute to the pollution of rivers, in addition to areas where there is agricultural activity and other agro-industrial activities, without despising the existence of domestic effluents and an important amount of drugs that are consumed in big quantities, and after their ingestion are excreted by the individual through urine and feces, continuously entering the waters residuals.

Studies on drug use in EU countries indicate their use in tons per year, and many of the most widely used, including antibiotics, are used in pesticide-like quantities (Barceló, 2003). Among the most used or medicine-occupied drugs are antibiotics such as amoxicillin and sulfamethoxazole, and among the most reported antibiotics in the bodies of water are tetracyclines (Dang et al.,2007), omitting the fact that there was no presence of tetracyclines in the samples of the study performed.

From the variance analysis and the calibration curves, it is verified that the results obtained indicate that the recovery percentage is 96%. The correlation coefficient (R^2) of the calibration curve is 0,9946 and the variation coefficient is 1,86% (Aguilera et al., 2010). In this particular case, there was a correlation coefficient value (R^2) of the calibration curve between 0,9484 and 0,9648 close values for the applied method, in which it is considered that values greater than 0,95 are acceptable for the analysis.

For most tests with sensitive microorganisms, betalactam behaves as bactericide because the minimum bactericidal concentration (CBM), or the minimum concentration of antimicrobial eliminated 99,9% of viable microorganisms (Taroco et al., 2006). This has also been discussed with respect to the maximum concentrations of the antibiotics present in wastewater in studies conducted in the United States. In the case of beta-lactams, the value of amoxicillin was verified, which was 150 $\mu g/l$, and sulfonamides as sulfamethoxazole shows a maximum concentration of 2,8 $\mu g/l$ (Kim et al., 2007; Kim and Aga, 2007; Morse and Jackson, 2003). Whereas the water analysis of the River Seine in France was taken into account for the comparison, since the authors analyzed the antibiotics under study and their relation with the human activities as agriculture and industrial, and it presented antibiotics in concentrations that reached 544 ng/l.

In pH conditions of 7 and temperature of 4°C (Tamtam et al., 2008). Values that for the comparison with the current study would be: $1{,}5 \times 10^{-8}$ mg/L of beta-lactams and $2{,}8 \times 10^{-6}$ mg/L of sulfonamides, and the values of the sampling results are: $1{,}24 \times 10^{-2}$ mg/L of beta-lactams and $8{,}74 \times 10^{-3}$ mg/L of sulfonamides, whose difference is due to the amount of the sample taken since the US study took a sample of 0,1mL (Morse and Jackson, 2003; Kim and Aga, 2007), while only 1 ml of sample was used in this research. There is no standardized test to assess the susceptibility or bacteria resistance in the environment.

Table 6. Concentrations of positive specimens with beta-lactam and sulfonamide antibiotics, where, red band R, green band G, Blue band B, Beta-lactamic "Beta" and sulfonamides "Sulfa".

Date	Points	River	R	G	B	Presence	Concentration (mg/mL)	
							Beta	Sulfa
Nov 11th, 2017	2	SAN PEDRO	174	175	184	Beta, Sulfa	2.19E-04	6.09E-05
	3	SAN PEDRO	173	174	185	Sulfa	-	7.37E-05
	4	SAN PEDRO	175	176	185	Sulfa	-	5.03E-05
	6	SAN PEDRO	170	172	182	Beta, Sulfa	3.83E-04	-
	7	SAN PEDRO	172	174	183	Beta	2.90E-04	-
	8	SAN PEDRO	165	170	170	Sulfa	-	1.58E-04
	9	SAN PEDRO	157	164	176	Sulfa	-	1.66E-04
	12	PITA	145	149	156	Beta, Sulfa	1.24E-02	8.74E-03
Nov 20th, 2017	3	SAN PEDRO	176	176	186	Beta	1.66E-04	-
	8	SAN PEDRO	159	162	176	Beta	1.77E-03	-
	11	PITA	160	162	170	Beta	1.54E-03	-
	12	PITA	158	158	169	Beta	2.03E-03	-
	13	PITA	159	160	170	Beta	1.77E-03	-
Dec 4th, 2017	1	SAN PEDRO	170	171	183	Beta	3.83E-04	-
	2	SAN PEDRO	172	170	182	Beta	2.90E-04	-
	6	SAN PEDRO	172	168	180	Sulfa	-	2.32E-04
	11	PITA	173	171	184	Beta, Sulfa	2.52E-04	1.31E-04
	13	PITA	172	171	183	Beta, Sulfa	2.90E-04	1.31E-04
Dec 18th, 2017	1	SAN PEDRO	154	159	173	Beta	3.54E-03	-
	5	SAN PEDRO	166	167	181	Beta	6.67E-04	-
	6	SAN PEDRO	167	168	181	Beta	5.81E-04	-
	7	SAN PEDRO	162	162	179	Beta	1.16E-03	-
	8	SAN PEDRO	170	170	182	Beta	3.83E-04	-
	11	PITA	169	170	185	Beta	4.40E-04	-
	13	PITA	168	170	184	Beta	5.05E-04	-
Jan 1st, 2018	6	SAN PEDRO	176	177	191	Beta	1.66E-04	-
	9	SAN PEDRO	170	176	188	Beta	3.83E-04	-
	10	PITA	163	168	180	Beta	1.01E-03	-
	11	PITA	161	167	179	Beta	1.34E-03	-
	12	PITA	154	162	176	Beta	3.54E-03	-
	13	PITA	147	156	171	Beta	9.36E-03	-
Jan 17th, 2018	2	SAN PEDRO	171	171	182	Beta	3.33E-04	-
	3	SAN PEDRO	172	172	183	Beta	2.90E-04	-
	5	SAN PEDRO	169	171	183	Beta	4.40E-04	-
	6	SAN PEDRO	167	170	182	Beta, Sulfa	5.81E-04	1.58E-04
	7	SAN PEDRO	160	165	178	Beta	1.54E-03	-
	9	SAN PEDRO	153	160	174	Beta, Sulfa	4.06E-03	1.07E-03
	11	PITA	170	175	186	Beta	3.83E-04	-
	12	PITA	175	177	188	Beta, Sulfa	1.91E-04	4.16E-05
	13	PITA	175	177	188	Beta	1.91E-04	-

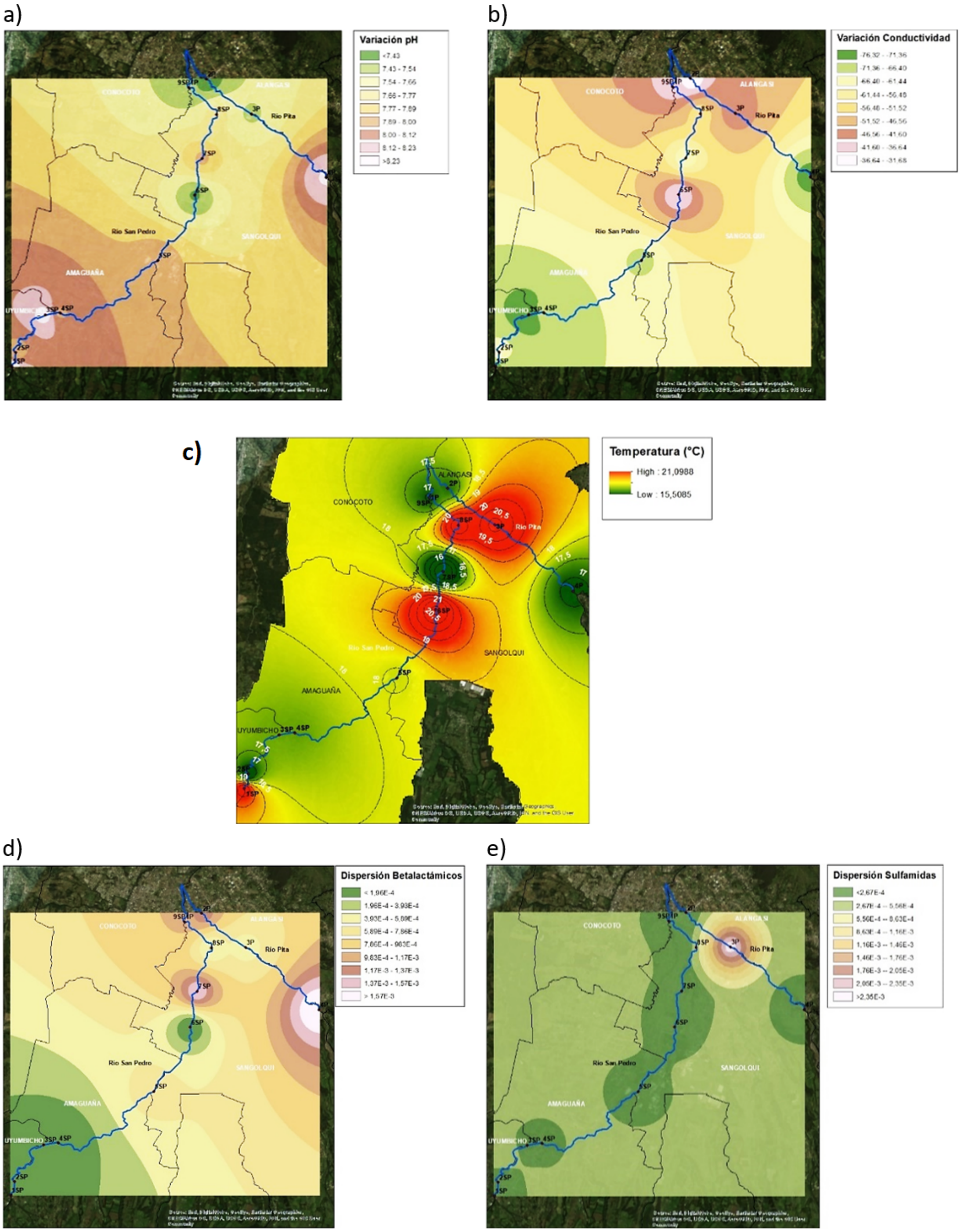

Figure 4. Illustrative maps in the conditions under study, where: a) pH condition in the area, b) conductivity condition in the area, c) temperature condition (presented with isotherms) of the area, D) Beta-lactam dispersion in the area and e) Sulfonamide dispersion in the area ARCGIS (2016).

5 Conclusions

The study carried out in the parishes Uyumbicho-Amaguaña-Sangolquí indicates that there is a contamination problem by organic matter and other wastes, especially in areas where there are populated centers such as Amaguaña, where San Pedro river crosses the parish, as in the parish of Sangolquí that is crossed by Pita river. These results were obtained when analyzing the sowings of microorganisms that were carried out in the laboratory, obtaining the presence of bacteria mostly found in organic matter, due to their growth in the culture media that determine this affirmation.

The positive cases in the samples with antibiotics were presented in greater number to the derivatives of betalactams, followed by Sulfonamides, and for the Tetracyclines no results were presented, understimating the calculations according to the results obtained from the kit. In the three months of sampling, river water samples were collected and analyzed, observing a significant presence of positive cases; it was in January the month that showed a number of 16 positive cases out of the 41 positive cases for the three months of sampling, representing 39 % of the positive samples.

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References

Aguilera, C., Herrera, C., and Ponce, J. (2010). Implementación, validación y aplicación de un nuevo método para la determinación de oxitetraciclina por hplc en tejido muscular de salmonídeos. *Latin american journal of aquatic research*, 38(2):227–233. Online:https://bit.ly/2VkreSZ.

Alvarez Mendoza, C. I., Teodoro, A., and Ramirez, C. L. (2019). Improving ndvi by removing cirrus clouds with optical remote sensing data from landsat-8–a case study in quito, ecuador. *Remote Sensing Applications: Society and Environment*, 13:257–274. Onl.

Alvarez Mendoza, C. I., Teodoro, A., Torres, N., Vivanco, V., and Ramirez Cando, L. (2018). Comparison of satellite remote sensing data in the retrieve of pm10 air pollutant over quito, ecuador. In *Remote Sensing Technologies and Applications in Urban Environments III*, volume 10793, page 107930I. Online:https://bit.ly/2IDCIzB. International Society for Optics and Photonics.

Amaguaña, G. (2013). ActualizaciÓn del plan de desarrollo y ordenamiento territorial gad parroquial de amaguaÑa – d.m.q. Technical report, G.A.D. Parroquial de Amaguaña.

APHA (1970). *Standard Methods for the Examination of Dairy Products. 15th ed.*, apha. (1985), iso 4833:2003. edition.

ARCGIS, editor (2016). *Arcgis, ESRI.* ARCGIS-ARCMAP 10.3.

Barceló, D. (2003). Emerging pollutants in water analysis. *Trends in Analytical Chemistry*, 10(22):xiv–xvi. Online:https://bit.ly/2XtDfY7.

CIJUL (2013). El derecho a un ambiente sano y ecológicamente equilibrado como derecho humano de tercera generación. Technical report, Centro de Informacion Juridica en Línea.

Dosal, M. A. and Villanueva, M. (2008). Introducción a la metrología química: Curvas de calibración en los métodos analíticos. *Antología De Química Analítica Experimental*.

Elena, A., Ramírez, N., and García G., A. (2009). Las matemáticas limpian el agua. *Política y cultura*, (31):259–288. Online:https://bit.ly/2KQrdCW.

Ferrer, I. and Thurman, E, M. (2012). Analysis of 100 pharmaceuticals and their degradates in water samples by liquid chromatography/quadrupole time-of-flight mass spectrometry. *Journal of Chromatography A*, 1259:148–157. Online:https://bit.ly/2TctxdF.

Gimeno, E. J. (2001). La resistencia bacteriana transmitida al hombre a través de los alimentos y el uso responsable de los antimicrobianos como moduladores de crecimiento.

Guevara Granja, M. F. and Ramirez Cando, L. J. (2015). Eichhornia crassipes, its invasiveness and phytoremediation potential. *GRANJA-REVISTA DE CIENCIAS DE LA VIDA*, 22(2):5–11. Online:https://bit.ly/2NALSMc.

Henríquez Villa, D. (2012). Presencia de contaminantes emergentes en aguas y su impacto en el ecosistema. estudio de caso: productos farmacéuticos enla cuenca del río biobío, región del biobío, chile. page 138. Online:https://bit.ly/2Epn6vu.

INEM, N. (2013). Norma técnica ecuatoriana nte inen 266: 2013 primera revisión. *First Edit*, pages 7–12.

Kim, S. and Aga, D. S. (2007). Potential ecological and human health impacts of antibiotics and antibiotic-resistant bacteria from wastewater treatment plants. *Journal of Toxicology and Environmental Health, Part B*, 10(8):559–573. Online:https://bit.ly/2tEjQ99.

Kim, S., Jensen, J. N., Aga, D. S., and Weber, A. S. (2007). Tetracycline as a selector for resistant bacteria in activated sludge. *Chemosphere*, 66(9):1643–1651. Online: https://bit.ly/2SvQ2pb.

Martínez Rodríguez, E. (2005). Errores frecuentes en la interpretación del coeficiente de determinación lineal. *Anuario jurídico y económico escurialense*, (38):315–331. Online:https://bit.ly/2IFLiOq.

Mátyás, B., Andrade Chiluisa, M. E., Chida Yandun, N. C., Velasco Taipe, C. M., Morales Gavilanes, D. E., Montero Miño, G. N., Cando Ramirez, L. J., and Lizano Acevedo, R. X. (2018). Comparing organic versus conventional soil management on soil respiration. *F1000Research*, 7:Online:https://bit.ly/2IGwLBR.

Morse, A. and Jackson, A. (2003). Fate of a representative pharmaceutical in the environment. Technical report, Texas Water Resources Institute, Online:https://bit.ly/2Nu7hq4.

Olea, F. (2016). Técnicas estadísticas aplicadas en nutricion y salud. *Departamento de Nutrición y Bromatología. UGR*, pages 15–31.

Ramírez Cando, L., Spugnoli, P., Matteo, R., Bagatta, M., Tavarini, S., Foschi, L., and Lazzeri, L. (2017). Environmental assessment of flax straw production for nonwood pulp mills. *Chemical Engineering Transactions*, 58:787–792. Online:https://bit.ly/2HbBvxh.

Ramírez Cando, L. J., Guerra Guevara, S. P., and Reinoso Molina, G. A. (2017). In vitro evaluation of lead removal in wastewater by photobacterium damselae. *LA GRANJA. Revista de Ciencias de la Vida*, 26(2):155–162. Online:https://bit.ly/2T7EUo1.

Reig, M. and Toldrá, F. (2008). Veterinary drug residues in meat: Concerns and rapid methods for detection. *Meat science*, 78(1-2):60–67. Online:https://bit.ly/2IGBmE7.

RStudio, editor (2016). *RStudio Version 1.0.143.*

Rumiñahui, G. (2014). Plan de desarrollo y ordenamiento territorial de rumiñahui. Technical report, Gobierno Autónomo Descentralizado del Cantón Rumiñahui.

Scientific, B. (2018). Pruebas de tira de auroflow^{TM}. Technical report, PerkinElmer Company, Copyright 2018 Bioo Scientific Corporation, Austin TX.

Talero Pérez, V., Medina, O. J., and Rozo-Núñez, W. (2014). Técnicas analíticas contemporáneas para la identificación de residuos de sulfonamidas, quinolonas y cloranfenicol. *Universitas Scientiarum*, 19(1):11–28. Online:https://bit.ly/2IIuFl4.

Tamtam, F., Mercier, F., Le Bot, B., Eurin, J., Dinh, Q. T., Clément, M., and Chevreuil, M. (2008). Occurrence and fate of antibiotics in the seine river in various hydrological conditions. *Science of the Total Environment*, 393(1):84–95. Online:https://bit.ly/2IBEi4P.

Taroco, R., Seija, V., and Vignoli, R. (2006). Métodos de estudio de la sensibilidad antibiótica. *Temas de Bacteriología y Virología Médica, Oficina del libro FEFMUR, Uruguay*, 36(1):665–668. Online:https://bit.ly/2VtA7df.

Toledo, M. (2017). *SevenGo Duo TM PH / Conductivity Meter SG23.*

Uyumbicho, G. (2014). Actualización del plan del desarrollo y ordenamiento territorial de la parroquia rural de uyumbicho 2015 - 2019. Technical report, Gobierno Autónomo Descentralizado Parroquial rural de Uyumbicho 2014 - 2019.

Volfredo Camacho, J. (2010). Los antimicrobianos en la pr´ctica m´dica. Technical report, Online:https://bit.ly/2vNpl9I.

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SUSTAINABLE DEVELOPMENT

Small-farmers Dynamics in the Sierra of Ecuador

Dinámica de los pequeños productores de leche en la Sierra centro de Ecuador

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Resumen

La estructura agraria en el Ecuador tiene una marcada diferenciación debido a la tenencia y acceso a la tierra. El crecimiento de la producción pecuaria dentro de las pequeñas y medianas explotaciones ha sido constante en los últimos años, así como la feminización del campo. En la serranía del Ecuador, estos procesos pueden observarse con mayor detalle, especialmente en aquellas provincias que se encuentran en el centro del país. Esto ha motivado a analizar la dinámica de los pequeños productores de las provincias de Chimborazo, Cotopaxi y Tungurahua, por medio de la aplicación de una encuesta a 793 agricultores, donde se revisan las características socio-productivas relacionadas con la producción de leche de ganado bovino. Los resultados demuestran que, comparativamente, la producción de leche se concentra en extensiones entre 0,5 y 1 hectárea, siendo la provincia de Tungurahua en donde existe una mayor distribución del tamaño de las explotaciones; sin embargo, la provincia de Chimborazo mantiene un rango de ingresos familiares superiores a las otras dos provincias. Se concluye que los incentivos sobre factores que mejoren la modernización de las explotaciones pueden incidir directamente en los ingresos familiares que no superan el 40% la remuneración básica mensual del Ecuador.
Palabras clave: Producción lechera, economía familiar, Tungurahua, caracterización agricultura familiar.

Abstract

The agrarian structure in Ecuador has an unequal access to land. The growth of livestock production within small and medium farms has been constant in recent years, as well as the feminization of the agriculture. In the Sierra of Ecuador, these processes can be observed with more detail, especially in provinces located in the Sierra center. This has motivated to analyze the dynamics of the small producers of the provinces of Chimborazo, Cotopaxi and

Tungurahua. This work shows the results of a survey that allows to analyze, from a sample of 793 farmers, the socio-productive characteristics of the bovine milk farms. Results show that, comparatively, milk production is concentrated in extensions between 0.5 and 1 hectares, being the province of Tungurahua the one with more size distribution of the farms; however, the province of Chimborazo maintains a higher range of family income than the other two provinces. Finally, it is concluded that incentives on factors that improve the modernization of farms can affect family income that does not exceed 40% of the basic monthly remuneration.
Keywords: Milk production, family income, Tungurahua, household-farming characterization

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1 Introducción

Agriculture is an important area in the economies of countries. In many cases, livestock production is more important than agriculture, providing milk and meat with high-demand in the population. According to Steinfeld and Chilonda (2006), since the 1990s the consumption of beef and cow milk has increased as the incomes of the middle class in developing countries have increased. Producing countries such as China, India and Brazil account for 65 % of meat production and 52 % of milk production worldwide. It is estimated that by 2024, developing countries will expand their supply by about 80 % of the world market (OECD-FAO, 2015). As for Latin America, Brazil and Argentina are at the forefront of livestock supply, while Colombia owns 58 % (5.8 million cows) of livestock production (Ormel, 2013). On the other hand, Ecuador in 2016 registered about 4.1 million head of cattle above countries such as Peru or Bolivia (Corporación Financiera Nacional, 2017).

Milk production in Ecuador is concentrated in the province of Pichincha with more than 845 000 liters/year (2016); the province of Azuay is in the second place with 561 000 liters/year, and Cotopaxi in the third with approximately 484 000 liters/year. Ecuador's Sierra Andean encompasses the largest amount of milk production domestically, equivalent to 64 % of production, while the Costa region occupies 30 %, and the Eastern region maintains 6 % (INEC, 2016). According to the National Institute of Statistics and Census (INEC, 2016), 73 % of milk produced (3.86 million liters) is marketed. During this period, dairy sales totaled USD 23 million, without considering export revenues.

Dairy production maintains a defined structure in each region in Ecuador. For example, in the Sierra, production units have a size of three hectares on average (Requelme and Bonifaz, 2012). However, three production levels are identified between 1-5 ha, 7-20, and between 20-120 hectares. In addition, Requelme and Bonifaz (2012) mention that the average milk production in the first level (1-5 ha) is 4.7 liters/cow/day. For this reason, the aim of this research is to analyze the dynamics of the small milk producers of three provinces that make up the Central Sierra of Ecuador: Cotopaxi, Tungurahua and Chimborazo, through a study comprising 793 surveys carried out to small producers in order to know the socio-productive dynamics, starting from the need to deepen on the studies that analyze small milk farms, income and distribution of the herd in the center Sierra.

1.1 Literature review

Agriculture is one of the sectors that generates employment, especially in developing countries. In many cases, this happens due to the lack of technology of the production units, which requires more labor, both wage-earners and family (Sumpsi, 2010). Therefore, agriculture is a source of income, if not the only one, of peasant families. In Latin America, two production systems are identified: agro-export extensive agriculture, and intensive agriculture or family farming. This division is marked by unequal access to production factors such as: land, irrigation, credit or information, limiting the capacity of farmers, as well as their economic development (Franco-Crespo and Sumpsi Viñas, 2017).

Family farming is credited with 65 % of food that reaches local markets. However, reluctance to risk has enabled the adaptation of production systems to earn short-term household income through diversification of family production. On the one hand, the production of vegetables has become a source of income in a short production cycle. Family farms of milk production by women have also been established, generating weekly income (Glikman, 1991).

FAO (2013) concludes that economic processes at the territorial level have led to a high concentration of the feminization of agriculture. In this sense, the role of women in agricultural activities is increasingly leading given the need for men to carry out wage activities in the city. In particular, small producers have found in milk production an alternative to earn cash on a weekly basis, as well as establishing a system of insurance and resilience to the risk that can address economic emergencies in the family nucleus through livestock holdings (Mena-Vásconez et al., 2016).

Family farming has an important role in the agricultural structure of Ecuador and other South American countries. The subdivision of the land, as well as the limitations generated by the market failures faced by this group of farmers, causes family farming to be in an environment of inequality in access to resources. As such, family farming is concentrated in extensions of between 1 and 5 hectares (ha), with a majority contribution to the use of family-type labor for agricultural tasks (Schejtman, 2008).

In the case of Ecuador, around 377 434 production units with 1 to 20 hectares are registered by 2013, i.e., 89 % of production units, categorized as smallholder farmers, hold about 55 % of the total agricultural area available (MAGAP, 2016). If the group of smallholder farmers who own between 1 and 5 hectares is detailed, it is observed that 69 % of producers are concentrated with only 5,7 % of land tenure (MAGAP, 2016) (Table 1).

In Table 1, a comparison of milk production can be seen between the provinces of Cotopaxi, Tungurahua and

Chimborazo. The comparison between 2015 and 2017 demonstrates instability in the production in the three provinces. In addition, in terms of the yield measured in the number of liters (l) and the Adult Bovine Unit (UBA), it is observed that the province of Tungurahua has a higher yield (8.71 l/UBA), Cotopaxi is in the second place (8.05 l/UBA) and Chimborazo has the lowest yield (6.65 l/UBA).

Limited access to land is the main feature of small agriculture, the same one that is concentrated in the central Sierra of Ecuador. Thus, labor use and the presence of market failures influence the behavior of farmers (Wiggins et al., 2010; Mumba et al., 2011; Louhichi and Paloma, 2014), especially their productive and economic dynamics of milk production in small producers (De Janvry and Sadoulet, 2006; Grisa and Schneider, 2008; Murphy et al., 2014).

Table 1. Description of the characteristics of dairy production in the Central Sierra area of Ecuador between 2015 and 2017.

Year	Description	Provinces					
		Cotopaxi		**Tungurahua**		**Chimborazo**	
		Quantity	**Variation(%)**	**Quantity**	**Variation(%)**	**Quantity**	**Variation(%)**
2016	Positioning of National Milk Production*	7.00%		6.00%		7.00%	
2015	Raw milk production (liters)	529 614		330 239		405 036	
2016		483 699	-9	355 679	8	458 181	13
2017		514 759	6	297 060	-16	431 325	-6
2015	Number of cattle	234 615		120 199		208 509	
1016		221 960	-5	126 754	5	228 500	10
2017		254 709	15	108 133	-15	222 316	-3
2015	Number of cows milked	65 673		39 505		59 990	
2016		61 179	-7	40 470	2	72 524	21
2017		63 932	4	34 103	-16	64 846	-11

* National Index
Source: (INEC, 2016; MAGAP, 2016)

On the other hand, studies related to the description of the characteristics of small milk producers focus on an analysis of socio-economic variables that considers the province as the structure in which the dynamics of exchange between rural producers and the cities take place (Escobar and Berdegué, 1990; Tobar, 2010). Thus Landín, in Escobar and Berdegué (1990), proposes the characterization of dairy producers in Ecuador from previous studies (Barsky, 1984; ILDES, 1988). There is a greater presence of medium (>10 ha) and large (>50) holdings in farms between 2300 and 2800 masl (Larrea et al., 2008); meanwhile, holdings with less than 5 ha area located in areas with irrigation problems, between 2900 and 3500 masl (Bretón, 2012).

In Ecuador, a group of renter producers who do not participate in improvement processes and technological innovation is identified; on the other hand, there are other groups of producers where the level of income is in direct proportion to the capacity of technological investment (Barragán, 2010). Then, in the provinces of Cotopaxi, Tungurahua and Chimborazo the role of agriculture, particularly of milk production, can be observed in the family agricultural production units (Chiriboga, 2003). Because of their structure, these provinces have characteristics of family farming participation, in addition to farms that have wage labor. This determines that agriculture becomes a source of family income (Louhichi and Paloma, 2014).

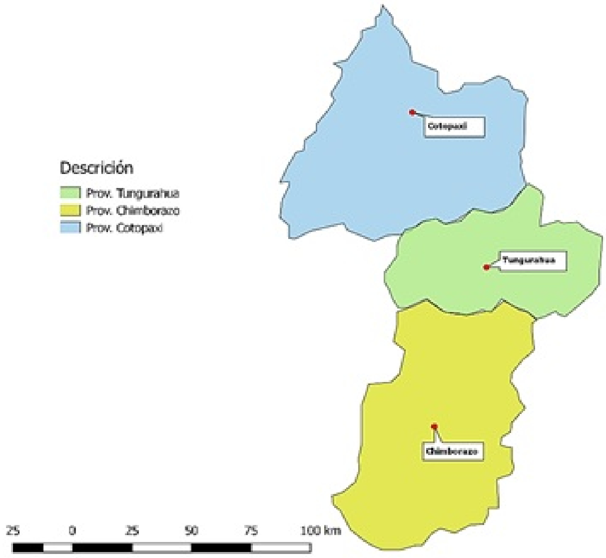

Figure 1. Identification of the provinces participating in the study between June and October 2018.

2 Materials and Methods

This study is based on three provinces of the central Sierra of Ecuador: Cotopaxi, Tungurahua and Chimborazo. The purpose of this research is to know the characteristics of small milk production farms between provinces. To meet this objective, a sample was established based on information from the Ministry of Agriculture and Livestock (MAG) for the databases of raw milk producers in the three provinces in 2017. The classification conditions according to Landín in Escobar and Berdegué (1990) were also analyzed.

The information instrument was applied according to the randomized sample. The components of the survey were fixed on the collection of information about the socio-economic situation of producers, as well as their relationship to production factors and market access. The formula used (Mantilla, 2015) for the calculation of the sample is indicated in Equation 1.Where $n =$ the sample, $Z =$ is the deviation from the mean value accepted to achieve the desired confidence level (95 %), $p =$ proportion of the population, and $e =$ is the accepted margin of error (3 %).

$$n = \frac{Z^2 p(1-p)}{e^2} \quad (1)$$

The survey was applied between June and October 2018. A total of 793 surveys were collected. In this regard, the simple random sampling formula was applied to a population of 28 270 producers of Cotopaxi (Salcedo, Latacunga), Tungurahua (Pelileo, Píllaro), Chimborazo (Riobamba, Chunchi and Guamote). Surveys conducted by province are 366 in Cotopaxi, 321 in Tungurahua and 106 in Chimborazo.

The survey form had as pilot in the year 2015 the application in San Andrés parish, canton Píllaro, Tungurahua province. The structure of the instrument referred to the Living Conditions Survey, developed by INEC in 2015. The information and evidence are in the archives of the Project "The milk and productivity production chain of Cotopaxi, Latacunga canton.ªnd 'Productive chain of the dairy sector in the province of Tungurahua, canton Pillaro'. Producer records were codified according to each province, and verification questions were asked in the production and revenue cases for more accuracy of the results obtained. For the validation of the questionnaire, a pilot was applied with a total sample of 10 producers per canton with a total of 140, once the pilot test adjustments were made to the instrument applied. In this way, 8 blocks of questions were raised.

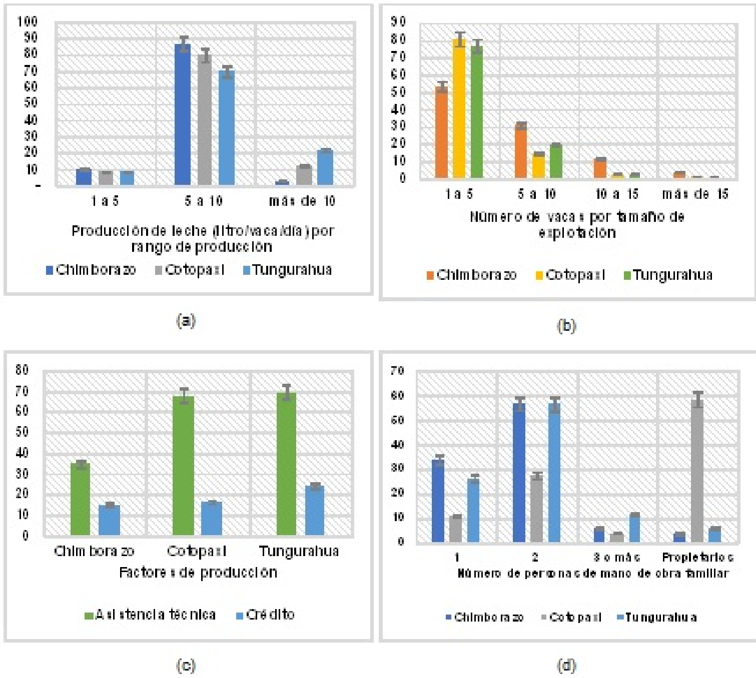

Figure 2. Summary of data from the sample of the provinces of Chimborazo, Cotopaxi and Tungurahua, (a) Milk production by production range, (b) Number of cows by operating size, (c) Production factors accessed by producers, and (d) Number of family workforce.

The survey was conducted in the parishes of the three provinces. The questionnaire collected the information based on a group of variables and indicators. For the correlation validation of the instrument, tabulated results were analyzed by the application of Cronbach's Alpha, and Cotopaxi (0,561), Chimborazo (0,686) and Tungurahua (0,657) were observed. Excel was used for the statistical processing, as well as for obtaining correlations by establishing comparative graphs, simple correlations, and a measurement analysis of variation and overall quadratic value, respectively. The variables correspond to the production factors, as well as parameters related to technology, such as pastures and livestock breed, relative to the improvement of productivity. The analyses presented select the relationships that show a level of significance less than 0.05 with a confidence level of 95 %, which allows an inference to the entire population. In Table 2 is the descriptive results of the milk producers in the three provinces.

Table 3 presents the descriptive statistic of the sample, considering the variables studied in this work. This table shows the statistical values that indicate the data distribution for the total data obtained by surveys in the three provinces.

3 Results and Discussion

The study identifies that 92,01 % of producers in Cotopaxi with up to 1 hectare own between 1 and 10 bovine units in production. In Tungurahua province, 86,36 % own between 1 and 5 bovine units. Also, in Chimborazo province, 82,64 % are in the same range of bovine units. In general, farms are identified by land size given in three categories: (1) 0.1 to 0.5 ha, (2) more than 0.5 to 1 ha, and (3) more than 10 hectares. Table 2 shows the production system, available resources (number of cows, cultivated area, irrigation and labor) and other production factors (credit and technical assistance), found among the producers. In addition, Table 4 provides a description of the socioeconomic factors of the population analyzed. It can be observed the composition by labor in the production unit, source of credit and technical assistance. In general, it is observed that the family workforce is more common compared to the hired labor, as well as the eventual workforce. As for technical assistance in Chimborazo, more than two-thirds report not receiving it, unlike Cotopaxi and Tungurahua. Also, the Cooperatives are the main source of funding in the three provinces.

Table 2. Descriptive statistics of the sample.

Statistics	Credit	Food Type (Balanced)	Food Type (Banana)	Family Workhand	Hired Labor	Eventually Hired Labor	Amount of Hectares Cropped With Grass	Quantity of Natural Hectares Of Grass	Irrigation	Area Irrigated	Access to Technical Assistance
Average	2563	1295	1842	1704	1176	1333	469	854	1081	2553	1359
Typical Error	78	20	16	29	128	142	29	30	10	30	17
Median	2000	1000	2000	2000	1000	1000	180	625	1000	3000	1000
Mode	2000	1000	2000	2000	1000	1000	90	350	1000	3000	1000
Standar deviation	903	456	365	694	529	492	527	666	273	834	480
Variance Sample	815	208	134	482	279	242	277	443	74	696	231
Kurtosis	-1032	-1188	1532	3593	9795	-1650	4874	3249	7533	-235	-1659
Assimetry Coefficient	921	904	-1878	1150	3136	812	2066	1957	3085	-1329	587
Rank	3000	1000	1000	5000	2000	1000	2960	3750	1000	2000	1000
Minimun	1000	1000	1000	1000	1000	1000	40	100	1000	1000	1000
Maximun	4000	2000	2000	6000	3000	2000	3000	3850	2000	3000	2000

Table 3. Characterization of farms by province, according to the information collected in 2018.

Factor	Description (ha)	Province					
		Chimborazo		Cotopaxi		Tungurahua	
		Frecuency	Percentage (%)	Frecuency	Percentage (%)	Frecuency	Percentage (%)
Number of Cows	1 to 5	57	53.77	296	80.87	247	76.95
	5 to 10	33	31.13	55	15.03	63	19.63
	More than 10	16	15.09	15	4.1	11	3.42
	Total	**106**	**100**	**366**	**100**	**321**	**100**
Production (Liter/Cow/Day)	1 to 5	11	10.38	31	8.47	27	8.41
	5 to 10	92	86.79	291	79.51	224	69.78
	More than 10	3	2.83	44	12.02	70	21.81
	Total	**106**	**100**	**366**	**100**	**321**	**100**
Quantity of Hectares cultivated with grasss	0.1 to 0.5	33	31.13	201	54.92	18	5.61
	0.5 to 1	-	-	46	12.57	40	12.46
	More than 1	-	-	16	4.37	8	2.49
	Does not have	73	68.87	103	28.14	255	79.44
	Total	**106**	**100**	**366**	**100**	**321**	**100**
Quantity of natural hectares of grass	0.1 to 0.5	49	46.23	28	7.65	45	14.02
	0.5 to 1	57	53.77	73	19.95	137	42.68
	More than 1	-	-	8	2.19	85	26.48
	Does not have	-	-	257	70.22	54	16.82
	Total	**106**	**100**	**366**	**100**	**321**	**100**
Has water to irrigate the land	Yes	106	100	347	94.81	276	85.98
	No		-	19	5.19	45	14.02
	Total	**106**	**100**	**366**	**100**	**321**	**100**
Irrigation source	Public	85	80.19	22	6.01	61	19.00
	Junta de Agua	21	19.81	344	93.99	218	67.91
	N/C	-	-	-	-	42	13.08
	Total	**106**	**100**	**366**	**100**	**321**	**100**

Table 4. Identification of socio-economic factors by province, according to the information collected in 2018.

Factor	Descripction	Chimborazo		Cotopaxi		Tungurahua	
		Frecuency	**Percentage(%)**	**Frecuency**	**Percentage(%)**	**Frecuency**	**Percentage(%)**
Quantity of family labor in the milk production	1	36	33.96	39	10.66	84	26.17
	2	60	56.60	100	27.32	181	56.39
	3 or more	6	5.66	14	3.83	37	11.53
	Owners	4	3.77	213	58.20	19	5.92
	Total	**106**	**100**	**366**	**100**	**321**	**100**
Quantity of hired labor in the milk production	1	4	3.77	2	0.55	9	2.80
	2	-	-	-	-	1	0.31
	3 or more	-	-	-	-	1	0.31
	Do not hire	102	96.23	364	99.45	310	96.57
	Total	**106**	**100**	**366**	**100**	**321**	**100**
Quantity of eventual hired labour in the milk production	1	-	-	3	0.82	5	1.56
	2	-	-	1	0.27	3	0.93
	3 or more	-	-	-	-	-	-
	Do not hire	106	100	362	98.91	313	97.51
	Total	**106**	**100**	**366**	**100**	**321**	**100**
Access to technical assistance	Yes	37	34.91	248.0	67.76	223	69.47
	No	69	65.09	118.0	32.24	98	30.53
	Total	**106**	**100**	**366**	**100**	**321**	**100**
Financing sources of the activities	Own	90	84.91	306	83.61	243	75.70
	Credit	16	15.09	60	16.39	78	24.30
	Total	**106**	**100**	**366**	**100**	**321**	**100**
Source of credit	Suppliers	-	-		-	1	1.28
	Coop. de Ahorro y Crédito	11	68.75	47	78.33	47	60.26
	Financing	-	-	-	-	3	3.85
	Banks	1	6.25	12	-2	25	32.05
	Family	4	25.00	-	-	-	-
	Do not require	-	-	1	1.67	2	2.56
	Total	**16**	**100**	**60**	**100**	**78**	**100**

In summary, the figure above highlights that milk production maintains absolute frequencies between 5 and 10 l/UBA/day, being Chimborazo province the one with the highest production (Figure 2a). In the case of the number of cows per production unit, the absolute frequency is observed in 1 and 5 UBAs, with the largest quantity for the province of Cotopaxi (Figure 2b). In addition, it is noted that technical assistance is most commonly developed in the provinces of Tungurahua and Cotopaxi (Figure 2c). Finally, as regards the family workforce employed by production unit, Cotopaxi concentrates the largest number of direct owners working on the farm, while in Chimborazo and Tungurahua the average is two family members working in the farm (Figure 2d).

On the other hand, with regard to uncultivated pastures, the percentage has the same relationship. Thus, in Cotopaxi province, 87,16 % of producers own between 1 and 10 bovine units in production. In Chimborazo province, 96,97 % of producers are in the same range; however, in Tungurahua province only 67,79 % of the interviewed are in this range. As regards the variation between bovine units and size of production units, Figure 3a shows the concentration of bovine units between production units not exceeding 1 ha, especially those between 0.5 and 1 ha. Compared to Figure 3b, there is a dispersion of bovine unit tenure between units of smaller size at 0.5 ha up to 1 ha. (Figure 3).

Meanwhile, Figure 3c shows that the distribution of the number of bovine species is distributed among the production units of 0.5 ha and 3 ha. However, the largest number is between 0.5 and 1 ha. The comparative analysis mentions that Cotopaxi maintains dairy farms with extensions of less than 0.5 ha. Moreover, in the Province of Chimborazo these milk production farms are located between 0.5 and 1 ha. By contrast, milk production farms in Tungurahua province have a wider range, although the concentration between 0.5 and 1 ha persists.

When analyzing this comparison between larger farms (more than 101 cases analyzed), in Tungurahua farms that have a larger size tend to be more efficient compared to those located in Cotopaxi province. If these results are analyzed with the description presented in Figure 2c and Figure 2d, technical assistance is higher in the provinces of Tungurahua and Cotopaxi. However, the greatest amount of family labor occurs in Chimborazo province.

Figure 4 shows the results of direct revenue from consolidated milk production for the three provinces. By comparison, the number of UBAs in the three ranges considered (1-5, 6-10 and 11-20) poses a productivity condition based on the amount of income earned from the sale of milk. Farms with between 1 and 5 cows earn income under USD 386.00 per month. On the other hand, herds between 6 and 10 cows obtain incomes between USD 386/month and USD 900/month. Lastly, there are farms with more than 11 bovine units that generate more than USD 900/month. As a particular case, Tungurahua presents in the range of 1-5 UBAs income of more than $900. On the other hand, Cotopaxi presents in the range 6-10 UBAs the same level of income, while Chimborazo is the province with the lowest number of UBAs in this income range

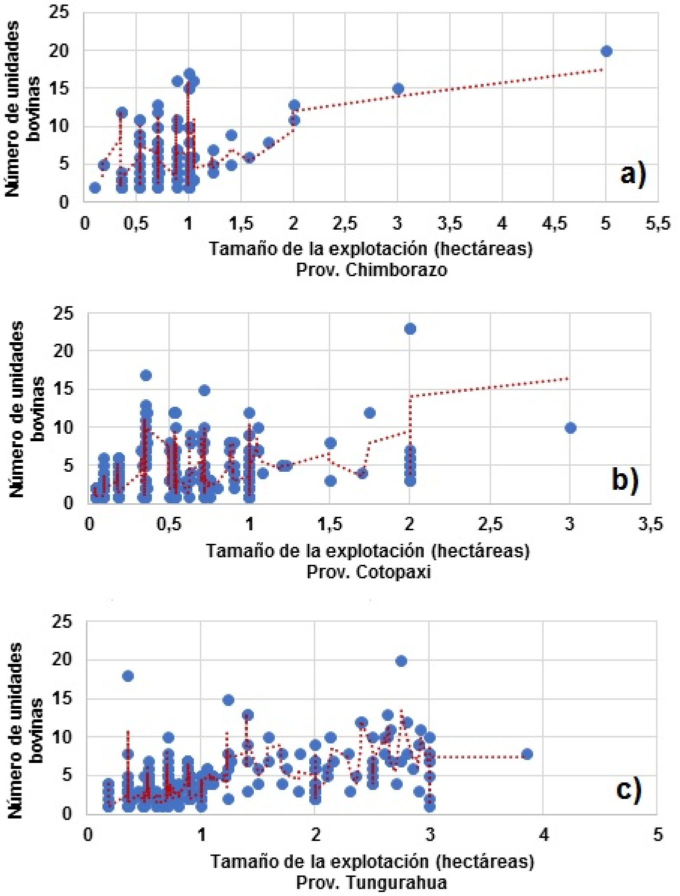

Figure 3. Ratio of the number of bovine units per farm size per province (a) Bovine Units in Chimborazo Province, (b) Bovine Units in the Cotopaxi Province, and (c) Bovine Units in the Tungurahuahua.

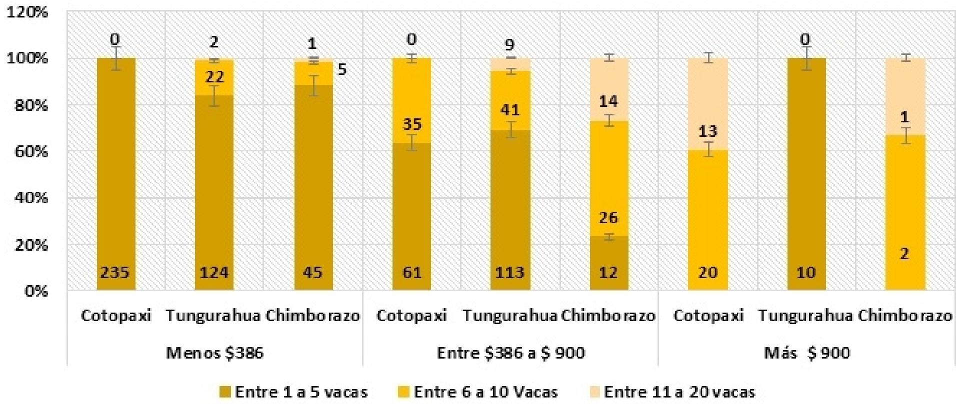

Figure 4. Range of bovine units and income level from milk sales by province.

In relation to the comparative income generated by farms according to their province, those in Chimborazo have an income of between USD 300/month and USD 800/month on farms over 0.5 ha and 1 ha. Farms of more than 1 have generated higher incomes in the same province, but the number of cases is lower. Furthermore, it should be noted that farms of more than 1 ha of Cotopaxi and Tungurahua maintain a constant in the generation of income (less bovine units in production) between USD 100 and 200/month (Figure 5).

Family income from milk sales is highest in Chimborazo province at USD 485/month. In second place, Tungurahua province maintains farms that allow household income of more than USD 360/month. By contrast, farms located in Cotopaxi province generate just over half of the income earned in the first case, with family income being more than USD 260/month (Figure 6).

In this case, the variables that influence a better yield of the livestock herd are those that have led to the modernization of the farms, i.e., it is assumed that farms that maintain these innovation characteristics will have the capacity to produce income, even if they correspond to small size extensions (0.5 to 1 ha) or have fewer bovine units (1 to 5 cows). The results obtained show that the province of Chimborazo has a higher yield compared to Cotopaxi and Tungurahua. While the results proposed by INEC for 2015 indicate that the province of Chimborazo maintains, comparatively with the other two provinces, a lower yield (6.65 l/UBA); also the revenue analyzed by families by concept of milk production and sales (up to five bovine units equivalent to 42,25 %), achieve less than a unified wage (USD394). When comparing household income by province, Cotopaxi Province shows that the farms analyzed receive less than USD260/month.

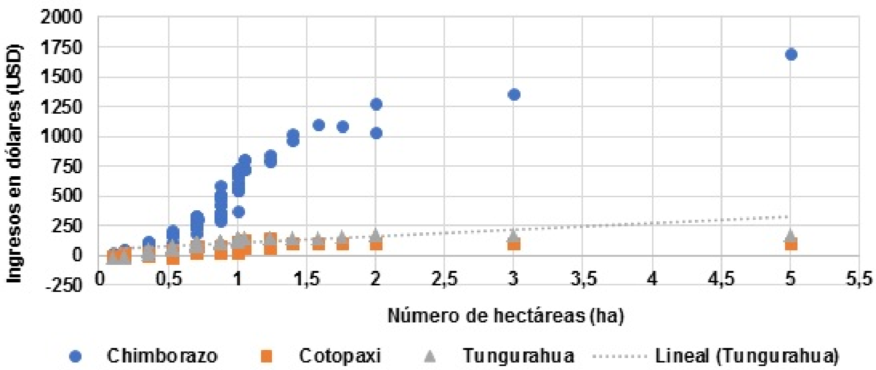

Figure 5. Comparative income per province.

Furthermore, Table 5 presents the correlation results of the variables determined at the beginning of the application of the instrument. These significant correlations correspond to those factors that relate to the innovation of livestock production farms in the three provinces. Factors related to cultivated pasture surface, genetic improvement, complementary food, technical assistance and technical facilities appear as significant.

Table 5. Results of the correlation analysis for the proposed variables of the sample in each province.

		Has Cultivated Grass	Cattle Breed Holstein	Cattle Breed Bown Swiss	Mixed Breed Cattle	Jersey Cattle Breed	Food Type (Grass)	Food Type (Balanced)	Food Type (Banana)	Training	Access to Technical Assistance	Dairy Breed Improvement	Information to Technological Improvements	Installation modernization	Food Improvements	Number of cows	Milking Type
TUNGURAHUA PRODUCTION (HERD/MONTH)	Pearson Correlation	.644**	.856**	.b	.149*	0.09	-.156**	-.402**	.160**	-0.083	-.388**	-.124*	.189**	.155**	0.038	.911**	.447**
	Sig. (bilateral)	0	0	-	0.034	0.655	0.005	0	0.004	0.139	0	0.026	0.001	0.006	0.501	0	0
	N	66	201	1	203	27	321	321	321	321	321	321	321	321	321	321	321
CHIMBORAZO PRODUCTION (HERD/MONTH)	Pearson Correlation	.547**	.745**	.-b	.614**	0.761	-.b	.212*	-.b	-.b	-.b	-.b	-.b	-.b	-.b	.965**	.390**
	Sig. (bilateral)	0	0	-	0	0.239	-	0.029	-	-	-	-	-	-	-	0	0
	N	104	49	0	81	4	0	106	0	0	0	0	0	0	0	106	106
COTOPAXI PRODUCTION (HERD/MONTH)	Pearson Correlation	.481**	.767**	-0.409	.666**	0.421	-0.034	.216**	0.097	-0.009	0.024	0.022	-0.049	-.159*	-0.019	.950**	.363**
	Sig. (bilateral)	0	0	0.42	0	0.104	0.656	0	0.198	0.908	0.748	0.768	0.52	0.035	0.806	0	0
	N	262	77	6	338	16	176	364	176	176	176	176	176	176	176	364	364

**. The correlation is significant at 0.01 (bilateral).
*. The correlation is significant at 0.05 (bilateral).
c. It cannot be calculated, because at least one of the variables is constant.

By applying the measurement variation analysis along to the data obtained in the three provinces (Cotopaxi, Tungurahua and Chimborazo), significant differences are found between them, for which a post-hoc test (Tukey) is applied, in order to identify the province with more differences from the others, depending on the most significant variables (Table 6). Table 6 presents the results of the variation measurement analysis between the group of variables identified with significant correlation, so that they are used to perform Tukey post-hoc that are presented in the following tables.

Table 6. Result of the variation measure and quadratic value for the three provinces.

Description		Sum of Squares	gl	Quadratic Mean	F	Sig.
Type of Livestock Feed (Banana)	Among groups	10.791	1	10.791	95.985	.000
	Inside groups	55.651	495	.112		
	Total	66.443	496			
Number of cows per herd	Among groups	528.929	2	264.465	28.875	,000
	Inside groups	7217.336	788	9.159		
	Total	7746.265	790			
Production (Herd/mounth)	Among groups	40645527.511	2	20322763.756	24.544	.000
	Inside groups	652466338.734	788	828002.968		
	Total	693111866.245	790			
Quantity of cultivated hectares of Grass	Among groups	13.419	2	6.709	25.760	.000
	Inside groups	111.738	429	.260		
	Total	125.157	431			
Quantity of natural hectares of Grass	Among groups	23.419	2	11.709	26.975	.000
	Inside groups	175.799	405	.434		
	Total	199.217	407			
Quantity of livestock Holstein breed	Among groups	169.186	2	84.593	9810	.000
	Inside groups	2794.031	324	8.624		
	Total	2963.217	326			
Quantity of livestock mixed/ creole	Among groups	571.364	2	285.682	74.019	.000
	Inside groups	2389.073	619	3.860		
	Total	2960.437	621			
Access to technical assistance	Among groups	10.474	2	5.237	24.055	.000
	Inside groups	171.559	788	.218		
	Total	182.033	790			
Modification of herd facilities	Among groups	5.723	1	5.723	26.857	.000
	Inside groups	105.488	495	.213		
	Total	111.211	496			

Table 7 shows that the province with the greatest differences from the number of cows per herd is Chimborazo. The average number of cows per herd in Chimborazo corresponds to 6, higher than the average of Tungurahua and Cotopaxi, both with an average of 4.

Moreover, in Table 8 the comparative results show that the province with the greatest differences in the variable number of hectares cultivated of grass is Cotopaxi. The average of Cotopaxi is 0.39 hectares of cultivated pasture, lower than in the provinces of Chimborazo (0.74 ha) and Tungurahua (0.76 ha).

Table 7. Results of the correlation analysis by number of cows per herd.

Multiple comparisons

Dependent variable: HSD Tukey

(I) Provinces		Mean differences (I-J)	Standar erros	Sig.
TUNGURAHUA	COTOPAXI	.,665*	0.232	0.012
	CHIMBORAZO	-1.869*	0.339	0
COTOPAXI	TUNGURAHUA	-.665*	0.232	0.012
	CHIMBORAZO	-2.534*	0.334	0
CHIMBORAZO	TUNGURAHUA	1.869*	0.339	0
	COTOPAXI	2.534*	0.334	0

*. The mean difference is significant at 0.05 level.

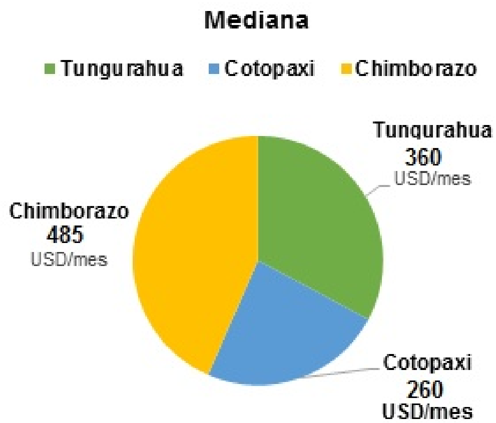

Figure 6. Family income of dairy production by province.

In Table 9 the province of Tungurahua exhibits greater differences in the variable natural hectares of pasture. The province of Tungurahua has the largest area of natural pastures with an average of 1.10 ha, compared to Cotopaxi (0.65) and Chimborazo (0.45 ha).

Table 10 shows that the province of Cotopaxi reflects the largest differences from Holstein cattle with an average of 3 cows (Holstein) per herd, lower than Tungurahua (5) and Chimborazo (4). Finally, Chimborazo province has the biggest differences in technical assistance. Sixty-five percent of respondents in Chimborazo say they have not received technical assistance, i.e., only 35 % have. Moreover, 68 % in Cotopaxi and 69 % in Tungurahua indicate that they received technical assistance (Table 11).

3.1 Discusión de los resultados

The results obtained in this research show that there are parameters that increase the capacity of small dairy farmers. Considering the inequitable access to production factors, in particular the size of the holdings (1 ->10 ha) this is a limitation by the availability of pastures for food of the UBAs. In this sense, a concentration of the number of cows in the range of 1-5 UBAs in the three provinces is observed, highlighted Cotopaxi province by having the highest value (80,87 %). In addition, on average the amount of milk produced per day in the herd is higher for the range between 5-10 UBAs. Also, the employment of family labor predominates.

Differences observed at the level of the three provinces identify that the province of Tungurahua maintains a higher participation level of (a) technical assistance and (b) credit for producers, while Cotopaxi is in the second place and Chimborazo in the last. In this regard, the size

Table 8. Results of correlation analysis by number of hectares of pasture grown.

Multiple comparisons

Dependent variable: HSD Tukey

(I) Provinces		**Mean differences (I-J)**	**Standar error**	**Sig.**
TUNGURAHUA	COTOPAXI	.37435*	0.07029	0
	CHIMBORAZO	0.02267	0.08032	0.957
COTOPAXI	TUNGURAHUA	-.37435*	0.07029	0
	CHIMBORAZO	-.35168*	0.05915	0
CHIMBORAZO	TUNGURAHUA	-0.02267	0.08032	0.957
	COTOPAXI	.35168*	0.05915	0

*. The mean difference is significant at 0.05 level.

Table 9. Results of correlation analysis by number of hectares of natural pastures.

Multiple comparisons

Dependent variable: HSD Tukey

(I) Provinces		**Mean differences (I-J)**	**Standar error**	**Sig.**
TUNGURAHUA	COTOPAXI	.44687*	0.07513	0
	CHIMBORAZO	.64429*	0.12157	0
COTOPAXI	TUNGURAHUA	-.44687*	0.07513	0
	CHIMBORAZO	0.19742	0.13105	0.289
CHIMBORAZO	TUNGURAHUA	-.64429*	0.12157	0
	COTOPAXI	-0.19742	0.13105	0.289

*. The mean difference is significant at 0.05 level.

Table 10. Results of correlation analysis in the three provinces by quantity of Holstein cattle.

Multiple comparisons

Dependent variable: HSD Tukey

(I) Provinces		**Mean differences (I-J)**	**Standar error**	**Sig.**
TUNGURAHUA	COTOPAXI	1.439*	0.394	0.001
	CHIMBORAZO	-0.739	0.468	0.256
COTOPAXI	TUNGURAHUA	-1.439*	0.394	0.001
	CHIMBORAZO	-2,178*	0.537	0
CHIMBORAZO	TUNGURAHUA	0.739	0.468	0.256
	COTOPAXI	2.178*	0.537	0

*. The mean difference is significant at 0.05 level.

Table 11. Results of correlation analysis for the three provinces for accessing to technical assistance.

Multiple comparisons

Dependent variable: HSD Tukey

(I) Provinces		Mean differences (I-J)	Standar error	Sig.
TUNGURAHUA	COTOPAXI	-0.016	0.036	0.894
	CHIMBORAZO	-.346*	0.052	0
COTOPAXI	TUNGURAHUA	0.016	0.036	0.894
	CHIMBORAZO	-.330*	0.051	0
CHIMBORAZO	TUNGURAHUA	.346*	0.052	0
	COTOPAXI	.330*	0.051	0

*. The mean difference is significant at 0.05 level.

of farms per province varies in terms of their extent. In other words, in the province of Chimborazo, there is a concentration 0.5-1 ha, Cotopaxi varies between 0.1 and 1 ha, however, in Tungurahua this concentration expands in the range of 0.5 and 3 ha. In this way, it is generally observed that the ranges of about 1 ha can reach incomes of between USD 250 and 500/unit. However, the provinces of Cotopaxi and Tungurahua are those with the lowest threshold of revenue received.

On the other hand, the variables that have a significant correlation are: herd size, milking type, modernization of facilities, breed of livestock and type of feed. In particular, this condition is maintained in the three provinces. In other words, policies aimed at improving the capacities of family farms that incentivize these factors can increase farmers' incomes, as well as the quality of life of families

4 Conclusions

The purpose of the research was to analyze the dynamics of small milk producers in three provinces that make up the central Sierra of Ecuador: Cotopaxi, Tungurahua and Chimborazo, through a study comprising 793 surveys of small producers. The results achieved in this study describe the conditions of family farming, specifically milk production. The typology identified from the methodology allows to recognize extension lands between 1 and more than 10 hectares, such as the farms that predominate in the sample analyzed. In this sense, there are differences in the production capacities by province. In other words, in the case of Tungurahua, there are better conditions for developing a small-scale dairy production, considering limitations on land access, technology and production factors.

Access to resources related to the modernization and innovation of herds represents an important factor with a positive impact on the production and generation of household income. Therefore, those farms where the modernization (technology, food and livestock breed) has been incorporated favor the improvement of their productivity.

Finally, it is concluded that public policy over the past few years, where resources were introduced for the development of agriculture, does not present evidence of improved resource access in the characteristics for small producers, impacting the amount of family income received, i.e., income levels remain below minimum wage at the household level, even though there are attempts so the performance exceeds the national average. In addition, limitations on sub-units and the establishment of livestock 'micro-herds' that provide income to the families of producers continue, with limitations that frame it as subsistence production units.

References

Barragán, F. (2010). Redes espaciales de abastecimiento de lácteos en ecuador. *PRODIG-Universidad París 1 Panteón-Sorbona*, page Online: https://bit.ly/2Z7Orxk.

Barsky, O. (1984). *Acumulación campesina en el Ecuador*, volume 1. Facultad Latinoamericana de Ciencias Sociales.

Bretón, V. (2012). *Toacazo: en los Andes equinocciales tras la reforma agraria*. Number 333.31091724. FLACSO-ABYA YALA, Online: https://bit.ly/2Z5BQ9G.

Chiriboga, M. (2003). Innovación, conocimiento y desarrollo rural. In *Segundo Encuentro de la Innovación y el Conocimiento para Eliminar la Pobreza Rural*, page Online: https://bit.ly/303DdHv.

Corporación Financiera Nacional (2017). Ficha sectorial: Cría y reproducción de ganado bovino. Technical report, Corporación Financiera Nacional, Online: https://bit.ly/304RqUm.

De Janvry, A. and Sadoulet, E. (2006). Progress in the modeling of rural households' behavior under market failures. In *Poverty, inequality and development*, pages 155–181. Online: https://bit.ly/2OVn3ig. Springer.

Escobar, G. and Berdegué, J. (1990). Tipificación de sistemas de producción agrícola. page Online: https://bit.ly/2uD9tmH.

FAO (2013). Fao: la agricultura familiar produce más del 70 % de los alimentos de centroamérica. Technical report, Online: https://bit.ly/2KPjswH.

Franco-Crespo, C. and Sumpsi Viñas, J. (2017). The impact of pricing policies on irrigation water for agrofood farms in ecuador. *Sustainability*, 9(9):1515. Online: https://bit.ly/33B7HCX.

Glikman, P. (1991). *Encadenamientos de producción en la economía campesina en el Ecuador*, volume 1. Agroamerica, Online: https://bit.ly/2L5SO4n.

Grisa, C. and Schneider, S. (2008). "plantar pro gasto": a importância do autoconsumo entre famílias de agricultores do rio grande do sul. *Revista de Economia e Sociologia Rural*, 46(2):481–515. Online: https://bit.ly/2ZZxFh4.

ILDES (1988). El problema agrario en el ecuador. ILDIS.

INEC, editor (2016). *Encuesta de Superficie y Produccion Agropecuaria Continua*. INEC.

Larrea, C., Landín, R., Larrea, A. I., Wrborich, W., and Fraga, R. (2008). Mapas de pobreza, consumo por habitante y desigualdad social en el ecuador: 1995-2006; metodología y resultados. *Documento de trabajo/Programa Dinámicas Territoriales Rurales. RIMISP-Centro Latinoamericano para el Desarrollo Rural; no. 13*, page Online: https://bit.ly/33yevRI.

Louhichi, K. and Paloma, S. (2014). A farm household model for agri-food policy analysis in developing countries: Application to smallholder farmers in sierra leone. *Food Policy*, 45:1–13. Online: https://bit.ly/2MimkW7.

MAGAP (2016). La política agropecuaria ecuatoriana. Technical report, Ministerio de Agricultura, Ganadería, Acuacultura y Pesca.

Mantilla, F. (2015). Técnicas de muestreo. un enfoque en la investigación de mercados. *Universidad de las Fuerzas Armadas-ESPE*, page Online: https://bit.ly/2NFuCrd.

Mena-Vásconez, P., Boelens, R., and Vos, J. (2016). Food or flowers? contested transformations of community food security and water use priorities under new legal and market regimes in ecuador's highlands. *Journal of Rural Studies*, 44:227–238. Online: https://bit.ly/302pYGN.

Mumba, C., Samui, K., Pandey, G., Hang'ombe, B., Simuunza, M., Tembo, G., and Muliokela, S. (2011). Economic analysis of the viability of smallholder dairy farming in zambia. *Foot*, 42:26–8. Online: https://bit.ly/2KQaAHp.

Murphy, M., O'Mahony, M., Shalloo, L., French, P., and Upton, J. (2014). Comparison of modelling techniques for milk-production forecasting. *Journal of dairy science*, 97(6):3352–3363. Online: https://bit.ly/2Z7YgqW.

OECD-FAO (2015). Agricultural outlook 2015-2044. Online OECD.

Ormel, P. (2013). América latina y el caribe en el contexto mundial de los productos de origen animal: Leche vacuna.

Requelme, N. and Bonifaz, N. (2012). Carcaterización de sistemas de producción lechera de ecuador. *La Granja*, 27(1):68–109. Online: https://bit.ly/2TFJfOJ.

Schejtman, A. (2008). La agricultura familiar en américa latina.

Steinfeld, H. and Chilonda, P. (2006). Perspectiva mundial. Roma.

Sumpsi, J. M. (2010). El nuevo sistema agroalimentario en una crisis global. Madrid.

Tobar, J. (2010). Criterios de tipificación y caracterización de la agricultura familiar en el salvador. Technical report, Online: https://bit.ly/2InFEQv.

Wiggins, S., Kirsten, J., and Llambí, L. (2010). The future of small farms. *World development*, 38(10):1341–1348. Online: https://bit.ly/2TvLVvC.

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SUSTAINABLE DEVELOPMENT

Spatial analysis of Millennium Educational Units in Ecuador and its coverage over poverty areas

Análisis espacial de las unidades educativas del milenio en el Ecuador y su cobertura en zonas de pobreza

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Resumen

Uno de los parámetros que más influyen en la pobreza es la mala calidad en la educación. El estudio sistemático de la pobreza es fundamental para mejorar la aplicación de planes y proyectos. En el Ecuador, a partir del año del 2005 inicia el "Proyecto para mejorar las condiciones de escolaridad, el acceso y la cobertura de la educación" en zonas de alto índice de pobreza a través del Gobierno Nacional Educacion2016. Este estudio realiza un análisis espacial de dicho proyecto gubernamental del Ecuador mediante el uso del software libre. Dicho análisis se fundamenta en la existencia de las instituciones educativas públicas denominadas "Unidades Educativas del Milenio" (UEM), cuyo fin es mejorar la calidad académica, satisfacer la demanda estudiantil rural y atender a sectores históricamente relegados, partiendo de 57 unidades educativas operativas en el año 2016 y utilizando técnicas de análisis espacial estadístico, apoyados en una base de datos relacional robusta como es el caso de PostgreSQL, con el fin de determinar cuál es su área de afectación a la población, creando varios tipos de coberturas para identificar las parroquias y el porcentaje de pobreza que es atendido por este proyecto educacional, logrando determinar que existe un 77 % y el 96 % de UEM, en zonas de extrema pobreza.

Palabras clave: Análisis espacial estadístico, UEM, unidades educativas del milenio, análisis espacial, PostgreSQL-PostGIS, pobreza.

Abstract

One of the most influence parameters in poverty is the poor quality of education. The systematic study of poverty is essential to improve the implementation of plans and projects. Since 2005, Ecuador began the 'Project to improve education conditions, schooling access and coverage of education' on high poverty areas through the National Government Educacion2016. This study performs a Spatial Analysis of the above governmental project of Ecuador by

the use of free software. This analysis is based in the existence of public educational institutions called 'Millennium Educational Units', whose purpose is to improve academic quality, meet rural student demand and serve historically relegated sectors. It is sought using statistical spatial analysis techniques, supported by a robust relational database such as PostgreSQL for determining their impact area on the population by creating various types of coverage to identify the parishes and the poverty percentage that is being benefited by this educational project, managed to determine that there is a percentage between 77 % and 96 % of UEM, located in areas of extreme poverty.
Keywords: Statistical Spatial Analysis, UEM, millennium educational units, spatial analysis, PostgreSQL-PostGIS, poverty.

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1 Introduction

UNICEF, and particularly the Economic Commission for Latin America and the Caribbean (ECLAC), remarks the importance of a systematic monitoring of poverty in order to reduce poverty and achieve a more equitable country (Unicef Ecuador, 2015). Education in Ecuador lacks of an academic quality level in the poorest populations; in 2005 the Millennium Educational Units education project started, aiming to reduce this gap and offer education to children with limited economic resources (Ministerio de Educación, 2016).

The Millennium Educational Units (MEU) is a project to endow primary and secondary public educational institutes that were created to improve the country's education and reach the poor sectors, reason for which these institutions are located in poor areas at the national level, with high rates of unmet basic needs and social problems such as internal and external migration, schools characterized by low educational quality and the absence of minimum conditions for the training of girls, boys and young people (Ministerio de Educación, 2016).

The first MEU was built in 2008 in the parish of Zumbahua, in the province of Cotopaxi. According to information from the Ministry of Education (1 November 2013) 31 MEU were created by 2013, at a cost of USD 69'318,199.30, attending 23,282 students; and 33 MEU are being built (the "New Educational Infrastructure"program). The Ministry's website presents updated information to 2015, and indicates that there are 53 MEU in operation, 60 in construction and 212 will be created (Ministerio de Educación, 2016). Geoportals in Ecuador allow to have a georeferenced inventory of state projects such as: risk zones, nature reserves and everything that can be observed on a map (Navas and Prieto, 2011). The information from the Geoportal of (Ministerio de Educación, 2016) was the basis of the study carried out.

On January 19th, 2016, the (Ministerio de Educación, 2016) publishes the news about the inauguration of the Millennium Educational Unit (MEU) Nueva Generation in Morona Santiago province, celebration in which attended the Education Minister Augusto Espinosa and the President of the Republic, Rafael Correa Delgado. This study is based on 89,8 % of educational units created up to 2016. Millennium Educational Units are an integral part of a government policy to improve the quality of public education. Each MEU is created to ensure access to school in rural areas which are excluded from educational services (Ministerio de Educación, 2016). MEU is based on various location criteria for its construction.

The main criteria for the study are (Peñafiel Larrea, 2014): a) Location of the property, it must not be located in risky areas; must be located in a location with easy access to the population; and it should be located near green areas for public use and recreational areas. b) Accessibility to the property, it must have a first, second and third order road infrastructure; it must provide easy access conditions for emergency service vehicles, firefighters, transportation, garbage collectors and input entry and it shall have two clearly defined access routes. c) Land area, the land area for the construction of a Millennium Educational Unit is 2.2 hectares, equivalent to 22,000 square meters.

This paper proposes a method that has allowed to measure the poverty coverage that each MEU has, using free software tools and statistical spatial analysis techniques; likewise, it allows to observe the relationship with the poor parishes of Ecuador, using techniques proposed by the model (Bertolotto and McArdle, 2011) that include the use of free software spatial analysis tools PostgreSQL - PostGIS and the Open layer web viewer, geoserver maps to display the results obtained.

The representation of the geometric properties of spatial objects, as well as their structures are essential for GIS operations, analysis and visualization (Groger and Betsy, 2012). Spatial data types refer to shapes such as points, lines, and polygons parenciteBoundless2012a, the data itself are vector elements which can be points, lines, and polygons with their attributes, and these can be represented by bar and pie charts indicating percentages or trends (Peters, 2012). Geographic feature data can also be displayed with spatial distributions (Fu and Jiulin, 2011), to achieve this the data have been stored in a PostgreSQL database with its spatial extension PostgreSQL-PostGIS. Spatial analysis has multiple applications in health, agriculture, defense, security, cadastres, planning, location services, transportation, geology, energy, and it uses various formats for information management such as: XML, GeoJson, Xslt, among others (Shklar and Rich, 2011; Babar, 2010), (Accessibility of Web based GIS applications 2010) (Ayen López, 2012). The spatial analysis is generated through a series of operations such as layer overlay, joints, spatial intersections, erase operation, and proximity analysis (Martínez Llario, 2013).

For this work, join, intersection and buffer operations have been used, which by specialized statements in the handling of point and polygon geometry and with the help of statistical tools can be used to check whether the MEU are located in Ecuador's poorest parishes and to determine what percentage of the poverty level is covered by each parish.

There are many tools that allow to run each of the aforementioned operations, for example, ArcGIS and MapInfo, which are paid applications whose cost is high, and

QGis which is a free application. The advantage of using a relational database like PostgreSQL with its PostGIS extension is that it is not required to enter the graphical interface of the GIS application, which warrants specific knowledge of the tool by the user. A relational database allows to enter the information and operations that are required to be executed, the same as being linked to the graphical application allows the result to be displayed transparently to the user. Additionally, the registration of new information in the database does not prevent all established operations from continuing to be applicable to the new data.
The use of a relational database allows to enhance the use of the tools available to these technological programs of spatial analysis; one example is to get the geographic location of these educational units, as well as to identify which and what type of populations will be benefited.

1.1 Description of the data

Poor areas are located on Ecuador's socio-economic map, where poverty rates are presented for each parish, including data on estimates of the gap between rich and poor according to the World Bank; this information was obtained from the website of Universidad de Azuay (Universidad del Azuay, 2018) (http://gis.uazuay.edu.ec/).

Poverty measurement requires a prior conceptual definition of that social reality; therefore, there are several poverty indicators or indices that inevitably refer to poverty paradigms or approaches, such as the GINI index, and the unsatisfied basic needs (UBN) index that serves to identify critical gaps in basic needs such as education, health and housing. The GINI index (Montero Castellanos, 2018), is an economic measure for calculating income inequality among the inhabitants of the study area; it is normally used to measure income inequality within a country, but can be used to measure any form of unequal distribution. The GINI coefficient is a number between 0 and 1, where 0 corresponds to perfect equality (all have the same income) and where 1 corresponds to perfect inequality (one person has all income and the others none) (Damm, 2013).

UBN is a direct method to identify critical deficiencies in a population and characterize poverty using four areas of basic people's needs (housing, health services, basic education and minimal income) available in the population and housing censuses conducted by INEC (INEC, 2010), and it has been considered as the most appropriate index for this study; being also the method employed by the Economic Commission to Latin America (CEPAL) (INEC, 2017).
The information provided by INEC has data on the poverty rates of each parish tabulated in an Excel file, but without geospatial data, unlike data obtained from the website of Universidad de Azuay website, where poverty data are represented by the GINI index for each parish, with the corresponding geographic coordinates stored in a shapefile. In order to have a table with NBI indexes and geographical location per parish, a merger of the two tables mentioned above was carried out, for which a PostgreSQL - PostGIS query was developed by linking these two tables by means of the name of parishes, cantons and provinces. The result obtained in this consultation was 60% of the total parishes, where the remaining 40% was prepared manually. The following code snippet is an SQL query to the database to bind the results.

```
select pp."provincia", pp."canton", pp."
    parroquia", pp."no_pobres", pp."pobres", pp
    ."porcentaje_no_pobres", pp."
    porcentaje_pobres", po.the_geom
from "pobreza_porcentaje" pp, public."POBREZA"
    po
where pp."provincia"=po."PROVINCIA"
and pp."canton"=po."CANTON"
and pp."parroquia"=po."PARROQUIA"
```

The information and position of the MEU were downloaded from the geoportal of Ministerio de Educación (2016) in KML extension; the obtained coordinates are in the worldwide geographic coordinate system WGS84, whose equivalence is the code EPGS: 4326. The WGS84 (World Geodetic System, 1984) is a global-covered datum of the entire planet and is the most commonly used today (Westra, 2013). In short, for this analysis it is necessary to obtain two data tables, the first containing the poverty information at the parish level, which is the fusion of the data of Universidad de Azuay and INEC, and the second table corresponding to the geospatial location of the MEU.

1.2 Methodology

The data used for the study were obtained from the geoportal of Ministerio de Educación (2016) which displays 53 geographical coordinates representing the position of each educational unit. To identify whether the MEU is in the poorest areas of the country, a spatial analysis was performed with PostgreSQL - PostGIS statements. Spatial analysis is a set of methods whose results change when the locations of the analyzed objects also change (Huang et al., 2011).

The difference between a database and a spatial database are spatial data that represents geographic elements. This spatial data isolate spatial structures such as boundaries and dimensions. A uniform area of study around each educational unit was established (5, 10 and 20 Km), to be able to quantify the poverty level of people attending these educational institutions, since the fact of identifying and clarifying the type of the students attending each MEU is a very complex task because the population of Ecuador is located in several scattered areas of the country.

In order to carry out this calculation, the area to be considered as coverage of each institution was distributed with respect to the different existing centers, which are the coordinates of the MEU (Peter, 1977), where the movement from the center area to its peripheral sectors should be minimal (Buzai, 2011).

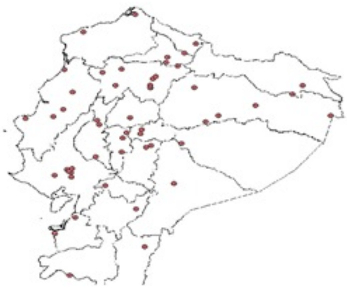

Figure 1. Map of MEU location in a circular 5Km area.

Figure 2. Map of MEU location in a circular 10Km area.

In a study (Buzai, 2011), states that regular polygons provide better results than irregular polygons, and that the circle is the regular polygon of greater desirable conditions. The circular influence area is a simple and easy approach method to implement, but it should be noted that this methodology does not consider the existence of barriers nor the road network where students normally move; in this type of analysis it is recommended that the circular area has a radius of 0.5 km in urban areas, taking into account that a person takes from 5 to 10 minutes to walk and in the rural area it can increase considerably, since the overlap possibility between institutions is low (Córdoba, 2012).

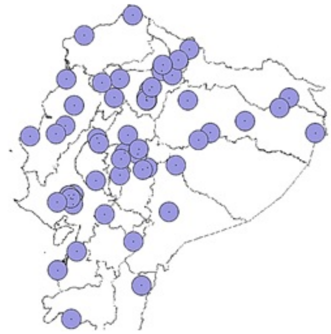

Figure 3. Map of MEU location in a circular 20Km area.

In this study, the areas where MEU are located were not classified as rural or urban, for this reason these were analyzed in a homogeneous way, generating for each MEU three different circular coverages with radiuses of 5, 10 and 20 km around, taking into account that the time to move is approximately 5 to 30 min in public transportation. It should be mentioned that the municipal ordinance of Quito also considers circular areas where it is provided that students must live two kilometers away from the educational institutions in urban area (Secretaría de Educación y Deporte, 2015). Figures 1, 2 and 3 show Ecuador divided by provinces and the location of each millennium educational institutions, where MEUs are represented by points generated in the worldwide geographic coordinate system WGS84, whose equivalence is the code EPGS:4326, which are the centroids of each circular area of 5, 10 and 20 km radius respectively, intended to indicate the coverage area of each educational unit.

For this analysis process, another ordinance of municipal schools in Quito has also been taken into account with respect to the rural sector, considering that the student must live in the parish in which is located the educational institution (Secretaría de Educación y Deporte, 2015). The poverty results of each study with the different parameters of the MEU with respect to the population will help to answer the question of this research, and will allow to see if the educational institutions are located in poor areas of Ecuador. The coverages will be separated by circular influence areas with radiuses of 5, 10 and 20 km, and the study will be deepened in the analysis of circular area and areas of influence at the parish level, and these will be discussed in the following sections.

1.3 Analysis by circular areas

For this analysis, an intersection was performed in PostgreSQL - PostGIS, between the circular areas of the MEU and the poverty map as shown in Figure 4. This intersection indicates the coverage that each MEU has with respect to the parishes on the poverty map. The resulting map shows circumferences divided into several segments; these segments are the area covered by each parish with respect to the circular influence area of each MEU. Each segment has two important data, the area percentage of the intersection between the parish and the MEU and the poverty percentage that each parish has.

The influence area of each MEU covers several parishes with different poverty percentages. Each parish fragment within the circumference has been weighted by reason of the value of its area, thus facilitating the use of the weighted average, which is the average number to which a coefficient, called weight, has been assigned to take into account its relative importance. The weighted average of a data group $X_1, X_2, ..., X_n$, with its corresponding weights $W_1, W_2, ..., W_n$, can be obtained through the following formula (1) (Paz, 2007).

$$\overline{X_w} = \frac{\sum_{i=1}^{n} X_i W_i}{\sum_{i=1}^{n} W_i} \quad (1)$$

Likewise, in order to know the index of unsatisfied basic needs (UBN) for each school, the weighted average was calculated with the data obtained from the intersection, as well as the geospatial poverty data tables and MEU location performed with a PostgreSQL - PostGIS query in which the poverty calculation by circular coverage is analyzed.

```
select u."UEM",
mp."provincia",
mp."canton",
mp."parroquia",
mp."porcentaje_pobres",
mp."porcentaje_no_pobres",
 st_area (u.st_buffer) as "area_uem",
st_area(st_intersection(st_transform(st_setsrid(mp.the_geom,4326),32717),u.st_buffer)) as "
    area_parroquia_uem",
st_area(st_intersection(st_transform(st_setsrid(mp.the_geom,4326),32717),u.st_buffer))/ st_area
    (u.st_buffer) as porcentaje_area,
sum((st_area(st_intersection(st_transform(st_setsrid(mp.the_geom,4326),32717),u.st_buffer))/
    st_area (u.st_buffer))*"porcentaje_pobres")
OVER (PARTITION BY "UEM" ORDER by UEM",1)/sum(st_area(st_intersection(st_transform(st_setsrid(
    mp.the_geom,4326),32717),␣u.st_buffer))/␣st_area␣(u.st_buffer))
OVER␣(PARTITION␣␣BY␣␣"UEM"␣␣ORDER␣␣by␣␣"UEM",1) as␣␣media_ponderada,
st_intersection(st_transform(st_setsrid(mp.the_geom,4326),32717),u.st_buffer)
from␣"mapa_pobreza"␣mp,␣"cobertura_uem"␣␣u
WHERE␣ST_intersects(st_transform(st_setsrid(mp.the_geom,4326),32717),
u.st_buffer)
```

Table 1. PostGIS query code to obtain poverty by circular coverage.

1.4 Poverty calculation by circular coverage

The *st_buffer* function is used to obtain the circular polygon around the point representing the educational institutions. It shows a geometry that included the object with a set distance to the input geometry, in this case the resulting geometry will be a circle representing the circular buffer around the MEU. The circular area analysis focuses on an intersection between circular polygons representing the coverage of MEU and parish polygons contained in Ecuador's poverty table; i.e., the result of this study is based on the spatial analysis that was performed between two polygon-type geometries. Subsequently, the weighted average was calculated with the data, the weights of which are given for each resulting area of the intersection. This analysis was obtained using the code presented in Table 1.

Columns resulting from the above-mentioned consultation are the name of the MEU, the province, canton, parish and the poverty percentage of each parish. These first data were obtained directly from their corresponding tables. The following data are detailed below with their corresponding statements. It can be seen in Figure 4 that the MEU coverage is the red circle defined as the circular influence area.
The code indicated below is used to determine the surface of this figure with their corresponding radiuses of 5, 10 and 20 km. It should be emphasized that this section only indicates how to obtain the area with a radius of 10km, since for 5 and 20 km the value must be changed in the *st_buffer* function of the sentence, for the use of this function, the radius must be transformed into meters:

First, the table is created in the database:

```
Create table cobertura_uem  as (select *,
    st_buffer(the_geom,10000) from
        Ubicacion_UEM      )
```

As the next step, the table created was used to calculate the circular area.

```
select area  (st_buffer).
```

For the intersection area between the MEU coverage and the parishes, the coordinates of the intersection boundary, i.e., the geometry (*the_geom*), were first calculated with the *st_intersection* function for later performing the transformation to the 32717 system and then obtaining the area with the *st_area*, where the code is as follows:

```
Select st_intersection(st_transform(st_setsrid(
    mp.the_geom,4326), 32717), u.st_buffer)
    from "mapa_pobreza" mp, "cobertura_uem" u
```

The area percentage was calculated by dividing the previous two areas, i.e.,:

```
st_area(st_intersection(st_transform(st_setsrid
    (mp.the_geom,4326),32717),u.st_buffer))/
    st_area (u.st_buffer) as porcentaje_area,
```

Each MEU must have its poverty percentage relative to the poverty data of the parishes that intersect it, so it is necessary to calculate the weighted average of each MEU, for which the query must be sorted and partitioned to carry out the sum of the product and the value of each poverty percentage (X_i) of each parish by the area that covers the circular area to each parish that intersects, this value is the weight (W_i) that is given to the value (X_i).

Therefore, the PostgreSQL - PostGIS query to define equation (1) is given by the following code:

```
sum((st_area(st_intersection(st_transform(
    st_setsrid (mp.the_geom,4326),32717),u.
    st_buffer))/ st_area (u.st_buffer))* "
    porcentaje_pobres") over (PARTITION BY "
    UEM" ORDER by "UEM",1)/sum(st_area(
    st_intersection(st_transform(st_setsrid(mp.
    the_geom,4326),32717),u.st_buffer))/
    st_area (u.st_buffer)) OVER (PARTITION BY
    "UEM" ORDER by "UEM",1) as media_ponderada,
st_intersection(st_transform(st_setsrid(mp.
    the_geom,4326),32717), u.st_buffer)
```

1.5 Analysis by parish

This analysis took into consideration that the influence area is given by the boundaries in which the MEU is located, for this reason the poverty percentage covered by each MEU is given by the UBN index of the parish where it is located.As in the previous analysis, the poverty map and the timely location of each MEU were used.

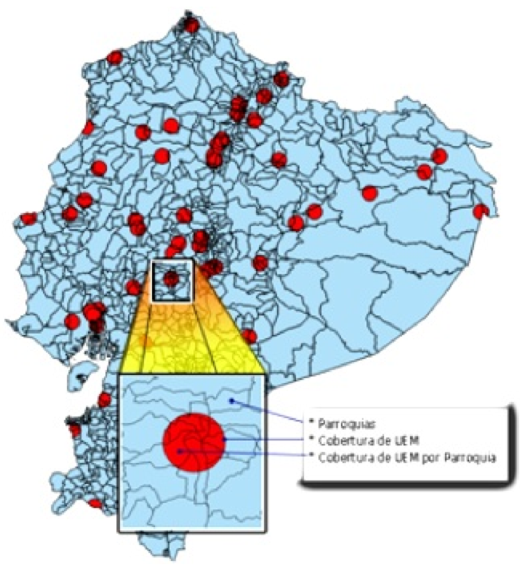

Figure 4. Mapa de las áreas que cubren las UEM en cada parroquia del Ecuador.

1.6 Poverty calculation by parish coverage

First, an assessment will be carried out to verify which points belong to the location of the MEU located in the irregular polygons representing the parish, this is achieved thanks to the *St_contains* statement, which determines whether one geometry is fully within another. PostgreSQL - PostGIS statement used in this case is as follows.

```
CREATE TABLE UEM_PARROQUIAS AS (select u."UEM", mp."provincia", mp."canton", mp."parroquia", mp.
    "porcentaje_pobres", mp.the_geom
from mapa_pobreza mp, ubicacion u
where st_contains (mp.the_geom,st_setsrid(u.the_geom,4326)))
```

1.7 Geospatial Viewer

To make these results easy to read and understand, a geographic viewer has been created with the help of the programs already mentioned above, which are part of OpenGeo suite (Boundless Server, 2012) which is a free software development kit (SDK) that provides the following tools:

1.7.1 PostgreSQL-PostGIS

As already mentioned PostgreSQL - PostGIS is a PostgreSQL extension that allows to store map information and perform spatial analysis between points, lines, polygons and other geometric shapes (Boundless, 2012)

1.7.2 GeoServer

It is a web server that can serve in isolation or over a Tomcat application container or similar. GeoServer has a web management interface that allows to serve maps and data of different formats for web or desktop applications such as GIS.

1.7.3 OpenLayers

It is an open source library in javascript to make interactive maps, mainly visible in Web environments able to connect with GeoServer (or other map sources, such as google maps), to present the layers of a server of maps/data in a browser. It provides a simplified user interface that seamlessly attacks WMS and WFS services for the user and developer (Morales, 2012; Hazzard, 2011; Perez, 2012). Each of these components performs a specific job joined under a diagram to have a map web application as shown in Figure 5.

Figure 5. Geographic visualizer diagram.

2 Results

The data presented in Table 1 are the result of the first analysis showing the number of MEU belonging to each range of poverty percentages, and the influence area of educational establishments for students living within the circular area of 5, 10 and 20 km radius, including the analysis in which those living in the parish where the MEU is created will be benefited.

If 50% of poverty is taken as a midpoint, Table 2 shows that the ranges above this value cover more than 70% of MEU in all influence areas, indicating that most of these institutions are created in poor areas to extreme poverty. A total absence of MEU can also be seen in areas where poverty is less than 25%. Figure 2 shows the percentage of MEUs in the different coverages in 25% poverty ranges. It can be observed that:

- In the four types of coverage, no MEU is found in poverty below to 25%. .
- In all four coverages, the MEU percentage increases while the poverty percentage is higher.
- There is a significant amount of MEU in ranges higher than 75% of poverty.

The percentages are 81%, 81%, 96% and 77%, respectively, considering a universe of 53 MEU, also taking as a midpoint 50% and performing a sum between the ranges of 50%-75% and 75%-100% with each circular coverage area of 5, 10, 20 km by parishes; for this reason, poverty rates higher than 50% divided into quintiles of 10% will be taken into account to identify the number of educational institutions for each poverty range. Having the data correctly structured in a relational database ensures the consistency of the data and the results obtained.

UEM COVER	INBI poverty percentage 0 %-25 %	INBI poverty percentage 25 %-50 %	INBI poverty percentage 50 %-75 %	INBI poverty percentage 75 %-100 %
5 Km circle	0	10	18	25
10 Km circle	0	10	12	31
20 Km circle	0	2	16	35
By parish	0	12	14	27

Table 2. Number of MEU in poverty ranges per coverage area.

Poverty levels are divided by quintiles with the aim of easing the investigation; these quintiles are called: low (50 % – 60 %), low average (60 % – 70 %), average (70 % – 80 %), high (80 % – 90 %) and very high (90 % – 100 %). The distribution of schools with poverty higher than 50 % is more equitable, however, Figure 6 shows a trend ranging from high average poverty onwards.

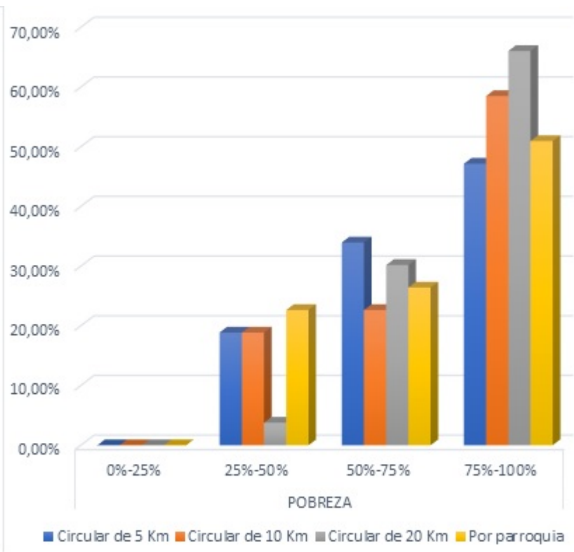

Figure 6. MEU percentage in poverty ranges.

It can be seen in Figure 7 that in the four coverage areas the values tend to areas with average poverty, increasing in the first three cases to high and very high poverty. The lowest poverty level covering a MEU belongs to Réplica Montufar educational institution located in Quito, Quito Canton, Pichincha province with 34,16 %; and the highest level is that of the MEU Chontapunta located in Chontapunta, Tena canton, Napo province, with 99,61 % of poverty.

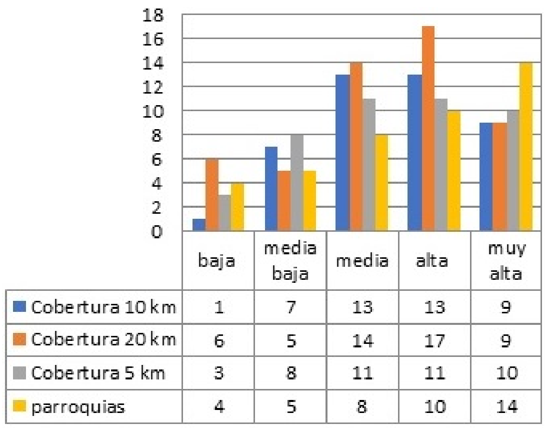

Figure 7. Number of MEUs covering poverty ranges higher than 50 %.

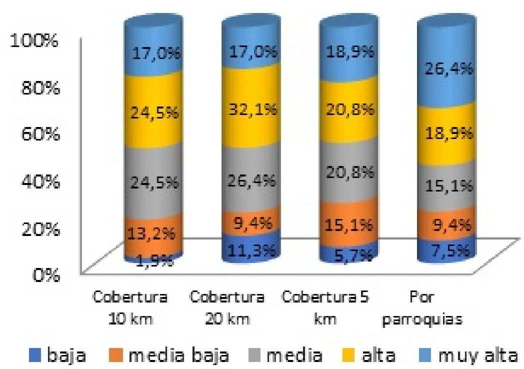

Figure 8. MEU percentage in quintiles by poverty coverage.

The median calculated in this data set corresponds to 76,65 % (orange color), whose value belongs to MEU Paiguara, indicating that 26 educational institutions are above this value and 26 institutions have lower-than-median values. The graph of the frequency distribution in Figure 4 has a right bias, indicating that the median is higher than the average; reason for which it can be inferred that most MEUs tend to be located in the poorest sectors of the country. In other words, the value of the arithmetic mean is 74,29 % (green), which indicates that the average covered by the educational institutions in this study is about 50 % of poverty.

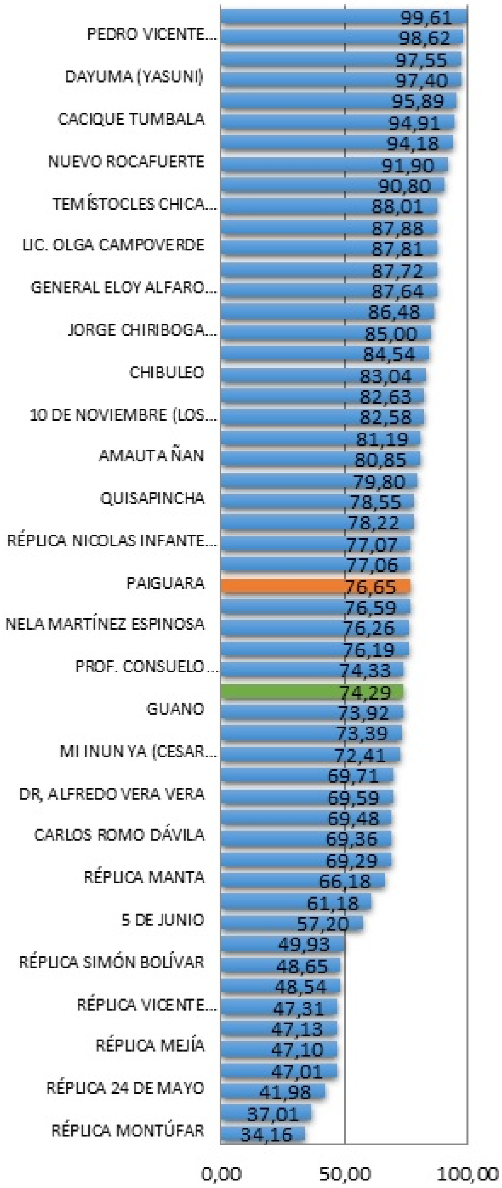

Figure 9. Poverty percentage covered by each MEU.

3 Conclusions

It has been shown with polygon intersection methods in PostgreSQL-PostGIS and using mathematical methods that 84 % of the created MEU are in areas where the unsatisfied basic needs are above 50 %. It has been possible to deduce using circulars with variable radiuses of 5,10 and 20 km and irregular polygons such as the areas of the parishes of each MEU, that the educational units mentioned in this research are built in rural areas and satisfy the most deprived population.

It can be concluded in the individual analysis of each MEU that there are 33 educational institutions above the arithmetic poverty average with ranges higher than 74,29 %, being MEU Chontapunta the institution in an area where its UBN index is 99,61 %, located in the province of Napo, Amazon region. There are 21 institutions below average, being the educational institution Réplica Montufar located in Quito, Quito canton, Pichincha province the MEU that covers the lowest poverty level with 34,16 %.

References

Ayen López, J. A. (2012). Catastro y nuevas tecnologías. Technical report, Saaerbrucken: Lap Lambert Academic Publishing GmbH & Co.

Babar, S. (2010). Accessibility of web based gis applications. Technical report, Saaerbrucken: Lap Lambert Academic Publishing AG & Co.

Bertolotto, M. and McArdle, G. (2011). Data reduction techniques for web and mobile gis. *Advances in Web-based GIS, Mapping Services and Applications*, 9:139.

Boundless (2012). Postgis. Online. último acceso: 04 de 09 de 2015.

Boundless Server (2012). Introduction boundless server. Online.

Buzai, G. D. (2011). Geografía y sistemas de información geográfica. *Revista Geográfica de América Central*, pages 15–67. Online:https://bit.ly/2Ni3SN6.

Córdoba, G. (2012). Áreas de influencia, tipos y aplicaciones en geomarketing. Online. último acceso: 12 de 01 de 2015.

Damm, A. (2013). Thatcher y el coeficiente de gini. Asuntos Capitales. Online: https://bit.ly/2ZdiYKp.

Fu, P. and Jiulin, S. (2011). *WebGIS Principles and applications*. Esri Press.

Groger, G. and Betsy, G. (2012). *Handbook of Geographic Information*, chapter Geometry and Topology, pages 303–321. Springer.

Hazzard, E. (2011). *Openlayers 2.10 beginner's guide*. Packt Publishing Ltd.

Huang, H., Li, Y., and Gartner, G. (2011). A load balancing method to support spatial analysis in xml/gml/svg-based webgis. *Advances in Web-based GIS, mapping services and applications*, pages 153–168.

INEC (2010). Población: Necesidades básicas insatisfechas total nacional. Technical report, Instituto Nacional de Estadística y Censos. Online: https://bit.ly/2xTLcuj.

INEC (2017). Reporte de pobreza y desigualdad. Technical report, Instituto Nacional de Estadística y Censos. Online: https://bit.ly/2FnRsRb.

Martínez Llario, J. C. (2013). Postgis 2. análisis espacial avanzado.

Ministerio de Educación (2016). Visualizador geográfico. Online: http://geoportal.educacion.gob.ec/.

Ministerio de Educación (2016). Proyecto emergente de unidades educativas del milenio y establecimientos réplica. Online: https://bit.ly/2ZUdQHO.

Montero Castellanos, Y. (2018). Índice de gini. Economipedia. Online: https://bit.ly/2T7nraQ.

Morales, A. (2012). Las mejores aplicaciones gis open source. MappingGIS. Online:https://bit.ly/1mWhK9e.

Navas, G. and Prieto, P. (2011). Geoportales en el ecuador. *La Granja*, pages 58–64. Online: https://bit.ly/2Zfbzdb.

Paz, I. K. (2007). Media aritmética simple. *Boletín Electrónico*, (7):1–13. Online: https://bit.ly/2KUgojd.

Peñafiel Larrea, F., editor (2014). *Acuerdo Nro. MINEDUC-ME-2014-00034-A*. Ministerio de Educación del Ecuador. Online: https://bit.ly/2Mrd3LM.

Perez, S. (2012). *OpenLayers Cookbook*. Packt Publishing Ltd.

Peter, H. (1977). *Análisis Locacional en Geografía Humana*. Ed. gustavo Gili.

Peters, D. (2012). Building a gis. Technical report, Redlands: Esri Press.

Secretaría de Educación y Deporte (2015). Secretaría de eduación y deporte. inscripciones instituciones municipales. Online: https://bit.ly/33kxtep.

Shklar, L. and Rich, R., editors (2011). *Web Application Architecture*. John Wiley & Son Ltd, Chichester. Online: https://bit.ly/2ZocEQl.

Unicef Ecuador (2015). Pobreza y pobreza infantil multidimensional. Online: https://uni.cf/31uNc9c.

Universidad del Azuay (2018). Infraestructura de datos espaciales. Online: https://bit.ly/2MqKqOv.

Westra, E. (2013). *Python Geospatial Development*. Packt Publishing Ltd.