The Metabolism of the Amazon nut Productive Chain: An Analysis through the MuSIASEM Methodology.

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ABSTRACT
Understanding socio-environmental systems in a holistic way has been a challenge for Environmental Accounting. In this sense, the understanding of human organizations as a social metabolism proposes lenses capable of covering these scopes. One way to promote metabolism analysis is the MuSIASEM methodology. In Brazil, the Amazonian biome, as one of the most diverse and complex metabolisms, stands out in this context the historical exploration of the Brazilian Chestnut, also known nationally as Brazil nut. Thus, the objective of the study was to analyze the socio-environmental metabolism of the Amazon nut production chain in the northwest of the State of Mato Grosso through the MuSIASEM approach. The MuSIASEM methodology was proposed for this study by European researchers in order to be tested in micronarrative analyzes. The study is characterized as exploratory with a qualitative approach, using a case study strategy. It was established for the narrative the construction of a human activity and income fund, besides an energy and production flows. The analyzes showed that the narrative presents a balanced state. However, it was verified the inefficient use of energy, domestic work overload in the settled women, besides the interference of the figure of the middlemen who influenced some indicators.

Palavras-chave: Social Metabolism Theory. Pará’s Nut. Brazil Nut. MuSIASEM. NTFP.

1. INTRODUCTION

The concept of metabolism is used to define how the human activity perpetuates or fades over time. When we think of Brazil, one of the metabolisms that compose it is the Amazonian biome, as well as all the human activity that occurs there.

Understanding this complex environment in which the metabolism is configured, we sought alternatives that could effectively cover the sustainability problem in the region so that social, economic-financial and environmental aspects were contemplated. In this scenario, the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism approach (MuSIASEM), a methodology or model of sustainability assessment in socio-environmental metabolisms, is also used to verify the robustness of analyzes, which challenges the reductionist methods that were developed until then. (Giampietro, Mayumi & Ramos-Martin, 2009).

The methodology was used in several occasions, initially used in an ecological reserve in Scotland (Matthews *et al.*, 2010), on land use in Cambodia (Scheidel, Giampietro & Ramos-Martin, 2013), China (Xiaohui, Tiansong, Piano & Mayumi, 2015), in the Balearic Islands, Spain (Ginard-Bosch & Ramos-Martín, 2016), in the energy systems of Brazil (Aragão & Giampietro, 2016), and in Peru water use (Schwarz & Mathijs, 2017).

The Amazon colonization process by the white man, begins in the period of the empire but only occurs expressively in the 20th century. Since 1970, encourages the occupation of the region with land at low cost, which attracted immigrants from various parts of the country who have gone to live with traditional peoples who inhabited the above region, as quilombos, rubber tappers, riverine, indigenous peoples , and they ended up sharing their culture. (Hurtienne, 2008; De Souza Filho, Pedrozo & Paes-de-Souza, 2011).

The north-west of Mato Grosso is particularly important in this context, since it illustrates well the migration policies of the 1970s, with the arrival of new inhabitants especially from the south and southeast of the country, which, in addition to existing cultures in the region are characterized by expressive cultural diversity. The territory in question is composed of social groups with distinct political, economic and social interests, such as indigenous populations, landowners, prospectors, settlers of the agrarian reform, extractivists and merchants, constituting a complex metabolism composed of several others, some in extinction phase as is the case of the diamond chain. (WWF, 2012; Alves Júnior, 2013).

With the consolidation of livestock and timber extraction, residents of the region incorporated the local indigenous culture and then began to explore other resources that are characteristic of the locality, also known as Non-Timber Forest Products (NTFP). Among the most historically exploited products in the region up to the present time, Amazonian nut constitutes an important source of income for Amazonian families and communities.

The brazil nut, popularly known as Brazil nut, and worldwide as Brazil nuts, is a fruit extracted from *Castanheira*. (*Berthollethia excelsa*) , a tree that is found throughout the Amazon. In this biome, the exploitation of Amazon nuts is historical and constitutes an important source of income for the families and communities that inhabit this metabolism (Homma & Menezes, 2008). In Brazil, the plant is present and its fruit is exploited mainly in the States of Mato Grosso, Rondônia, Acre, Amazonas, Pará, Roraima, Amapá and Tocantins. As the fruit affects several locations, including outside Brazilian territory, in 1992, its nomenclature was designated as Amazon nut at the opportunity of the 3rd World Convention of Dried Fruits (Embrapa-RO, 2005).

In this way, the productive chain of the Amazon nut is understood as a metabolism component of the region, and the need to measure the result of this metabolism (organization and activities and sustainable performance), we ask: how is the eco-socio-environmental metabolism characterized of the Amazon nut production chain in the northwest of the State of Mato Grosso?

Placing studies with extractivist communities in the Amazon region becomes important, firstly because the social actors involved are distant from public policies, access to education and technology. Second, promoting activities that promote income with low environmental impact contributes as much to the development of the region's inhabitants as to the forest, which ends up being preserved due to local interests. And also, because extractivist[1] activities of NTFP are activities that are directly linked to the preservation of common goods.

The region in question is considered to be the last untouched region of Mato Grosso, research involving the aspects of sustainability is important because it contributes with diagnoses and recommendations for the maintenance of its metabolism. In particular, due to its environmental characteristics, its biodiversity is seriously threatened, due to being considered a deforestation corridor towards the Amazon (WWF, 2012). Deforestation is one of the main problems faced by the forest and traditional communities, since NTFP play a predominant role in the survival of these communities, used both for subsistence and for economic purposes.

2. SOCIAL METABOLISM

Originated in the natural sciences, the concept of metabolism was also used in studies of social systems. Currently, its use refers to the consistency of energy and material processes within societies and the economy. The concept echoed in the social theories, however, its development occurred gradually becoming more or less restricted, and with oscillating interest of the researchers. (Fischer-Kowalski, 1998).

[1] The term refers to activities that usually involve NTFP, and which are not predatory.

In the social sciences, the concept reappears in scientific discussions with the expansion of environmental issues in the 1960s, when criticism of unbridled economic growth allowed us to turn the attention of scholars to the concept of metabolism (Figure 1). (Wolman, 1965; Ayres & Kneese, 1969; Boyden, 1969; Kneese, 1971; Meadows, Meadows, Randers & Behrens III, 1972; Daly, 1973; Fischer-Kowalski, 1998).

(Marx & Engels, 1887)	They used the term together with the descriptions of the work process, describing it as human action for the production of consumer goods, appropriation of natural substances according to human needs and, therefore, a necessary condition for the interchange between man and nature being this conditioner of human existence. Subsequently, Marx will use the term "corporate metabolism" to represent trade in industrial societies.(Schmidt, 1971).
Patrick Geddes (1902)	Noted and argued that energy flows were common to all societies and developed a unified calculation based on energy and material flows. In order to demonstrate a homogeneous result for any economic and social activity, the author defended a measure of the economy not more for currency, but for energy and resources. Geddes (1885, cited by Fischer-Kowalski, 1998) developed a model of economic inputs and outputs in physical terms, initially placing the energy sources and materials used in the process, and showing the transformation process in 3 steps.
Wolman (1965)	Explains that the metabolic conditions of a city can be defined as "the materials and commodities needed to sustain the city's inhabitants at home, at work and at play. (...) The metabolic cycle is not completed until the wastes and residues of daily life have been removed and disposed of with a minimum of nuisance and hazard." (p. 179).
Keneth Boulding (1966)	It describes a shift from what he calls "cowboy economy" to "spaceship economy". The current world economy; on this approach; is an open system in relation to energy; to the subject and the information, that the author calls "econosphere".
(Ayres & Kneese, 1969)	They are the first to submit a complete program of analysis, which was later considered a material flow analysis. Using the principles of the fundamental law of mass conservation, its basic argument revolves around the economic axis, the authors explain that the economy relies heavily on precious environmental goods such as air and water, and this prevents optimal Pareto allocations in the markets at these common goods free of charge. From this, they argue that the failure of an economic system can be a result of misuse of resources.

Figure 1. Main Theorists of Social Metabolism.

In contemporary times, theoretical currents have been organized around the concept, the development of thought that involves the theme, for Newell and Cousins (2015) it is possible to identify three main theoretical currents in the present day to what the authors called "the three 'ecologies' ": industrial ecology, urban ecology and Marxist ecology. The first one, developed by Ayres and Kneese (1969) and who generally uses Material Flow Analysis [MFA] and Life Cycle Assessment [LCA] methodologies (Baccini, 1996). For this thought nature is used as a structural and functional model for the analysis of industrial systems (Jelinski, Graedel, Laudise, McCall & Patel, 1992). This current has two subdivisions, one called "traditional urban metabolism" and another of "Vienna School of Socioeconomic Metabolism", which differ from one another by the temporal cuts, in the first generally transverse, while the second longitudinal, in addition to the variables of an analysis which in the Vienna School considers the construction of societies via historical materialism.

In the current of Marxist ecology, the concept of metabolism is applied to investigate themes that address the tensions between nature and society proposed by Marx (Cronon, 1991), to the function of social power in the construction of urban space and access to goods (Swyngedouw, 2004), and the ruptures between the environment and human production action brought about by globalization and urbanization (Foster, 1999; Moore, 2000). The current is also divided into two sub-currents, Urban Political Ecology, which groups thinkers who understand the concept of metabolism as active and networked circulations that rearrange physical and social environments in "socialist assemblies" (Swyngedouw, 2006). The second, based on the Metabolic Rift Theory (Foster, 1999), in this the concept of metabolism is developed for the understanding of the relations between man-nature, however, the thought differs by being oriented in the belief that there is a metabolic rupture between rural and urban.

Urban ecology finally consolidates as the third and most recent current to be established, has a unique focus on urban environments (cities), and work on the concept of metabolism in a

less constant way. Constantly influenced by Eugene P. Odum's concepts of industrial ecology (Newell & Cousins, 2015), the authors of this group believe that industrial metabolism theorists misinterpreted the writings of E. P. Odum (Golubiewski, 2012), acreditando que o autor ao cunhar o conceito não se referia a comunidades inteiras mas apenas ao nível de metabolismo individual. believing that the author coining the concept did not refer to entire communities but only to the level of individual metabolism. However, a review of the E. P. Odum's work easily demystifies this thinking, for example, the construction of the concept of community metabolism of self-sustaining micro ecosystems (Odum, 1968, p. 16).
Several methods have been improved or built from the Theory of Social Metabolism and explain that the boundaries of these theoretical approaches are still flexible and that theory, as the very concept of the idea, is constantly adapting to reality, especially MuSIASEM Methodology which is located in Industrial Metabolism, permeates urban Ecology, perhaps with the objective of overcoming the criticisms dedicated to this current.

3. MUSIASEM

MuSIASEM is conceived in two main main axes: the semantic axis, the pre-analytic stage in which the structure of the representations of the systems is conceived, and the syntactic axis that comprises the selection, production and use of indicators, and is where the analysis and benchmarks are properly implemented. According to Giampietro, Gamboa, Lobo, Sorman and Waldron (2008), the creation of indicators needs, fundamentally, to adequately define criteria and attributes (semantic categories) to be taken into account in the analysis, and to elect formal hierarchies and rules of production, as well as proxies that are capable of providing adequate data for evaluations and determine causal relationships where appropriate.

What allows MuSIASEM to encompass different dimensions and different variables is the versatility that the instrument enjoys. At the moment of definition of the semantic axis, the description of the narrative is made from a "Multipropouse Grammar", process that will give meaning to the analysis of the system under study. (Giampietro & Mayumi, 2000b, 2000a; Giampietro *et al.*, 2008; Giampietro *et al.*, 2009). For the purposes of this vocabulary, a preliminary definition of:

(A) a *taxonomy* – the set of semantic categories and formal categories used in the grammar – the types of types that are used in the grammar;

(B) a set of *dictionaries* for the various categories included in the taxonomy – the elements of the different sets (relevant meanings/information; names and tokens);

(C) a set of *production rules* to be applied to formal categories using the distinction between "tokens" and "names". Tokens are associated with a data set which must be assigned to the grammar for its operation (data input). Then, the production rules are associated with the formal system of inference determining the values of "names" starting from the data input. (Giampietro *et al.*, 2008, p. 71).

Thus, this concept suggests the establishment of three component elements: the establishment of a lexicon (semantic and formal classes); the establishment of a set of production principles (syntactic and semantic rules to be used for class items, defining the structured set of relations); the ability to apply the meta-tool (Giampietro *et al.*, 2008; Giampietro *et al.*, 2009).

The syntactic axis, in turn, is signaled by the quantitative relations to be realized from the establishment of the grammar of the narrative. Its concept is based on Georgescu-Roegen's 'Flow-Fund' model. This author has understood that industrial and agricultural activities do not obey the same economic laws and thus need to be individualized (Walker, 2005). Based on this understanding, the author conceives the Flow-Fund model of production and consumption processes. Where, flows are understood as the elements that do not maintain their characteristics from the beginning to the end of the narrative, and determine "what the system does", what the system actually processes. The pace of these flows is governed by factors external to the system such as the availability of a resource, and by factors internal to this system. (Giampietro & Mayumi, 2000a; Giampietro *et al.*, 2009). The funds, in turn, cover the items that are fixed throughout the duration of the representation. The elements grouped in the background category must maintain their characteristic of metabolic converters and narrate "what the system is", the conjuncture in which the flows will be metabolized. Thus the funds will determine the rate of consumption of the flows and legitimize in fact what is an entry and exit of the system, therefore, the funds must be renewed cyclically due to their fixity. (Giampietro *et al.*, 2009).

In a characteristic term of these parts, the author discusses that the dynamic budget of metabolism (total resources available in a system) is analyzed in two structures analogous to the structure of the ecosystem, similar to the idea proposed by Ulanowicz (1986, cited by Giampietro *et al.*, 2008), which state that the flow of materials and energy can be seen in two parts, the first as a hypercycle and the other as a merely dissipative part of the system. By incorporating the Georgescu-Roegen model,Giampietro and Mayumi (2000b, 2000a), divided it into a multi-level matrix composed, as the name suggests, of several hierarchical levels of analysis that allow to describe the metabolism with greater efficiency. Thus, the chosen background is then called Matrix, which is confronted with the flow (s) with which the rules of production established in the proposed grammar allow. Thus, funds and flows allocated are labeled as "extensive variables", i.e., which represent volumes and characterize the size of the compartments. When the production rules established in the semantic axis occurs, so-called "intensive variables" indicators are produced, that indicate a potential or pressure of the metabolism, these variables mark the metabolic rhythm of a compartment under analysis [EMRi – Exossomatic Metabolic Rhythm], defining when a flow is metabolized by a given fund, the intensive variables produced are then used as benchmarks to provide a qualitative overview of these items. (Giampietro & Mayumi, 2000b, 2000a; Giampietro *et al.*, 2008; Giampietro *et al.*, 2009).

The sum of the compartments listed in the matrix comprises the total of the extensive variables presented which allows the application of the so-called 'Sudoku effect'. (Sorman, Serrano & Giampietro, 2009). The Sudoku effect refers to the mechanism by which it is possible to perform a proof of quality in the representation based on non-equivalent descriptive domains arranged in multi-level matrices related to definitions of funds and flows between non-equivalent variables. In this way, these domains are forced to combine according to initial parameters, but not fixed, combining all the expected dimensions, being one restrictive of the other. (Giampietro *et al.*, 2008; Giampietro & Bukkens, 2015).

Following this thought, the methodology then allows the execution of the Impredicative Loop Analysis [ILA]. The term impredicativity (Kleene, 1950) is defended by Giampietro *et al.* (2009) in its use in MuSIASEM because without the understanding of this concept the scientific activities within the field of sustainability are obscure. When studying metabolisms that are narrated in different hierarchies and diverse scales, establishing a linear relationship compromises the robustness of the analysis. Hence, unpredictability disrupts scientific reductionism, since it is impossible to establish a common linear link in traditional scientific instruments. For a linear relationship to occur, it is necessary to arbitrate a narrative (as a single scale) that is able to avoid the influence of causal externalities on the intended result, since in complex systems where scales and hierarchies are essentially heterogeneous, it is not effective since there will always be alternative ways to determine causality..

In this way, it is possible to ascertain the feasibility of the exosomatic metabolisms of social complexes, evaluating the consistency of the values attributed to the flows and funds over two grammars that will determine the impredicative cycle: the consumption sector metabolism (HH), which represents the demand for products and services, which represents the demand for products and services, paid work (PW), and the metabolism of the productive sector (PS), which denotes the demand for PW and the supply of products and services.(Giampietro & Mayumi, 2000a, 2000b). Therefore, the ILA allows studying the viability and desirable patterns, which are biophysical and socioeconomic constraints within a proposed scenarios. (Giampietro *et al.*, 2008).

Thus, when applying the MuSIASEM methodology in a particular socioeconomic metabolism, it is possible to establish a set of expected relationships that restrict the values that can be attributed to the group of intensive and extensive variables selected in the preanalytical phase, through the ILA, the Sudoku effect and the multifunctional grammar. It is also important to consider that the accounting mechanisms of MuSIASEM are not deterministic, since even with the choice of variables as parameters of analysis a simple change in any one of them implies structural changes in all extensive and intensive variables.

4. METHODOLOGICAL PROCEDURES

The research uses interpretative epistemology and is characterized as descriptive-exploratory with a qualitative approach since it intends to analyze the eco-socio-environmental metabolism of the Amazon nut production chain in the northwest of the State of Mato Grosso through the approach MuSIASEM (Ander-Egg, 1978; Creswell & Clark, 2011; Creswell, 2013). Regarding the research strategy, the study sets up as a case study being the production chain of the Amazon nut in the northwest of the State of Mato Grosso the unit of analysis (Yin, 2005). Interviews, documents and secondary data were used as data collection procedure. Regarding the temporal range, a cross-cut with an ex post facto approach was used, since only 2016 was analyzed in this study. For the data analysis, the MuSIASEM approach (Giampietro & Mayumi, 2000a).

The case selected for study was the productive chain in the northwestern state of Mato Grosso, primarily because of the importance of the activity in this region as an alternative to stop the deforestation that advances through this ecological corridor. Secondly due to the fact that the activity has for many families and traditional communities in the region, and finally to present characteristics that allow to calibrate and verify the effectiveness of the MuSIASEM methodology in a micro level analysis.

The main focus of the analysis is the Vale da Amanhecer farmers Cooperative [COOPAVAM – Cooperativa dos Agricultores do Vale do Amanhecer], since in terms of organization, access to reliable data, as well as political influence in the region, it is a central actor in the production chain. COOPAVAM stands out as the main agent in the region, all the Amazon nut that circulates in the region, or passes through the cooperative or receives its influence, the collection is carried out mainly by indigenous peoples of the region, and farmers who have access to the forest. The nut is then sold to the cooperative or middlemen, at this point the political strength of the entity is emphasized since the price per kilo paid by the Amazon nut in that environment is determined by the amount paid by the cooperative, so the organization is also a regulating agent of the value chain.

We conduct few interviews focused primarily on a representative person, select a small number of data to fulfill the proposal in a non-random manner. The semi-structured interviews was made to understanding how the residents of the area use their time, in physiological overload, House chores, education and leisure, we have a saturation in 4 interviews. he second interview, unstructured, was designed as unique, since the social actor is a unique case, the interview was granted by E1, a professional linked to ADERJUR and who has a long experience with the chestnut theme in the region, since his work began in the 1990s. E1 is the main articulator of the communities, being responsible for the coordination of almost all the projects developed by ADERJUR and COOPAVAM, having access and respect, above all by the indigenous community of the region, besides E1 is a delegate of the United Nations Development Program and is responsible for the Amazon.

In relation to the procedure for data analysis, we used what is established in the MuSIASEM methodology, in this way, we set the variables that will perform the semantic composition of the narrative, as well as establish the rules of production and the tokens that make up the proposed grammar (Figure 2), which will produce the expected output variables.

Variable	Definition	Production Rules	*Tokens*
THA	Total Human Activity	Multiply the total number of hours available in the day, considering the particularities between men and women, minus the time of physiological overload by the number of days available and then multiply by the number of individuals covered by the representation; the sum of hours in HA_{HH} e HA_{PW}. $THA = \sum h - \sum HA_{PO}$ Ou $THA = HA_{HH} + HA_{PW}$	-Amount of hours in HA_{PO}. -Number of days available. -Number of individuals. - Amount of hours of HA_{PO} - HA_{HH} Value. - HA_{PW} Value.
HA_{HC}	Total hours of human activity dedicated to housework.	Multiply the total number of hours devoted to housework by the number of days available, multiplied by the number of existing individuals. $HA_{HC} = h_{HC} \times Days \times Pop.$	- Average time spent on domestic services. -Number of days available. - Number of individuals..
HA_{LE}	Total Hours of human activity dedicated to leisure and education.	Multiply the total number of dedicated study / learning and leisure hours by the number of days available, multiplied by the number of existing individuals. $HA_{LE} = h_{LE} \times Days \times Pop.$	- Average time spent on leisure and education.. - Number of days available. - Number of individuals.
HA_{PO}	Total Hours of human activity dedicated to physiological overload.	Multiply the total number of hours dedicated to personal care, sleep, food, etc. by the number of days available, multiplied by the number of existing individuals. $HA_{PO} = h_{PO} \times Days \times Pop.$	- Average time used in physiological activities and personal care. - Number of days available. - Number of individuals.
HA_{HH}	Total hours of human activity dedicated to the Household sector.	Add up the total hours spent on house chores, education and leisure. $HA_{HH} = HA_{HC} + HA_{LE}$	- HAHC Value. - HALE Value.
HA_{PW}	Total hours of human activity devoted to paid work.	Multiply the total number of hours devoted to paid work by the number of days available, multiplied by the number of existing individuals or; the hours allocated to the household sector are subtracted from the THA. $HA_{PO} = h_{PW} \times Days \times Pop.$ Ou $HA_{PW} = THA - HA_{HH}.$	- Average time spent on paid activities. - Number of days available. - Number of individuals. -HH Value. -THA Value.
HA_i	Total hours of human activity transferred to a specific sub-compartment.	Multiply the total number of hours of human activity devoted to the selected sub-compartment by the number of available days, multiplied by the number of existing individuals. $HA_i = h_i \times Days \times Pop.$	- Average time used in the sub-compartment. - Number of days available. - Number of individuals.
TET	Total Exossomatic Throughput.	The sum of the amount of energy of all the sources used in joules for the whole system in the studied period, or; the sum of ETHH e ETPW. For the conversion of the energy metrics in joules: 1 kW = $3.6.\ 10^6$ J 1 Kg of wood= $1.50.\ 10^7$ J	-Amount of electric energy used in the period. -Conversion value from kW of electric energy to joule.

Variable	Definition	Production Rules	*Tokens*
		1 l diesel oil = 3.64. 10^7 J 1 kg de of liquefied petroleum gas (LPG) = 4.70. 10^6 J $TET = \left(\sum kw \times V_{kw}\right) + \left(\sum m^3/Kg \times V_{m^3}\right) + \left(\sum l \times V_l\right) + \left(\sum kg \times V_{kg}\right)$ Ou $TET = ET_{HH} + ET_{PW}$	-Amount of wood used in the period. -conversion value of m³/Kg of wood for joule. -Amount of fuel used in the period. -Conversion value from diesel to joule. -Amount of LPG used in the period. -Conversion value of kg of LPG to joule. -ET_{HH} Value. -ET_{PW} Value.
ET_{HH}	Energy Throughput to Household sector.	A sum of energy quantity of all sources in joules in the household sector no studied period. For the conversion of the energy metrics in joules: 1 kW = 3.6. 10^6 J 1 Kg of wood= 1.50. 10^7 J 1 l diesel oil = 3.64. 10^7 J 1 kg de of liquefied petroleum gas (LPG) = 4.70. 10^6 J $ET_{HH} = \left(\sum_{HH} kw \times V_{kw}\right) + \left(\sum_{HH} m^3/Kg \times V_{m^3}\right) + \left(\sum_{HH} l \times V_l\right) + \left(\sum_{HH} Kg \times V_{Kg}\right)$	-Amount of electric energy used in the period in HH. -Conversion value from kW of electric energy to joule. -Quantity of wood used in the period in HH. -Conversion value of m³/Kg of wood for joule. -Amount of fuel used in the period in HH. -Conversion value from diesel to joule. -Amount of LPG used in the period in HH. -Conversion value of kg of LPG to joule.
ET_{PW}	Energy Throughput to use in the production of goods and services.	The sum of the energy quantity of all the sources used in joules for the production of goods and services in the studied period. For the conversion of the energy metrics in joules: 1 kW = 3.6. 10^6 J 1 Kg of wood= 1.50. 10^7 J 1 l diesel oil = 3.64. 10^7 J 1 kg de of liquefied petroleum gas (LPG) = 4.70. 10^6 J $ET_{PW} = \left(\sum_{PW} kw \times V_{kw}\right) + \left(\sum_{PW} m^3/Kg \times V_{m^3}\right) + \left(\sum_{PW} l \times V_l\right) + \left(\sum_{PW} Kg \times V_{Kg}\right)$	-Amount of electric energy used in the period in PW. -Conversion value from kW of electric energy to joule. -Amount of firewood used in the period in PW. -Conversion value of m³ of firewood to joule. -Amount of fuel used in the period in PW. -Liter conversion value from diesel to joule. -Amount of LPG used in the period in PW. -Conversion value of kg of LPG to joule.
ET_i	Energy Throughput to a specific sub-compartment.	The sum of the amount of energy of all sources used in joules in the sub-compartment of analysis selected in the studied period. For the conversion of the energy metrics in joules: 1 kW = 3.6. 10^6 J 1 Kg of wood= 1.50. 10^7 J	- Amount of electric energy used in the period in the sub-compartment analyzed.

Variable	Definition	Production Rules	*Tokens*
		1 l diesel oil = 3.64. 10^7 J 1 kg de of liquefied petroleum gas (LPG) = 4.70. 10^6 J $$ET_i = \left(\sum_i kw \times V_{KW}\right) + \left(\sum_i m^3/Kg \times V_{m^3}\right) + \left(\sum_i l \times V_l\right) + \left(\sum_i Kg \times V_{Kg}\right)$$	-Conversion value from kW of electric energy to joule. -Amount of firewood used in the period in the sub-compartment analyzed. -Conversion value of m³ of firewood to joule. -Amount of fuel used in the period in the sub-compartment analyzed. -Conversion value from diesel to joule. -Amount of LPG used in the period in the sub-compartment analyzed. -Conversion value of kg of LPG to joule.
GDP	Total values circulated in metabolism.	The sum of all the wealth generated in the system. The values of the sales of the nuts are added by the collection sector and the sum of all the products sold by the cooperative in the sector PS: $$GDP = \sum \$\, collect + \sum Revenues + \sum Others$$ Where: PP= Purchase price $$\$\, collect = PP \times \sum Kg$$	- Amount of nut delivered to the cooperative. -Value paid for the kg of nut. -Retire sale with sale of products.
GDP_i	Total of values circulated in a specific sub-compartment.	The sum of all the wealth generated in a sub-compartment. $$GDP_i = \sum Revenues\ in\ the\ sub-compartment.$$	- Value of Revenue in the sub-compartment analyzed.

Figure 2. Set of semantic category choices, establishment of production rules and tokens.
Source: Prepared by the Authors based on Giampietro and Mayumi (2000b, 2000a); Giampietro *et al.* (2008); Giampietro *et al.* (2009).

Thus, it is expected after the execution of the production rule, the production of exossomatic metabolic rates, energy intensity, work efficiency and productivity (Figure 3).

Variable	Cálculo
EMR_{SA}	Total Exossomatic Energy Throughput/Total Human Activity (TET/THA).
EMR_i (PW; HH;...)	Energy Throughput to the sector/ Human Activity in the sector. (ET_i/HA_i)
PR_{SA}	Total produced / Total Human Activity (PT/THA)
PR_i	Total produced on sector/ Human Activity on sector. (PT_i/HA_i)
ELP_{SA}	GDP/ Total Human Activity. (GDP/THA)
ELP_i	GDP on Sector/ Human Activity on Sector (GDP_i/HA_i)
El_{SA}	Total Exossomatic Energy Throughput / PIB. (TET/GDP)
El_i	Energy Throughput to the sector / GDP on Sector. (ET_i/GDP_i)
EE_{SA}	GDP/ Total Exossomatic Energy Throughput
EE_i	GDP on Sector / Energy Throughput to the sector
SEH	TET / HA_{PS}
BEP	TET / HA_{PS}

Figure 3. Intensible variables used in the study.
Source: Prepared by the Authors based on (Giampietro & Mayumi, 2000b, 2000a; Giampietro *et al.*, 2008; Giampietro *et al.*, 2009).

5. RESULTS AND DISCUSSIONS

For the construction of the narrative funds and flows, the production rules established for the system were executed, from the tokens obtained in the interviews and documents searched, the totals of the intensive variables can be observed in Table 1.

Table 1:
Total Intensive Variables.

Variable	Total
Total Human Activity (THA)	469,7 kh
Total Exossomatic Throughput (TET)	12,753 TJ[b]
Production (PD)	91.000 kg
Money (GDP)	R$ 1. 499.954,47

Note. [a] Kilo hours (1.10^3 h). [b] Tera Joules ($1.\ 10^3$ J).

From the establishment of the sizes of flows and funds chosen for the narrative, we then applied the production of desired intensive variables. The multi-level analysis matrix proposed for this study was constructed on 3 levels (Figure 4) where the compartments can be visualized for understanding the analyzes below.

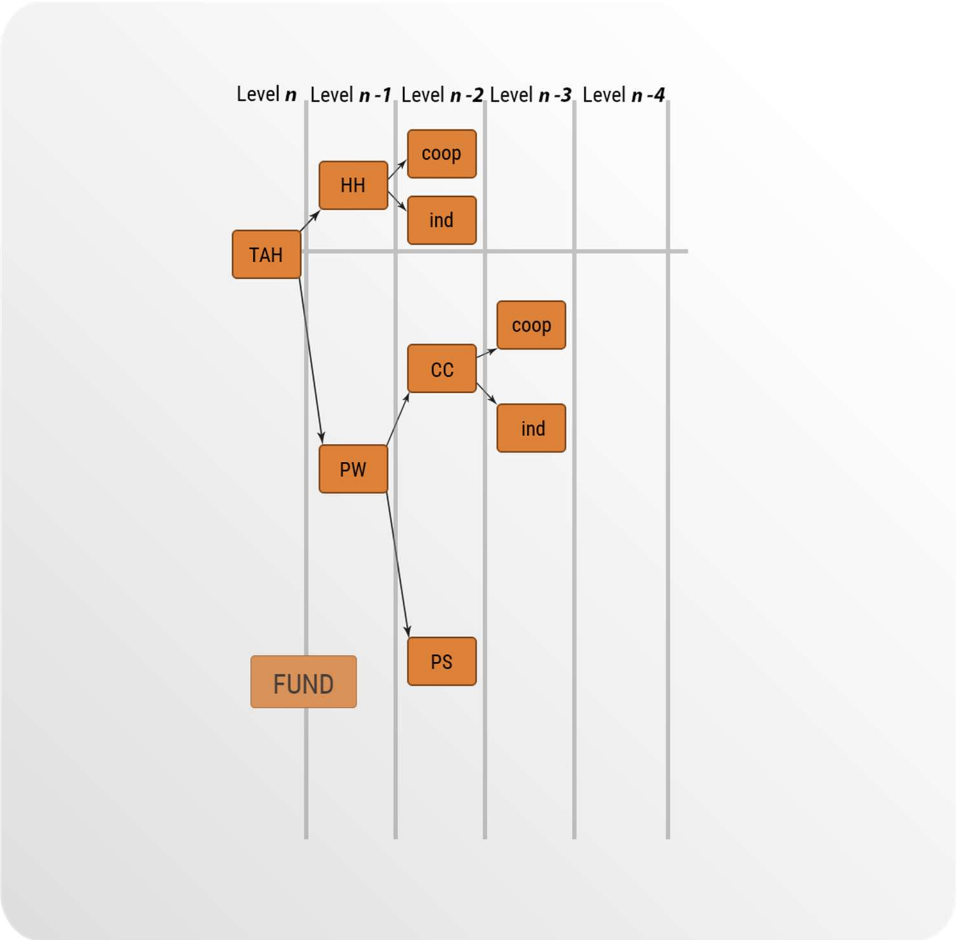

Figure 4. Structure of the proposed multi-level analysis matrix.
Source: Prepared by the authors.

The first relation studied was between the proportion of human activity and the use of energy, considered by MuSIASEM as the background and flow, respectively, the most important of a narrative. For this study it was not possible to establish adequate benchmarks due to the fact that the works published in the theme used whole country narratives, with the exception of Matthews *et al.* (2010) that analyzed a smaller area in Scotland, however, the use of analyzes via MuSIASEM was restricted to land use and the PW fund.

For the determination of the first analysis matrix, the totals related to the human activity fund (HA) and the energy flow (ET) previously established from the collected data were used, cf. Figure 5.

The narrative presented significant indicators for the year 2016, as an EMR_{SA} of 27 MJ/h compared to that established by Giampietro *et al.* (2008) is similar to the developed countries metabolic rate, (Spain in 1996 EMR_{SA} = 20 MJ/h), however, it is important to note that this figure refers to an EMR of 20 years ago. In South America Recalde and Ramos-Martin (2012) found for Argentina an EMR_{SA} of 11.47 MJ / h in 2007. In this narrative the expressiveness of this value may have been increased due to the consumption of primary energies such as wood burning, which has high workforce values.

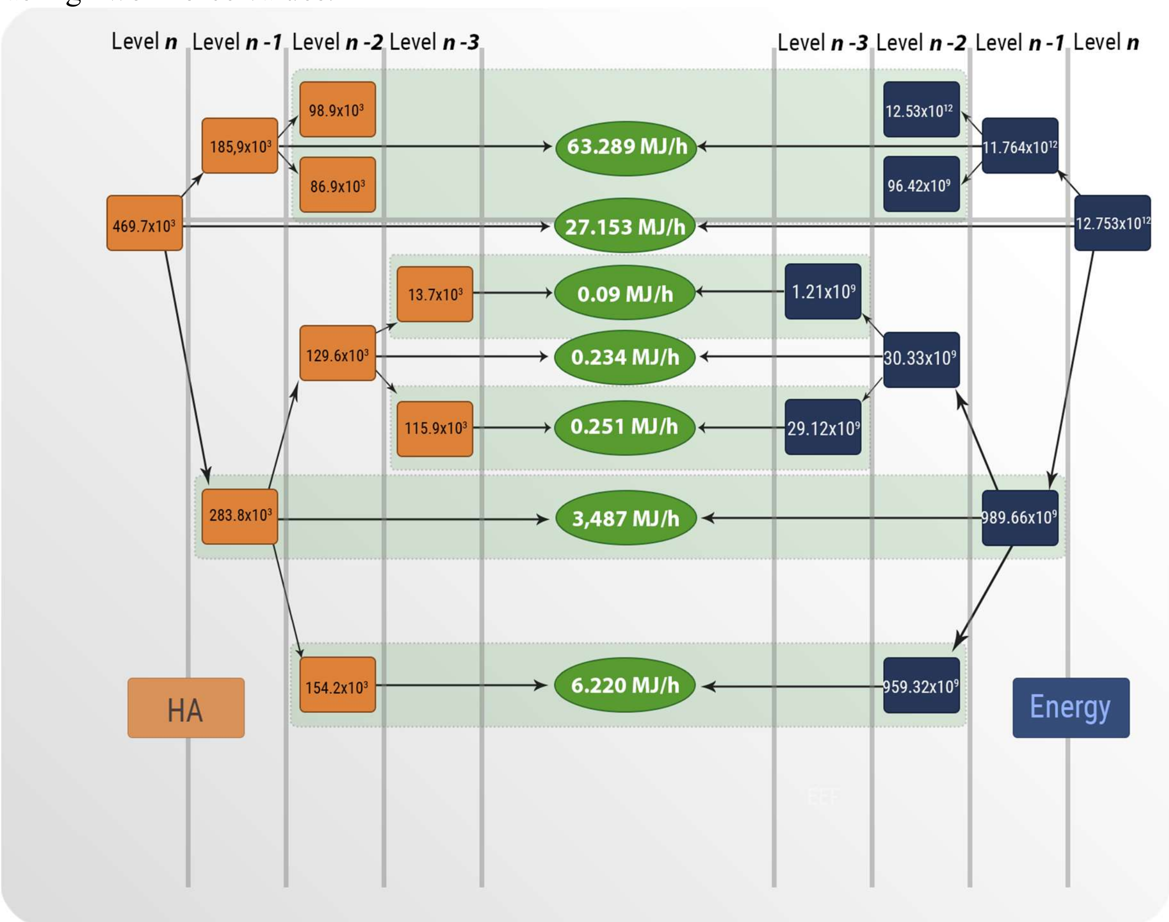

Figure 5. Analysis Matrix Human Activity X Energy of the Productive Chain of the Amazon Nut in the northwest of the Mato Grosso State in 2016.
Source: Research data.

Another indication of this observation is corroborated when comparing the metabolic rhythms of the consumer sector (HH) and the production sector (PW), where the main demand for energy is clearly made by the consumer sector. In a preliminary analysis this would confirm a state of development where people are more likely to engage in leisure activities, education and so on. However, this is not confirmed when we verified the distribution of HA to the narrative, where HA_{HC+LE} consists essentially of the amount of hours allocated to the activities of domestic tasks (115,801 hours). Another sign, which does not apply to this narrative is the demographic situation of the population studied, high energy demand in HH suggests an elderly population, however, the average age of the cooperative is 41 years, while the indigenous population was not possible access this information. In addition, the comparison with a state of full development is not confirmed, since 60% of the human activity is destined to work, cf. Figure 6.

Still in this sense, the narrative becomes unique because, despite having an EMR_{SA} and a high EMR_{HH}, its metabolic rate for the productive sector is low, with a rate of 3.48 MJ/h, which is not analyzed at the country level, e.g., the authors Giampietro *et al.* (2008) point out that in China considered a developing country, in 1999, the PW sector demanded 15.81 MJ/h, in Argentina, 82.96 MJ/h. However, it is believed that this value is a reflection of the low technology used in the processes, especially as it is an extractive activity, and during processing machines are in a higher position of production aid.

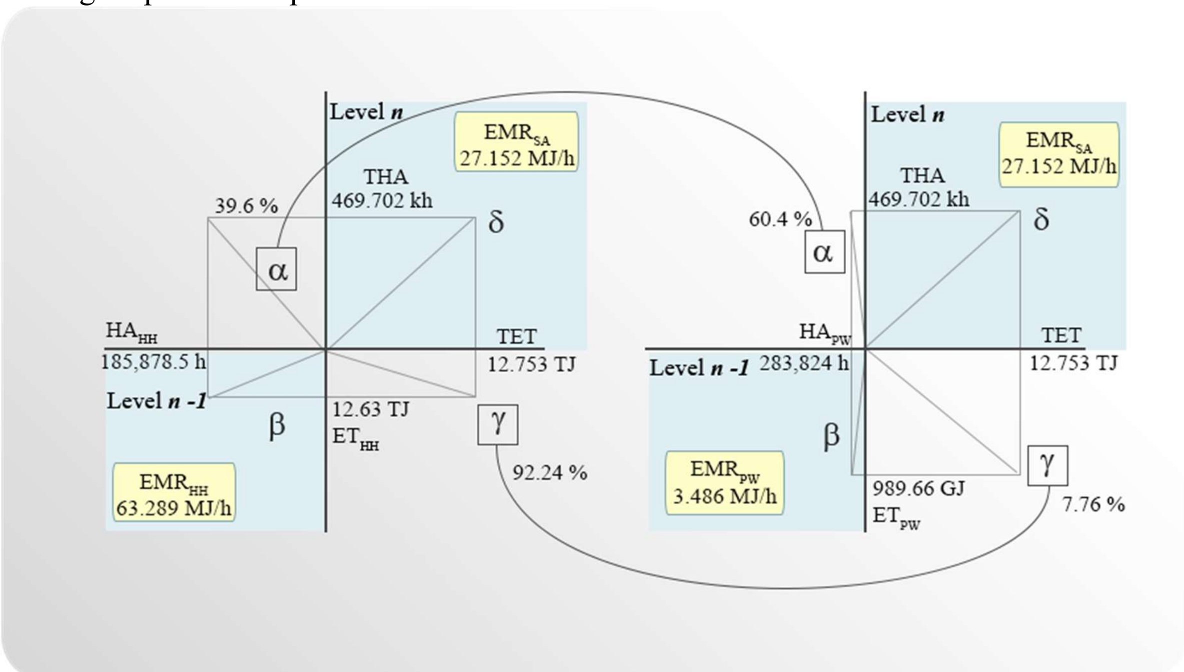

Figure 6. Composition Chart of Energy X Human activity Energy of the Productive Chain of the Amazon Nut in the northwest of the Mato Grosso State in 2016.
Source: Research data.

Another indicator demonstrated by this rate is the low environmental impact in the activity, since it demands little external energy, especially in the collection period that demands 0.234 MJ/h for its realization, where the indigenous communities demand 0.25 MJ / h due to need for carriage of the nut and more people involved in this process, while the process of processing requires 6.22 MJ/h, an amount that could perhaps be reduced by the replacement of wood in the production process.

Later, the relationship between production and labor is analyzed, the indicators have relatively low values, which is justified by the nature of the activity, generally in the collection work, about 702 grams of Amazon nut per hour of human activity in this function. At this point it is interesting to note that indigenous communities, even with a larger number of people collecting about 44% less brown than the cooperative who do the work in the Vale do Amanhecer settlement. This may occur as a function of the time that the indigenous communities take to reach the chestnuts and transport the chestnut collected by the forest to the point of delivery. Already in the processing of the product, each hour of work processes about 600 grams of the almond, which can occur due to the manual process of processing in most of the processes, as well as the time spent in drying the lots of nuts that can be left only in the rotary dryer more than 24 hours.

In terms of income, the relationship with human activity was also established. This analysis suggests in particular the amount of value added for each hour of activity, best visualized in the analysis matrix produced (Figure 7).

The results show an average labor productivity in the Amazon nut production chain, slightly lower than expected when comparing this value with that of a person earning a minimum wage in 2016 (Brasil, 2015) and working the same amount of hours, R$ 3.76/h (Reais per hour) of human activity in paid work. However, this value may be influenced by the collection work of the indigenous communities, which registers the lowest average value of R $ 2.24 / h, which in turn places the collection work as low value, however, the low value presented for the collection does not suggest exploration of this group.

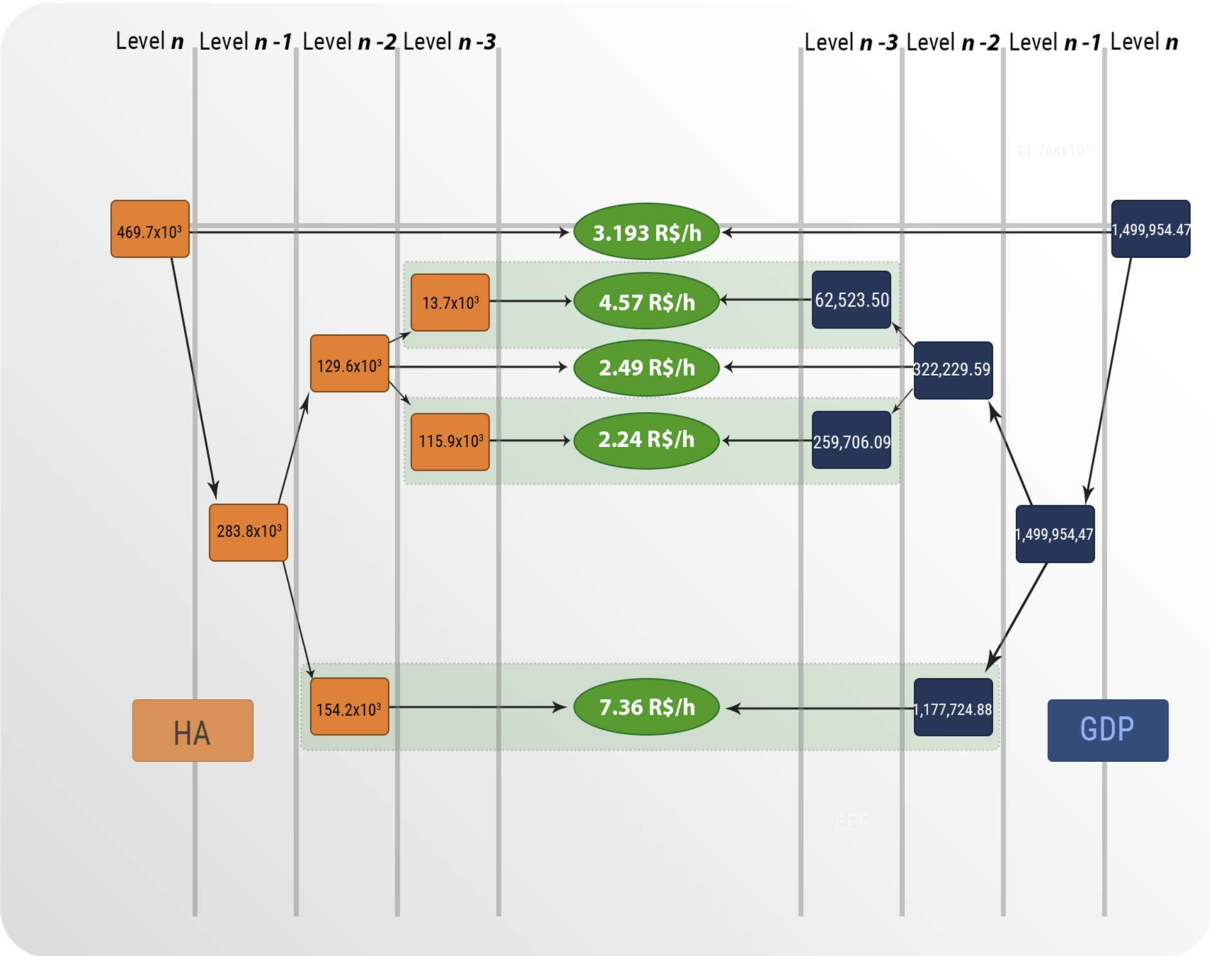

Figure 7. Analysis Matrix of Human Activity X Income of the Productive Chain of the Amazon Nut in the northwest of the Mato Grosso State in 2016.
Source: Research data.

If we compare the average amount paid for the kilo of Amazon nuts to this group, it is perceived that it is about 8% higher than that paid to the cooperative that carries out the same work (R$ 3.55/kg for the communities Indians and R$ 3.27/kg for workers in the Vale do Amanhecer). The justification for this low value lies in the lower productivity of these communities, which can be explained, as previously mentioned, by the time spent in displacement, and may also suggest a strong relation with the middlemen, which would indicate a higher productivity for this group, however, these values could not be ascertained.

When observing the value of $ELP_{cc(cp)}$ (4.57 R$/h), which refers to the collection work of the cooperative, this worker received 21% more than a common worker who received a minimum wage in the analyzed year , coming close to the average income of the Brazilian who lives in the state of Mato Grosso this year, 4.87 R$/h (IBGE, 2017). However, the processing of the nut proved to be encouraging in the aggregation of narrative value, accounting for 78.52% of all the income generated in the system, cf. Figure 8.

The analysis confirms the potential for income generation in the chestnut processing, since using almost the same labor potential, this sector produced almost 80% of all the money circulated in the system if we compare ELP rates for this year , the processing sector added triple the value of the primary collection activity. Even if we consider the highest ELP for the level of collection (CC_{cp}), the processing of the Brazilian nut in manufactured products accounts for about 40% more value than the commercialization of the nut in natura. However, some alternatives should be considered for the moment of processing when it comes to the energetic intensity of this narrative.

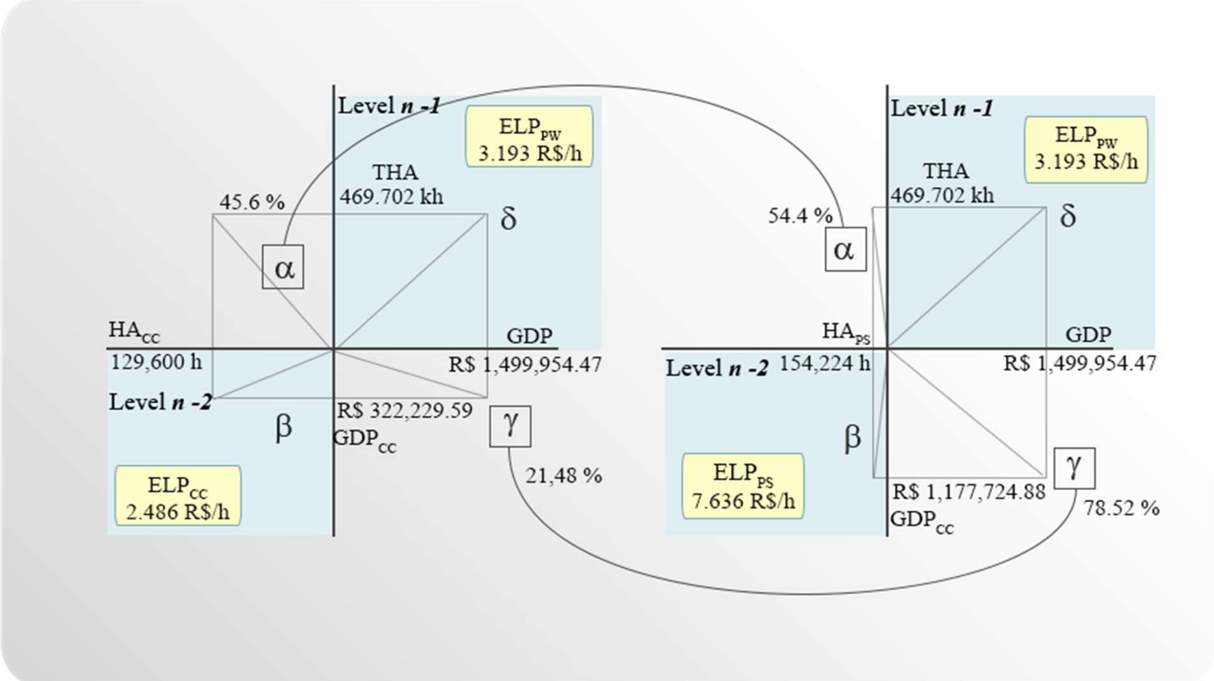

Figure 8. Composition Chart of Income X Human Activity of the Productive Chain of the Amazon Nut in the northwest of the Mato Grosso State in 2016.
Source: Research data.

Energy intensity rates demonstrate a low energy efficiency in the Amazon nut production chain as a whole EE_{SA}= R$ 0.12/MJ (Reais per Mega Joule), similar to the value found by Recalde and Ramos-Martin (2012) for the agricultural sector of Argentina, and that for them is an excessively low value. However, this figure does not include the high consumption of the HH sector of the narrative, so the focus of the analysis will be on the PW sector. The activity that presents the best relation in energy consumption and value aggregation is in the collection phase, where each mega Joule of energy consumed produced R$ 10.62 for the system. This value is even more significant if we analyze at the n -3 level the harvesting activity of the farmers of the settlement of the Valley of the Dawn, far superior to any other activity of the narrative, the process of processing, however, was well below expectations.

The verified EE_{PS} indicates a low energy efficiency in the manufacturing process, in 2016 each mega Joule used in the processing of Amazon nuts generated only R$ 1.23. This low aggregation of value can be explained, once again, by the use of primary energies from the biomass burning. This is confirmed by excluding from the calculation of ET_{PS} the Joules values for the 80 m³ of firewood used in 2016 for the drying process of the nut, presenting an 8 times higher rate of energy efficiency. However, this value should be viewed with caution because the value of the excluded energy must be replaced by another more sustainable energy that meets the needs of the process.

6. FINAL CONSIDERATIONS

The goal of this study was to analyze the eco-socio-environmental metabolism of the Amazon nut production chain in the northwest of the State of Mato Grosso through the MuSIASEM approach. Thus, it is considered that the metabolism of the production chain of the Amazon nut in the northwest of Mato Grosso State presents a state of equilibrium, although some problems must be observed as the influence of external agents, especially intermediaries, that need to be studied for understanding their role and scope in metabolism. The use of inefficient energies has also been a frequent problem influencing the values of some indicators.

The extraction activity of the Amazon Chestnut has an important role, both in the income generation of local and indigenous vulnerable groups, riverside, settled agrarian reform, and in the environmental preservation of the Amazonian biome. The analyzed metabolism can be characterized as a complex environment where the activity involves social, cultural and economic factors for the inhabitants of this region. It was verified the influence of the figure of middlemen and glimpsed its permeability in the global trade of the nut. Indians and middlemen seen as actors of the cycle by the fact that although not much is known of the role of these actors should be considered as a suggestion for future studies.

Finally, this study is concluded by suggesting for future research the application of the MuSIASEM methodology in other micronarratives, especially extractivists chains, in order to establish benchmarks more appropriate to this level of analysis. It is also suggested to carry out a study with scenario projections for subsequent crops, which could provide the social actors involved with information pertinent to their future planning, besides the importance of the production of an intensive variable, if there is an opportunity to establish a land use fund, so that it is possible to verify the extractive process as a whole and can establish relations of productivity per hectare. Studies are also needed on the relationship and performance of the middlemen in the region, since these components of metabolism have a great influence on the functioning of the system as a whole, as well as the social influence they represent above all in the indigenous communities.

As limitations of the research, list some points. we point out as limitation of the study the impossibility of determining the size of the chestnut areas used by indigenous communities that prevented the formation of a land use fund and that could produce interesting intensive variables to be observed. It is also important to note that it was not possible to perform the impredictive loop analysis and to establish the BEP and SEH indicators. This was due to the specificity of the analyzed system, the methodology when it was developed was based on analyzes of whole countries, in this case, since it is a specific value chain it is not possible to determine the values of HA in PW that were used for the supply of HH. Furthermore, due to the specificity of the case, it was not possible to establish adequate benchmarks at the level of analysis proposed, and it is necessary to carry out more studies in extractive chains in order to obtain a better overview of the real situation of the researched context.

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