Publisher: Sapienza Grupo Editorial
R. Santa Cruz, 2187, Vila Mariana
São Paulo, Brazil
editor@sapienzaeditorial.com

Sapienza
International Journal of Interdisciplinary Studies
ISSN: 2675-9780

Contamination of the Esmeraldas River basin by industrial wastes from palm cultivation

Contaminação da bacia do Rio Esmeraldas por resíduos industriais da palma

Contaminación de la cuenca Río Esmeraldas por desechos industriales de la palmicultura

Enma Elena Espinoza-Echeverría
https://orcid.org/0000-0002-7650-5318
Graduate Researcher. Technical University Luis Vargas Torres de Esmeraldas, Ecuador.
enma.espinoza@utelvt.edu.ec (correspondence)

María Elizabeth Canchingre-Bone
https://orcid.org/0000-0002-5575-9327
Graduate Researcher. Technical University Luis Vargas Torres de Esmeraldas, Ecuador.
elizabeth.canchingre@utelvt.edu.ec

Sara Elizabeth Tenorio Segura
https://orcid.org/0000-0002-9749-1103
Graduate Researcher. Technical University Luis Vargas Torres de Esmeraldas, Ecuador.
sara.tenorio.segura@utelvt.edu.ec

Víctor Arroyo Quiñonez
https://orcid.org/0000-0002-0711-4065
Graduate Researcher. Technical University Luis Vargas Torres de Esmeraldas, Ecuador.
victor.arroyo.quinonez@utelvt.edu.ec

ARTICLE HISTORY

Received: 19-03-2023
Revised Version: 04-07-2023
Accepted: 28-07-2023
Published: 30-07-2023

Manuscript type: Article

ARTICLE INFORMATIONS

Science-Metrix Classification (Domain):
Applied Sciences
Main topic:
Palm cultivation
Main practical implications:
The results presented can serve as a guide for the design of future public policies involving palm oil production wastes treatment.
Originality/value:
The article addresses in detail a subject that has been little explored in applied sciences in the Ecuadorian context.

ABSTRACT

The objective of this collection of information is to analyze the impacts generated by oil palm industrialization waste as pollutants in the lower basin of the Esmeraldas River in order to contribute theoretical information to its mitigation processes. Around the lower basin there is a group of 12 oil extraction plants in which they carry out their industrialization process of the fruit, generating liquid waste that is evacuated to the nearest tributaries, causing eutrophication problems, contamination of aquatic systems and health. of the population. Regarding the methodology, an analytical method was applied where information was extracted from completely reliable primary and secondary, physical and virtual sources of the topic raised. Using the aforementioned methodology, we leave the field open to carry out other investigations on the conditions of treatment and subsequent management of palm cultivation residues, since the bibliography is very brief regarding the final disposal of waste from of the extraction process, some documented cases on the production of fertilizers and fertilizers themselves.

Keywords: pollution, Esmeraldas River, industrial waste, oil palm, eutrophication.

RESUMO

O objetivo desta coleta de informações é analisar os impactos gerados pelos resíduos da industrialização do dendê como poluentes na bacia inferior do rio Esmeraldas, a fim de contribuir com informações teóricas para seus processos de mitigação. Ao redor da bacia inferior existe um grupo de 12 plantas de extração de óleo nas quais realizam o processo de industrialização da fruta, gerando resíduos líquidos que são evacuados para os afluentes mais próximos, causando problemas de eutrofização, contaminação dos sistemas aquáticos e da saúde. da população. Em relação à metodologia, foi aplicado um método analítico onde as informações foram extraídas de fontes primárias e secundárias, físicas e virtuais totalmente confiáveis do tema levantado. Com a referida metodologia, deixamos campo aberto para outras investigações sobre as condições de tratamento e posterior manejo dos resíduos da dendê, visto que a bibliografia é muito escassa quanto à disposição final dos resíduos provenientes do processo de extração, alguns casos documentados sobre a produção de fertilizantes e os próprios fertilizantes.

Palabras clave: poluição, Rio Esmeraldas, resíduos industriais, dendê, eutrofização.

RESUMEN

El objetivo de esta recopilación de información es analizar los impactos que generan los desechos de la industrialización de la palma aceitera como contaminantes en la cuenca baja del Río Esmeraldas para contribuir con información teórica a los procesos de su mitigación. Alrededor de la cuenca baja se encuentran un grupo de 12 plantas extractoras de aceite en la cuales realizan su proceso de industrialización del fruto generando residuos líquidos que son evacuados a las afluentes más cercanas provocándole problemas de eutroficación, contaminación a los sistemas acuáticos y en la salud de la población. En cuanto a la metodología se aplicó un método analítico donde se extrajo información de fuente primarias y secundarias, físicas y virtuales completamente confiables del tema planteado. Utilizando la mencionada metodología dejamos el campo abierto para realizar otras investigaciones sobre las condiciones de tratamiento y manejo posterior de los residuos de la palmicultura, ya que la bibliografía es muy escueta respecto a la disposición final de los desechos provenientes del proceso de extracción, algunos casos documentados sobre la producción de fertilizantes y abonos los mismos.

Palavras-chave: contaminación, Río Esmeraldas, desechos industriales, palma aceitera, eutroficación.

INTRODUCTION

Ecuador, a South American country with 283 561 km², and a population of 17'172,098 inhabitants, sustains its economy on agricultural activity, contributing 8% to its gross domestic product, of which 0.79% (INEC, 2019) comes from the cultivation of oil palm (*Elaeis guineensis*) with 200 908 hectares planted at the country level and 109 399 at the level of the province of Esmeraldas (General Coordination of Planning, 2020).

The Lower Esmeraldas River Basin is irrigating an area of great agricultural importance, as it is formed by the union of the Blanco, Quinindé, Viche, Teaone and smaller drains with an approximate length of 141 km, which flow into the Pacific Ocean, next to the city of Esmeraldas. This area is where oil palm crop production is concentrated (Sierra Márquez et al., 2017).

The cultivation of oil palm, treated as a monoculture to satisfy the fruit production demands of the different industries located along the lower basin of the Esmeraldas River, has not only depleted the soil by more than 45%, but the residues of its industrialization are released into the surface waters of the river, causing highly dangerous effects for living beings, according to the environmental organization Acción Ecológica and the Ministry of Environment and Water: "the communities surrounding the palm oil companies are extremely vulnerable... some of these processes such as: decantation, sterilization and centrifugation, generate a large amount of liquid effluents containing organic matter with high nitrogen (N), phosphorus (P) and potassium (K) content, which generate problems of eutrophication and contamination that increase phytoplankton populations, causing disturbances to aquatic ecosystems, water pollution, loss of biodiversity and effects on the health of the population" (Sierra Márquez et al., 2017).

Currently there are 40 extractors in the different production areas in the country 6 processors specialized in oil 4 in soap among which we can mention: Danec, La Fabril, Ales, Epacem, La Joya, Olytrasa (Corporación Financiera Nacional, 2017).

Man has to satisfy his basic needs and must use natural resources not his ambitions, for all is known that any intervention against nature generates negative effects which over time can be transformed into positive impacts, is the challenge that humanity has to solve for the subsistence of future generations without compromising future generations, to maintain the balance between production and conservation of the same.

Based on these premises, the study of the contamination of the Esmeraldas river basin by industrial wastes from palm cultivation is proposed, with the purpose of analyzing the repercussions of these wastes as contaminants in the Esmeraldas river basin in order to contribute with theoretical information to the processes of mitigation of their impacts, for which we will try to identify the types of wastes, disposal mechanism used, with a scientifically supported description that will serve as a basis for future research.

Background of the problem

In 2021, the United States Department of Agriculture (USDA) projects that world production of palm oil will be 75.46 million tons, higher than last year's production of 73.23 million tons, marketed in several countries, such as Colombia, Venezuela, Mexico, Peru and some European countries, generating foreign exchange earnings of more than US $180 million, according to studies by FEDAPAL (Federico & Jarrín, 2011).

As of the great economic globalization (Vite Pérez, 2006) entering the 21st century [year 2000], world policies are accentuated, which give way to the emergence of extractive industries at national level, in 1995 Esmeraldas had an area of 33,343 hectares of oil palm cultivated, this area grew rapidly to 83.789 hectares in 2005 (Potter, 2010), increasing the trend of exporting processed materials; positioning palm oil among the main items with a contribution of 4% to agricultural GDP with an average in the exporting producer sector of 8% annually between 2010 - 2016, while 58% of the national production of palm oil is exported, placing Ecuador in the seventh place of oil producers in the world (Ronderos & Cárdenas, 2019).

The Province of Esmeraldas is one of the 24 provinces that make up the Republic of Ecuador and is inhabited by 643,654 people. It is located in the geographical area known as the littoral region or coast. Its administrative capital is the city of Esmeraldas, which is also its largest and most populated city, with a territory of 14,893 km², making it the seventh largest province in the country (Coordinación General de Planificación, 2020).

The processing of fresh oil palm fruit bunches (FFP) results in a concomitant process as the waste is discharged into the effluents surrounding the oil extraction plants. In previous years, plant residues were burned and the ash from the bunches was incorporated into the plantation as a source of fertilizer. With the strict compliance of the regulation that prohibits burning, the RV are now returned to the field used as a substrate (Basiron et al., 1996), the same that are processed by 40 extractors in the different zones in the country, 6 processors in oil 4 in soap factory among which we can mention: Danec, La Fabril, Ales, Epacem, La Joya, Olitrasa (Corporación Financiera Nacional).

According to United Nations data, African palm has a high water footprint of 5,000 m3 per ton. Oil palm plantations require the use of agrochemicals, such as malathion, which is a pesticide used to eliminate insects such as flies that land on

the palm fruit. The constant use of these types of agrochemicals contaminates water sources, causing damage not only to the river but also to the species that inhabit the environment.

The hydrographic system of the Esmeraldas River is formed by the Blanco, Guayllabamba, Toachi and Quinindé rivers and covers 20,000 km². Its source is in the thaws of the mountain range and the Guayllabamba River is the longest tributary that collects the waters from the north of the inter-Andean alley. From the confluence of the Esmeralda and Guayllabamba in Quinindé (Rosa Zarate) to the mouth it is navigable. The capital, Esmeraldas, is located 3 km from the mouth. Quinindé is a territorial entity belonging to the province of Esmeraldas, with a population of 150,000 inhabitants, its economy is based on agriculture, livestock, industry and commerce. Due to the large extension of oil palm cultivation, it is considered the first palm-growing canton in the country (Fernando & Villacreses, 2020).

It takes 5000 m3 of water to extract oil from one ton of *Elaeis guineensis* palm fruit, if we multiply this need by the amount of metric tons of palm oil produced in Ecuador 320,408 MT [2017] (España John & María Cuvi, 2018), we will have a basic idea of the amount of water use that corresponds to the oil extraction process in the palm oil industry. In the end, the analysis of the volume of water used for productive purposes in the case of oil leads us to ask ourselves, what is the final destination of the water used in the production of oil by the industry.

On this question we are left with some inconclusive answers and specific cases of environmental accidents, for example "affectations caused by spillage of activated sludge occurred in the La Independencia sector of the Quinindé canton" (Paredes Alava et al... 2020), 2020), shed light on the damage caused to the ichthyological diversity and bioaquatic fauna of the water demarcations where these fluids are dumped without proper treatment. With respect to the specific case of Quinindé canton, the incident contaminated the White River by 42.9% due to the direct discharge of activated sludge from the SOPALIN factory, causing significant damage to the flora and fauna of the area by 85.7%, harming the local farmers due to the economic losses incurred (Paredes Alava et al., 2020).

The impacts of leachates, or spills from the oil palm industry along the lower Esmeraldas River basin, are very little documented, despite the complaints filed by the riverside inhabitants to the authorities in charge of the public entities that are responsible for the care of natural resources, therefore, it is very necessary to know and study them in order to take measures to avoid the environmental damages derived from them.

Literature review

General information about the crop

Oil palm cultivation in Ecuador began in the 1950s, on a 52-hectare property. This plantation could rather be described as a test of adaptation of the crop to the agro-climatic conditions of the country (Agronomist & Stalin Rivera Figueroa, 2020).

The African palm takes between 2 and 3 years to start producing fruits and can do so for more than 25 years, these fruits are born in thousands, in ovoid shape, to form compact clusters weighing between 10 and 40 kg. The fruits are dark violet, almost black, that when they reach maturity acquire a cheerful and colorful reddish-orange color, whose interior holds a single seed, the kernel or palm kernel, which they protect with the endocarp or woody bone surrounded in turn by a fleshy pulp. Both the kernel and pulp generously provide oil, the former, palm kernel oil and the latter, palm oil itself (Benavides Fueltala, 2017).

Through the last palm census conducted in 2017 by ANCUPA - FEDESPAL - AEXPALMA - APROGRASEC and MAG, it was determined that palm producers are distributed in 13 provinces nationwide, having Esmeraldas in first place with a total of 116,430.48 has, occupying 58 cantons and 144 parishes. Regarding the percentage of plantations, 51.41% is represented by farms of up to 10 hectares, while the lowest percentage is represented by the range of areas larger than 1,000 hectares, with 0.22% in plantations (Agronomist & Stalin Rivera Figueroa, 2020).

African palm fruit

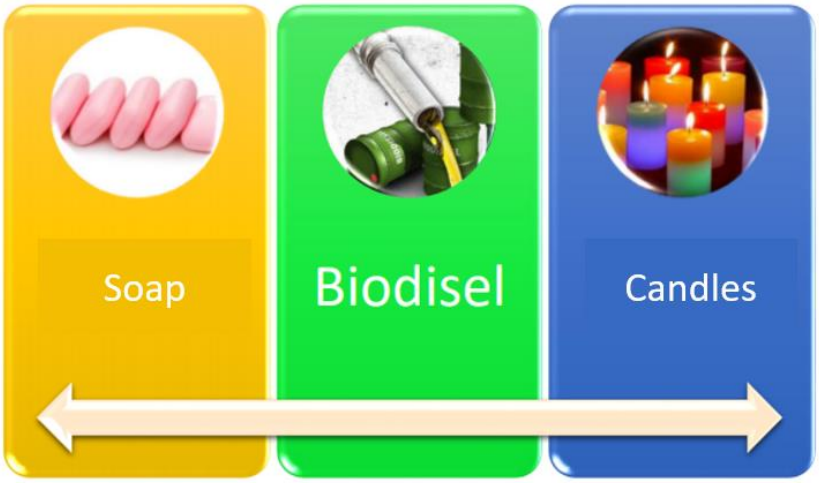
The African palm fruit is ovoid in shape, 3 to 6 cm long and weighs approximately 5 to 12 grams. They have a smooth and shiny skin (Exocarp), a pulp or fibrous tissue containing the cells with oil (Mesocarp), a nut or seed composed of a lignified kernel (Endocarp), and an oily kernel or palm kernel (Endosperm). The fruits inserted in the spikelets that surround the rachis in a helical shape, form the clusters (with variable weight between 5 to 40 kg) (Gonzáles & Alvarado, 2017).

African Palm Derivatives

Palm oil is important for daily consumption, so there are two main derivatives, crude palm oil and palm kernel oil, which are obtained from the pulp of the African palm fruit, respectively. From these, products such as: Bleached Palm Kernel Oils, RBD Palm Kernel, High Oleic Palm, RBD Refined Palm, Stearin, Olein, Palm Distilled Fatty Acids, Palm Biodiesel and Palm Kernel Cake are obtained (Holguín, 2018).

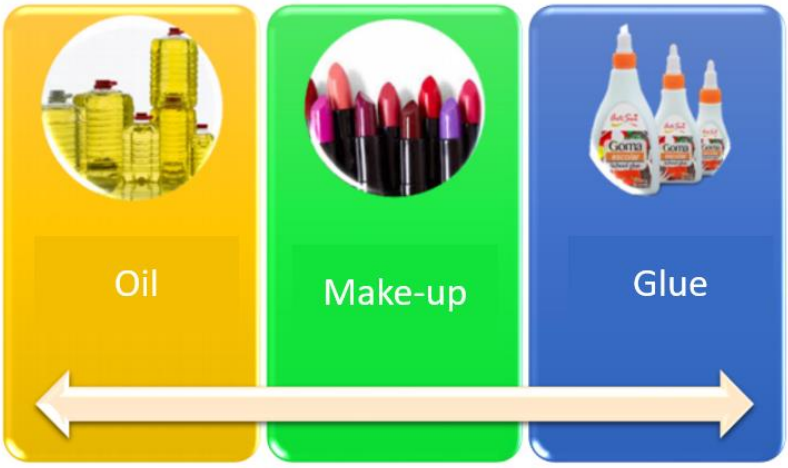
That is to say that from the African Palm are derived several products for human consumption, which vary in cost according to their level of added value, goods that are important to improve the quality of life of human beings.

Figure 1. Palm derivatives.



Source: (Ponce Mora, 2018)

Figure 2. Other African palm derivatives.



Source: (Ponce Mora, 2018)

Conditions of the factors for production

Oil palm is grown especially in warm environments, it needs some special conditions for its production, that is to say, some aspects such as climate and soil type must necessarily be considered.

Soil specifications

To improve the development and yield of the crop from which palm oil is obtained, the type of soil must have a loam-loam to loam-clay texture, i.e. surfaces with a high percentage of porosity and a pH range of 5 to 6.5 this helps the correct development of the roots of the crop in its early stages, allowing its normal growth (Holguín, 2018).

Importance of the crop

Oil palm has been considered one of the fastest growing crops in Ecuadorian territory, having a total production of 280 000 hectares planted and an annual production of 500 000 tons of crude oil, of which about 300 000 tons are exportable (Gonzales & Alvarado, 2017), additional it must be taken into account that the crop needs an adequate fertilization plan considering the high nutritional requirements.

The economic importance of African palm (Elaeis guineensis Jacq) cultivation in the country drives its continuous and

accelerated growth, i.e. African palm production generates approximately 60,000 jobs and it is estimated that another 30,000 people are employed in activities related to the crop, such as marketing and industrialization of the fruit, according to data presented by MAGAP (Ayala Mantilla, 2012).

Palm oil in both crude and refined state is a great natural source of vitamins and nutrients, being an efficient alternative to produce food free of trans fatty acids, in Ecuador there are 7000 palm growers, 87% are small producers, the cultivation and processing of palm generates in the country more than 150 thousand jobs, the main irrigation methods used in its cultivation are sprinkling (32.35%) and micro-sprinkling (47.56%) (Corporación Financiera Nacional, 2017).

In reference to the price in 2016 the local price per metric ton on average had a value of USD 633 dollars, while the international CIF price of a metric ton in 2016 had a value of USD 700.19 and as of August 2017 is at USD 674 dollars per metric ton (National Finance Corporation, 2017).

However, by-products such as biomass, liquid effluents, activated charcoal from the cuesco and even the leaves of the plant, represent a value as they can be used in handicrafts, biocomposites, furniture, among others (Sierra Márquez et al., 2017).

Weather conditions

This crop must be established in climatic conditions with a temperature ranging between 21 and 28°C and a rainfall of between 1800 and 2200 mm, the relative humidity must be greater than 75% (Holguín, 2018), so that the crops from which palm oil is obtained obtain an optimal yield in its production, since if this is not met this could harm its natural growth process; therefore, deep, loose soils with good drainage are the most favorable for the growth of oil palm.

The African palm is a species that adapts well to altitudes of up to 500 meters above sea level and can be successfully planted on hilly terrain with slopes greater than 20°C, preferring flat or slightly undulating terrain with slopes no steeper than 15°C. This reduces establishment costs, harvesting and erosion risks. This reduces establishment and harvesting costs and erosion risks.

History of the oil palm (*Elaeis guineensis*)

The oil palm is native to the coasts of the Gulf of Guinea in West Africa, it was introduced in the American continent in the sixteenth century, there are two species in the genus Elaeis: the cultivated oil palm E. guineensis Jacq. and E. oleifera hbk, (Billotte, 2016) in countries such as Malaysia, Indonesia, Thailand and Nigeria, they concentrate 81.7% of production and about 80% of the world area. (Sierra Márquez et al., 2017).

In Latin America, the area planted between 2006 and 2013 grew by 73%, the countries with the highest growth were Mexico (275%), Panama (187%), Guatemala (185%) and Peru (167%).

Ecuador is the sixth largest producer of palm oil worldwide, a position it shares with 39 countries according to (MAGAP - SINAGAP, 2013), its geographical location favors the cultivation of African palm and its good adaptation to different latitudes data (Nieto, 2015).

Palm oil trade has grown 500% between 1996 and 2013. In these years, palm oil's share of the vegetable oil market increased from 8% to 58% (Billotte, 2016).

Oil palm is the world's most efficient oil crop, that is, the one that produces the highest amount of vegetable oil per hectare planted, and is concentrated in Southeast Asia, where countries such as Indonesia and Malaysia account for more than 85% of the world's oil production. Despite this geographic concentration, the industry is constantly looking for new areas of expansion.

Oil palm production is located in the coastal region, specifically in the province of Esmeraldas, on inceptisol soils. The 2016 INEC census showed a percentage of production in the provinces of Santo Domingo with 8.72, Los Rios 13.19%, Esmeraldas 50.73%; observing a decrease of the product in the fields, but we must emphasize that oil palm is a product of rapid development and has a great reception in international negotiations for the production of natural oils (INEC, 2019).

"At the national level, the harvested area presents a negative annual growth rate of 9.13%. Production presents a greater decrease with 25.18% compared to 2015, in 2016 1.05 million metric tons less than 2015. African palm crops are located mainly in the coastal region (INEC, 2019) (Rivera Grunauer, 2019).

Oil palm cultivation

Elaeis guineensis Jacq. reproduces sexually by seed since it is a strictly cross-pollinated plant, and crosses made to obtain progenies and hybrids must be directed to avoid variability in the offspring.

Generally, the first three years of oil palm cultivation require complete agronomic management, starting to produce

fruit from the thirtieth month and reaching its maximum production between the eighth and tenth year (Sierra Márquez et al., 2017).

It has a strong tubular stem that can reach up to 30 meters in height and ends in an apex with a vegetative bud protected by the young leaves and below these, the more adult ones are arranged in such a way that they give it a striking appearance (Rojas, 2017:10). Once the useful life of the plant is over, the trunk can be converted into wood strips, plywood, laminated wood veneers for the manufacture of furniture (Sierra Márquez et al., 2017).

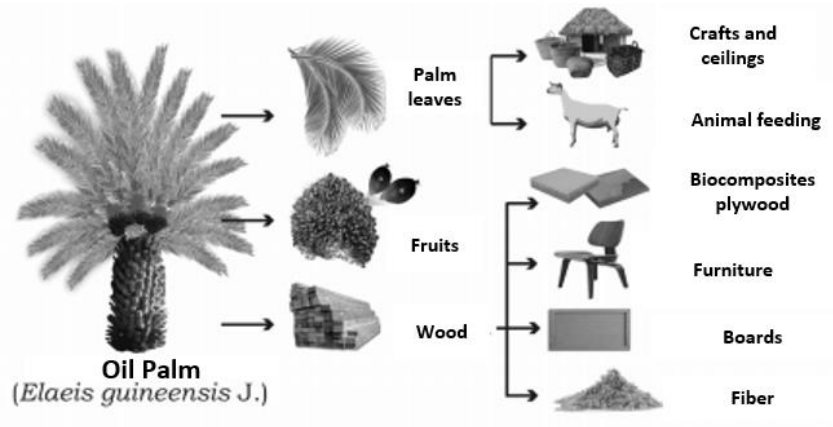
The African palm fruit is ovoid in shape, 3 to 6 cm long and weighs approximately 5 to 12 grams. They have a smooth and shiny skin (Exocarp), a pulp or fibrous tissue containing the cells with oil (Mesocarp), a nut or seed composed of a lignified kernel (Endocarp), and an oily kernel or palm kernel (Endosperm). The fruits inserted in the spikelets that surround the rachis in a helical form, form the clusters (with variable weight between 5 to 40 kg). The number of fruits that are shed daily is lower than in the rainy season. This causes the bunch cutting cycles to be 7 days during the rainy season and a maximum of 8 days during the dry season (Begoña & Kucharz, 2016).

According to Rojas (2017), "African palm leaves have a size of approximately 4 to 7 m in length, with a union of 200 to 300 leaflets in two planes arranged, has approximately a petiole of 1.5 meters long which spreads from its base, the inner side of the petiole is smooth and the outer side is rounded, its leaves are divided into ensiform laciniae joined downward" (Rojas Chapín, 2017).

The leaves of this plant have been evaluated in Malaysia for the feeding of growing goats, when treated with steam and supplemented with 30 g/kg urea. Results showed increases in consumption, digestibility, nitrogen absorption-retention and weight gain (Sierra Márquez et al., 2017).

It has been used as a base by-product in the production of plastic biocomposites for the manufacture of slates or boards, in the production of paper, in obtaining biomethanol, in the production of bioenergy through direct combustion systems, anaerobic digestion or pyrolysis in boilers together with the remains of the palm kernel cake, or in the generation of electricity, managing to supply the electrical needs of the mill, in the extraction of oil during three hundred days of operation (Sierra Márquez et al., 2017).

Figure 3. Utilization of African palm biomass: artisanal and industrial products reported for leaf material and stipe.



Source (Sierra Márquez et al., 2017)

Extraction process

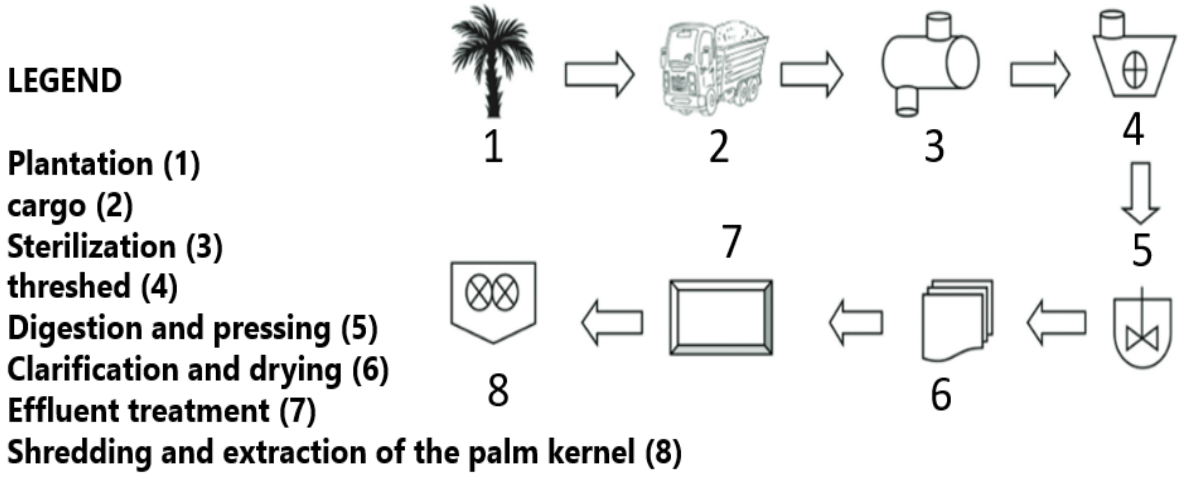
The fruit must be processed as soon as it is harvested, in order to avoid an increase in the content of free fatty acids that can affect the quality of the oil, which is why the extraction plants must be located close to the plantations.

The oil palm fruit undergoes a sterilization process, then the fruit is discarded from its rachis to be taken to the digesters, causing the mesocarp to be separated from the nuts to facilitate the extraction of the oil in the pressing process.

Once harvested, the three products of greatest commercial interest that are isolated from the palm are mesocarp oil, kernel oil and palm kernel cake, all obtained from the fruit bunch. Other by-products can be derived from this raw material by different physicochemical processes, such as olein, stearin, glycerin and fatty acids (Sierra Márquez et al., 2017).

However, by-products such as biomass, liquid effluents, activated charcoal from the cuesco and even the leaves of the plant, represent a value as they can be used in handicrafts, biocomposites, furniture, among others (Torres Ortega et al., 2017).

Fig.4 Description of the palm oil extraction process.



Palm oil

The fruit of the palm is reddish in color when ripe. Hundreds of these are attached to a cluster that can weigh up to 15 kg and when exposed to mechanical pressure can extract between 18 and 26% by weight of oil, with concentrations of carotenes between fifteen to seventeen times higher than those detected in carrots, in addition to a high presence of tocopherols, tocotrienols, phytosterols and phenolic compounds (Sierra Márquez et al., 2017).

Both mesocarp and kernel oil can be fractionated into olein and stearin. Olein, when mixed with oilseed oils, has the ability to withstand high temperatures for longer than other oils, so it is widely used for frying food in the manufacture of bakery, confectionery and ice cream products, as well as in the plasticizer industry, inputs that give flexibility to the final product. Stearin, due to its consistency and high degree of saturation, is used to produce margarines and soaps (Figure 2) (Sierra Márquez et al., 2017).

Biomass Residues

Like all plants, oil palm stores part of the energy produced in photosynthesis in the form of organic matter, which is made up of plant material such as leaves, trunk, empty bunches, fibrous material and other residues from oil industrialization (Sierra Márquez et al., 2017).

During the biomass pyrolysis process, ashes are produced that can be applied as an additive to cement, concrete or concrete (Figure 2), showing satisfactory results in strength tests, lower environmental impact and product cost. This residue increases the strength and ductility of concrete, and is used as an absorbent mechanism for flue gas desulfurization, with calcium hydroxide and calcium sulfate (Costs et al., 2018).

Almond shells are used as aggregate for the adequacy and maintenance of internal access roads to plantations, in the production of activated carbon, in wastewater and air purification processes, in the elaboration of natural filters, and may even have potential as a phytoremediant for the removal of heavy metals in wetlands (Sierra Márquez et al., 2017).

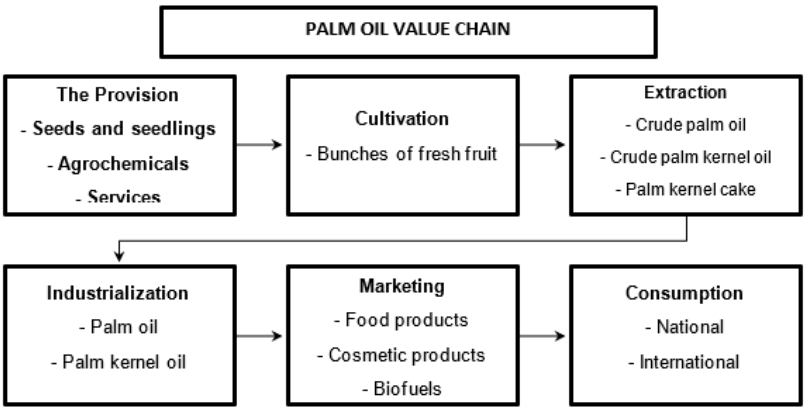
Wastewater

The decanting, sterilization and centrifugation processes generate a large amount of liquid effluents in proportions of 75, 17 and 8%, respectively. These mixtures contain significant amounts of organic matter with high nitrogen (N), phosphorus (P) and potassium (K) content, which when discharged into the environment can generate problems of eutrophication and groundwater contamination. To avoid effluent contamination, they must be treated in stabilization lagoons with anaerobic, facultative, methanogenic, aerobic and/or combinations of anaerobic processes. The final disposal of wastewater has been studied with the purpose of using it as fertilizer, and in composting processes with empty bunches as substrate for filamentous fungi decomposers of cellulose, hemicellulose and lignin (Sierra Márquez et al., 2017).

Derivative products

As indicated in the previous paragraph, the process of extraction of oil palm by-products is very well marked from beginning to end, however, for our analysis, it is also necessary to point out in a general way which are the products derived from oil palm, in this regard the range of products derived from oil palm are summarized in the following value chain**}**.

Fig.5 Description of the palm oil extraction process.



Source: Arroyo Víctor, Espinoza Enma, Estupiñán Iván, Tenorio Sara

Of the processes included in the value chain, the first two (Suppliers and Growers) correspond to the production and extraction process respectively, the next three (Extractors, Industrialists and Marketers) are covered in this section and the final process (Consumers) should be analyzed in the following section.

Extraction Process

In Ecuador there are 50 palm oil extraction plants, 12 of these are located in the Quinindé canton, let's see; Aceiteplacer, Danaima, Pexa, Aexav, Palcien, Palmera De Los Andes, La Comuna, La Sexta, Oleaginosas Del Castillo, Aiquiza, Danec and Unipal (Segura Caiza, 2017) from the extractors come two main products, i) crude palm oil and ii) crude palm kernel oil, from crude palm oil are obtained the by-products; RBD palm oil, RBD olein, RBD stearin, high oleic palm oil, distilled palm fatty acids and biodiesel, while the by-products of crude palm kernel oil are; bleached palm kernel oil, RBD palm kernel oil, RBD olein, RBD stearin and palm kernel cake (Holguín, 2018).

The aforementioned derivatives are part of the extraction process of red palm oil without refining, through a last refining the products are obtained; cooking oils, margarines, ice cream, special fats for bakery, soaps, cosmetics, printing inks, cleaning products, alkyd resins, animal feed (Holguín, 2018) between the years 2010 and 2020 in Ecuador an average of 2'539.614 metric tons of red palm oil (Gonzales & Alvarado, 2017), between the years 2006 and 2015 were harvested around 198.531 metric tons of palm fruit (Gonzales & Alvarado, 2017). Alvarado, 2017), within this context Ecuador is the second largest producer and exporter of palm oil in Latin America, production focused on production in the provinces of Esmeraldas, Santo Domingo, Guayas, Los Ríos, Manabí, in the coastal region, Cotopaxi and Bolívar in the highlands, and in the eastern region, Orellana and Sucumbíos (Tapia-Toral & Alvarado-Espinoza, 2018).

Export

4.1 % of the total red palm oil entering Europe comes from Ecuador, in Mexico these exports represent 7.4 % although the largest buyers of this Ecuadorian product are Venezuela and Colombia with a representation of 46.9 % and 35.2 % respectively (Gonzales & Alvarado, 2017).

Watersheds

The basic conceptualization of watersheds establishes that a watershed is a geographic area whose surface waters are discharged into a drainage system or common hydrological network formed by a river, it also contains its tributaries and it is also a water collecting area that can flow into a main river, lake, swamp, marsh, reservoir or directly into the sea. Its borders are marked by water dividing lines (Acuña Piedra & Campos Elizondo, 2018).

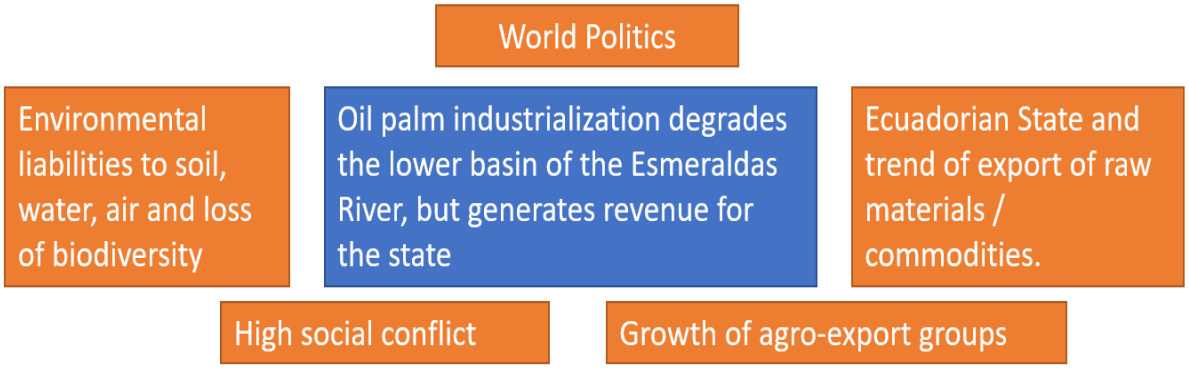
With respect to our case study, the total area that drains the basin corresponds to an area of 19665.10 km ,^{2} of which the Esmeraldas River occupies 53.31% of the study area, with 10483.25 km^2 , the highest point for the studies in this basin is located at 4100 m.The highest point for the studies in this basin is located at 4100 m.a.s.l., and the minimum elevation where the hydrometric station is located is approximately 120 m.a.s.l., located in the Quinindé canton (Pichasaca, 2020). The Esmeraldas River flows into the Pacific Ocean in the city of Esmeraldas, a territory that, according to the last INEC Census of 2010, has a population of 3088736 inhabitants.

Problematization

Oil palm industrialization is a degrading activity for the lower Esmeraldas River basin, but it is highly profitable for the Ecuadorian government.

The problem of oil palm cultivation at a global level is enclosed in a cycle that is rewritten in each of the territories where this activity takes place. In this article, the authors propose that this problem is circumscribed in the following scheme with the conceptual approaches that are developed below:

Figure 6. The problem of oil palm cultivation



Source: Arroyo Víctor, Espinoza Enma, Estupiñán Iván, Tenorio Sara

Global Policies

The expansion of oil palm in the global context corresponds to the growing demand for products for human consumption (vegetable oils), many of which are derived from this crop and are part of the cosmetics production chain. The world market for palm oil is dominated by Malaysia and Indonesia with 86% of tons of product of the global total, however around the world there are currently 18 million hectares cultivated (Borasino, 2016), a situation that requires a much broader view from the point of view of the actions taken by the States, to protect the affectations produced by the industrial process of obtaining palm oil, and its impact on the ichthyological biodiversity.

According to Elena Borasino, calculations on population growth, in addition to food production projections for humanity towards 2050, encourage palm cultivation to increase by a third of the total existing today, i.e. 6 million additional hectares, to cover the demand for palm oil, excluding from this analysis the production of biofuels derived from this product (Borasino, 2016), so we could quickly conclude, based on this analysis, that the policies of governments around the world, where this crop occurs naturally, will focus on increasing the areas of oil palm plantations in national territories.

The Ecuadorian State and the trend of raw material exports

In Ecuador, starting in 2013, the variable "CHANGE IN THE PRODUCTIVE MATRIX" was introduced as a national strategy, a variable that undoubtedly generated a starting point for the establishment of a new public policy on the institutionalization of investment funds, which would become the engine of this change in the productive matrix, which is concentrated on the production of raw materials. This policy that in the medium term was proposed to affect positively and significantly, Ecuador's trade relations and national competitiveness against foreign commodity markets (Palacios Molina & Reyes Vélez, 2016), lays its foundations in the objectives of the National Plan for Good Living, in that sense the plan indicates; "that the change in the matrix refers mainly to the diversification of national production, the sponsorship of different economic sectors and variety of use values: the extractivist, the industrial and agro-industrial" (Palacios Molina & Reyes Vélez, 2016, p. 420)

The Economic Commission for Latin America [ECLAC], which in 2012 in its Economic Survey of Latin America and the Caribbean, speaks of the imperatives of ensuring the full utilization of productive capacities and expanding the production frontier (ECLAC, 2012), so in Ecuador, in February 2013 the national government set as its main objective "to get out of extractivism, and establishing the prioritization of: biofuels, mariculture, refining, petrochemicals, shipyards, steel and metallurgy" (N. Díaz, et all, 2019), proposing biofuels as an important architect for the generation of this change to the productive matrix.

Growth of agroexport groups

The most outstanding national palm oil export groups in 2019 were Ciecopalma, La Fabril and Danec, taking into account that; (...), non-traditional exports were $5,312.1 million dollars FOB in 2019, of which vegetable extracts and oils contribute 3.1%, ranking 7th out of 21 products (Ronderos & Cardenas, 2019, p. 2).

High social conflict

The social conflicts that arise in the cultivation of oil palm are of diverse nature, most of them lie in the processes of accumulation by dispossession and even violent dispossession of the territories of natural and legal persons in rural communities far from large cities, however, the social problems mainly surround the processes of labor insecurity, violent

displacement, the rapid expansion of the agricultural frontier, the change in land use and therefore the change in the social activities of peoples and nationalities settled in territories that are now palm plantations (Castro, 2016).

In the northern area of the province of Esmeraldas, the absence of the state in palm-growing territories is notorious, shortcomings are listed and the model is replicated throughout the length and breadth of the most provided areas of oil palm cultivation in this area, then access to quality drinking water, electrical infrastructure, telecommunications, road infrastructure, the provision of public health, education and social welfare services are deficient (Arroyo, 2019), with respect to these assumptions it follows that under these conditions of poverty, exclusion, violence and discrimination, oil palm cultivation is very easily accentuated in some regions of the territory of the province of Esmeraldas (Roa Ovalle, 2018).

Permitted levels of contamination from palm oil extraction

With respect to this matter, it is of great importance the precepts established in the national regulation, same that will have as a premise to preserve water for human consumption and domestic use, water for the preservation of aquatic and wildlife life, agricultural or irrigation use, water for livestock use, water for recreational use, and water for aesthetic use (Official Register No. 387, 2015), from this standard we can rescue the following quality criteria as appropriate for human and domestic consumption.

Table1. Quality criteria for water sources for human and domestic consumption

Quality criteria for water sources for human and domestic consumption.			
Parameter	**Expressed as**	**Unit**	**Quality criteria**
Oils and Fats	Hexane soluble substances	mg/l	0,3
Arsenic	As	mg/l	0,1
Fecal Coliforms	NMP	MPN/100 ml	1000
Barium	Ba	mg/l	1
Cadmium	Cd	mg/l	0,02
Cyanide	CN-	mg/l	0,1
Copper	Cu	mg/l	2
Color	True color	Platinum-Cobalt Units	75
Hexavalent chromium	Cr +6	mg/l	0,05
Fluoride	F -	mg/l	1,5
Chemical Oxygen Demand	COD	mg/l	<4
Biochemical Oxygen Demand (5 days)	BOD5	mg/l	<2
Total iron	Faith	mg/l	1
Mercury	Hg	mg/l	0,006
Nitrates	NO3	mg/l	50
Nitrites	NO2	mg/l	0,2
Potential Hydrogen	pH	pH units	6-9
Lead	Pb	mg/l	0,01
Selenium	See	mg/l	0,01
Sulfates	SO4 -2	mg/l	500
Total Petroleum Hydrocarbons	TPH	mg/l	0,2
Turbidity	Nephelometric turbidity units	UNT	100

Source: own elaboration (2023)

METHODOLOGY

This research was carried out in the province of Esmeraldas, located in the Esmeraldas canton, at the following coordinates 78° 18' 51'' West longitude and 1°12' 21'' South latitude, at 132 meters above sea level. Since this is a bibliographic study, the analytical method was applied because the object of the study, which is "Contamination of the Esmeraldas River Basin by industrial waste from palm cultivation", requires an intensive treatment of each of the elements involved in the contamination process. The information was extracted from primary and secondary sources, both physical and virtual, completely reliable, such as scientific journals, websites - repositories, books and theses related to the topic .

RESULTS

The palm oil extraction process is limited to specific actions that correspond to the different stages through which the *Elaeis guineensis* fruit passes, which according to the researchers correspond to: i) reception of the fruit, ii) sterilization of the liquids from the fruit sterilization process, iii) fruit removal, iv) extraction of red palm oil, and v) clarification of the oil.

Table 2. Oil extraction process resiudual destination

The process	The residue	Destination of waste
Reception and washing of palm fruit.	Impurities	Fertilization of various plantations
Fruit sterilization.	Liquids	Liquid treatment pools
Fruity or pulped.	Rachis	Weed control in plantations of various crops
	Liquids	Liquid treatment pools
Extraction	Liquids	Liquid treatment pools
Clarification	Water and sewage sludge	Liquid treatment pools

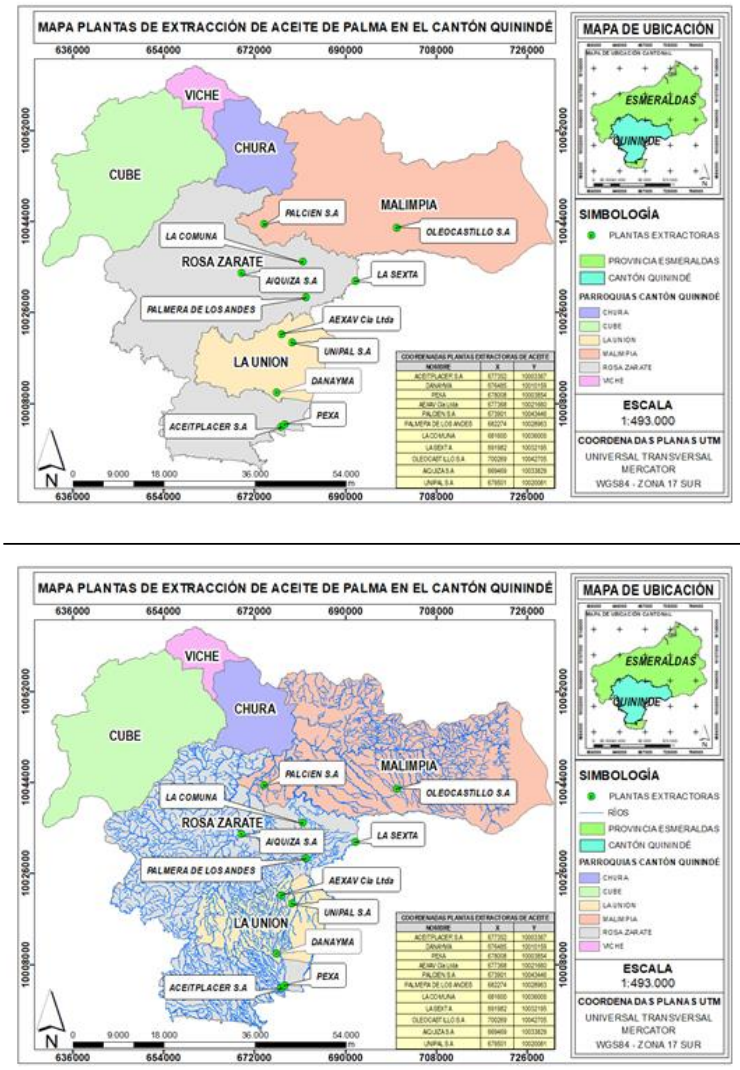
Source: own elaboration (2023)

From the above, it can be clearly identified that in four stages of the extraction process of red palm oil, liquid waste is generated and deposited in treatment ponds, of which there are not enough records on the conditions of treatment and subsequent management in Quinindé canton, in any case, the bibliography is very scarce regarding the final disposal of waste from the extraction process, some cases documented on the production of fertilizers and fertilizers.

The impacts of leachates, or spills from the oil palm industry along the lower Esmeraldas River basin, are very little documented, despite the complaints filed by the riverside inhabitants to the authorities in charge of the public entities that are responsible for the care of natural resources, therefore, it is very necessary to know and study them in order to take measures to avoid the environmental damage they cause.

With the bibliographic review and the generation of cartographic information, we were able to identify the location of the red palm oil extractors in the Quinindé canton, which are naturally arranged on the water demarcation network of the Esmeraldas River basin, as shown below. In order to carry out research on water, soil and air pollution.

Figure 5. Distribution of oil palm mills in Quinindé Canton.



Source: own elaboration (2023)

CONCLUSIONS

No specific record was found in the bibliography consulted, describing in precise detail what happens with the liquid waste generated in the palm oil extraction process, in addition to the above, there are also arguments from communities that denounce health impacts in the areas surrounding the red palm oil extractors (Rengam, Begoña & Kucharz, Reyes), which opens the door to further research and monitoring of these extractive processes in particular.

A total of 12 oil extractors were identified in the lower basin of the Esmeraldas River, located mainly in the Quinindé canton. With the information that has been visualized in the different sites observed through the bibliographic review, it is evident that there is not enough data on the final disposal of liquid wastes generated by the red palm oil industry.

REFERENCES

Acuña Piedra, J. F., & Campos Elizondo, M. J. (2018). Humedales de Costa Rica: frágiles ecosistemas bajo amenaza. *Ambientico*, 76. http://www.ambientico.una.ac.cr/pdfs/ambientico/269.pdf

Agrónomo, I., & Stalin Rivera Figueroa, J. (2020). Evaluación de dos herbicidas biológicos en el control de malezas en corona en el cultivo de palma africana (Elaeis guineensis Jacq.). In *UNIVERSIDAD TÉCNICA ESTATAL DE QUEVEDO FACULTAD DE CIENCIAS AGRARIAS CARRERA DE INGENIERÍA AGRONÓMICA*.

Ayala Mantilla, M. J. (2012). María José Ayala Mantilla. In *Análisis de la Huella de Carbono y del Crecimiento del Cultivo de la Palma Africana en el Ecuador*. http://192.188.53.14/bitstream/23000/2039/1/104355.pdf

Begoña, C., & Kucharz, T. (2016). La Insostenibilidad de los Monocultivos agro-industriales. *Terra*, *2015*, 1–26. http://www.ucm.es/info/ec/jec9/pdf/A08 - Fern%E1ndez Dur%E1n, Ram%F3n.pdf1%0Ahttp://antioquia.gov.co/Agricultura/Documentos/La_insostenibilidad_de_los_monocultivos_agroindustriales_como_la_palma_de_aceite.pdf%0Ahttps://spip.ecologistasenaccion.org/IMG/pdf

Benavides Fueltala, E. S. (2017). *Oferta de aceite de palma africana de Ecuador y la demanda del mercado colombiano*. UNIVERSIDAD POLITÉCNICA ESTATAL DEL CARCHI.

Billotte, N. (2016). Biotechnology and Breeding of Oil Palm : the Golden Palm of the Future. *Revista Palmas Vol. 37*, *37*(Tomo I), 159–174.

Coordinación General de Planificación, G. E. (2020). *Plan Estratégico Institucional*. 68–70.

Corporación Financiera Nacional. (2017). Ficha sectorial: Cultivo de Palma de Aceite. *GDGE – SUBG. De Análisis e Información*, 22. https://www.cfn.fin.ec/wp-content/uploads/2017/09/Ficha-Sectorial-Palmas-de-Aceite.pdf

Costs, E. P., Palms, O., Oil, C. P., & Producers, C. (2018). *Economic Production Costs for the Fruit of Oil Palms and Crude Palm Oil in 2016 : Estimation in a Group of Colombian Producers*. *39*(2), 13–26.

Gonzáles, B., & Alvarado, P. (2017). Análisis De La Producción De Aceite De Palma Africana En El Ecuador. *Tesis*, *PROYECTO DE FACTIBILIDAD TÉCNICA*, *ECONÓMICA Y FINANCIERA DEL CULTIVO DE OSTRA DEL PACÍFICO EN LA PARROQUIA MANGLARALTO*, *CANTÓN SANTA ELENA*, *PROVINCIA DE SANTA ELENA*, 121.

Holguín, A. (2018). *Las exportaciones de aceite de palma y su contribución al PIB agrícola de la economía ecuatoriana durante el período 2010-2016*.

INEC. (2019). Encuesta de superficie y producción agropecuaria continua. *Instituto Nacional de Estadísticas y Censos*, 23.

Pichasaca, R. (2020). *"MODELO INTEGRADO DE CAMBIO CLIMÁTICO Y RECURSOS HÍDRICOS EN LA CUENCA DEL RIO ESMERALDAS, PROVINCIA DE ESMERALDAS – ECUADOR*. UNIVERSIDAD DE ALCALA.

Ponce Mora, M. A. (2018). *La Palma africana: Producción y comercialización. Periodo 2015-2017"*.

Rivera Grunauer, R. E. (2019). *Características físicas, ubicación geográfica y calidad del suelo agrícola de las provincias de la costa ecuatoriana*. 29. http://repositorio.utmachala.edu.ec/handle/48000/10451

Rojas Chapín, O. G. (2017). *Respuesta de la palma africana (Elaeis guineensis Jacq.) bajo la aplicación de basacote, durante la etapa de pre vivero.* Quevedo: UTEQ.

Segura Caiza, J. P. (2017). *Análisis del proceso de comercialización del aceite de palma producido en el cantón Quinindé Provincia de Esmeraldas*. Ecuador PUCESE-Escuela de Comercio Exterior.

Sierra Márquez, J., Sierra Márquez, L., & Olivero-Verbel, J. (2017). Potencial económico de la palma aceitera (Elaeis guineensis Jacq). *Agronomía Mesoamericana*, *28*(2), 523. https://doi.org/10.15517/ma.v28i2.25927

Tapia-Toral, M. C., & Alvarado-Espinoza, F. G. (2018). Análisis correlacional entre la producción del aceite de palma, sus exportaciones y su contribución al PIB agrícola durante el período 2010 - 2017. *Dominio de Las Ciencias*, *4*(4), 270. https://doi.org/10.23857/dc.v4i4.840

Torres Ortega, J. A., Contento Rubio, O. F., & Herrera Orozco, I. (2017). Análisis de ciclo de vida para una biorefinería derivada de residuos agrícolas de palma aceitera (Elaeis guineeeensis). *Publicaciones e Investigación*, *11*(1), 13–36. https://doi.org/10.22490/25394088.2251

Contribution of each author to the manuscript:

	% of contribution of each author			
Task	**A1**	**A2**	**A3**	**A4**
A. theoretical and conceptual foundations and problematization:	25%	25%	25%	25%
B. data research and statistical analysis:	25%	25%	25%	25%
C. elaboration of figures and tables:	25%	25%	25%	25%
D. drafting, reviewing and writing of the text:	25%	25%	25%	25%
E. selection of bibliographical references	25%	25%	25%	25%
F. Other (please indicate)	-	-	-	-

Indication of conflict of interest:

There is no conflict of interest

Source of funding

There is no source of funding

Acknowledgments

There is no acknowledgments.