Articles

Circular economy vision for local development focused on waste derived from two agricultural crops in Ecuador

Visión de la economía circular para el desarrollo local enfocado en residuos derivados de dos cultivos agrícolas en Ecuador

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ABSTRACT
The circular economy is a fundamental axis to achieve sustainable development, applying these principles to the agricultural sector is essential, especially in countries that produce raw materials such as Ecuador. The objective of this research is to establish the use of residues derived from two agricultural crops in Ecuador, under a circular economy vision for local development. The inductive and deductive method was applied, the variables considered are the production of sugar cane and rice, based on this, the analytical method was used where the information obtained through surveys, interviews, literature review and data collected was interpreted. The results found show that sugar cane (Saccharum officinarum) cultivation in Ecuador represents 9% of the national agricultural GDP, and in the last decade an average of 81.5 ton/year*ha-1

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was cultivated, with an annual waste amount of 79,32283.38 ton*year-1 that represents an energy potential of 15746.26 TJ*year-1, On the other hand, rice (Oryza sativa) cultivation was cultivated with an average of 25.33 ton*year-1 at the national level, generating 2106695.86 ton*year-1 of annual residues of rice straw and husk, its energy potential of 28356.98 TJ*year-1. It is a real challenge in the country to opt for tools for the use of rice residues, since, although it is true that there are agroindustrial companies that have them, but there has not been an optimal organization in terms of waste generation with small producers engaged in this activity. however, despite the fact that the residues derived from these two add up to a great energy potential at the national level, it continues to be a challenge for Ecuador at present.

Keywords: sustainable development; energy potential; production process; waste.

RESUMEN

La economía circular es un eje fundamental para alcanzar el desarrollo sostenible, aplicar estos principios al sector agropecuario resulta fundamental, sobre todo en países productores de materias primas como el caso de Ecuador, siendo el objetivo de la presente investigación establecer el aprovechamiento de los residuos derivados de dos cultivos agrícolas en Ecuador, bajo una visión de la economía circular para el desarrollo local. Se aplicó el método inductivo y deductivo, las variables consideradas son la producción de caña de azúcar y arroz, en función a ello se empleó el método analítico donde se interpretó la información obtenida mediante encuestas, entrevista, revisión bibliográfica y datos recopilados. Los resultados encontrados demuestran que el cultivo de caña de azúcar (Saccharum officinarum), en Ecuador representa el 9% del PIB agrícola nacional, y en la última década se cultivó una media de 81,5 ton año*ha-1, con una cantidad de residuos anuales de 793283,38 ton*año-1 que representan un potencial energético 15746,26 TJ*año-1, Por otro lado, el cultivo de arroz (Oryza sativa) se cultivó con una media de 25.33 ton*año-1 a nivel nacional, generando 2106695,86 ton*año-1 de residuos anuales de paja y cascarilla de arroz, su potencial energético de 28356,98 TJ*año-1. Es un verdadero reto en el país optar por herramientas de aprovechamiento para los residuos del arroz, ya que, si bien es cierto, hay empresas agroindustriales que cuentan con aquello, pero no se ha llevado una organización óptima en cuanto la generación de residuos con los pequeños productores que se dedican a esta actividad.

no obstante, a pesar de que los residuos derivados de estos dos suman un gran potencial energético a nivel nacional continúa siendo un reto actualmente para Ecuador.

Palabras clave: desarrollo sostenible; potencial energético; proceso productivo; residuos.

INTRODUCTION

In the world, food production in agricultural crops is estimated to increase to 70% and 100% in developed countries, due to the strong demand for food that is expected by the year 2050 (FAO, 2011)However, the modern agricultural system is inefficient with waste management; in Europe, 700 million tons of agri-food waste are generated each year. (Toop et al., 2017)For this reason, the term sustainable agriculture sounds very promising to combat the increasing scarcity of natural resources that has generated concern in the world, despite the growing demand for food, the field of circular economy in the agricultural sector has not yet been adapted efficiently. (Velasco-Muñoz et al., 2021).

At the regional level (Latin America and the Caribbean), the circular economy is also proposed as a sustainable alternative for the development of agriculture (Burgo Bencomo et al., 2019). The main basis for applying circular economy principles to agricultural practices in the region is to move to "sustainable organic agriculture"; among the reasons is the lower degree of negative environmental impact generated by organic agriculture compared to conventional agriculture. (Anderson & Álvarez, 2021). However, the challenge lies in moving from large-scale agriculture, commodities and energy crops that drive deforestation and biodiversity loss to regenerative food systems; and how to create sustainable value chains for the new goods and services derived from biodiversity assets. (Mulder & Albaladejo, 2020).

Despite the challenge suggested by moving to a sustainable agriculture model, this is strictly necessary. According to FAO, in the region, 80% of the farms belong to family farming, including more than 60 million people. (FAO, 2014). All this results in the region consuming 9.3% of the pesticides used in the world and investing more than US$ 2.7 billion annually in pesticide imports. (Altieri & Nicholls, 2001). A specific case in the region is Peru, which has an important competitive strength for the development of the agricultural sector: biodiversity; however, the sector has developed under a linear economic model that is reaching its limits, causing, among other things, the degradation of soils due to this unsustainable model. (Altamirano et al., 2015).This model is reaching its limits, causing, among other things, soil degradation due to this unsustainable model; evidencing the importance of the search for a sustainable model over time.

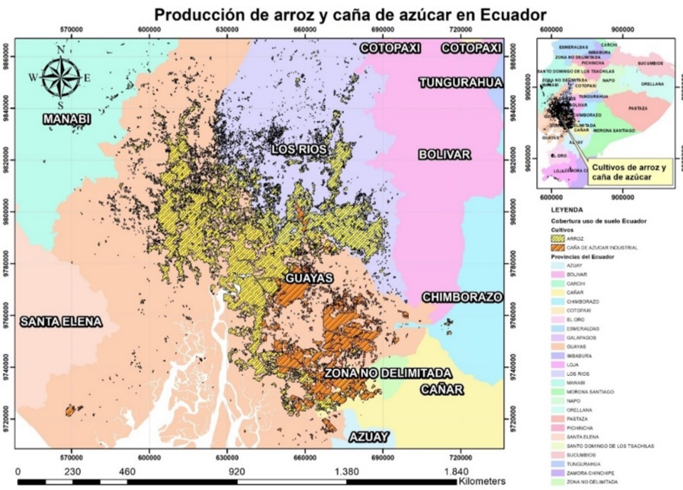
On a national scale, the principles of circular economy in agriculture are still scarce, especially in small farmers. For example, producers mention that organic fertilizers from their perception have better performance, however, prices are usually high, which leads to the continuity of the traditional method (use of chemical fertilizers). On the other hand, the useful organic residues generated in the production processes tend to be unused. A case in point is in the canton of Caluma, province of Bolivar, where cocoa shells are considered a waste product that is rarely used by farmers, much less by factories. (Gómez & Zapata, 2020)..

This study presents the use of residues derived from two agricultural crops in Ecuador, under a circular economy vision for local development. The production processes of perennial (sugar cane) and transitory (rice) crops generate residues that are not fully used for energy generation in Ecuador.

MATERIALS AND METHODS

The inductive and deductive method was applied, using primary and secondary sources of information and bibliographic information. The study analysis focuses on rice and sugar cane crops as sources of solid waste generation that can be used in agricultural activities; these crops are mostly concentrated in the province of Guayas and Los Ríos (Figure 1). Information gathering techniques were used, using a questionnaire based on the current regulations (Ministerial Agreement 061) of the Unified Text of Secondary Legislation, and the information obtained from historical series was projected using the equation of the straight line.

Figure 1. Rice and sugarcane producing provinces in Ecuador



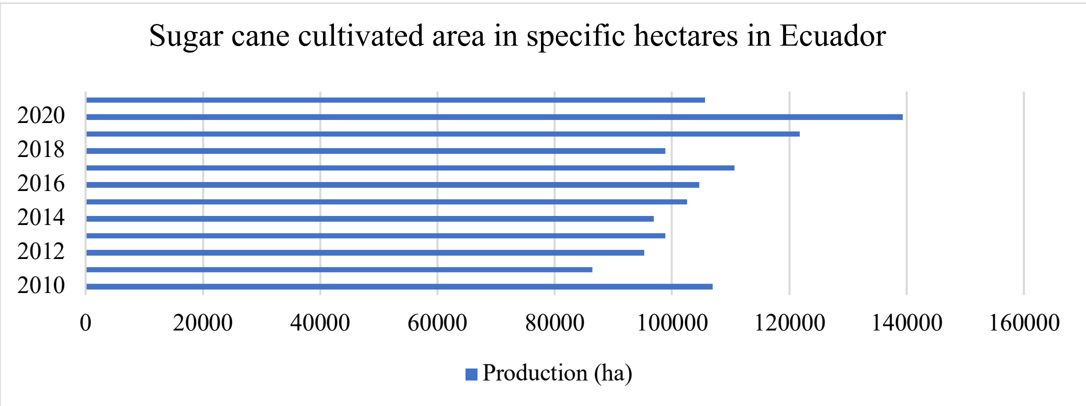
To determine the current situation of the application of circular economy principles in the sugarcane and rice production processes, the data provided by the Ministry of Agriculture, Livestock and Fisheries of Ecuador (MAGAP) in its Agricultural Public Information System (SIPA) and Bioenergy Atlas of Ecuador was used as the main information, obtaining the information in relation to the cultivated area and production per year of the crops.

RESULTS

The circular economy is a paradigm that seeks to generate economic progress while protecting the environment and avoiding pollution. (Sandoval et al., 2017)It serves to address the current problem of production models with increasingly high energy and environmental costs. (Balboa & Somonte, 2014). Therefore, on the basis of the circular economy, it is possible to affirm that agriculture as an economic sector must be governed under the framework of sustainability in order to be able to sustain itself over time. (Burgo Bencomo et al., 2019). applying ecological agriculture in harmony with nature based on the understanding of resources as a composite organism . (Koch, 2015). Therefore, the application of a sustainable model of agricultural production in Ecuador is fundamental to contribute to the sustainable development of the country.

Use of residues derived from sugarcane (Saccharum officinarum) cultivation. Figure 2 shows the hectares produced from sugarcane in Ecuador, which shows that the smallest cultivated area was in 2011 with 83,000 ha of production and the largest production was in 2020 with 1,400,000 ha, and this trend is maintained in the current period.

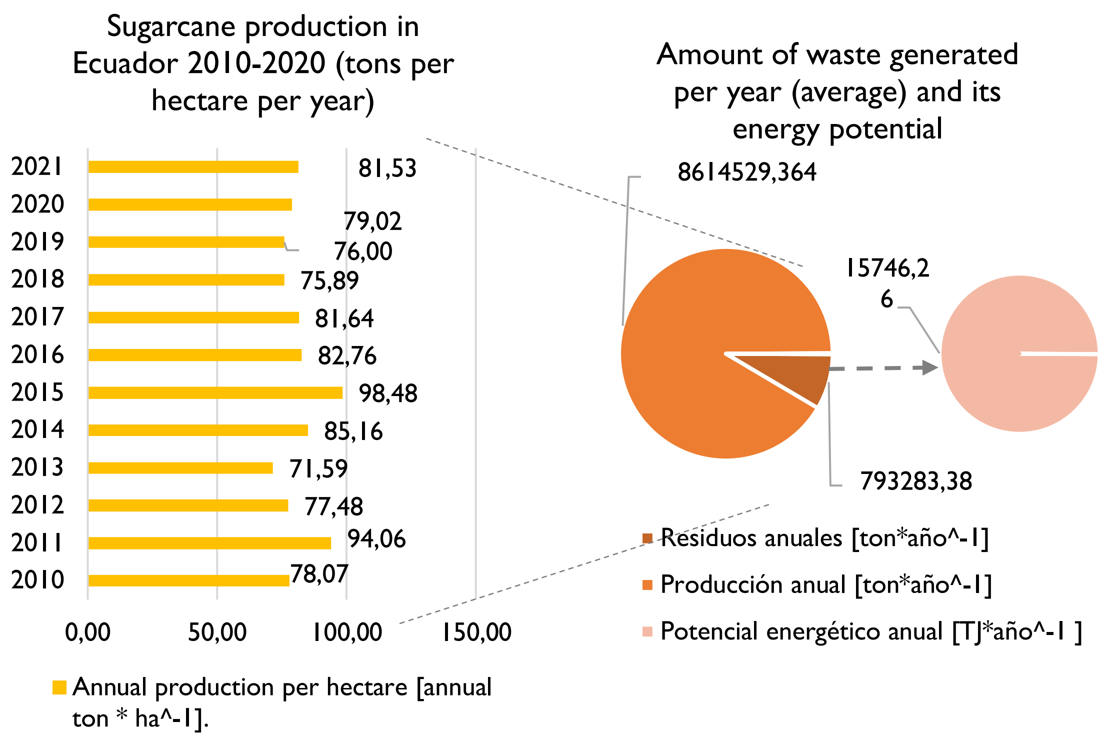
Figure 2. Hectares cultivated with sugarcane in Ecuador. (MAGAP, 2020)



From the entire cultivated area, significant amounts of usable residues are generated for the manufacture of various products. However, due to the great potential for utilization and the economic return that this means, many grow sugarcane no longer with the traditional intention (to produce refined sugar), but rather with the intention of manufacturing biofuel, which has generally been considered an alternative; according to data reported by (Salazar, 2014)from 2010 to 2013, the maximum number of hectares cultivated for biofuel production was 8945 ha, precisely in 2013, a situation that is presumed to have increased due to the boom in this type of fuel. The problem lies in the fact that these cultivated hectares are intended for the production of biofuel, losing the sense of the application of the principles of circular economy.

It is important to highlight the importance of this crop in the country based on figures that reveal its weight in Ecuador's GDP. Sugarcane cultivation represents 9% of the national agricultural GDP. In relation to the amount of waste generated from this productive process, and its respective energy potential, in the last decade an average of 81.5 tons per year*ha-1 was cultivated, with an annual waste amount of approximately 79,323,38 tons*year-1 in the entire national territory, representing an energy potential of 15746.26 TJ*year-1. The complete summary of figures can be seen in Figure 3.

Figure 3. Production, residues and energy potential of sugarcane in Ecuador, 2021. (INP et al., 2014; MAGAP, 2020).



Sugarcane production versus waste generated and energy potential, Ecuador.

The usable residues of this crop include branches, leaves and certain stems. In the sugarcane agroindustrial process, bagasse, cachaza and filter sludge can be used. (Roca-Pérez et al., 2017)The vinasse, which represents the largest organic residue of the process, can be used by means of physical and chemical treatments. (Cajamarca et al., 2018) Figure 3, it is possible to affirm that the cultivation of sugar cane is important in Ecuadorian territory. (Wisuthiphaet & Napathorn, 2016). is important in Ecuadorian territory. Due to the production process, it generates several usable residues that have not been fully utilized.

The model of waste utilization in the harvesting and agroindustrial processes is of utmost relevance in contributing to the sustainable development of the country; however, the linear economy model is still present in this and other productive processes. In Ecuador, there are cases of success, as well as cases in which the adaptation to the new time of sustainability has been a utopia. For example, the Ecuadorian company "El Ordeño" has adapted a production model by manufacturing cardboard packaging from sugarcane bagasse. (Ortiz Tinoco et al., 2021)However, there are also complications when the amount of bagasse produced is excessive, as is the case in the canton of Baños de Agua Santo, where 1.44 t/day of this waste is produced, which generates negative impacts to the environment (Moreno et al., 2012) The canton does not have the capacity/infrastructure to take advantage of its energy potential (the entire amount of waste generated), and its final destination is the canton itself, increasing environmental problems.

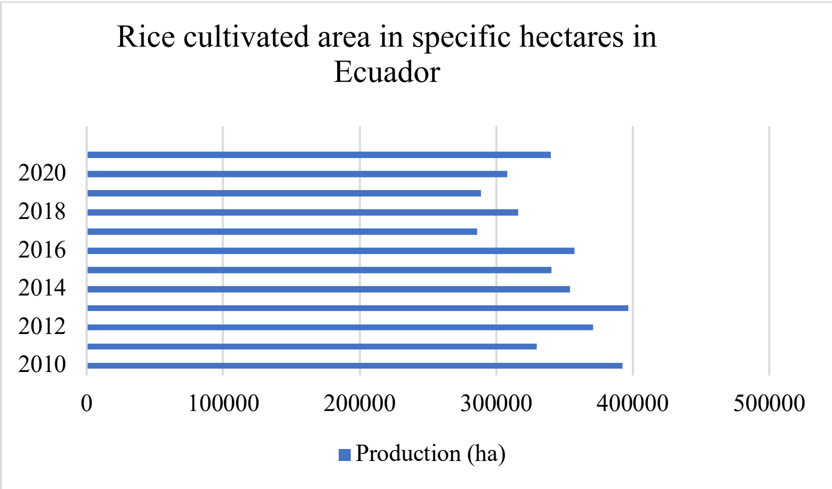
On the other hand, an efficient alternative for bagasse utilization is the cogeneration of energy to feed high-pressure boilers in sugar consortiums where this waste is generated. (Verdezoto et al., 2021)A great example is Azucarera Valdez, which generates energy from this waste. However, in spite of the large amount of sugar cane production, which results in a large amount of waste and great usable energy potential, there are few sources of energy from this waste. (INP et al., 2014)However, there are few sources that operate with such low environmental impact fuels as the one generated from sugarcane bagasse. (CONELEC, 2013). Another case is the organic residue of vinasse (produced in the agro-industrial process of sugar cane). In Ecuador, this residue is produced in large quantities in this process and is used for biofuel production. However, local consumers do not like it because of its cost, and it is more widely purchased abroad. (Cajamarca et al., 2018). On the other hand, biofuel from sugar cane is one of Ecuador's main commitments to sustainability. The problem lies in the fact that most of this biofuel production is done in a specific and intentional way; that is, it is not based on an integral use of other productive processes and the waste generated there.

From the results described above, it is evident that despite the fact that there is a great energy potential from the large amount of usable waste derived from the sugarcane production process in Ecuador, it is not used in the expected potential way. However, this is also the case in countries such as Colombia; according to (Zúñiga Cerón & Gandini Ayerbe, 2013) The residues produced from the harvest, such as leaves and buds, represent a contamination and health problem, so many are seeking to generate alternatives for reusing these by-products. The same is true in Peru, where, according to (Aldana et al., 2016) only 14.98% of the total hectares of sugarcane harvested in that country are used, despite the fact that there is great energy potential from the by-product residues. The problem in most of these sugarcane producing countries seems to be the lack of technological capacity and infrastructure to use these residues; for example, (Fleck Gallas, 2009) The problem in most of these sugar cane producing countries seems to be the lack of technological capacity and infrastructure to utilize these residues; for example, it mentions that the current sugar industries in Paraguay are not efficient enough to generate surplus bagasse that could be used in a large-scale utilization project.

Use of residues from rice (oryza sativa) cultivation

In Ecuador, the provinces with the highest rice crop generation focus are Guayas, Los Ríos, Loja and El Oro, with the most relevant production in 2013 with 380000 ha and the lowest in 2017 and 2019 with 270000 ha (Figure 4).

Figure 4. Hectares cultivated with rice. (MAGAP, 2020)



Current outlook for the utilization of derived wastes

Based on the initial perspective, it is important to highlight the importance of this crop in the country from figures that reveal its weight in Ecuador's GDP, as well as the large amount of waste generated in the production process; by virtue of this, rice cultivation during the last eleven years has managed to reach an average production value of 25.33 ton*year-1 at the national level, contributing with an amount of 210,6,695.86 ton*year-1 of annual rice straw and husk residues, resulting in an energy potential of 28,356.98 TJ*year-1 (Figure 5).

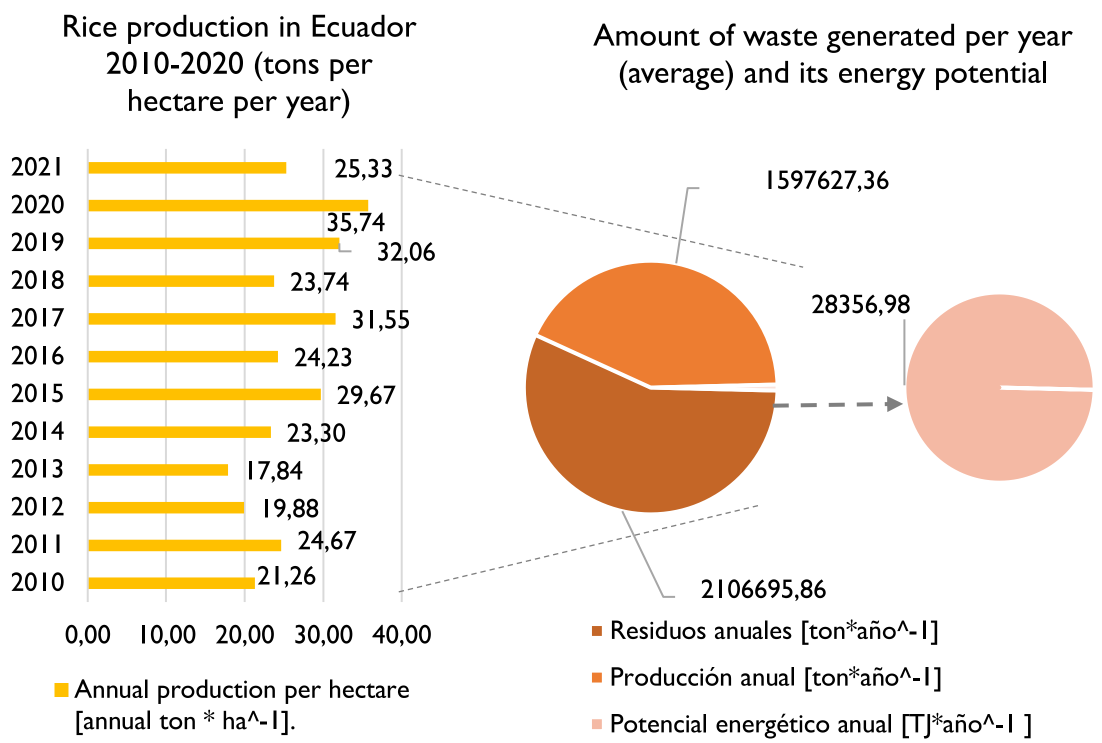


Figure 5. Rice production versus waste generated and energy potential, Ecuador. (MAGAP, 2020; Salazar, 2014).

Principles of circular economy in the rice production process

The current trend is oriented towards sustainability; therefore, it is necessary to find efficient and environmentally friendly processes to give added value to agroindustrial wastes that generate pollution, such as rice husks in a rice producing country like Ecuador. (Zambrano et al., 2021)..

A case study based on the above is located in the rice mills of the provinces of Guayas, Los Ríos and Loja, where the average between these provinces is 2,453 t/month in relation to rice husk production. Through an analyzed study, it indicates that rice husk waste has a high percentage of 90% silicon, which shows that it is a reusable component for the production of photovoltaic solar cells, with the objective of providing an added value and minimizing the environmental damage caused by uncontrolled open-air incineration. (López et al., 2021).

On the other hand, there is a case study for the use of rice husks in large agroindustrial mills located in Ecuador, which is, obtaining cellulosic fibers for the formation of Kraft paper fibers. Rice husk contains in its structure about 35 to 40% of cellulose, 15 to 20% of hemicellulose and 20 to 25% of lignin. (Gao et al., 2018). Among its physicochemical characteristics, it has a density of 1.125 kg/m3, with a calorific value of 1 kg of rice husk of 3300 kcal, which shows great importance in the use of rice husk. (LLanos et al., 2016).

Lignocellulosic residues from rice cultivation are mainly composed of rice husks. Therefore, with a yield of 50% bio-oil for rice there is a potential production of 16,394 tons respectively, and with a percentage of 75% bio-oil there is a production of 24,592 tons for rice in bio-oil generation. Likewise, in the potential production of biochar it is obtained that with a yield of 12%. These considerable quantities of bio-oil and biochar can have diverse applications, generating economic income. Bio-oil has several applications in the field of energy and fuels. (Ferrer et al., 2020).

Rice hulls are mostly incinerated in-situ by small farmers, causing an impact on the environment due to polluting emissions to the environment. A year 1'493,702 tons of rice hulls are generated in Ecuador. (Torres et al., 2015)According to a case study conducted in the canton of Quevedo, province of Los Ríos, rice hulls are an agricultural product used in animal feed by small farmers; in perspective, rice hulls have the following components for animal feed: dry matter (DM), gross energy (GE), crude protein (CP), ethereal extract (EE), crude fiber (CF), ash (C) and calcium (Ca). (Torres Navarrete et al., 2017)..

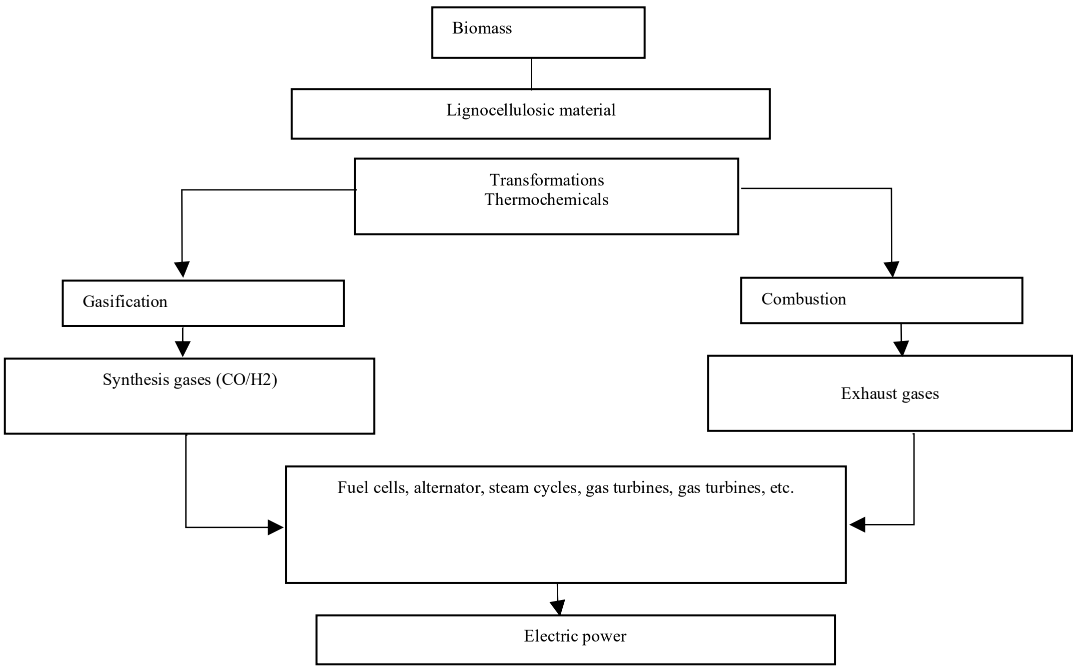
Most of the waste generated is not used, generating abundant pollution when burned or abandoned, which is why several international studies indicate the following; (Huang & Lo, 2018) They mention that rice husks are very common crop residues and that they provide raw materials for obtaining biomass, and that rice husks are superior to rice straw by approximately 3% (dry basis), which means that the proportion of fuel from rice straw is higher than that of rice husks by approximately 3%. Rice husk and rice straw are useful for activated carbon as they serve the applicability of removing impurities and contaminations. In addition, (Goodman, 2020) The rice husk and rice straw are used very little and are still incinerated at the production site, however, these lignocellulosic materials have potentially considerable values such as: cellulose, hemicellulose, lignin and silica. This is why rice husks are often used for the generation of ethanol, biogas and bio-oils.

Biomass potential in rice cultivation

This crop generates a large amount of biomass that can be used as energy by applying the circular economy. (FAO, 2013)The result of this is reflected in the 50% contribution to national energy; therefore, rice straw and husk residues are used, generating an energy production of 2.11 Mmt/year in relation to the 18.23 Mmt/year of residual biomass by the agricultural sector, being the third crop that contributes the most to biomass energy generation after African palm and bananas. (Vargas-García et al., 2021). In 2011, the Regional Office for Latin America and the Caribbean of the Food and Agriculture Organization of the United Nations published a study "State of the art and news on bioenergy in Ecuador", which highlights the policy to promote a change in the forms of common energies, guaranteeing the rights of nature, promoting the use of lignocellulosic biomass generated through rice and corn crop residues. (Orejuela-Escobar et al., 2021)..

At the national level, the energy use of agricultural residues does not yet have a great impact; however, residues such as rice are used due to their high lignocellulose content and their physical-chemical characteristics, implementing thermochemical transformations methods (Casas-Jiménez et al., 2021). Ecuador generates an amount of 2,106,696.00 tons of rice residues that are used for energy recovery, which are subjected to the technological process to obtain electric energy through the biomass used from these lignocellulosic material residues, as shown in Figure 6. (Calderón Loor et al., 2017)..

Figure 6. Technological process for obtaining energy from biomass.



Bioplastic generation in Ecuador: Case Study

The waste from rice processing is on average 20% of its production, indicating that every 100 kg of rice produces 20 kg of husk, with this volume of waste generated, small companies in the country could raise a process of the development of bioplastics on a smaller scale, which would function as an opportunity to create environmentally friendly ecological measures, In this case study it is proposed to use cellulose as a biodegradable polysaccharide from which cellophane films can be formed, purifying the residues of lignin, pectin and hemicelluloses, which being materials with fiber content hinder the creation of biofilms, giving volume for the creation of the bioplastic. (Riera et al., 2018).

The results obtained from the generation of biomass in Ecuador from rice crop residues indicated that rice straw and husk generate an energy production of 2.11 Mmt/year; they also (Lim et al., 2012) They also indicated that globally, 685 million tons of rice straw and 137 million tons of rice husks are generated annually, which contribute to the generation of 1,800 million liters of bioethanol from lignocellulosic biomass; (Arevalo et al., 2017) proposed in Peru a sustainable energy model for the use of rice residues to produce biomass briquettes to supply energy to domestic sectors and seek to replace non-renewable energy sources; (Biswas et al., 2017) indicates that one of the problems for countries including Ecuador not to adopt biomass as one of the main sources of energy is that the yield of rice husk and straw is only 28.4% and 38.1% respectively, causing low power levels in the production of energy through pyrolysis.

CONCLUSIONS

The residues derived from sugar cane cultivation, as well as from its agroindustrial process, add up to a great energy potential at the national level; however, its use in multiple sectors of the country continues to be a challenge (of considerable boom in Ecuador), losing the sense of the principles of circular economy, added to the fact that there is no technological capacity for the use of this type of residues, a minority group does have infrastructure for biofuel production which has generated economic income. Rice cultivation in Ecuador is very representative because it has a significant trend of waste in terms of rice husk and rice straw, and it is necessary to integrate efficient and environmentally friendly processes to reduce pollution; however, it is a real challenge in the country to opt for these tools because although it is true that there are agroindustrial companies that have them, there has not been an optimal organization in terms of waste generation with small rice growers. In addition, it is shown that rice husk and straw residues are not fully utilized for energy generation in Ecuador, because these residues only contribute with a yield of 28.4% and 38.1% respectively, causing the country not to apply a circular economy for the final disposal of these residues in this context of local development.

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