WATER-ENERGY-FOOD-FOREST NEXUS IN THE AMAZON CONSERVATION UNIT

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ABSTRACT

Objective: The general objective of this research is to analyze the integration of forests into the water-energy-food nexus in a Conservation Unit in the Brazilian Amazon, aiming to verify how traditional populations, in whose areas they inhabit, use two natural and non-wood resources for their survival.

Theoretical Framework: The approach to the water-energy-food nexus emerged in the last decade around concerns such as global trends in population growth, economic growth and climate changes that place pressure on water, energy, food and forest resources.

Method: The adopted methodology uses a qualitative approach, given the importance of understanding how the water, energy, food and forest resources in the Lago do Cuniã Extractive Reserve are explored. An exploratory-descriptive type of research, with a central concern in carrying out a preparatory analysis of a known context, meanwhile little explored in the Amazon. The collection of data was carried out by means of interviews with the application of questionnaire and application of non-participant observation techniques.

Results and Discussion: The results demonstrate that studies with a nexus approach with four elements provide no understanding of the exploration of sustainable development in the environment of conservation units. Furthermore, the study reveals that maintaining forest resources improves water quality not only, but also controls erosion and resilience against droughts and floods; Contributing to the energy supply, in addition, contributes to the safety of feeding the residents of the conservation unit.

Research Implications: For public policy makers, the results demonstrate the need for management practices for the conservation of forests, protection of the quantity and quality of existing rivers and lakes in the conservation unit and protection of aquatic and agricultural ecosystems.

Originality/Value: The originality of the article is in the analysis of the role of addressing water, energy and food within an area of environmental protection in the Amazon, and by including the element forest it was possible to find out its triangulation with the other elements and their implications for economic, social and economic factors. you set the mood.

Keywords: Integration, Water, Energy, Food, Forest, Extrativist Reserve.

RESUMO

Objetivo: O objetivo geral desta pesquisa é analisar a integração da floresta ao nexo-água-energia-alimento em uma Unidade de Conservação na Amazônia brasileira visando verificar como as populações tradicionais, em cujas áreas habitam, usam dos recursos naturais madeireiros e não madeireiros para sua sobrevivência.

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Referencial Teórico: A abordagem nexo agua-energia-alimento surgiu na última década en torno de preocupaciones como as tendencias mundiais de aumento populacional, de crescimento económico e de mudanzas climáticas que colocan pressión sobre os recursos hídricos, energéticos, alimentares e florestais.

Método: A metodología adoptada utiliza a abordagem qualitativa, dada a importância de comprender como são explorados os recursos hídricos, energéticos, alimentares e florestais na Reserva Extrativista Lago do Cuniã. A pesquisa do tipo exploratoria-descritiva, con a preocupación central en realizar unha análise preparatoria de un contexto conocido, entretanto pouco explorado na Amazónia. A coleta de dados foi realizada por medio de entrevistas con aplicación de questionario e aplicación da técnica de observacións non-particente.

Resultados e Discusión: Os resultados demonstran que estudos con abordagem nexo con quatro elementos proporcionan no entendimento da exploración do desenvolvemento sustentable en ambiente de unidade de conservación. Alm diso, o estudo revela que manter os recursos florestais, há melhoria na qualidade da agua no solo, controle da erosión e resiliencia contra secas e inundacións; contribuí con o fornecimiento de energia, alm diso, ocorre a segurança alimentar dos moradores de unidade de conservación.

Implicações da Pesquisa: Para os formuladores de políticas públicas, os resultados demonstran a necesidade de prácticas de gestión para a conservación das florestas, protección na quantidade e qualidade dos ríos e lagos existentes na unidade de conservação e a protección dos ecossistemas acuáticos e agrícola.

Originalidade/Valor: A originalidade do artigo está na análise do papel da abordagem agua, energia e alimento dentro de un área de protecção ambiental na Amazónia, e ao incluir o elemento floresta foi posible averiguar su triangulación con os demais elementos e suas implicações aos fatores económicos, sociais e ambientais.


NEXO AGUA-ENERGÍA-ALIMENTOS-BOSQUE EN UNA UNIDAD DE CONSERVACIÓN EN LA AMAZONÍA

RESUMEN

Objetivo: El objetivo general de esta investigación es analizar la integración del bosque con el nexo agua-energía-alimentos en una Unidad de Conservación en la Amazonia brasileña, con el objetivo de verificar cómo las poblaciones tradicionales, en cuyas áreas viven, utilizan madera y no madera. Recursos naturales para su supervivencia.

Marco Teórico: El enfoque del nexo agua-energía-alimentos surgió en la última década en torno a preocupaciones como las tendencias globales de aumento demográfico, crecimiento económico y cambio climático que ejercen presión sobre los recursos hídricos, energéticos, alimentarios y forestales.

Método: La metodología adoptada utiliza un enfoque cualitativo, dada la importancia de comprender cómo se explotan los recursos hídricos, energéticos, alimentarios y forestales en la Reserva Extractiva Lago do Cuniã. Investigación exploratorio-descriptiva, con la preocupación central de realizar un análisis preparatorio de un contexto conocido, por poco explorado que sea en la Amazonía. La recolección de datos se realizó a través de entrevistas mediante cuestionario y la aplicación de la técnica de observación no participante.

Resultados y Discusión: Los resultados demuestran que los estudios con el abordaje siguiente con cuatro elementos no proporcionan entendimiento de la exploración del desarrollo sostenible en el ambiente de la unidade de conservación. Alm diso, o estudo revela que manter os recursos florestais, há melhoria na qualidade da agua no solo, controle da erosão e resiliência contra secas e inundacións; contribuí con o fornecimiento de energia, alm diso, ocorre a segurança alimentar dos moradores de unidade de conservación.

Implicaciones de la investigación: Para los formuladores de políticas públicas, los resultados demuestran la necesidad de prácticas de manejo para conservar los bosques, proteger la cantidad y calidad de los ríos y lagos existentes en la unidad de conservación y proteger los ecossistemas acuáticos y agrícolas.

Originalidad/Valor: La originalidad del artículo radica en el análisis del papel del enfoque agua, energía y alimentación dentro de un área de protección ambiental en la Amazonia, y al incluir el elemento bosque se pudo conocer su triangulación con los demás elementos y sus implicaciones para económicos, sociales y ambientales.
1 INTRODUCTION

The nexus approach presents itself as an urgent demand today, aiming at the efficient planning and management of interactions between water, energy and food resources, as well as their respective systems. The main objective is to promote sustainability, reduce negative environmental impacts and maximize social and economic benefits, given the growing scarcity of these natural resources (Huntington et al., 2021; Chiodi et al., 2021; Oviroh et al., 2023; Abdelzaher et al., 2023).

This approach is based on the interpretation that current models to promote the sectoral management of these resources are not effective in guaranteeing greater levels of water, energy and food security for societies (Giatti et al., 2016; Zhang et al., 2021). The logic of the approach is that it changes the precaution of a sector to a more integrated vision, connecting resources and their impact on each other (Alves et al., 2022; Arcoverde et al., 2023).

Nexus research generally focuses on two or three sectors, such as energy and water (Ishimatsu et al., 2017), water and food (Tuninetti et al., 2017), or food and biodiversity (Glamann et al., 2017), water, energy and food (Hatfield-Dodds et al., 2015), water, energy and people (Zhang, 2021), water, energy and land (Bleischwitz et al., 2018). Furthermore, some studies have already addressed four or more sectors, such as energy, water, food and education (Kilkiş, 2017), food, energy, water and health (Miller-Robbie et al., 2017), climate change, water security and food, energy and social justice (Inglesi-Lotz et al., 2016), water, energy, food and environment (Correa-Cano et al., 2022).

Searching the Web of Science database for the nexus approach, we did not find research related to the nexus-water-energy-food in environmental conservation areas in the Amazon. Thus, considering the importance of environmental conservation areas, especially in Extractive Reserves (RESEX), whose areas are inhabited by traditional populations who use timber and non-timber natural resources for their own survival, with the commercialization of the surplus in a sustainable way, It is necessary to elucidate how the water-energy-food and forest nexus existing in these regions has generated solutions to these problems (Freitas et al., 2018).

The Brazilian government has adopted as an environmental protection policy the
creation of Conservation Units (CU), which are divided into two groups, depending on their purpose of creation: those of Integral Protection, which seek the total preservation of nature, allowing only the indirect use of resources; and those of Sustainable Use, which balance nature conservation with sustainable use based on adequate management of natural resources. Extractive Reserves (RESEX) are classified in this last category. However, RESEX have many challenges in their implementation or in accessing public sustainable development policies, and in this study, there is an opportunity to combine the policy of creating conservation units with the four-element nexus approach (Yamanaka, 2020).

In this context, the analysis of an extractive reserve through the nexus approach, covering the elements water, energy, food and forest, is justified as it enables the advancement of knowledge aimed at resolving pressing issues in these areas, whether with regard to exploration inadequate use of natural resources or for a deeper understanding of the economic, social and ecological aspects of a degraded or deforested landscape, such as those found in the Amazon biome. Although the Amazon is seen as a region with an abundance of natural resources and great water potential, which drives the implementation of hydroelectric plants and agricultural production, it is threatened by the lack of effective management of these resources (Freitas et al., 2018).

Understanding how water, energy, food and forest resources are used enriches the literature and contributes to a better understanding of sustainable development in conservation unit environments. Furthermore, this analysis can provide important insights for improving the livelihoods of local communities and fostering the resilience of natural resources. Therefore, this article aims to investigate the integration of the forest in the context of the water-energy-food nexus in a Conservation Unit in the Amazon, through the interactions observed in the Lago do Cuniã Extractive Reserve, located in the Municipality of Porto Velho, in Rondônia.

2 THEORETICAL FRAMEWORK

2.1 THE WATER-ENERGY-FOOD NEXUS APPROACH

Discussions on the conceptual bases of the nexus approach began with the Conference “The nexus between water, energy and food security: solutions for the green economy”, held in Bonn, Germany, in January 2011. In the same year, the approach it gained strength with the World Economic Forum, in Davos, Switzerland, and with the United Nations Conference on
Sustainable Development (Rio +20), held in Rio de Janeiro, in 2012 (Hoff, 2011; Albrecht et al., 2018).

For this approach, the provision of water, energy and food can be achieved through a theory that integrates management and governance across sectors and scales. A nexus approach can be a fundamental support for the transition towards a green economy, which seeks, among other aspects, efficiency in the use of resources and greater political coherence (Albrecht et al., 2018). With the increasing interconnectivity between sectors in space and time, a reduction of social, economic and environmental externalities can increase the overall efficiency of resource use and provide benefits and guarantee human rights (Zhang et al., 2021).

Increasing natural pressures and human action on the environment have increased the difficulty of continuing to meet the growing needs for water, energy and food in a sustainable way (Tian et al., 2018). The Food and Agriculture Organization of the United Nations (FAO) reports estimates that by 2050, human demand for water will increase by 40%, demand for energy will increase by 50%, and demand for food will increase by 35% compared to published data by the United States National Intelligence Council in 2012 (Endo et al., 2017).

Allouche et al (2019) describe the nexus approach as a systemic one that recognizes the inherent interdependencies of the water, energy and food sectors for resource use. Biggs et al (2015) explain nexus as a tool that aims to achieve sustainable development by raising the issue of livelihoods. Its purpose is to generate an integrative structure in order to measure and monitor security at institutional scales and levels.

The conceptual approach to the water-energy-food nexus is intricate and interdependent, requiring an integrated and comprehensive approach rather than an isolated analysis of each sector. To deal with this complexity, it is essential to adopt effective measures that aim at integrative solutions in the management of environmental resources, with special attention to preventing poverty and supporting sustainable development (Oliveira, 2018).

2.2 COMBINING FORESTS WITH THE WATER-ENERGY-FOOD NEXUS

Forests, whether natural, mature, secondary, planted, monitored or managed, are an essential natural resource that plays a fundamental role in the interconnection with water, food and energy. Furthermore, forests play a crucial role in mitigating and adapting to climate change. By evaluating the benefits of forests for humans on a global scale and, mainly, at a local level, we can better understand their importance (Melo et al., 2021).
Throughout the history of civilization, the intensification of logging, the development of agricultural land and the expansion of urban areas have resulted in the deforestation of around 46% of the world's forests (Díaz et al., 2019). The forest products industry supports a multibillion-dollar economy that millions of people depend on for their livelihoods. Even with the efforts made by international agencies and governments, the challenge of sustainable management of these precious resources persists, with approximately 7.6 million hectares of forests disappearing annually, mainly in tropical regions (FAO, 2015).

Balancing the protection of environmental services provided by forests with the sustainable use of their resources has become a complex challenge, often referred to as a “wicked problem” (Defries and Nagendra, 2017). Forests are interconnected systems with complex interdependencies: reforestation initiatives to replace lost ecosystems can result in excessive water demands and social deficiencies (Corlett, 2020).

Faced with increasing global urbanization and the challenges it entails, it is necessary not to tackle forests in isolation. When considering the value of forests in the context of the water-energy-food nexus, it is feasible to seek a balance that favors the achievement of a more sustainable lifestyle. The relationship between forests and water-energy-food resources is highlighted in Figure 1 as an illustration of this vital interconnection.

**Figure 1**

*Representation of the water-energy-food-forest nexus*

Source: Adapted from Melo et al (2021).

It is essential to highlight that Figure 1 highlights the relevance of forests in the provision of water, energy and food, as well as human well-being, showing the interaction and connection between these elements.
The interconnection between water, energy, food and forests is essential for the development of modern society. The presence of forests strengthens this interaction, highlighting the importance of conserving primary and secondary forests to protect the quantity and quality of water, as well as maintaining their functions of protecting aquatic and agricultural ecosystems against floods and erosion (Ozturk, 2015; Chang et al. al., 2016). Unfortunately, the continuous devastation of riparian forests has compromised many regions in Brazil, highlighting the urgent need for preservation measures.

Next, the forest's interactions with the other elements of the nexus will be presented: water, energy and food.

a) **Nexus between water and forest**

Water plays a crucial role in interconnecting the various United Nations sustainable development goals (SDGs). Its importance for human activities, such as industry, agriculture and livestock production, is widely recognized. The growing global demand for this resource is directly linked to deforestation and population growth, increasing the risk of use conflicts (Sales Filho et al., 2021).

The scarcity of water resources can be the result of ecological or socioeconomic restrictions, with the potential to worsen at a global level, causing a series of consequences for livelihoods and the health of ecosystems (Cadore and Tochetto, 2021). Vegetation cover has a strong influence on climate and water availability in river basins, establishing relationships that extend from local to continental scales (Ellison et al., 2017).

Implementing reforestation programs and forest security measures can play a crucial role in reversing this trend (Constant and Taylor, 2020). Forest planting and regeneration are essential strategies to protect and restore degraded watersheds (Sales Filho et al., 2021). However, maintaining or increasing forest cover in a watershed often conflicts with different land uses that generate more immediate economic returns, such as agriculture, pastures or plantations (Van Noordwijk et al., 2020).

The vegetation of the Lago do Cuniã Extractive Reserve is influenced by the water regime of the Madeira River and the main lakes, highlighting the presence of the Várzea Forests (Alluvial, Open and Dense Ombrófila Forest) and Chavascais (Pioneer Formations Influenced by Rivers and/or lakes). In areas of higher plateaus and terraces, the vegetation takes on the Terra Firme Forest pattern (ICMbio, 2018).

The predominant vegetation in the Extractive Reserve (RESEX), corresponding to 40.10% of its coverage, is the Alluvial Open Rainforest. This type of vegetation is present in environments close to watercourses and in humid areas, including temporarily flooded
lowlands, and is also known as riverine forest. In the RESEX forest, it is possible to find several species of commercial value, such as cedar (Cedrela odorata) and stone angelim (Hymenolobium modestum), highlighting their economic importance.

In this sense, the relationship between water resources and forest resources in the reserve becomes evident. Forests play a fundamental role in protecting water sources, regulating droughts, floods, soil erosion and improving water quality (Melo et al., 2021). Furthermore, this relationship plays an essential role in the local economy, providing a wide range of resources that boost different economic sectors.

b) Nexus between energy and forest

In the context of energy, wood is traditionally known as firewood and has historically played a fundamental role in the development of society. It was the first source of energy used by humanity, initially used for heating and preparing food (Ringler et al., 2013). Wood continues to be part of the global energy matrix, and is also used to generate energy, depending on the region of analysis.

According to the International Energy Agency (IEA), around 2.5 billion people use firewood to meet their essential cooking and heating needs. The constant need for firewood contributes to the degradation of natural ecosystems, which can result in the loss of other ecosystem services provided by forests, such as biodiversity conservation and carbon absorption.

A key role of forests in promoting energy security is supporting hydroelectric power generation. The presence of forest cover contributes to reducing soil erosion and siltation in areas around dams, problems often associated with hydroelectric plants (Wasti et al., 2011). This direct link between forests and energy highlights the importance of preservation and reforestation as essential tools to face the growing challenge of generating energy through firewood.

However, this relationship in the Amazon causes social and environmental impacts, which are systematically underestimated in Environmental Impact Studies (Fearnside, 2019). The formation of reservoirs resulting from land flooding has significant impacts on riparian ecosystems and displacement of human populations. Protected areas are often affected by this process, as evidenced by the reduction of extensions of conservation units to make way for the construction of hydroelectric plants. In addition to the loss of forests that are flooded, dams encourage deforestation in neighboring regions (Barreto et al., 2011; Jiang et al., 2018).

c) Link between food and forest

Despite the efforts of many developed countries to increase forest cover, deforestation still persists at a worrying rate in tropical and subtropical regions. The growth of international trade in forest risk commodities highlights the need to analyze trade links between nations when investigating the causes of forest losses and gains (Pendrill et al., 2019). According to FAO (2017), during the period 2005-2013, approximately 62% of forest loss was attributed to the expansion of commercial agricultural areas, pastures and plantations. Among the commodities most frequently linked to deforestation are beef, forestry products, palm oil, grains and soybeans, although there are significant variations between countries and regions (Xu et al., 2021).

The unequal distribution of land is a crucial factor in this problem, as many poor people do not have access to arable land and end up living in degraded peripheral regions (Van Noordwijk et al., 2020). Furthermore, their property rights often restrict their access to food from the forest (Van Noordwijk et al., 2020). Most forests play a fundamental role in providing food, and many low-income individuals depend on them as a source of subsistence, through non-timber forest products, such as Brazil nuts (Melo et al 2021).

In the Amazon region, the nexus between food and forest is intrinsic and crucial for the survival of local communities and the maintenance of biodiversity. Amazonian forests are not only sources of food for indigenous peoples and traditional populations, but they also play a fundamental role in providing essential resources for the subsistence and culture of these communities (Maciel et al 2018).

According to Yamanaka (2020), the Amazon forests provide a wide variety of foods, including fruits such as açaí, cupuaçu and peach palm, roots such as cassava and yam, as well as fish from rivers and meat from hunting. These local foods are essential to ensure balanced and healthy diets, providing vital nutrients for the well-being of communities.

Furthermore, collecting non-timber products from the forest, such as nuts, seeds and medicinal plants, is a traditional practice that contributes to subsistence and the local economy. According to Souza et al. (2020), Brazil nuts, for example, are an important source of income for several communities and play an important role in the regional economy of the Amazon.

Given this scenario, the preservation of forests and the promotion of sustainable practices in the use of natural resources in the Amazon are essential to guarantee food security, conservation of biodiversity and the well-being of local communities, keeping alive the important relationship between food and forest in the region.
2.3 EXTRACTIVIST RESERVES IN THE AMAZON

The idea of an Extractive Reserve originated in 1985, during the first National Meeting of Amazon Rubber Tappers. It emerged as an alternative to guarantee the permanence of rubber tappers in their work areas, which were threatened by the expansion of large pastures, real estate speculation and deforestation. This concept emerged from the observation of indigenous reserves, sharing characteristics such as land ownership by the Union and usufruct by local communities. Thus, the creation of extractive reserves responded to the need for adequate agrarian reform for forest inhabitants (Mendes, 2018).

According to Decree 98,897, of January 30, 1990, Extractive Reserves are territorial areas destined for the sustainable exploration and preservation of renewable natural resources through the activities of extractive populations. Article 3 of this decree establishes the criteria for the creation of each reserve, including the identification of the target population, made up mainly of rubber tappers, chestnut farmers and riverside dwellers, who mainly inhabit the North of the country. These communities coexist harmoniously with the ecosystem, extracting natural resources in an economically and ecologically sustainable manner, in line with the regeneration capacity of the environment itself.

In the state of Rondônia, the implementation of Extractive Reserves was driven by the Agricultural and Forestry Plan of Rondônia - PLANAFLORO in 1995. The main objective of this plan was to promote actions aimed at sustainable development and the preservation of biological diversity in the state of Rondônia (Dias, 2014). PLANAFLORO was responsible for significant achievements, including the creation of conservation units in Rondônia and improvements to local transport infrastructure (Carleial and Bigio, 2014; Paolino et al., 2021).

The Lago do Cuniã Extractive Reserve is part of the set of Conservation Units of the Purus-Madeira Interfluve, which encompasses 11 federal and 14 state conservation units, 9 of which are in the State of Amazonas and 5 in Rondônia. The history of the reserve began in the 1980s, with the creation of the Cuniã Ecological Station (ESEC Cuniã), an Integral Protection Conservation Unit that prohibited the use of internal natural resources, thus preventing the presence of traditional populations in its territory.

After a prolonged process of struggles and negotiations, in 1999, the Lago do Cuniã Extractive Reserve (RESEX) was created through Federal Decree No. 3,238. This type of Conservation Unit allows traditional communities to inhabit the area and use natural resources for their subsistence. Resex was established in a region that would initially be incorporated into ESEC Cuniã, resulting in shared borders between the two UCs. In 2018, the reserve, originally...
measuring 55,850 hectares, was expanded to 74,659 hectares, thus expanding the areas available for productive activities by local families and contributing to the preservation of the regional ecosystem and water resources in the Madeira River basin.

3 METHODOLOGY

Due to the importance of understanding the exploitation of water, energy, food and forestry resources in the Lago do Cuniã Extractive Reserve, which involves issues of territorial occupation and the integration of diverse practices such as agriculture, forest extractivism, sustainable management, fishing and hunting that contribute to food production, the research team felt the need to investigate the relationship between the forest and the water-energy-food tripod in a Conservation Unit in the Amazon.

This study adopts a qualitative approach, focusing on social issues that require reflection on the part of researchers and that cannot be adequately explored through quantitative data with predefined answers (Flick, 2008). The decision for this approach is based on the nature of qualitative research, which does not follow a single standard and allows considering the dynamic and contradictory aspects of the context and the social actors involved (Chizzotti, 2006).

The research is exploratory-descriptive in nature, focusing on carrying out an initial analysis of a recognized but little explored context in the Amazon region: the interconnection between water, energy, food and forest in the Lago do Cuniã Extractive Reserve, located in the municipality of Porto Velho, in Rondônia. The objective is to deepen the understanding of reality to enable subsequent studies in other conservation units.

The research strategy used was the case study, following the approach of Yin (2015), which focuses on the detailed analysis of a program, event, activity, process or individuals. The case study is bounded by time and activity, allowing researchers to collect detailed information through a variety of data collection methods.

To carry out the case study, the Lago do Cuniã Extractive Reserve was selected, which is categorized as a sustainable use conservation unit. The reserve is located approximately 130 kilometers from Porto Velho, on the banks of the Madeira River. Initially, the reserve covered 55,850 hectares, but in December 2018, its area was expanded to 74,659 hectares. It encompasses two distinct environments: a diverse ecosystem with great biodiversity, and a floodplain area subject to seasonal variations in water flow throughout the year. According to Gomes and Ferreira (2018), the rainy season lasts from November to April, while the drought
occurs from May to October. Figure 2 illustrates the geographic location of the extractive reserve chosen for the study.

**Figure 2**

*Research Locus – RESEX of Lago do Cuniã*

![Map of Lago do Cuniã](image)

Source: Prepared by the authors (2023)

As this is research carried out in a Conservation Unit, the study was submitted to the Chico Mendes Institute for Biodiversity Conservation (ICMBio), responsible for the administration of the Lago do Cuniã extractive reserve. In accordance with Normative Instruction nº. 03 of 09/01/2014 of ICMBio, scientific activities carried out within the UC must be registered and authorized through the Biodiversity Authorization and Information System (SISBIO). SISBIO approval under number 84469 was granted on September 8, 2022.

Approximately 400 people and 83 families live in RESEX Lago do Cuniã, divided into 4 groups, named Puninhas, Silva-Lopes-Araújo, Neves and Araçá. The centers are accessed by river, with small boats (flyboats or rabetas), with the exception of the Neves and Silva-Lopes-Araújo centers, where it is possible to use a trail that connects both centers only during the dry season (SILVA JÚNIOR, 2019).

Regarding sample size, researchers followed some procedures to determine the number of interviewees and interviews (Morse, 2000). Morse (2000) and Johansen and De Cock (2017) cite a number of 6 to 10 as sufficient for a homogeneous population and with similar questions for all interviewees. Considering that the object of study is specific (Body, 2016; Rego et al., 2018), RESEX Lago do Cuniã, and the residents present homogeneous characteristics such as low income levels, a large proportion of illiterate people, fragile social conditions (ICMBIO, 2018), a minimum number of respondents was established a priori.
A sample of 16 respondents was defined, all belonging to the population centers present in the Lago do Cuniã Extractive Reserve, including extractivists, residents, managers of the COOPCUNIÃ cooperative and the ASMOCUN association, the only entities existing in the location, and representatives of ICMBio. The interviews were semi-structured, following a script designed to collect information on water, energy, food and forestry resources, as well as on the different actors and their roles in the management of natural resources, analysis of production chains in the reserve and information related to sustainability economic, social and environmental at RESEX. The instrument used for data collection contained 59 questions. Figure 3 presents the profile of the interviewees:

**Figure 3**

*Nuclei, gender, level of education, age and housing*

<table>
<thead>
<tr>
<th>Category</th>
<th>Reference code in data analysis</th>
<th>Do you participate in an organization?</th>
<th>Core</th>
<th>Gender</th>
<th>Age</th>
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<td>E1</td>
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<td>ASMOCUN and COOPCUNIÃ</td>
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<td>ASMOCUN and COOPCUNIÃ</td>
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<td>Masculine</td>
<td>56</td>
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<td>45</td>
<td>Elementary School</td>
</tr>
<tr>
<td>Extractivists from Resex Lago do Cuniã Cooperados/Associado (ERLCC)</td>
<td>E8</td>
<td>ASMOCUN and COOPCUNIÃ</td>
<td>Silva-Lopes-Araújo</td>
<td>Masculine</td>
<td>47</td>
<td>Elementary School</td>
</tr>
<tr>
<td>Residents of Resex/Non-Cooperator/Non-Associate (MRN)</td>
<td>E9</td>
<td>No</td>
<td>Neves</td>
<td>Masculine</td>
<td>69</td>
<td>Elementary School</td>
</tr>
<tr>
<td>Residents of Resex/Non-Cooperator/Non-Associate (MRN)</td>
<td>E10</td>
<td>ICMBio</td>
<td>Not applicable</td>
<td>Masculine</td>
<td>62</td>
<td>Elementary School</td>
</tr>
<tr>
<td>Residents of Resex/Non-Cooperator/Non-Associate (MRN)</td>
<td>E11</td>
<td>No</td>
<td>Arrack</td>
<td>Masculine</td>
<td>23</td>
<td>Elementary School</td>
</tr>
<tr>
<td>Residents of Resex/Non-Cooperator/Non-Associate (MRN)</td>
<td>E12</td>
<td>No</td>
<td>Not applicable</td>
<td>Masculine</td>
<td>37</td>
<td>University education</td>
</tr>
<tr>
<td>Residents of Resex/Non-Cooperator/Non-Associate (MRN)</td>
<td>E13</td>
<td>No</td>
<td>Peach palms</td>
<td>Feminine</td>
<td>22</td>
<td>High school</td>
</tr>
</tbody>
</table>
Residents of Resex/Cooperado/Associado (MR) | E14 | ASMOCUN and COOPCUNIÁ | Silva-Lopes-Araújo | Masculine | 59 | Elementary School
Cooperative Managers (GC) | E15 | ASMOCUN and COOPCUNIÁ | Neves | Masculine | 43 | High school
Association Managers (GA) | E16 | ASMOCUN and COOPCUNIÁ | Neves | Masculine | 55 | Elementary School

Source: Survey data (2023)

Subsequently, the technique of non-participant observations and the documentary technique were used to identify the secondary data necessary to familiarize the researcher with the object of study and analyze different events in different periods of time (Yin, 2015). Data content analysis was carried out according to the method proposed by Bardin (2010), which consists of three stages: 1) data organization; 2) data categorization; and 3) final analysis. Four main categories were established for content analysis, focusing on related elements: Water, Energy, Food and Forest.

Each category was divided into three main subcategories: water, energy, food and forestry resources; actors and their roles in natural resource management; analysis of production at RESEX Lago do Cuniã. Figure 4 describes the factors considered in each category and subcategory.

**Figure 4**

*Categories and Subcategories of data analysis*

<table>
<thead>
<tr>
<th>Analysis Categories</th>
<th>Analysis Subcategories</th>
<th>Factors covered for interviews, documentation and recording in files</th>
</tr>
</thead>
</table>
4 ANALYSIS AND DISCUSSION OF RESULTS

Regarding the interaction of the forest with the elements of water, energy and food in the Lago do Cuniã Extractive Reserve, located in Porto Velho-RO, a connection was identified in the interviewees' responses that is aligned with the perspective presented by Melo et al. (2021). The authors highlight that the preservation and recovery of forests are effective strategies to promote security in access to water, energy and food.

During the interviews, issues related to the use of forest resources, residents' perception of deforestation in the Extractive Reserve (RESEX) and the practice of forest restoration were addressed. According to those interviewed (E4, E10, E12, E13), the reserve's residents deforest areas to plant fruit trees or to build new homes. Furthermore, interviewees E11 and E13 mention the presence of people outside the community who remove valuable trees, such as cedar (Cedrela odorata) and angelim-pedra (Hymenolobium modestum), from the margins of the reserve.

Interviewees E1, E2, E12 highlighted that the community shows care when planting native species during forest recovery practices. E4, E6, E8, E13, E14, E16 mentioned that some residents replant fruit trees in degraded areas, contributing to environmental protection. Only resident E15 reported that some residents are against forest recovery in the region, preferring to expand urban centers in deforested areas.

All interviewees mentioned the use of Resex forest resources for consumption and sale, highlighting açai, Brazil nuts, peach palm, cupuaçu and soursop as the main products exploited for this purpose. On a smaller scale, babassu, buriti, cashew and cajá were also mentioned. Interviewee E1 emphasized that the production of fruit pulp in the region has potential for growth, but there is a lack of investment so that extractivists can sell products with greater added value in other areas.

It is possible to observe, from the interviewees' answers, a connection between the forest and the elements water, energy and food, which are used in different ways by local inhabitants.
and extractivists. The connection between the reserve's water resources, energy, food and vegetation can be seen in figure 5.

**Figure 5**

*Relationship between the elements water, energy, food and forest in the Cuniã Resex*

<table>
<thead>
<tr>
<th>Interconnection</th>
<th>Factors</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food-Water</td>
<td>Rain-based harvest</td>
<td>Cassava and banana production; Alligator Management; Fish Management.</td>
</tr>
<tr>
<td>Water-Energy</td>
<td>Collect water</td>
<td>Water security in the reserve; Water availability for production chains;</td>
</tr>
<tr>
<td></td>
<td>Distribute water</td>
<td></td>
</tr>
<tr>
<td>Water-Forest</td>
<td>Maintain forests</td>
<td>Reduce flooding; Control erosion; Improve water quality in the soil; Resilience to drought and floods.</td>
</tr>
<tr>
<td></td>
<td>Plant forests</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recover watersheds</td>
<td></td>
</tr>
<tr>
<td>Energy-Forest</td>
<td>Provide biomass/firewood</td>
<td>Preparation of food for self-consumption; Production of products for sale; Production of cassava flour; Energy security.</td>
</tr>
<tr>
<td></td>
<td>Support energy generation</td>
<td></td>
</tr>
<tr>
<td>Energy-Food</td>
<td>Store food</td>
<td>Food conservation for residents; Conservation of products for commercialization; Processing of the alligator production chain; Processing of the pulp production chain;</td>
</tr>
<tr>
<td></td>
<td>Process food</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Produce energy</td>
<td></td>
</tr>
<tr>
<td>food-forest</td>
<td>Preserve forests</td>
<td>Food security for reserve residents; Availability of food for sale; Exploration of the nut production chain; Exploration of the açai production chain.</td>
</tr>
<tr>
<td></td>
<td>Regenerate forests</td>
<td></td>
</tr>
</tbody>
</table>

Source: Survey Data (2023)

Based on the responses of interviewees E2, E3, E5, E7, E8, E14 and E16, it was found that the Lago do Cuniã Extractive Reserve has few deforested areas and abundant water resources. Participants stated that the RESEX forest plays a crucial role in water availability, water quality, the hydrological cycle, water purification and the prevention of desertification within the reserve. These claims are supported by the study by Melo et al., (2021), which details how forests contribute to protecting water sources, preventing droughts, floods, soil erosion and improving water quality. According to Okumu et al. (2021), the preservation and restoration of forests are essential for the balance of water resources and represent a fundamental strategy in the protection and recovery of degraded river basins.

When analyzing the relationship between energy and forestry resources, all interviewees highlighted the use of wood from the RESEX forest for fire production, aiming to prepare food for their families and the manufacture of cassava flour for consumption and commerce. Interviewee E5 mentions that residents use trees that have already been felled to generate energy. Interviewees E4, E5 and E7 note that this practice has decreased significantly in recent years, due to the improvement in the living conditions of families who have started to acquire
stoves and use gas. However, this is a common custom in the region, and, according to the considerations of Ringler et al. (2013), this practice has always played an important role in human development, being frequent in needy and developing areas.

However, the researchers highlighted that the reserve provides electricity for the use of household appliances, residential lighting, public lighting and for the production chains available at RESEX. However, it is worth highlighting that this energy is generated by a diesel plant, despite the presence of two hydroelectric plants on the Madeira River, the Jirau and Santo Antônio plants, close to the extractive reserve. All of the energy produced by the two plants is directed to Araraquara, a city in the interior of the state of São Paulo, which is part of the integrated national grid, responsible for distributing energy to different regions of Brazil (NAPRA, 2021).

The relationship between the forest and food supply in the reserve is evident in the opinions of respondents and in the production chains developing in the region. When interviewees were asked about the importance of the forest for the community on a scale of 1 to 5, where 1 represents little importance and 5 very important, they all stated that the forest is extremely relevant and essential for the survival of the community and biodiversity. These responses corroborate the vision of Gombeer et al., (2021), who highlight forests as important sources of food, on which thousands of people depend to obtain income through forest products, both wood and non-wood.

According to 43% of those interviewed, extractivists play a fundamental role in the sustainable exploitation of forests, contributing to their preservation and demonstrating concern about the disorderly use of forest resources. According to research participants, the main non-timber forest products exploited in the region include Brazil nuts, açaí, bananas, mangoes, ingá, avocado and jackfruit. In addition, there is a small sale of timber forest products in the reserve, with emphasis on household utensils such as boards, supports and wooden spoons.

The percentage of forest resources in the interviewees' income and the feasibility of surviving exclusively with products from RESEX were also investigated. According to 62% of participants, these resources represent 1 to 20% of their income, making it necessary to seek other sources of support to meet their families' needs. Regarding exclusive survival with RESEX resources, some interviewees stated that it is possible for some families, while others depend on additional work, often in other locations such as São Carlos and Porto Velho.

Finally, it was possible to verify the functioning of the forest in relation to the interconnection between water, energy and food in an Extractive reserve environment, as represented in figure 6.
The theoretical framework starts from the broad context of the water-energy-food nexus and covers the dimensions, categories and variables of the Lago do Cuniã Extractive Reserve, with the aim of analyzing the uses and consumption of water, energy, food and forestry resources by the RESEX residents and extractivists. This analysis allows us to visualize the interconnections between the forest and other elements in an Amazonian environment, enabling the construction of a theoretical framework covering these four elements. In this way, we contribute to knowledge by integrating the forest into the traditional nexus between water, energy and food.

5 FINAL CONSIDERATIONS

The research carried out aimed to analyze the integration of the forest with the water-energy-food nexus in the Lago do Cuniã Extractive Reserve, located in the Municipality of Porto Velho, in the state of Rondônia, in the Amazon region. The study adopted a case study methodology, with a deductive method and a qualitative, exploratory and descriptive approach, using questionnaires for 16 individuals directly or indirectly linked to the extractive reserve.

Based on the results obtained, it was possible to verify the complex interactions that occur between the forest and natural resources in the reserve, and how these interactions have
a direct impact on the region's vital resources, such as water, energy and food. The analysis carried out contributes significantly to understanding the need to preserve the forest and the lifestyle of local inhabitants, who directly depend on nature for their survival. Thus, the research carried out in the Lago do Cuniã Extractive Reserve highlighted the importance of the relationship between the forest and the essential water-energy-food resources, highlighting the urgent need to conserve these ecosystems to guarantee the sustainability of the Amazon region and the well-being of local communities.

The results obtained show that the maintenance of forest resources results in benefits such as improved water quality in the soil, erosion control and greater resilience against droughts and floods in the reserve. Furthermore, preserving the forest guarantees the supply of biomass/firewood for preparing food and producing products for commerce. Another relevant point is the food security provided to the reserve's residents and the availability of food for sale, resulting in the expansion of several production chains, such as the alligator, açai, cassava and chestnut chains.

The results indicate that extractivists explore the full potential of water, energy, food and forestry resources to integrate various activities, such as agriculture, forest extractivism, hunting, fishing and handicrafts. The inclusion of the forest in the water-energy-food context within an environmental conservation area strengthens the approach and analysis, contributing to the growth of local economies as a fundamental part of sustainable development strategies. This approach associates nature conservation, ecosystem services and sociocultural values, promoting a holistic and integrated view of natural resource management.

For future research, it is recommended that studies be carried out on the approach and its implementation in other Extractive Reserves in the Amazon Region, aiming to expand understanding and implement the nexus theory involving the elements of water, energy, food and forest in an environment of environmental conservation. In this way, it will be possible to contribute to the planning of actions aimed at improving the management of environmental, social and economic resources, aiming at human well-being.

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