Chapter

Bioeconomic Potential of Sustainability Indicators in a Ceramic Production Center in the Western Amazon

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Abstract

The use of Amazonian biodiversity has great potential to produce bioproducts in diverse production chains and segments of industry. The combination of public policies with biotechnological development represents an important indicator for the implementation of sustainable production chains that adhere to the Sustainable Development Objectives (SDO). The ceramic industries in the Amazon region represent activities that promote local economic development through the use of biological resources that can be transformed into bioproducts that are considered a reference for sustainable production in world markets. The operations of these industries have great potential to incorporate technologies that can be used for fabrication of ceramic products on a biological base that is compatible with bioeconomic guidelines. The principle of a bioeconomy is centered on the possibility of transformation of natural resources into bioproducts that aggregate technologies and contribute to increase incomes and reduce environmental impacts. In this way, the integration of different fields of science should be stimulated to incorporate new technologies that favor business models that comply with the premises of sustainability.

Keywords: Amazon, biodiversity, production chain, bioeconomy, bioproducts

1. Introduction

The Amazon contains about a third of all tropical forests in the world and forms a mosaic of ecosystems in an area of about 6 million km^2 [1]. The extensive variety of species of flora and fauna spread out across widely differing landscape patterns, coupled with a hydrological system that is rich in biodiversity, makes this region the most biodiverse in the world.

The enormous biological diversity and territorial extension of the Amazon makes governance and sustainable management difficult considering the many different sources of anthropogenic pressure [2]. However, geological, hydrological, and climatic patterns of the Amazon, allied with its megadiversity favor sustainable use of its natural resources. Provision of inputs and raw materials for production of bioproducts and biofuels, energy generation, and phytotherapeutic products are examples of Amazonian bioeconomic potential.

Biodiversity is defined as the composition of all species of all forms of life and organizational levels present in ecosystems [3], a characteristic that is typical of the Amazon. The ecologic-economic interface at a large scale generally leads to persistent degradation of the natural environment and a loss of ecosystem services and biodiversity [4].

The value of ecosystem services is hotly debated due to the difficulty in establishing a monetary value for intangible goods [5, 6]. Studies have indicated that one of the largest gaps or deficits in knowledge of biodiversity is the real magnitude and quantity of microorganisms and species that have been formally described by science [7, 8]. However, the dynamics and multiple facets that characterize the tradeoff between development and sustainability presupposes the necessity to discuss the bioeconomic potential of the Amazon, focused on balancing the magnitude of consumption of natural resources with the capacity to replace them in nature.

Even without knowing the exact quantity of species present in nature, biodiversity has great biological importance for all forms of life [9], such as:

- *Ecosystem functionality*: biodiversity facilitates the functioning of ecosystems, maintaining the planet habitable through carbon exchange, maintenance of surface- and groundwaters, protection and fertilization of soils, and regulation of temperature and climate.

- *A storehouse of values that are intangible and non-monetary*: biodiversity offers to humanity values that are universally recognized, such as those of esthetic, scientific and cultural character.

- *A storehouse of values that are tangible and monetary*: the beauty and uniqueness of many ecosystems provide value in the form of a diversity of recreational activities and ecotourism.

- *Provision of inputs and bioproducts that are destined for human consumption*: biodiversity is the base for agricultural crops and for the development and improvement of new varieties for human consumption.

- *Provision of raw material for production chains and industrial sectors*: biodiversity is the source of many products used by contemporary societies, such as fibers, pharmaceutical products, chemical, and is a source of information for the development of biotechnology.

Besides the economic value and biological importance to human survival, biodiversity provides ecosystem services in the form of provision, regulation, and support, and is also important for its contribution to cultures around the world [10–13]. This results in tangible and intangible benefits based on the diversity and functioning of ecosystems.

The challenge presented by the global market is to satisfy the assumptions of the Organization for Economic Cooperation and Development (OECD) in productive sectors in the Amazon, since the expansion of certain industrial activities necessary to meet national and international market demand generally results in loss of biodiversity, and consequently compromises ecosystem services.

Among the diverse initiatives that utilize biodiversity, there is great preoccupation with the sustainability of production chains, and if these adhere to the Sustainable

Development Objectives (SDO), as adopted by the United Nations Organization (UNO). The conceptual approach of sustainable development as elaborated in its most recent version, incorporates the necessity of adoption of sustainability parameters that take into account aspects that include efficiency (economically sustained), inclusion (socially desirable), and equilibrium (ecologically prudent).

It is understood that the concept of sustainable development is complex, and it is often interpreted imprecisely, ambiguously, or in a contradictory manner based on a complex and dynamic perspective rooted in the relationship between societies and nature [14]. This concept has been gaining strength and political expression, especially during the last quarter century of the twentieth century, due to a worldwide environmental crisis [15].

The trajectory of sustainability demands ethical compromises, ecological conscience, and social respect, and the demand for sustainable products has been intensifying [16]. Consumers now question how a product was made, if it is in compliance with the legislation of its country of origin, and what were the benefits generated for the agroextractivists and communities that obtained these products.

These requirements impose the necessity of introducing technologies and business models that are compatible with the tools of the bioeconomy.

The bioeconomy is organized around the concept of sustainable and innovative use of natural resources and biological knowledge in order to produce food, industrial products, bioenergy, and ecological services [17]. This concept arose as a new paradigm through the extension of new ideas and knowledge in the fields of biology, economics, and the environment in general, with the goal of providing solutions to complex problems. The concept of the bioeconomy integrates different fields of science, sectors of society, and market demands as a function of providing products that are sustainable, competitive and that adhere to policies of sustainability and applied biotechnology.

Ceramic industries in the Amazon are examples of businesses that use biodiversity resources and promote local economic development. However, the manufacturing operations of these companies have been engaged in a growing effort to achieve a pattern of development that incorporates economic, social, and environmental aspects [18].

Preoccupation with depletion of natural resources has increased interest in biologically based products. Productive activities in the Amazon, especially those derived from biological resources, as is the case of ceramic industries, have created a positive perspective with respect to the implementation of developmentalist models that incorporate innovation, technology, and sustainability.

The advance of the "Fourth Industrial Revolution", or Industry 4.0, has integrated technology and sustainability and created new practices and standards for products and services which are based on concepts of a sustainable economy [19].

Market strategies that search for alternatives that can differentiate a product based on its quality and on attributes that respect the environment normally allow for access to new markets that have higher aggregated value and purchasing power. Cluster analysis shows the potential to track and identify the origin of products, thus aggregating value and confidence in products from the Amazon region.

In this context, this research has as objective the analysis of the potential of the principal bioeconomic variables inherent to the production and marketing of ceramic products in the ceramic production center of Iranduba, state of Amazonas.

2. Characterization of ceramic production in the western Amazon

In the Amazon, the development of ceramic production techniques was a pioneering effort by indigenous people that was engaged in before agricultural activities and plant domestication [20]. The production of utensils and other artifacts was not done to sell them in a market, but rather the focus of this production was to make vases, jars, and plates for domestic use. Beginning with the industrial revolution and the introduction of machines and equipment to production processes, the production of ceramics ceased to be merely an artisanal activity and took on an industrial scale. Population growth and the expansion of large urban centers in the region created a new commercial niche, the civil construction market. The demand created by the civil construction production chain altered production models and required the fabrication of new products and consolidated the ceramic industries involved in production of specialized ceramic products.

In the state of Amazonas there are records that show that the first ceramic production activities were artisanal, especially with respect to production of plates, cups, and other utensils for domestic use by the local indigenous population [21]. Up to the decade of the 1970s, the ceramic sector of the state of Amazonas was concentrated in the region of the city of Manaus. Starting in the 1980s these companies migrated from the capital of Manaus to the district of Cacau-Pirêra, city of Iranduba [22–25].

The factors that contributed to the installation and strengthening of the ceramic sector in this region of the Amazon were: a) the existence of extensive deposits of clay raw material; b) proximity to the principal consumer center, connected by the Manoel Urbano – AM-070 highway; and c) large supply of unskilled labor that receives low salaries [18, 26].

2.1 Geographic and geologic aspects of the study area

The study area is located in the city of Iranduba, metropolitan region of Manaus, consisting of an aggregation of 18 industries situated on the right bank of the Negro River, in front of Manaus, with access and shipping of production done using the Negro River bridge (**Figure 1**).

Geologically, the study area is on a dissected plain, where sedimentary rocks of the Alter do Chão formation predominate. This sedimentation occurred in continental, fluvial, and lacustrine environments, constituted by intercalation of sandstones, mudstones, and conglomerates, which are principally composed of clay [27], which is used in the production of red ceramic products. The sandstones have a fine to medium texture and are red in color; the mudstones, massive or laminar,

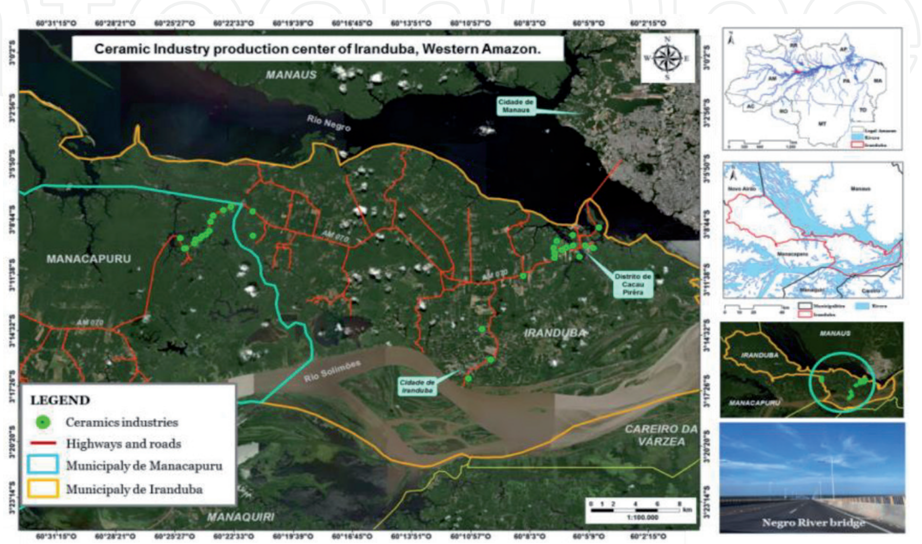

Figure 1.
Location of the ceramic production center of Iranduba, Amazonas, Brazil. Source: Geocartographic data from the Brazilian Institute of Geography and Statistics (IBGE) and ArGis (2020).

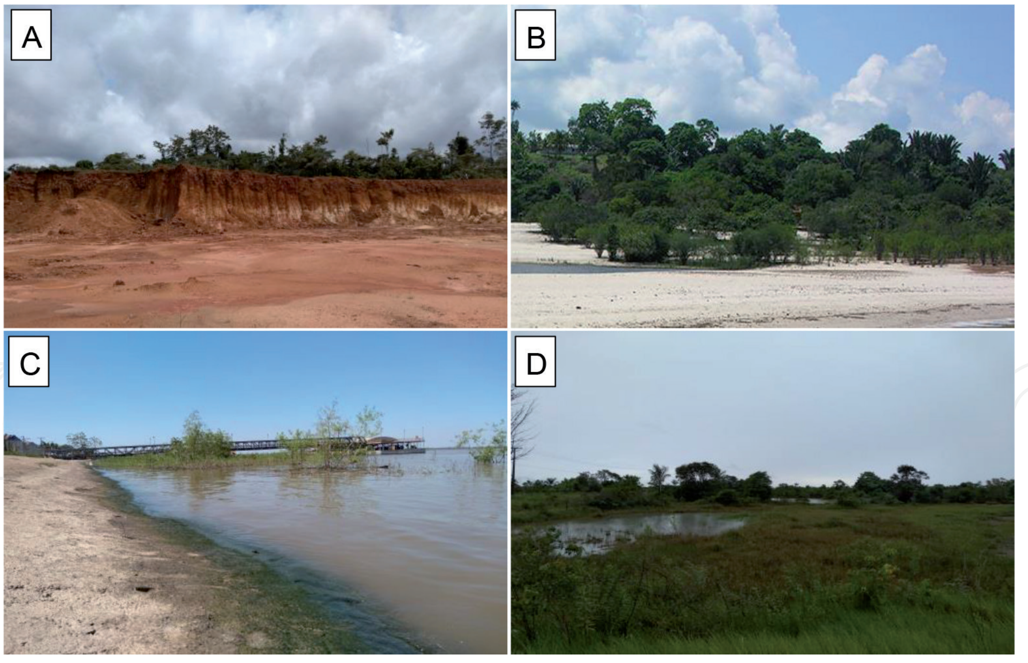

Figure 2.
Landscape heterogeneity of Iranduba: Lateritic profile (A); Sandy deposits (B); fluvial plain (C); floodplain (D). Source: The authors (2020).

are poorly consolidated, and have clasts of sand that are irregularly distributed; the conglomerates are quartz pebbles and silicified sandstone [28].

The ceramic industries are inserted in the Holocene Várzeas pedological sector, which is composed of várzeas (floodplains along riverbanks) that developed over Holocene sediments with a variable mineralogical composition. Geoenvironmental studies have indicated that the city of Iranduba is characterized by a heterogeneous landscape, with different soil types that are classified as a lateritic profile, sandy deposits, fluvial and flood plains [29] (**Figure 2**). The clay deposits, which are white to rose colored, together with the yellow Oxisols that overlay the Alter do Chão formation, are used as raw material for the production of red ceramics in the ceramic production industries of Iranduba. The principal products of this red ceramics industry are blocks, bricks, roof tiles, hollow ornamental bricks, slabs, floor tiles, encaustic tiles, tubes, ornamental objects, and domestic utensils, all using common clay as raw material.

Recent research conducted in the ceramic production center of Iranduba indicates that the area has a high level of geological diversity and potential for clay extraction at depths of 15 cm, 30 cm and 60 cm, and that this extraction has been occurring without interruption during the last four decades [18]. Even with the obstacles and the technological limitations confronted by this sector the ceramic industry in Amazonas has actively contributed to social and economic development in the region. It has been estimated that at the height of the real estate boom in Brazil between 2008 and 2013 the annual production of ceramics in Amazonas was approximately 35 tons of bricks per month, with the cities of Iranduba and Manacapuru being the principal producers of red ceramics. Just the city of Iranduba was responsible for about 75% of all brick production in the state, producing between 1700 and 2000 direct and indirect jobs [18, 30].

3. Bioeconomic and sustainability potential of the ceramic production center of Iranduba

The market for the ceramics industry in Brazil is highly heterogenous and is formed mostly by small companies that are located near the consumer markets in their regions. These companies basically use common clay as their principal source of raw material.

In the Iranduba ceramic production center, production is concentrated in red structural ceramics, with 8-hole bricks being the principal product that is made. With competition and an increasing demand for environmentally sustainable products, it has become of fundamental importance that the ceramics sector promotes biotechnological innovations in its production chain through integration of companies, technology, and sustainability (**Figure 3**).

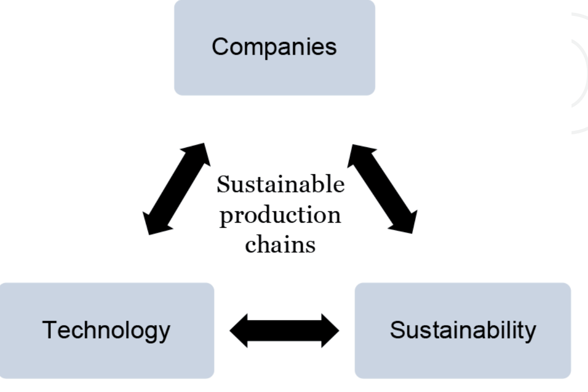

Figure 3.
Structure of sustainable production chains. Source: The authors (2020).

Sustainable production chains seek to improve business models by adding economic and social value to the goods that are produced. For this reason, the bioeconomy is seen as an opportunity to enhance production standards and strengthen relationships between agroextractivists, transformation industries, public authorities and research and development institutions. Companies and governments around the world have been acting to create public policies that strengthen the commitment to use biological resources in a way that favors a more sustainable economic model [31, 32].

An important principle underlying sustainable production chains is that they contemplate changes and or a reorientation of productive systems through necessity or opportunity (entrepreneurship), resulting in lower environmental impact (social sustainability), generation of work and income (economic sustainability), and maintenance of urban and rural characteristics (spatial sustainability) [33]. The combination of these elements requires a set of actions that incorporate scientific knowledge, innovation, and organizational experience (tacit knowledge) to produce, market, and distribute products that are competitive and that are sustainable.

As a result of globalization of markets, a growing number of companies has been striving to create technological tools that are able to track commodities and products, with the objective of supplying a consumer market that is becoming more and more demanding with respect to sustainability of productive processes [34]. The creation of tracking mechanisms that display the routes and management schemes of the entire production chain, from the extraction of raw material (inputs) to the final consumer is highly challenging. However, these initiatives incorporate practices and attitudes that represent a technological and sustainable advance for the industries of the ceramic production center at Iranduba.

3.1 Structural steps that integrate the production chain of the ceramic production center at Iranduba

The ceramic production chain at Iranduba encompasses three different steps of macroprocesses: extraction of raw material, production of ceramic artifacts, and marketing of the finished product (**Figure 4**).

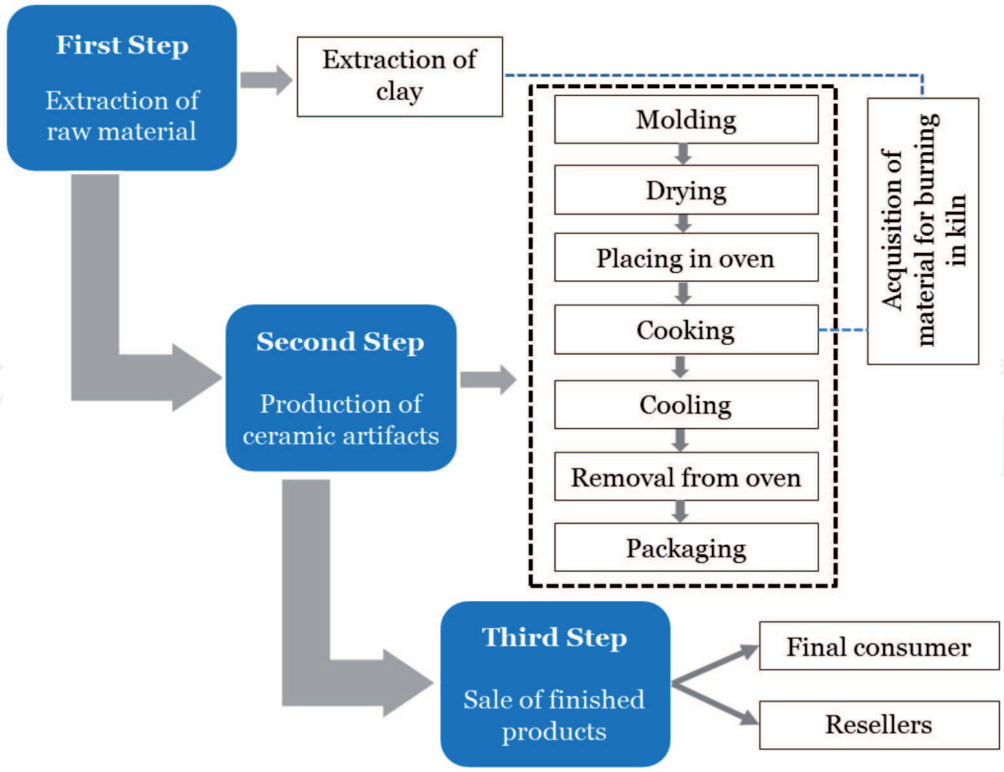

Figure 4.
Structure of the ceramic production chain at Iranduba. Source: The authors (2020).

The first step in the production chain consists of acquisition of raw material, which in this case is clay. The extraction of clay is one of the most important links in the production chain, and is done using machines and motorized equipment, principally a hydraulic backhoe, excavator shovel, and dump trucks (**Figure 5A** and **B**). It is important to highlight that before beginning the clay excavation process the excavation sites must be properly licensed to have permission for these activities. In general, these industries do not conduct any specific treatment on the extracted clay, and the clay is simply deposited under the roof of a large hangar or outside in large piles with no covering where it will remain for up to three months (**Figure 5C** and **D**). It is thought that this up to three-month period serves to eliminate impurities and microorganisms that can compromise the quality of the final product.

Clay extraction is permitted by law in article 3° of Law n° 12.651/2012 (Forest Code) and the process of concession/extraction is authorized by different federal agencies, principally the National Mining Agency – ANM, and state and municipal environmental agencies. In the state of Amazonas, licensing of exploitation of mineral substances is done by the Institute of Environmental Protection of the State of Amazonas (IPAAM), by means of three types of licenses that are issued either isolated or in succession, based on the National Environmental Council's (CONAMA) Resolution n° 237/1997 [35], which outlines the rules that organize this activity:

- Preliminary License (LP): issued in the preliminary phase of planning, analysis, and viability of the project in its basic form.

- Installation License (LI): issued in the execution phase of the project and the installation of the infrastructure, as well as during the phase of implantation of an Environmental Control Plan (PCA) which outlines methods of recuperation.

- Operation License (LO): issued during the extraction phase of the project and during the phase of execution of the proposed measures in the Plan for Recuperation of Degraded Areas (PRAD).

Figure 5.
Processes of extraction (A), transport (B), and storage of clay raw material (C, D) in the study area. Source: The authors (2020).

From the point of view of sustainability, the extraction of clay in open-air conditions without any subsequent processing represents an activity that promotes environmental degradation with significant impacts on biodiversity, which require mitigating actions and/or the reestablishment original ecosystem conditions.

Although the extraction of raw material for the fabrication of tiles, bricks, and other artifacts made of clay cooked in kilns can be considered an activity that causes environmental degradation of medium to strong intensity, the geographic location of the clay extraction sites used by the ceramic industries of Iranduba have high potential for recuperation using strategic mechanisms from bioeconomic principles. The clay extraction sites licensed by IPAAM are essentially situated in areas prone to flooding or are perpetually under water, which therefore have potential to be used for bioeconomic activities such as pisciculture (**Figure 6A** and **B**).

Most of the clay deposits are located on the land of the ceramic factory or near them (**Figure 6A** and **B**). Clay extraction is done between the months of August to November, which is the dry season where there is a large reduction in rainfall (considered the Amazonian summer). The principal clays that are extracted are kaolinite, with traces of gibbsite, and rarely illite, feldspar, and quartz.

Figure 6.
Clay extraction sites used by the ceramic industries of Iranduba, Amazonas, Brazil: RN Ceramic (A), RO Ceramic (B). Source: Geocartographic data from the Brazilian Institute of Geography and Statistics (IBGE) and ArGis (2020).

Besides the compensatory environmental recuperation measures, these areas have excellent potential for pisciculture, especially for the species called tambaqui (*Colossoma macropomum*). Raising tambaqui in captivity is perfectly compatible with the culture, infrastructure, and technology available in the local market. In this context, during the rainy season when river levels are high (Amazonian winter), principally between January to June, the areas used for clay extraction could be reused following a new economic and social perspective. This option would foster additional insertion into local markets incorporating practical aspects of the bioeconomy and would mitigate the environmental impacts of the degraded area (**Table 1**).

It is important to emphasize that the fishing sector represents one of the most important parts of the local economy, since freshwater fish are one of the natural resources that is most abundant and consumed in the Amazon region [36, 37]. Between the years 2018 to 2019, pisciculture production increased by 34% in the region, especially for native species such as tambaqui (*Colossoma macropomum*), matrinxã (*Brycon amazonicus)* and pirarucu (*Arapaima gigas*). This points to a scenario of an increase in productive capacity during the rainy season when water levels are high in the region (**Figures 7** and **8**).

Studies indicate that fish is the principal protein source for the populations that live along the river margins in Amazonas, with the upper, middle, and lower regions of the Solimões River having one of the highest levels of fish consumption, a reflection of the strong link that Amazonians have with regional fish populations [37, 38]. A person from Amazonas consumes, on average, 60 $kgyear^{-1}$ of fish, which represents more than ten times the national average per $capitayear^{-1}$, estimated at 5.8 kg [36, 37]. The high rate of fish consumption in the region, besides providing the basic necessities for survival, there are many natural benefits of fish to the health of consumers since fish is rich in protein, mineral, fatty acids, and omega 3 [37]. Furthermore, the introduction or intensification of pisciculture in areas of clay extraction at the ceramic production center at Iranduba will decrease the pressure on natural stocks of fish and will help to meet the guidelines set out in the sustainable development objectives of the UNO.

In this context, the regime high and low water fluctuation over the course of a year in Iranduba represents a bioeconomic alternative that has great potential reconciling several needs in the same natural environment by providing raw material for ceramics production as well as production of fish for subsistence and sale of the excess (**Figure 9**). These actions will stimulate an increase in income, access to new technologies and a reduction in impacts caused by the extraction of biodiversity resources [25].

The second step in the ceramic production chain at Iranduba occurs internally at the site of the company where the ceramic products are made. The principal changes in the physical–chemical characteristics of the raw material to obtain the finished product occur during this step of the production process. The operational activities are conducted using industrial equipment such as a laminator, extruder, conveyer belt, and cutter, which are operated by the factory workers. Socioeconomic studies done involving managers and workers from ceramic companies in Iranduba have indicated that these activities began in a completely artisanal manner and were then modified over the course of years of operation, to the point today where this process can be considered semiautomatic [21].

The ceramic companies in Iranduba are responsible for about 50% of all red ceramics produced in the state of Amazonas, generating approximately 1200 direct jobs and 6000 indirect ones, with an estimated production of 4.5 million pieces/month. The portfolio of products consists of bricks (80%), structural ceramic blocks (12%), roofing tiles (5%) and floor tiles and accessories (3%), as shown in **Figure 10**.

Bioeconomic potential	Months												Extraction of natural resources
	January	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	
Operational cycle of fish production													Operational cycle of clay extraction

Source: The authors (2020).

Table 1.
Bioeconomic proposal for areas of clay extraction used by the ceramic industries of Iranduba, Amazonas, Brazil.

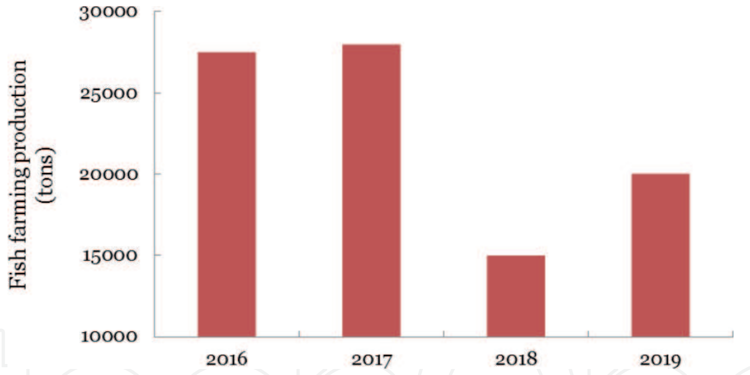

Figure 7.
Pisciculture production in the state of Amazonas (2016 to 2018). Source: Brazilian yearbook of fish farming (2020).

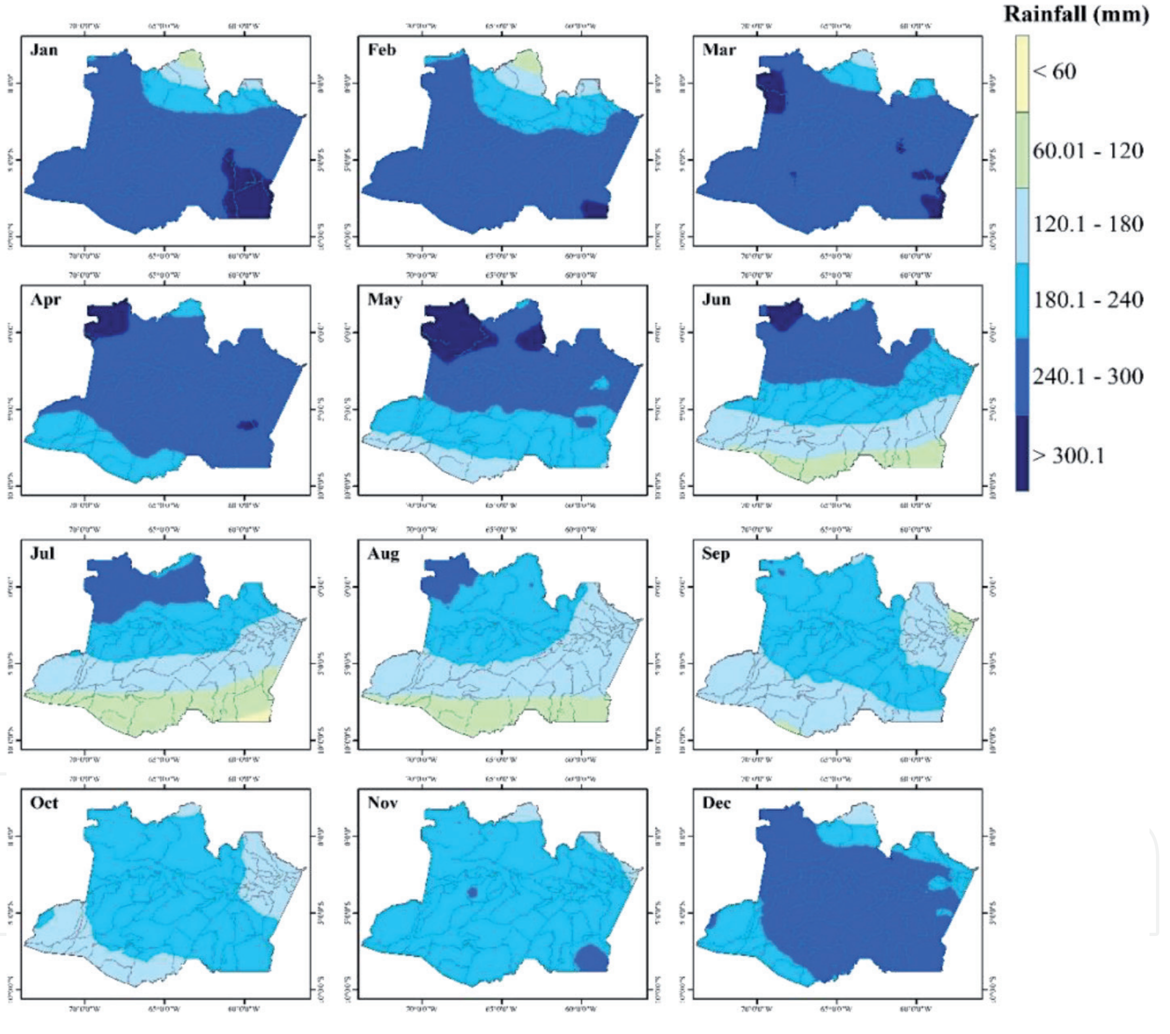

Figure 8.
Characterization of monthly pluviometric in the state of Amazonas (1989 to 2017). Source: European Centre for Medium-Range Weather Forecasts (2020).

As is the case for raw material extraction (clay), the manufacture of ceramic products requires environmental licensing and proof of origin of the input materials used in the ceramic kilns. The generation of thermal energy for heating and baking the ceramics demands creative strategies that adhere to bioeconomic principals. Wood from residuals generated from native forest timber processing is currently the principal fuel used by companies in the ceramic processing sector in the region [18, 39, 40]. However, bioeconomic principals require inclusion of new resources used as fuel for kilns to be based on renewable biomass [17]. In this sense, biomass is generally understood to be

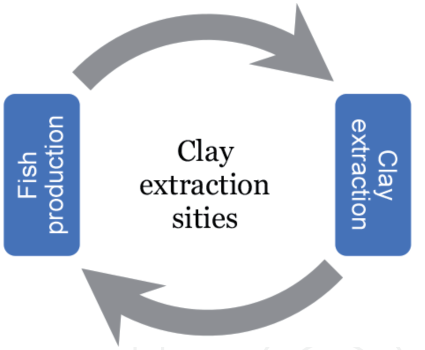

Figure 9.
Operational and bioeconomic cycle of clay extraction at the ceramic production center at Iranduba, Amazonas, Brazil. Source: The authors (2020).

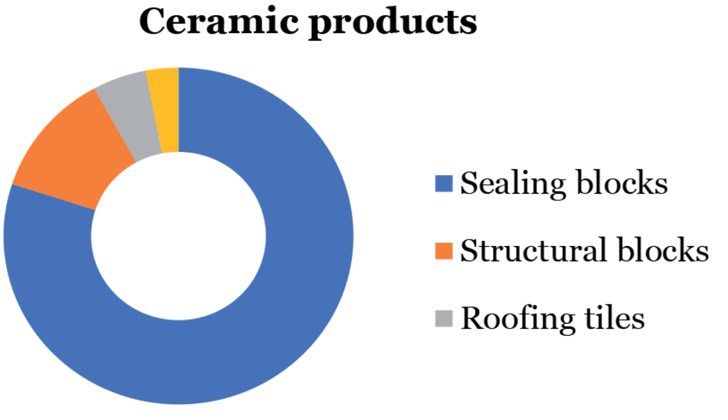

Figure 10.
Variety of products made at the ceramic production center at Iranduba, Amazonas, Brazil. Source: The authors (2020).

any non-fossil organic matter from plants, animals, or microbes that has economic potential and that can be used to generate energy [41, 42]. For example, residuals generated from silvicultural management in agroforests are normally left on the soil surface and will eventually contribute to CO2 release to the atmosphere. Alternatively, this biomass could be reutilized and technologically adapted into an energy source by industries, including those that produce ceramics.

The Amazon possesses an extensive variety of sources of residual biomass, whose reutilization could result in tangible and intangible benefits for transformational industries. In the geographic area of the ceramic production center at Iranduba there are agroindustries that produce and process plant fibers such as malva (*Urena lobata L.*) and juta (*Corchorus capsularis L.*), whose organic residual wastes are underutilized and discarded into the environment. A mix of these plant fibers and other sources of biomass such as seeds of açaí-do-Amazonas (*Euterpe precatória* Mart.) could be used as an innovative alternative for burning in the ceramic kilns of the ceramics industry in the region. Despite the rudimentary production system that uses only a low level of technology, the residuals of these plant fibers represent a promising biotechnological solution for thermal energy generation. During the fiber extraction process about 95% of the plant is discarded at the collection site, and this represents an opportunity to create an alternative destination for this material. A similar situation occurs during the processing of açaí, wherein approximately 83% of the fruits are discarded due to a lack of an alternative use in the market. These residuals, which are generated in abundance in the Amazon and subsequently disregarded, could become subproducts, such as briquettes, for transformational industries. The manufacture of briquettes through mixing different types of residual biomass such as pellets used for products made from açaí, malva and juta, is an innovative biotechnological solution that can provide an alternate destination for residual solids as well as generate thermal energy in the ceramic kilns.

Another regional residual biomass that is commonly and abundantly discarded into the environment is the outer shell that contains the nuts of the Brazil nut tree (*Bertholletia excelsa Bonpl.*), whose chemical composition is primarily lignin and cellulose. This residual biomass rapidly enters combustion and has a high calorific value, thus being easily converted into thermal energy [43–46]. The use of this source of biomass in the ceramics production process as an alternative source of thermal energy will reduce the demand for wood from residuals of native forest and aid in decreasing deforestation in the western Amazon [18].

From the perspective of innovation, the adoption of a production system based on new types of inputs for energy generation should occur in an integrated manner, with active participation of research institutions, agroextractivist communities, and ceramic industries.

A production chain based on bioeconomic principles requires knowledge and technology to incorporate biomass resources used as an energy source and to manufacture ecological products (bioproducts), and also needs a sustainable business model. **Figure 11** summarizes the sequence of activities of a ceramics production chain that will result in bioproducts and a sustainable business model.

The third step in the production chain consists of the process of marketing and distribution of the products to resellers or final consumers.

In terms of market competition, the structural characteristics of a sector are generally affected by an efficient combination of the processes of production, distribution, and sale. In the case of the ceramic industries of Iranduba, there is a certain level of homogeneity in the characteristics of internal processes, suppliers, and clients. These ceramic companies have operational structures like those categorized as Microcompanies (Microempresas (ME)) or small businesses (EPP) by the federal government. The principal characteristics of companies classified as ME or EPP are levels of revenue and tax bracket. According to Brazilian legislation, a company classified as ME must have gross annual revenue less than or equal to R$ 360,000,00 and pay taxes through one of the following options: (National Simple Method, Actual Profit Method, or Deemed Taxable Income). The legislation permits that the ME be registered in one of its four subcategories: Ordinary Partnership, Individual Limited Liability Company, Enterprise Corporation, and Sole Proprietorship. Companies classified as EPP gross annual revenue less than or equal to R$ 4,800,000,00, and can opt for either the National Simple, Actual Profit, or Deemed Taxable Income tax payment methods.

The consumers of the products made by the ceramic industry in Iranduba are principally the resellers, with physical store locations in the city of Manaus, and on a smaller scale in the upper Negro River region (**Figure 12**). These clients are responsible for about 65 to 75% of the purchases of ceramic production made in Iranduba. The remainder of the production is sold and distributed to endpoint consumers, principally civil construction companies that are responsible for public and private construction projects that used financial resources from the federal government. Among the endpoint consumers is a small proportion of purchases made by individual people who buy products directly from a ceramic company for use in their own homes.

Figure 11.
Aspects of the bioeconomy that should be incorporate into a production chain. Source: The authors (2020).

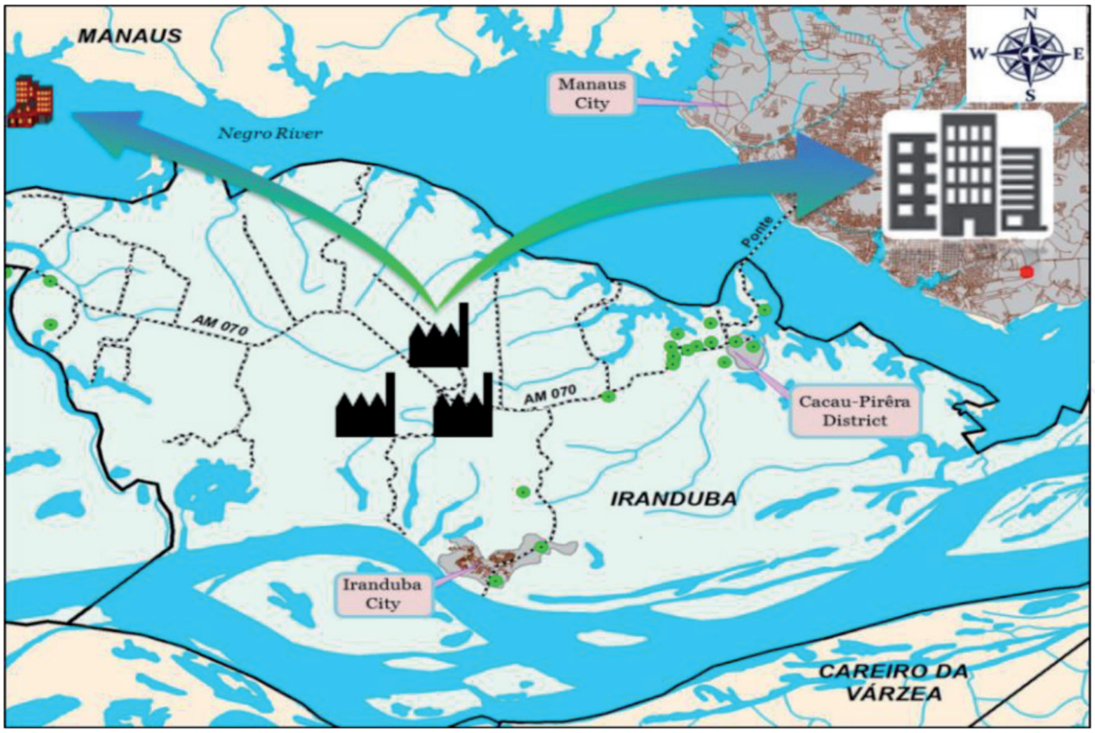

Figure 12.
Routes used to distribute products made in the ceramic production center at Iranduba. Source: ArGis (2020).

Normally, the sectorial or competitive environment in which a company operates is characterized by competing forces that drive companies to reinvent themselves through organizational strategies with the goal of increasing profits. A strategy can be defined as a set of operations that can create a competitive advantage by generating greater economic value compared to competitors. A competitive advantage is perceived through greater profitability, liquidity, leverage, and activity [47].

In the bioeconomy field, a competitive advantage can be related to the perception of the consumer that a certain company is more ecologically correct than its competitors, or that it is completely dedicated to producing and marketing products in harmony with principles of sustainability (**Figure 13**). This characteristic of ecological products imposes upon production systems the necessity of incorporating technologies that can aggregate value and attenuate impacts on biodiversity.

The search for sustainable competitive advantages has become an objective of all managers who are focused on the global market. The challenge consists in efficiently maintaining the skills that have been acquired over time while searching for novel strategies that will facilitate the manufacture and offer of ecologically

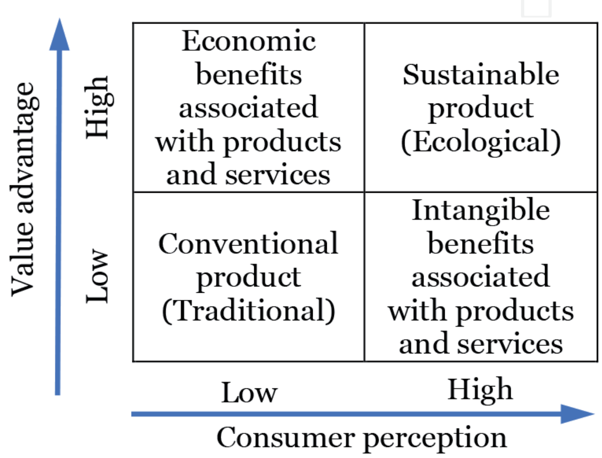

Figure 13.
Competitive advantages associated with biologically-based products. Source: The authors (2020).

sustainable products. For the ceramic industries of Iranduba, the commercialization and distribution of ceramic products is conducted through a simple, unsophisticated process, without innovative characteristics that would differentiate a product from its competition. In general, the ceramic products that are sold are stored on pallets and wrapped in thin, transparent plastic film (**Figure 14**).

To maintain a sustainable competitive advantage, companies need to innovate and acquire more highly developed marketing skills than their competitors. Products that have a seal of origin or any characteristic that conveys ecological correctness will normally aggregate intangible values that are translated into a competitive advantage.

In strategic terms, the ceramic industries of Iranduba represent an activity that efficiently transforms natural resources into bioproducts that are a reference for the entire Amazon region. On the other hand, structural changes in the production chain through addition of biotechnology and manufacture of sustainable products, requires a detailed analysis and identification of possibilities and vulnerabilities that involve the ceramics sector in the region.

Figure 14.
Finished product, wrapped and ready for sale. Source: The authors (2020).

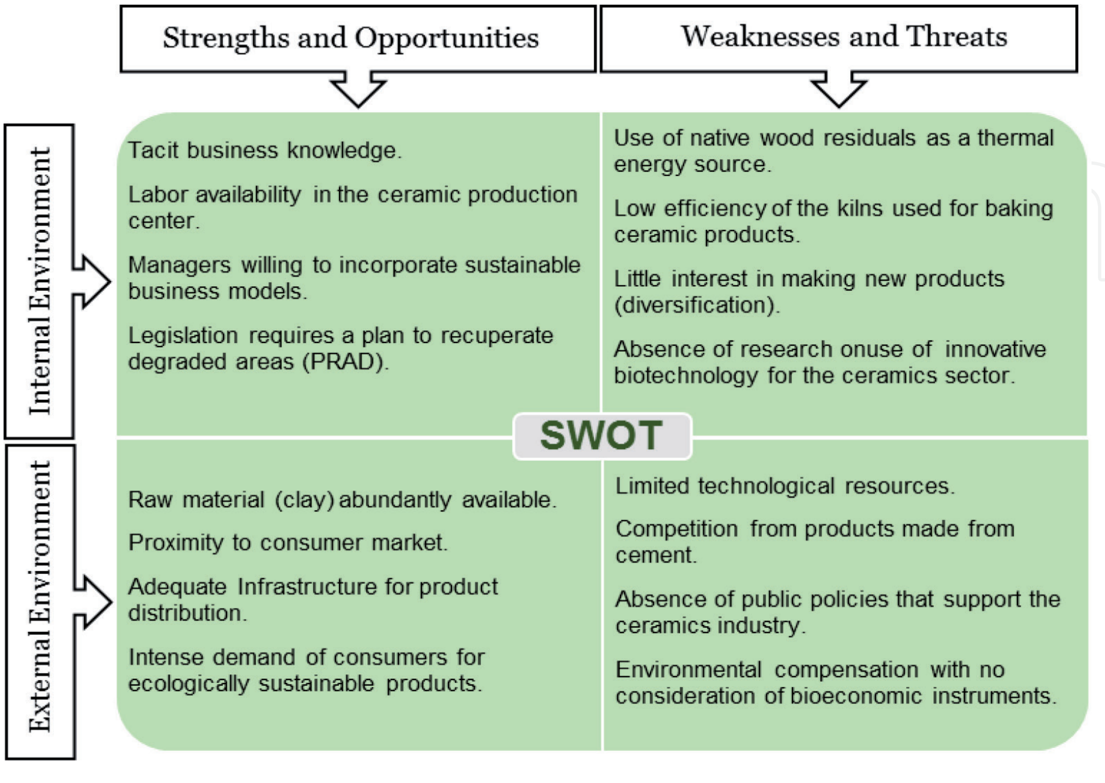

Figure 15.
Possibilities and vulnerabilities identified using the SWOT matrix. Source: The authors (2020).

In a geopolitical context, the ceramic production center at Iranduba has great economic and social importance for regional development. A redefinition of strategies and objectives together with the creation of participative public policies focused on bioeconomic principles will result in positive results in markets and will generate business models that will have a global impact. An important incentive to foster the implementation of new market strategies is the elaboration of strategic planning that identifies the possibilities and vulnerabilities that involve the ceramics sector. A tool that is commonly used for the elaboration of strategic planning is the SWOT (Strength, Weaknesses, Opportunities and Threats) matrix. The SWOT analysis allows for evaluation of how a company or group of companies behave in relation to competitors, identification of the factors that are responsible for this difference, fragilities, and the market opportunities that can be explored.

The SWOT matrix below synthesizes the principal environmental, economic, and social aspects necessary for the implementation of production of bioeconomic products in the ceramic production center at Iranduba (**Figure 15**).

Each segment of industry acts in a dynamic environment where companies must concentrate their efforts to establish a set of activities that can explore new markets, balancing development with conservation of biological resources.

The simplified strategic diagnostic in **Figure 13** will help ceramic industries identify points of rupture in their production chains and the bioeconomic alternatives necessary for organizational and technological restructuring.

4. Conclusions

In the red structural ceramics production chain, there are biotic and abiotic elements that interfere in the conditions of biodiversity. The industries in the ceramic production center in Iranduba have high potential to improve their production standards, strengthen relationships between stakeholders, and offer products that are competitive and ecologically correct.

The geological diversity of clays and the strategic location of the companies favors the manufacture and distribution of sustainable products, principally bricks and tiles, that are based on bioeconomic resources and principles.

The areas where clay is extracted to produce red ceramic products present excellent conditions to be able to, in the same natural environment, extract raw material, and engage in pisciculture to produce fish for subsistence and for sale in markets. These actions will stimulate an increase in income, access to new technologies, and a reduction of the impacts on biodiversity caused by natural resource extraction.

With respect to the production process that occurs at the ceramics manufacture facility itself, the burning of wood derived from native forest timber is currently the principal fuel used by these companies in the region. Strategies based on bioeconomic principles should be adopted so that there is a gradual substitution of this wood source for residual biomass materials. The introduction of different types of biomass including a biotechnological combination of plant fibers with seeds, fruits, and other materials that are discarded from agroforestry operations represent a promising alternative as a fuel source for the kilns of ceramic industries in the Amazon.

The cultural, socioenvironmental, and economic dynamics of the ceramic production center at Iranduba are very complex and challenging. The logic involved with providing incentive to produce red ceramic products based on bioeconomic strategies is not only rooted in the need to increase productive efficiency, but also in the necessity to respect the environment and develop a series of products made in the Amazon that are considered highly sustainable.

Business strategies that seek excellence and product differentiation normally succeed in obtaining a competitive advantage and greater profits. In this context, well-structured, robust planning should be conducted that strives to make the operational activities of the ceramic industries of Iranduba conform to sustainability criteria and thus make their products a reference for the global market.

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