Ann. For. Res. 65(1): 10180-10197, 2022
ISSN: 18448135, 20652445

ANNALS OF FOREST RESEARCH
https://www.e-afr.org/

SOIL QUALITY IN THE PITAHAYA PRODUCTION SYSTEM IN THE CANTON OF PALORA, PROVINCE OF MORONA SANTIAGO

Anghela Viviana Rodriguez Tacuri 1
(https://orcid.org/0000-0002-3389-0957); anghela451997@gmail.com

Miguel Angel Osorio Rivera 2
(https://orcid.org/0000-0002-8641-2721); miguel.osorio@espoch.edu.ec

Sandra Elizabeth López Sampedro 3
(https://orcid.org/0000-0003-0209-2087); salopez@espoch.edu.ec

Juan Pablo Haro Altamirano 4
(https://orcid.org/0000-0001-8538-3191); juanpablo.haro@espoch.edu.ec

Jessica Paola Arcos Logroño 5
(https://orcid.org/0000-0002-9462-2219); paola.arcos@espoch.edu.ec
Independent Researcher1; Escuela Superior Politécnica de Chimborazo 2,3,4,5

Abstract

The study's main objective was to evaluate the soil quality to carry out the methodology; a reconnaissance of the studied farms was made, then monitoring was made where 16 simple subsamples were extracted and from them, 4 composite samples were obtained for each farm, the points were located with the help of a GPS, to subtract the soil samples a depth of 20 cm was considered, which also served to identify the macrofauna of the place, these soil samples were sent to the private laboratory of INAIP for the corresponding analysis, and were also evaluated in the laboratories of ESPOCH. The parameters were pH, electrical conductivity, texture, macro and micronutrient concentrations and macrofauna; the results were as follows: QIn F1: 152.34 (Very High Quality), QIn F2: 68, 49 (Very High Quality) and QIn F3: 88.12 (Very High Quality). In conclusion, it was demonstrated that the three study farms have a very high quality despite the fact that their production years are different. It was also shown that there is no significant difference in concentrations between the parameters analyzed; ph, electrical conductivity and phosphorus are important parameters that influence the performance of these soils by allowing the accumulation, retention and adequate transport of micro and macronutrients. This research made it possible to identify the conditions in which these soils are found due to pitahaya monoculture and how farmers in the area consider good agricultural practices. Finally, a model of a management plan for agricultural use was developed, which will contribute with considerations that producers in this area can take into account for the care and management of this fruit and thus safeguard the health of the soil.

Keywords: < SOIL>, < QUALITY INDICATORS>, < AGRICULTURAL SOILS>, < MACROFAUNA>, < MONOCULTURE>.

1. Introduction

Soil is a natural and essential resource that contributes to the development of life (Moreno et al., 2015: p.1; García et al., 2012: p.126). However, the increase in population and the objective of satisfying its needs has led to the overexploitation of this resource without due precautions, so that now "it has become a natural resource that requires proper and rational management" (Burbano, 2010, p.55). This will make it possible to safeguard its use and avoid its degradation due to the depletion of its physical, chemical and biological properties (Novillo et al., 2018, p.178).

According to Moreno et al. (2015: p.2); Bautista et al. (2004: p.90), soil quality is the state or capacity by which its functions can be recognized and interact with the environment. This tool facilitates the assessment when applying management practices in agricultural systems (Barrera et al., 2020: p.183). It is determined by analysis, comparison and evaluation of various physical, chemical and biochemical properties or parameters known as indicators, which are obtained from samples of the soil under study and whose purpose is to determine the modifications or changes that it has undergone due to the change in use or management (Gómez and Hoyos, 2020: p.15).

Agriculture has become one of the main livelihood activities for human beings, so the presence of monocultures has been leading to the loss of fertility and overuse of agricultural land or soil. (Martinez, 2018, p.2). On the other hand, Leal et al. (2014: p.2) also mention that when these soils are used for this type of activity, they need to have large amounts of inputs and agrochemicals added to them to make them more productive without considering the consequences that these can cause, such as the degradation of the resource and the contamination of the surrounding environment. From these observations and identifying the inefficient use of the soil resource, countries around the world must protect the soil as a resource of great importance for the quality of life of the population in general, create public policies and try to find strategies and measures to conserve and recover the soil (Silva and Correa, 2009: p:15).

Ecuador has not been able to save itself from the global problem of contamination, degradation and loss of soil quality, either (Suquilanda, 2008, p.4). According to SIPA (2021), of the 12,316,607 million hectares (TOTAL), the agricultural surface that occupies the territory of our country is between 5,354,674 million hectares with agricultural work and 6,961,933 million hectares without agricultural use, increasing every year by its main actors such as the extension of agricultural plantations. In Ecuador, red and yellow pitahaya production and cultivation occur, especially in Pichincha, Morona Santiago and Loja provinces (Huachi et al., 2015: p.50). As shown by Vargas et al. (2020: p. 6), the lack of knowledge and preparation in the agronomic management of farmers to handle these crops has caused problems in the contamination of the environment, its productive capacity and changes in the properties of the soil.

The Municipality of Palora (2022) states that 43% of the population living in these lands are dedicated to agriculture, livestock, forestry and fishing activities, where the most outstanding products are pitahaya and tea (Diéguez et al., 2020: p.115). In the same way, it is mentioned that "the canton has 1,500 hectares of pitahaya, of which 700 are in production and about 650 producers are involved in this activity." Pitahaya production is taking an important role in this canton, which means that these plantations can contribute to the deterioration of the soil, causing variations in its quality and characteristics that have come to generate an overall environmental impact (Quezada et al., 2021: p.122). These plantations for their commercial use are cultivated as monoculture and are given conventional agronomic management in which they make great use of agrochemicals, causing some negative impacts on natural resources, such as the loss of biodiversity, and especially the degradation and erosion of soils by using production technologies that abuse agrochemicals (Vargas-Tierras et al., 2021: pp.1-2).

The present research, once it analyzes the problems presented in the previous paragraphs, has the objective of evaluating the quality of the soils of the canton of Palora with Pitahaya cultivation by determining its quality index, where physical, chemical and biological analyses will be carried out, which will allow to collect important data to make a comparison and to know the quality of the soil in the presence of this monoculture. This written work will consist of five chapters, which will be distributed with the statement of the problem, its theoretical framework, the methodology used, the proposal of the design of a management plan for agricultural use and finally, the conclusions and recommendations according to the results obtained.

2. Methodology

The present investigation had a mixed approach because a qualitative type of investigation was carried out, where it was possible to identify characteristics of soil quality in the different types of land dedicated to agriculture, together with the necessary information on how pitahaya cultivation is carried out in the canton of Palora, province of Morona Santiago. On the other hand, it was also considered that the investigation had a quantitative approach based on the objective and its complexity, where it was focused on making a description based on the score and the results obtained after analyzing soil quality characteristics.

2.1 Research Design

The design of the present investigation was experimental and descriptive, where an analysis was carried out in the study farms, and the extraction of soil samples was obtained at different points to analyze them ex situ in the laboratory, thus achieving to see the modification of its components, such as pH, texture, electrical conductivity, nitrate, phosphate, organic matter, and others, obtaining with these results the current state in which these soils of the pitahaya productive system were found in the 3 farms analyzed, and thus finally complying with an explanatory level of study that allowed gathering necessary and effective information that was helpful for the opening of various studies that can be implemented according to the subject.

2.1.1 According to manipulation or not of the variable

According to the manipulation of the independent variable that is the soil quality index, a comparison was made between the quality indexes of the 3 farms under study to perform an analysis of variance using Tukey's method to differentiate which is the most affected soil with pitahaya plantations in the producing lands of the Palora canton, the research was considered as an experimental design. The research was considered an experimental design, based on the monitoring in 3 producing farms where there was a manipulation of the samples for soil quality analysis, so it was considered the location of the farms, soil sampling, measurement of in situ analysis, analysis of ex-situ data and the proposal of a management plan based on the data collected in the titling work.

2.1.2 According to the interventions in the fieldwork

To observe specific characteristics that occurred in this research, it was determined that it is a longitudinal study design to collect this information by measuring various parameters in two monitoring carried out on different dates, as well as to start from past research and data in order to explain the problem and the hypothesis of how the monoculture of pitahaya affects the production system of the canton of Palora in each of the 3 farms of study in a longitudinal time.

3. Results

3.1. CMD selection

Of the twenty parameters sent to analyze, through descriptive statistics for each soil property (Table 1 and Table 2) using the InfoStat application, it was possible to determine the mean, minimums, and maximums to determine the minimum set of data as expressed by Wilson (2017: p.95); Barrera et al. (2020: p.185); and Barrezueta et al. (2017: p.20).

According to the proposed tables, it was evident that similar variables were considered both in the private laboratory analyses and in the analyses performed in the university laboratories, which were used to select the CDM.

Once the results were obtained, the same indicators of the two analyses were selected to determine the QIN, these indicators were pH, electrical conductivity (E.C), organic matter (O.M), phosphorus (P) and potassium (K). The values obtained for these indicators allowed the application of the formula to determine soil quality, and the maximum and minimum permitted levels were used to obtain the standard deviation, which was key data for determining the scoring coefficient, which is obtained by the difference between the standard deviation (SD) and the average of the maximum and minimum levels (SD/average (maximum; minimum)).

Table 1 Results of physical-chemical analysis of soil samples with Pitahaya cultivation in INIAP laboratories.

REPORT OF SOIL ANALYSIS OF PITAHAYA PRODUCING FARMS IN THE CANTON OF PALORA, PROVINCE OF MORONA SANTIAGO

VARIABLE	**UNIT**	**MEDIA**	**MINIMUM**	**MAXIMUM**	**DS**	**CV%**
pH	01:02,5	5,49	5,27	5,86	0,32	**0,06**
Electrical Conductivity	dS/m	0,18	0,09	0,33	0,13	**0,62**
NH4	ppm	76,63	69,50	83,90	7,20	**0,09**
P	ppm	11,50	6,80	18,30	6,03	**0,48**
Zn	ppm	16,47	5,21	33,30	14,85	**0,77**
Cu	ppm	17,01	13,39	23,16	5,36	**0,29**
Mn	ppm	10,35	7,36	15,12	4,18	**0,37**
B	ppm	0,18	0,17	0,19	0,01	**0,06**
S	ppm	12,51	2,25	22,32	10,04	**0,82**

Ca/Mg	ppm	6,80	4,40	8,20	2,09	**0,33**
Mg/K	ppm	2,70	1,80	3,60	0,90	**0,33**
(Ca+Mg)/k	ppm	19,87	16,70	23,60	3,48	**0,17**
K	meq/100ml	0,29	0,18	0,36	0,09	**0,33**
Ca	meq/100ml	5,04	2,36	7,53	2,36	**0,48**
Mg	meq/100ml	0,73	0,58	0,96	0,20	**0,26**
∑ Bases	meq/100ml	6,06	3,66	8,85	2,62	**0,42**
M.O %	%	12,87	4,93	19,65	7,43	**0,60**
Sand	%	50,67	48,00	52,00	2,31	**0,05**
Limo	%	40,33	39,00	43,00	2,31	**0,06**
Clay	%	9,00	9,00	9,00	0,00	**0,00**

Source: INIAP Laboratories
Performed by: Authors (2022)

Table 2. Results of soil analysis of pitahaya-producing farms in the canton of Palora, province of Morona Santiago - ESPOCH Laboratories.

		MONITORING JUNE 12, 2022					MONITORING JULY 03, 2022				
PARAMETER	UNIT	MEAN	MINIMUM	MAXIMUM	DS	CV%	MEAN	MINIMUM	MAXIMUM	DS	CV%
pH	01:02,5	6,22	6,21	6,24	0,01	0,002	6,22	6,09	6,41	0,16	**0,03**
C.E	(dS/m)	0,56	0,47	0,65	0,09	0,16	0,67	0,55	0,81	0,13	**0,19**
M.O	%	13,08	10,99	15,50	2,28	0,17	15,99	13,04	20,91	4,29	**0,25**
P	(ppm)	16,27	7,51	26,98	9,88	0,57	11,10	7,57	17,10	5,23	**0,42**
K	(meq/100ml)	1,91	0,91	2,64	0,90	0,51	1,64	0,88	2,74	0,97	**0,54**

Made by: Authors. 2022

3.2 Determination of the soil AQI

From obtaining the results of the principal component analysis (PCA) and the scoring coefficient, the normalized soil quality index was determined where the parameters are respectively taken into account both from the private laboratory and those carried out at the university, explaining that there is 84 and 95% of the total variance of the original data, so pH was selected as principal component one, electrical conductivity as principal component two, organic matter as principal component three, potassium as principal component four and phosphorus as principal component five, in order to apply with these the respective formula and obtain the result of QIN which according to the table of function levels will be able to know in what state these soils are in (Barrezueta et al. 2017: p. 21).

Table 3. Results of the physicochemical principal component analysis of soil INIAP results.

VARIABLE	UNIT	FARM 1	FARM 2	FARM 3
pH	01:02,5	5,86	5,27	5,33
Electrical Conductivity	dS/m	0,11	0,33	0,09
NH4	ppm	83,9	69,5	76,5
P	ppm	18,3	6,8	9,4
Zn	ppm	33,3	5,21	10,91
Cu	ppm	23,16	14,47	13,39
Mn	ppm	7,36	15,12	8,57
B	ppm	0,19	0,17	0,18
S	ppm	22,32	2,25	12,96
Ca/Mg	ppm	7,8	8,2	4,4
Mg/K	ppm	2,7	1,8	3,6
(Ca+Mg)/k	ppm	23,6	16,7	19,3
K	meq/100ml	0,36	0,32	0,18
Ca	meq/100ml	7,53	4,77	2,83
Mg	meq/100ml	0,96	0,58	0,65
∑ Bases	meq/100ml	8,85	5,67	3,66
M.O %	%	4,93	14,03	19,65
Sand	%	52	48	52
Limo	%	39	43	39
Clay	%	9	9	9
QIn		152,33 Very High Quality	68,49 Very High Quality	88,11 Very High Quality

Table 4. Results of the principal component analysis of the physical-chemical variables of the soil ESPOCH laboratories

		Monitoring June 12, 2022			Monitoring July 3, 2022		
PARAMETER	UNIT	FARM 1	FARM 2	FARM 3	FARM 1	FARM 2	FARM 3
pH	01:02,5	6,24	6,22	6,21	6,41	6,18	6,09
C.E	dS/m)	0,47	0,58	0,65	0,81	0,55	0,64
M.O	%	10,99	15,50	12,73	20,91	14,01	13,04
P	(ppm)	26,98	7,51	14,31	17,10	7,57	8,61
K	(meq/100ml)	2,19	2,64	0,91	2,74	1,31	0,88
QIn		83,14 Very High Quality	57,59 High Quality	61,77 Very High Quality	85,74 Very High Quality	52,94 Moderate Quality	52,33 Moderate Quality

Realizado por: Autores, 2022

As shown in the tables above, the green colored results indicate the quality index value with a very high-quality rating, the light blue color with a high-quality rating and the yellow color with a moderate quality rating.

After the samples were sent to the INIAP laboratory and the results obtained, the QIN was determined, with a positive result, verifying that the quality of the 3 farms analyzed was at very high-quality levels; however, the analyses carried out at ESPOCH were from the 2 monitors, so the second has a slight variation in the results, This is because in the second monitoring the climatic conditions played a role as they were different from those of the first monitoring, with precipitation on the day the samples were collected, which caused the soils to be washed with rainwater, so it is considered that this is the reason for the alteration of the indicators, since there was an infiltration of macro and micronutrients, thus changing the quality of the soil.

3.3 Variations of variables analyzed

3.3.1 pH

As already stated in the previous sections, the main components used to evaluate soil quality were five, but the most important was pH, because, thanks to the pH concentration, macro and micronutrients can remain in the soil, providing a balance and the necessary conditions for optimum production and adequate soil quality.

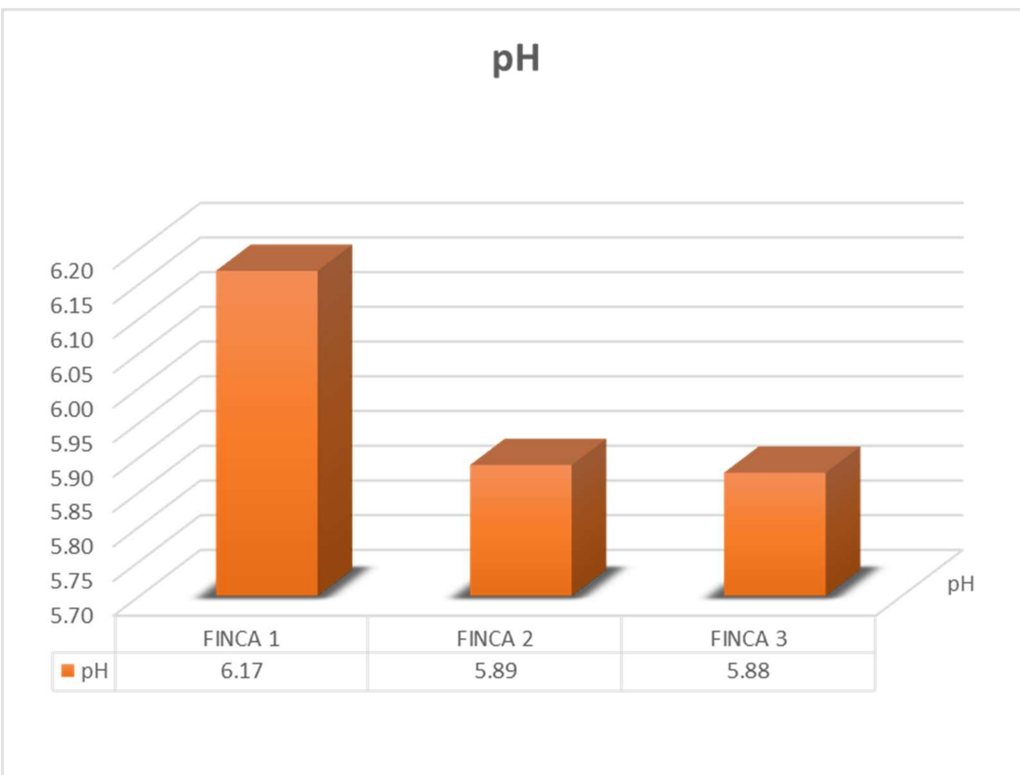
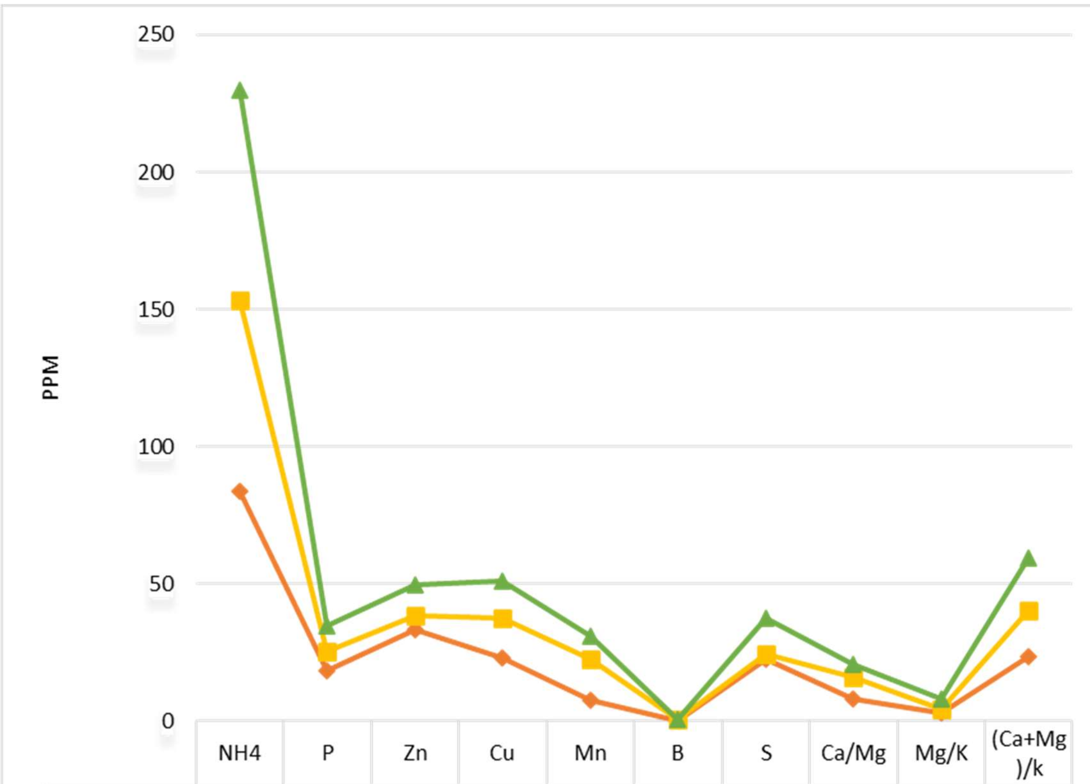


Figure 1. Comparison of pH in pitahaya farms.
Performed by: Authors. 2022

It can be observed that farm number one, as evidenced in the QIN previously obtained, has a higher pH compared to the other two farms, which makes it a slightly acidic soil and of very high quality because it is within the permitted range so that the micro and macronutrients are in their necessary concentrations. Furthermore, when mentioning the pitahaya-producing soils, these results can also be confirmed since, as mentioned before, pitahaya needs acid soils with limits between 5 and 6.5 to have adequate production.

3.3.2 Macro and Micronutrients

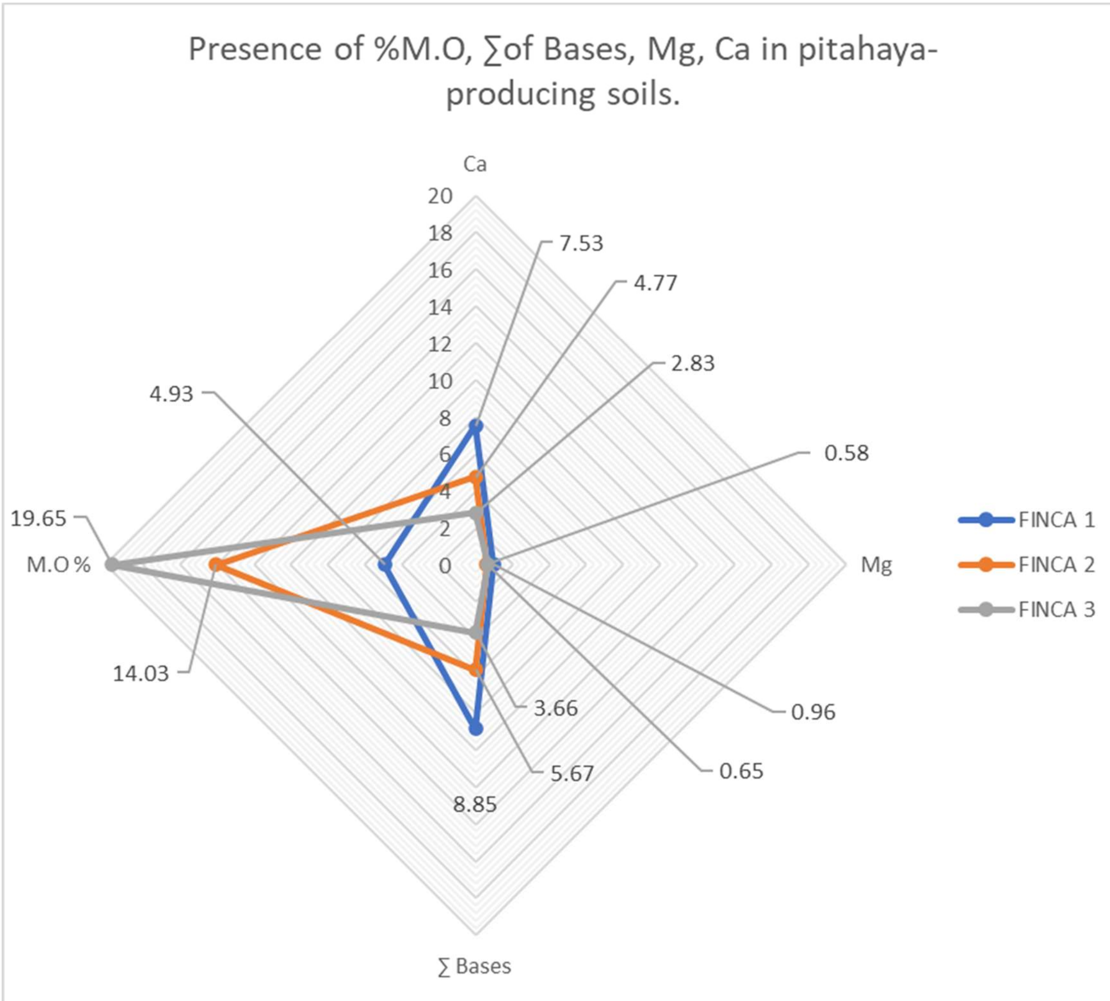


	NH4	P	Zn	Cu	Mn	B	S	Ca/Mg	Mg/K	(Ca+Mg)/k
FINCA 3	76.5	9.4	10.91	13.39	8.57	0.18	12.96	4.4	3.6	19.3
FINCA 2	69.5	6.8	5.21	14.47	15.12	0.17	2.25	8.2	1.8	16.7
FINCA 1	83.9	18.3	33.3	23.16	7.36	0.19	22.32	7.8	2.7	23.6

Figure 2. Accumulation of macro and micronutrients in pitahaya crop soils.
Performed by: Authors, 2022

The macro and micronutrients present in these soils are relatively in the three farms within the permissible limits and the needs of the crop, so as shown in the image, boron is not an essential micronutrient in these plantations compared to NH4, which is found with a higher concentration and this is because as stated in the previous graph the pH of farm 3 is more acidic than farm 1 and 2, altering these soil nutrients and causing an oversaturation and shortage of them, Therefore, once again it is verified that farm number 1 continues to maintain its optimal conditions and both the pH and the macro and micronutrients are within their permissible limits of life and concerning the requirements for the cultivation of pitahaya.

3.3.3 Presence of % M.O, ∑of Bases, Mg and Ca.



Results of %M.O, Mg, Ca and ∑Bases of soils with pitahaya crops.
Performed by: Authors, 2022

Once the results of each of the quantified and analyzed variables were obtained, it was also possible to verify that the organic matter is present with a high degree in these three farms; this goes hand in hand with the good retention of micro and macronutrients such as magnesium and calcium(Figure 3), being within the permissible limits and almost a balance between these three farms analyzed. This is one of the reasons for the high levels of organic matter, allowing the organisms that live in the soil to survive and also helping to provide adequate ecosystemic processes and services for the recycling of nutrients, the decomposition of organic matter and the conservation of soil structure.

3.4 Determination of soil quality from macrofauna

Table 5. Macrofauna present in the pitahaya-producing soils of the canton of Palora.

MONITOREO 1 MONITOREO 2

	MONITOREO 1						MONITOREO 2					
	Farm 1		Farm 2		Farm 3		Farm 1		Farm 2		Farm 3	
Macrofaunal Organisms	No. of Types of Organizations	N° of Individuals by type	No. of Types of Organizations	N° of Individuals by type	No. of Types of Organizations	N° of Individuals by type	No. of Types of Organizations	N° of Individuals by type	No. of Types of Organizations	N° of Individuals by type	No. of Types of Organizations	N° of Individuals by type
Earthworms		23		87		97		35		117		89
Millipedes										2		1
Snails		2				19		7		6		34
Slugs								2				
Cockroaches		3		2				8		5		2
Adult Tenebrionidae beetles		4		1				2		3		1
Flies		1						1				
Total, by Detritívoros	**5**	**33**	**3**	**90**	**2**	**116**	**6**	**55**	**5**	**133**	**5**	**127**
Ants		2		3		1		5		3		2
Total, by Omnivores	**1**	**2**	**0**	**3**	**0**	**1**	**1**	**5**	**1**	**3**	**1**	**2**
Bedbugs and leafhoppers		3		3		3		4		8		5
Beetles Elateridae larvae		1						2		1		
Scarabaeidae Beetles larvae		3						3				1
Caterpillars								1				
Total, of Herbivores	**3**	**7**	**1**	**3**	**1**	**3**	**4**	**10**	**2**	**9**	**2**	**6**
Spiders												
Centipede		6						50		27		23
Adult Carabidae beetles		2						3		1		5
Total, from	**2**	**8**	**0**	**0**	**0**	**0**	**2**	**53**	**2**	**28**	**2**	**28**

Predators												
Other unidentified organisms	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**
TOTAL, OF MACROFAUNA	**11**	**50**	**4**	**96**	**3**	**120**	**13**	**123**	**10**	**173**	**11**	**164**

Performed by: Authors, 2022

The macrofauna collected in each of the farms analyzed was of great importance because it was used to calculate the quality index based on this biological parameter. Giving us positive results and following the same sequence and results of the normalized QIN. The O.M., being present in high concentration and with acceptable limits are, contributing positively that this macrofauna can be present in these soils, the earthworm was a great indicator of quality in this research; these were found in their great majority in each of the farms, proving that if there is biological activity in each of these soils.

Table 6. Soil AQI results based on macrofauna

RESULTS MONITORING 1		
FARM 1	**FARM 2**	**FARM 3**
Detrívoros/No Detrívoros (Omnívoros+Herbívoros+Depredadores)		
1,94 **HIGH QUALITY**	**HIGH QUALITY**	**HIGH QUALITY**
EARTHWORMS / ANTS		
HIGH QUALITY	**HIGH QUALITY**	**97** **ALTA CALIDAD**

Performed by: Authors, 2022

Table 7. Soil AQI results based on macrofauna

RESULTS MONITORING 2		
FARM 1	**FARM 2**	**FARM 3**
Detrivores/Non Detrivores (Omnivores+Herbivores+Predators**)**		

0,80 LOW QUALITY	3,32 HIGH QUALITY	3,43 HIGH QUALITY
EARTHWORMS / ANTS		
HIGH QUALITY	HIGH QUALITY	44,5 HIGH QUALITY

Performed by: Authors, 2022

The high quality that was given as a result of these soils is due to the great quantity of earthworms found in these soils, with the exception of farm number 1 in the second monitoring that gave as a result a low quality, but this does not mean that this soil is of bad quality since there were external factors that were unforeseen to affect the sample the day of the monitoring, among these factors we can mention the time, since when the monitoring was done as the time was advancing the macrofauna was not visible, because as the literature says and as mentioned in previous sections, in order to obtain a good result of the macrofauna it is preferable that it is collected in the early hours of the morning, as is known as the dew point, and another factor that was unforeseen that day was the rainfall. Another unforeseen factor that day was the rainfall, since despite having a good weather forecast, it varied, with heavy rains at the time that the monitoring was being carried out, which could have caused the macrofauna to go deeper into the profiles or deeper horizons of the soil.

3.5 Multivariate analysis for the correlation of macrofauna and micronutrients in pitahaya producing farms in the canton of Palora

To carry out the correlation analysis between the macrofauna and the micronutrients present in the soils of the pitahaya producing farms, the statistical program Past3 was also used, where employing principal component analysis and non-metric multidimensional scaling, it was possible to show how these play an important role among themselves since for the different organisms to survive in the soil they also need to acquire nutrients which they absorb from the soil. The statistical unit will be based on the macrofauna found with the association of the micronutrients analyzed. The set of these data allowed to perform these multivariate analyses, which are not observed by conventional statistical analysis.

3.6 Principal Component Analysis

This statistical method made it possible to distinguish among the original variables, which are the principal components that capture most of the micronutrients and represent most of the variability in the statistical units. This analysis was obtained through the graphic representation of a biplot, which consists of representing in the same space the samples according to the variables analyzed.

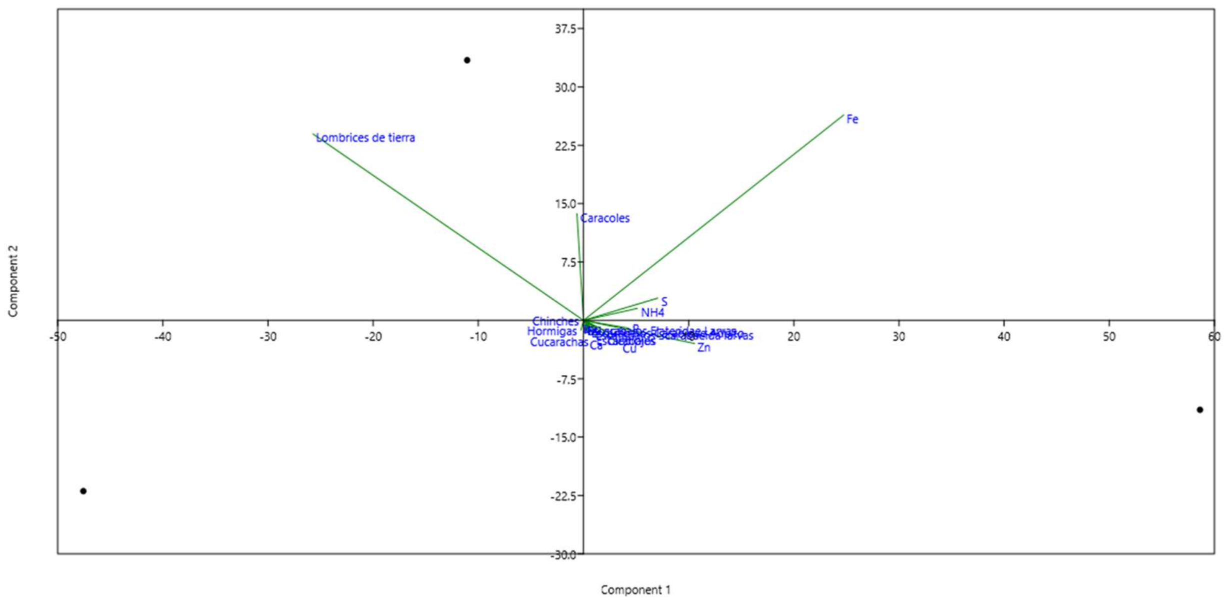


Figure 4. Correlation between macrofauna and micronutrients of pitahaya farms in Palora. Performed by: Authors, 2022.

Figure 4 shows that there is a great relationship between the micronutrients and the macrofauna and that they complement each other, but it also shows that among the most outstanding components, the earthworm is one of the most important, so they contribute and are great indicators of the good condition of these soils. As a second component, Fe (iron) represents a significant value to the variability of all these nutrients, so it is also considered a major contribution for the survival of these organisms and the soil.

Figure 5 below is the one obtained with the principal component analysis. The correlation between each variable is represented by the angles formed between the vectors represented by each farm. At the same time, the biplot plotted nutrients represent positive correlations between these and the macrofauna; when forming the ellipse at 95% that gives the statistical software shows that this tube has a stable or strong correlation between all these variables analyzed, likewise it can be compared with the same polygon present in the graph to demonstrate its surface less indicates that this correlation is positive and that it is framed between all the macrofauna and the nutrients that were found in the pitahaya producing farms that were analyzed.

In the first and second quadrants corresponding to farms 1 and 2, there are intermediate points between the different kinds of beetles, cockroaches, ants that absorb Cu (Copper), Ca (Calcium), Zn (Zinc) and P (Phosphorus). On the other hand, in quadrants 3 and 4, plasma and snails stay more with S (Sulfur) and B (Boron).

Earthworms, together with iron, which is located on the axis and can be seen in the previous graph, are the main components since they are located at an intermediate point between the 3 farms and are associated with all other nutrients and organisms.

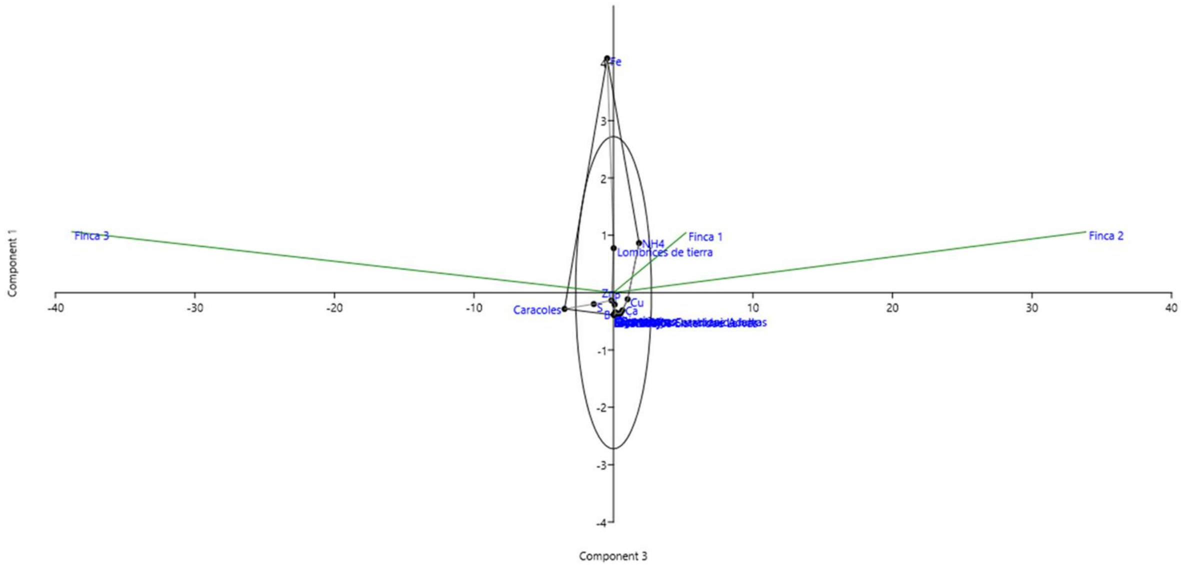


Figure 5. Biplot of the principal component analysis between macrofauna and micronutrients of pitahaya farms in Palora canton.
Performed by: Authors, 2022.

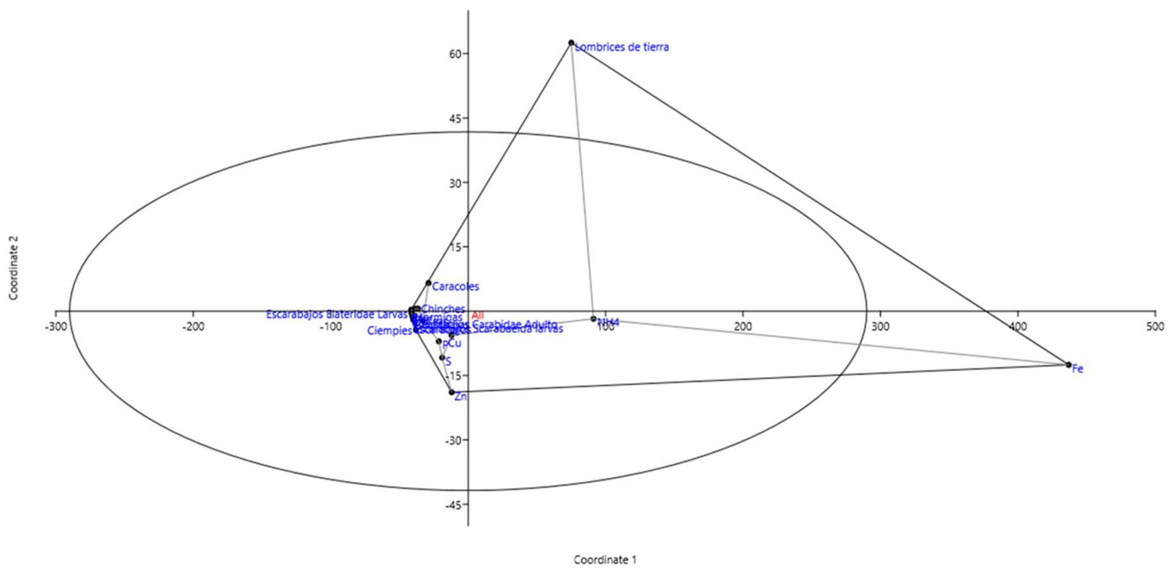


Figure 6. Biplot of component analysis between macrofauna and micronutrients from a 3D angle.
Performed by: Authors, 2022.

3.7 Non-metric multidimensional scaling

Like the principal component analysis, the non-metric multidimensional scaling adjusts to a dimension with Euclidean distances (encompasses higher dimensions with the variables) where the organisms' separation and structuring about the micronutrients needed to nourish themselves was evidenced. In addition, all the variables are found within the four quadrants, so they were considered nutritional positives for the soil; a connection is linked to all the nutrients analyzed in this research.

The species of beetles, flies, centipedes and bugs are far from the earthworms, snails and ants of the nutrients for the simple fact that, as already mentioned and proved previously, these last ones are the best indicators of quality, so they are those organisms that need and absorb all these nutrients in greater quantity than the ones mentioned at the beginning of the others. This does not diminish the importance of their existence, because as has been mentioned throughout this research, the more macrofauna there is and according to the taxonomy of the different living organisms, the better the quality of the soils can be calculated.

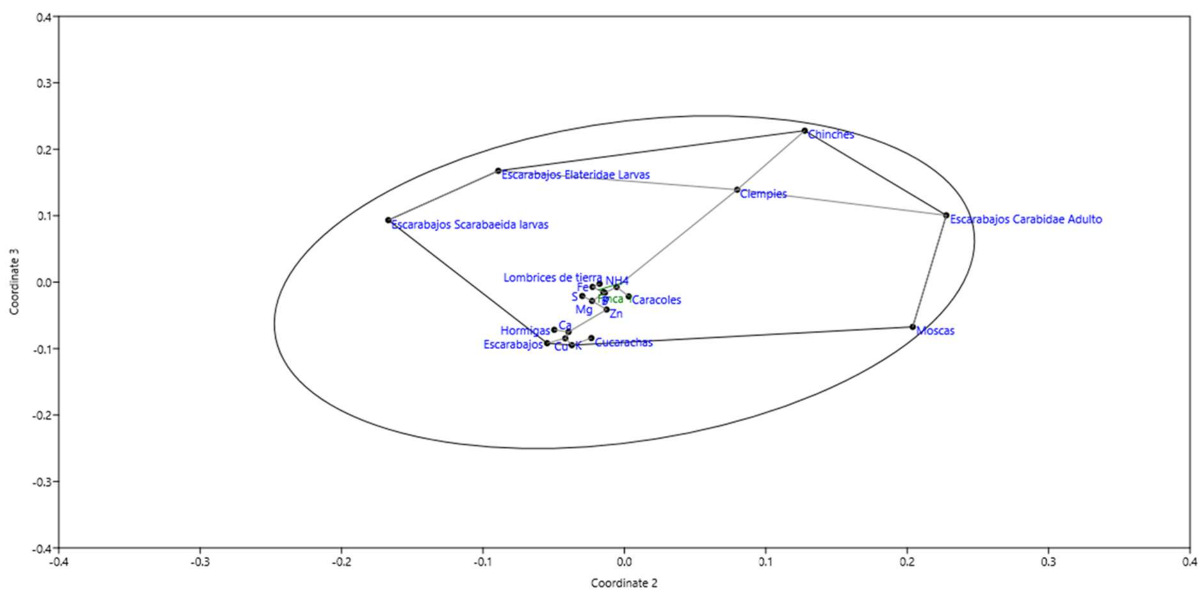


Figure 7. Non-metric multidimensional scaling in Euclidean distance of the macrofauna and micronutrients of the pitahaya producing farms in the canton of Palora.
Performed by: Authors, 2022.

4. Conclusions

It was possible to demonstrate, quantify and determine the physical, chemical and biological characteristics of 3 pitahaya producing farms in the canton of Palora through 2 samplings with 16 simple subsamples and 4 composite samples of 1 hectare of land for each farm, the variables analyzed were pH, electrical conductivity, organic matter, macro and micronutrients and macrofauna. The results obtained allowed these to be taken as the main components to determine the AQI of the soil. As a result, farm 1 has the best quality with a QIN 152.34 (Very High Quality) despite being the one with more years of production. This is due to the good agricultural practices of its owner; however, the other two farms are not far behind, also having very high quality with QIn F2: 68.49 (Very High Quality) and QIn F3: 88.12 (Very High Quality). The pH was one of the fundamental variables to know this quality, resulting in 84% and 95%, respectively %variation. On the other hand, the organic matter is a variable that is also of great importance; this soil being in good condition has allowed the macrofauna of these lands not to be lost, so that when obtaining the AQI from the macrofauna this could show us the good quality in which these soils are found with results greater than 1.

The data obtained from the soils studied to comply with the soil quality limits established in the Ecuadorian legislation Annex 2 (TULSMA 2015). The data obtained from the soils studied to comply with the soil quality limits established in the Ecuadorian legislation, and there is no significant difference between the three types of soils analyzed, which goes hand in hand with the conditions required for pitahaya cultivation, according to Vargas, Yadira et al. (2020).

The comparison of the indices between the 3 farms according to their years of production employing statistical analysis showed that even though some of these soils have been in production for many years, the good agricultural practices of their owners have influenced them so that they are not affected on a large scale.

Using the physical-chemical indicators, it was possible to verify their established ranges and their determined index; it used the statistical program InfoStat, to calculate the analysis of primary components and evaluate the soil quality through the Normalized ICA taking as a reference to Barrezueta et al. (2017); Jenner Barrera et al. (2020); and Wilson (2017). The analysis concluded that pitahaya monoculture does not represent a major alteration to these producing soils, since their owners work together with the municipality of the canton to implement good agricultural practices, this is demonstrated by the close values obtained between these three producing farms with different years of production, so it is evident that the difference in these results is not significant.

However, this does not mean that the monoculture of this crop cannot affect the surrounding soils since using fertilizers, fungicides, and pesticides can affect the soil. Furthermore, together with the climate of the Amazon, the remains of these products can reach virgin soils on the agricultural frontiers through runoff or infiltration.

A scheme was proposed for a model management plan for agricultural use that can be used for this type of land with crops, where the farmer can take as suggestions and include them in their good agricultural practices to continue establishing and producing crops friendly to the environment and especially with the soil resource that has become the main base for this canton to contribute significantly in the development and continued progress of the same with its production of pitahaya fruit.

5. References

Barrera, Jenner., Salomón. Barrezueta, and Rigoberto. García. 2020. "Evaluación de Los Índices de Calidad Del Suelo de Diversos Cultivos En Diferentes Condiciones Topográficas." Revista Metropolitana de Ciencias Aplicadas. 3(1):182–90. doi: ISSN: 2631-2662.

Barrera, Jenner, Salomón Barrezueta, and Rigoberto García. 2020. "EVALUATION OF SOIL QUALITY INDICES OF DIFFERENT CROPS UNDER DIFFERENT TOPOGRAPHIC CON-." REVISTA METROPOLITANA DE CIENCIAS APLICADAS, 183–90.

Barrezueta, Salomón, Antonio Paz, and Julio Chabla. 2017. "Determinación de Indicadores Para Calidad de Suelos Cultivados Con Cacao En Provincia de El Oro-Ecuador." Revista CUMBRES 3(1):17–24. doi: https://www.edafologia.net/revista/tomo13c/articulo125.pdf.

Bautista, A., J. Etchevers, R. .. Del Castillo, and C. Gutiérrez. 2004. "La Calida Del Suelo y Sus Indicadores." Ecosistemas, 90–97.

Burbano, Hernán. 2010. "El Suelo Al Servicio de La Sociedad y Su Rol En El Contexto de Los Cambios Globales." Tendencias 11(2):53–62.

Diéguez, Karel., Adriana. Zabala, Kasandra. Villarroel, and Liliana. Sarduy. 2020. "Evaluación Del Impacto Ambiental Del Cultivo de La Pitahaya , Cantón Palora , Ecuador." TecnoLógicas 23(49):113–28. doi: https://doi.org/10.22430/22565337.1621.

García, Y., Wendy Ramirez, and Saray Sánchez. 2012. "Indicadores de La Calidad de Los Suelos: Una Nueva Manera de Evaluar Este Recurso." Pastos y Forrajes 35(2):125–37.

Gómez, Anyi, and Wendy Hoyos. 2020. "Evaluación de La Calidad de Un Suelo Sometido a Diferentes Usos." Universidad de los LLanos.

Huachi, Laura, Elizabeth Yugsi, María Fernanda Paredes, Daniel Coronel, and Pablo Coba. 2015. "DESARROLLO DE LA PITAHAYA (Cereus SP.) EN ECUADOR." La Granja_ Revista de Ciencias de La Vida 22(2):50–58. doi: 10.17163/lgr.n22.2015.05.

Leal, Sergio., Ana. Valenzuela, María de Lourdes. Gutiérrez, María del Carmen. Bermúdez, Jaqueline. Garcia, María Lourdes Aldana, Patricia. Grajeda, María. Silveira, María Mercedes. Meza, Susana. Palma, Germán. Leyva, Beatriz. Camarena, and Clara Valenzuela. 2014. "RESIDUOS DE PLAGUICIDAS ORGANOCLORADOS EN SUELOS AGRÍCOLAS." TERRA LATINOAMERICANA 32(1):1–11. doi: ISSN 2395-8030.

Martínez, Karla. 2018. "'EVALUACIÓN DE LA CALIDAD DEL SUELO DE LA FARM PALMICULTORA LAS PALMERAS, CANTÓN LA CONCORDIA.'" Escuela Superior Politécnica de Chimborazo.

Moreno, Carla., María Isabel. González, and José Antonio. Egido. 2015. "Influencia Del Manejo Sobre La Calidad Del Suelo." Ecuador Es Calidad, 1–8.

Municipio de Palora. 2022. "GAD Municipal de Palora." GAD Municipal de Palora. Retrieved (https://www.palora.gob.ec/web/home).

Novillo, Indira., Manuel. Carrillo, Jessica. Cargua, Virginia. Moreira, Karla. Albán, and Fátima Morales. 2018. "Propiedades Físicas Del Suelo En Diferentes Sistemas Agrícolas En La Provincia de Los Ríos." TEMAS AGRARIOS 23(2):177–87.

Quezada, Vicente., Marco. Avila, and Yonimiler. Castillo. 2021. "Propuesta de Lineamientos Normativos Para El Uso Del Suelo Rural En El Caso Del Cantón Palora – Provincia de Morona Santiago." Ciencia Digital, 114–32.

Silva, Sandra, and Francisco Correa. 2009. "Análisis de La Contaminación Del Suelo: Revisión de La Normativa y Posibilidades de Regulación Económica." Semestre Económico 12(23):13–34.

SIPA. 2021. INFORMACIÓN PRODUCTIVA TERRITORIAL: CIFRAS AGROPRODUCTIVAS 2021.

Suquilanda, Manuel. 2008. “El Deterioro De Los Suelos En El Ecuador Y La Produccion Agricola.” XI Congreso Ecuatoriano de La Ciencia Del Suelo 1–10.

TULSMA. 2015. “LIBRO VI. ANEXO 2. NORMA DE CALIDAD AMBIENTAL DEL RECURSO SUELO Y CRITERIOS DE REMEDIACIÓN PARA SUELOS CONTAMINADOS.” 31.

Vargas-Tierras, Yadira, Alejandra Díaz, Carlos Caicedo, Julio Macas, Alfonso Suárez-Tapia, and William Viera. 2021. “Benefits of Legume Species in an Agroforestry Production System of Yellow Pitahaya in the Ecuadorian Amazon.” Sustainability (Switzerland) 13(16). doi: 10.3390/su13169261.

Vargas, Yadira, Jimmy Pico, Alejandra Díaz, Dennis Sotomayor, Armando Burbano, Carlos Caicedo, Nelly Paredes, Carlos Congo, Leider Tinoco, Servio Bastidas, Javier Chuquimarca, Julio Macas, and William Viera. 2020. Manual Del Cultivo de Pitahaya Para La Amazonia Ecuatoriana.

Wilson, Marcelo. 2017. Manual de Indicadores de Calidad Del Suelo Para Las Ecorregiones de Argentina. 1a ed.