INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA - INPA

PROGRAMA DE PÓS-GRADUAÇÃO EM BIOLOGIA (ECOLOGIA)

Impactos potenciais da exploração madeireira sobre os produtos do capital natural: Composição e distribuição de produtos e serviços fornecidos por árvores de interesse madeireiro em uma Reserva de Desenvolvimento Sustentável

Tainá Silva Figueiredo

Manaus, Amazonas
Maio 2024

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Dissertação apresentada ao Programa de Pós-graduação em Biologia (Ecologia), Instituto Nacional de Pesquisas da Amazônia INPA, como requisito parcial para obtenção do grau de Mestre em Ecologia.

Orientador: William Ernest Magnusson
Co-orientador: Sérgio Santorelli Junior

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ATA DA DEFESA PÚBLICA DA DISSERTAÇÃO DE MESTRADO DO PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA DO INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA.

Aos 06 dias do mês de Maio do ano de 2024, às 09:h00min, via videoconferência, reuniu-se a Comissão Examinadora de Defesa Pública, composta pelos seguintes membros: o Dr. **Felipe Soter de Mariz e Miranda**, da Universidade Federal do Rio de Janeiro – UFRJ, o Dr. **Mário Sérgio Muniz Tagliari**, da Faculdade Municipal de Educação e Meio Ambiente – FAMA/PR e a Drª. **Flora Magdaline Benitez Romero**, do Instituto Nacional de Pesquisas da Amazônia – INPA, sendo as suplentes a Drª. Clarissa Alves da Rosa e a Drª. Rita de Cássia Guimarães Mesquita, ambas do Instituto Nacional de Pesquisas da Amazônia – INPA, sob a presidência do orientador, a fim de proceder a arguição pública da **DISSERTAÇÃO DE MESTRADO** de **TAINÁ SILVA FIGUEIREDO**, intitulada: **"IMPACTOS POTENCIAIS DA EXPLORAÇÃO MADEIREIRA SOBRE OS PRODUTOS DO CAPITAL NATURAL: COMPOSIÇÃO E DISTRIBUIÇÃO DE MORFOESPÉCIES DE INTERESSE MADEIREIRO, PRODUTOS E SERVIÇOS ECOSSISTÊMICOS EM UMA RESERVA DE DESENVOLVIMENTO SUSTENTÁVEL"**, orientada pelo Dr. William Ernest Magnusson, do Instituto Nacional de Pesquisas da Amazônia – INPA e coorientada pelo Dr. Sergio Santorelli Junior, da Universidade Federal do Amazonas – UFAM.

Após a exposição, o(a) discente foi arguido oralmente pelos membros da Comissão Examinadora, tendo recebido o conceito final:

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Nada mais havendo, a presente ata foi lida, lavrada e assinada pelos membros da Comissão Examinadora.

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Sinopse: Neste estudo avaliamos se as morfoespécies exploradas por madeireiros ilegais na RDS Rio Negro variam entre as associações de vegetação. Investigamos também se isso ocorre porque as árvores nos solos arenosos são menos adequadas para a exploração ou porque a composição florestal é mais pobre em espécies comerciais. Além disso, investigamos se a retiradas dessas árvores implica em maior redução no Produtos Extrativistas Não Madeireiro fornecido por espécies de valor comercial.

Palavras-chaves: Exploração madeireira; produtos extrativistas; economia de ecossistemas; recursos florestais.

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Gostaria de agradecer a todas as pessoas que estiveram na minha caminhada até esse momento, e a todos aqueles que vieram antes de mim, abrindo portas que hoje me permitem ocupar esse lugar. E principalmente aos amigos e familiares que fizeram a trajetória ter significado e valer a pena.

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"A tarefa não é tanto ver aquilo que ninguém viu, mas pensar o que ninguém ainda pensou sobre aquilo que todo mundo vê.” - Arthur Schopenhauer

RESUMO

A exploração ilegal de madeira em reservas de desenvolvimento sustentável representa uma ameaça à conservação da biodiversidade, à manutenção da qualidade de vida das populações locais e ao fornecimento de produtos e serviços ecossistêmicos. As informações sobre a distribuição das morfoespécies comumente exploradas para a extração de madeira e os possíveis impactos da extração sobre alguns produtos e serviços do ecossistema contribuem para o desenvolvimento de políticas públicas e econômicas adequadas à perspectiva local e para operações de controle mais eficientes.

Avaliamos se as morfoespécies exploradas por madeireiros ilegais na Reserva de Desenvolvimento Sustentável do Rio Negro variam entre as associações de vegetação, com a distância dos cursos d'água, e se a remoção de árvores de interesse madeireiro implica uma redução dos produtos extrativistas não madeireiros e das cavidades disponíveis relacionadas a essas morfoespécies. Um total de 1.270 indivíduos de 38 morfoespécies foi amostrado em três tipos de associações de vegetação na parte oeste da reserva. Houve uma tendência de as morfoespécies de valor comercial se concentrarem em florestas com solos mais argilosos (Iwité). A área de pesquisa é rica em cursos d'água e a extração dessas árvores teria um impacto direto na manutenção e conservação dos recursos hídricos locais, além de promover a perda de oportunidades econômicas para o desenvolvimento sustentável das comunidades locais.

Palavras-chave: Exploração madeireira; produtos extrativistas; economia de ecossistema; recursos florestais.

ABSTRACT

Illegal logging in sustainable development reserves poses a threat to biodiversity conservation, to maintaining the quality of life of local populations and to the supply of ecosystem products and services. Information on the distribution of morphospecies commonly exploited for logging and the possible impacts of logging on some ecosystem products and services contributes to the development of public and economic policies appropriate to the local perspective and to more efficient control operations.

We assessed whether the morphospecies exploited by illegal loggers in the Rio Negro Sustainable Development Reserve vary between vegetation associations, with distance from watercourses, and whether the removal of trees of timber interest implies a reduction in non-timber extractive products and availability of cavities in these morphospecies. A total of 1,270 individuals of 38 morphospecies were sampled in three vegetation associations in the western part of the reserve. There was a tendency for commercially valuable morphospecies to be concentrated in forests with more clayey soils (Iwité). The research area is rich in watercourses and the extraction of trees close to streams would have a direct impact on the maintenance and conservation of local water resources, as well as promoting the loss of economic opportunities for the sustainable development of local communities.

Keywords: Logging; extractive products; ecosystem economics; forest resources.

Sumário

Capítulo Único

Figueiredo et al., 2024. Potential impacts of logging on natural-capital products: Composition and distribution of commercially valuable trees and ecosystem services in a Sustainable Development Reserve. Manuscrito formatado para o periódico Ecological Economics.

Potential impacts of logging on natural-capital products: Composition and distribution of products and services provided by commercially valuable timber trees in a Sustainable Development Reserve

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ABSTRACT

Illegal logging in sustainable development reserves poses a threat to biodiversity conservation, to maintaining the quality of life of local populations and to the supply of ecosystem products and services. Information on the distribution of morphospecies commonly exploited for logging and the possible impacts of logging on ecosystem products and services contributes to the development of public and economic policies appropriate to local perspectives and to more efficient control operations.

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Keywords: Logging; extractive products; ecosystem economics; forest resources.

1. INTRODUCTION

The Sustainable Development Reserve (RDS) is a category of the Brazilian National System of Conservation Units (SNUC). It is defined as a natural area set aside for traditional human populations, whose existence is based on sustainable systems for exploiting natural resources, developed over generations and adapted to local ecological conditions (BRASIL, 2000). The basic objectives of an RDS are to preserve nature and, at the same time, ensure the conditions and means necessary for the maintenance of ways of life and exploitation of natural resources by traditional populations, as well as to value, conserve, and improve the knowledge and techniques of environmental management developed by these populations (Federal Law No. 9.985/2000 - SNUC). However, just categorizing and regulating the use of natural areas is not enough to conserve these places. The lack of information on ecosystem functioning in each region creates knowledge gaps and consequently limits effective actions to conserve forest areas.

Logging forest, especially in sensitive ecosystems such as the Amazon, has significant ecological implications (Veríssimo et al., 1992). The correlated processes of habitat loss and fragmentation are probably the most important threats to global biodiversity (Laurance and Cochrane, 2001). Deforestation causes collateral damage to forests and their surroundings by drying the forest floor, increasing the frequency of fires, and reducing productivity (Foley, J. A., et al., 2007). The tropical forests of the Amazon provide crucial ecosystem goods and services for humanity, which have considerable economic and social value (Myers, 1997). Deforestation and selective logging can negatively affect the flow of many ecosystem goods and services, such as carbon storage, limitation of vector-borne diseases, and cause an imbalance in regional and global climate regulation (Foley, J. A., et al., 2007). Changes in land cover also have a substantial effect on large river systems (Costa et al., 2003), as they facilitate erosion due to the loss of riparian forest, interfering with water volume and reducing surface runoff (Lima, 1989; Bren, 1993). It is important to understand the complexity of synergy and ecosystem dynamics to understand the real impacts of logging on the functioning of the environment.

The Amazon region has the largest river basin and the largest rainforest in the world, covering parts of nine countries and forming a complex mosaic of environments (Nobre et al., 2016). It plays a crucial role in the global water and carbon cycle and is of great ecological, economic, and cultural importance (Davidson et al., 2012). Despite its relevance to the balance of global dynamics, there is still little information on the functioning and environmental diversity of the region.

This study was conducted in the Rio Negro Sustainable Development Reserve (RDS do Rio Negro), located on the right bank of the lower Rio Negro, which is part of the Central Amazon Ecological Corridor and the Mosaic of Protected Areas of the Lower Rio Negro. The Rio Negro RDS has significant socio-environmental value and is home to 19 traditional communities, with a network of social actors that includes traditional peoples, such as riverside communities, indigenous peoples, artisanal fishers, family farmers, and *arumã* collectors (AMAZONAS, 2016).

The reserve has a complex mosaic of soil types with various physical and chemical characteristics, which determine the structural characteristics of the vegetation (AMAZONAS, 2016). The soils are predominantly sandy, poor in nutrients, and generally unsuitable for intensive agriculture. The reserve has several phytophysiognomies, but the research focused on the predominant environments in the western portion: campinas, campinaranas, and "terra firme" forests. The vegetation on white-sand soils is known locally as campina and campinarana. The campinas are characterized by shrubs and open sandy areas, without the juxtaposition of tree canopies, and the sparse trees are generally limited to a few species (Anderson, A., 1981), while the campinaranas have taller trees with a relatively homogeneous canopy and are found on sandy soils with shallow water tables (Oliveira, A., 2001). The forests designated as "terra firme" in the reserve's management plan grow on more clayey soils ("Iwité" in the general indigenous language). However, all of these associations are on "terra firme" soil (not seasonally flooded). To avoid misunderstandings, from here on we will call this formation "Iwité." Despite its unique characteristics and biodiversity, there are few studies on the flora of the Rio Negro RDS that can provide information for decisions regarding the management and conservation of forest resources.

Campinas and campinaranas, when accessible, are commonly subject to sand and timber extraction, or conversion to agriculture (Adeney et al., 2016). However, local people report that illegal logging is more frequent in Iwité forests. It is unclear whether this is because extraction on sandy soils is inviable or because the composition of the forest is poorer in commercial species.

Trees play a crucial role in the functioning of ecosystems. In this context, it is essential to identify the distributions of morphospecies commonly exploited by illegal loggers in the Amazon. These commercially valuable morphospecies not only offer timber but also provide economic opportunities and important ecosystem services such as wood and carbon stocks, non-timber extractive products, and evapotranspiration. They have significant ecological value, are fundamental for protecting the forest's genetic heritage, provide food, and the cavities in trees serve as refuges for fauna and flora (Larrieu et al., 2018). In addition to their ecological value, these trees also hold social and cultural significance. Non-timber extractive products generate "invisible income" by enhancing the health and nutrition of the local population (Shanley and Medina, 2005). If these ecosystem services are concentrated in areas with the greatest potential for exploitation, the impact of illegal logging could be much greater than the size of the affected area would suggest

In this study, we evaluated whether the concentration of morphospecies is significantly influenced by environmental variables, such as distance from water, altitude, and vegetation association. We also assessed whether areas with the lowest potential for exploitation by illegal loggers in the Rio Negro RDS can serve as refuges for the exploited morphospecies, and whether the removal of trees of timber interest implies a reduction in non-timber extractive products and cavities available in exploited species.

2. METHODS

2.1 STUDY AREA

The research was carried out in the Rio Negro Sustainable Development Reserve (RDS do Rio Negro), located to the west of the city of Manaus, Amazonas, and covering an area of 102,979 hectares (Fig. 1). The region's climate is of the Köppen Af type (tropical rainy climate), with the dry season running from June to November and the wet season extending from December to May. The area has a relative humidity of over 60% and an average annual rainfall of 2,362 mm (INMET, 2020).

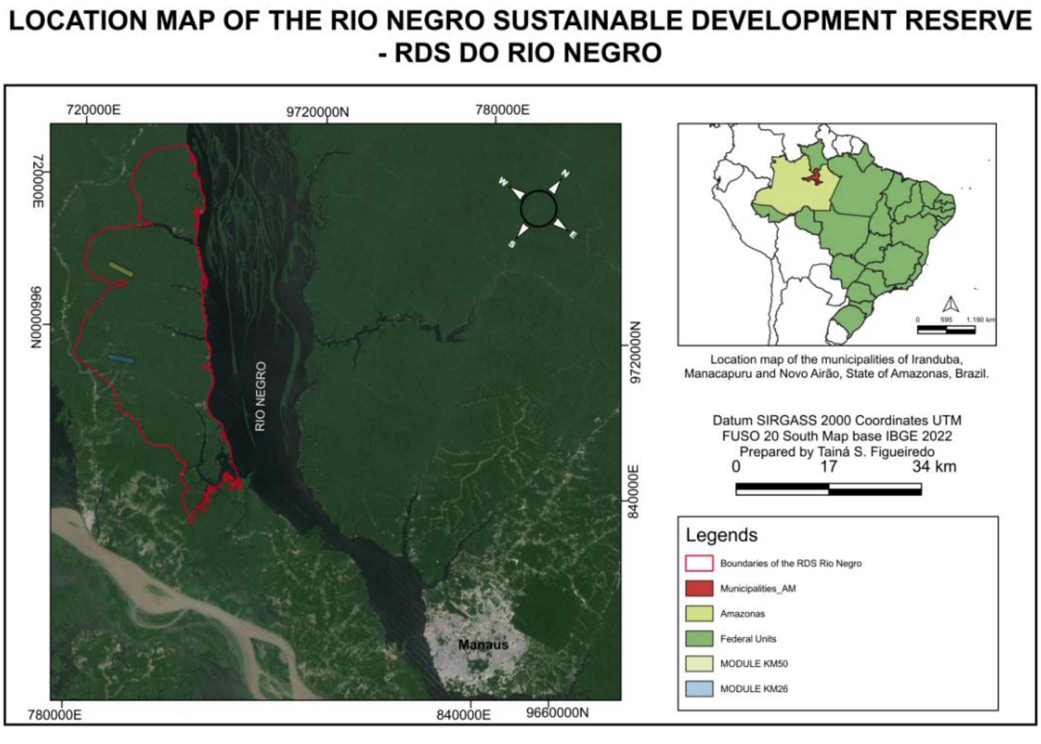

Figure 1: Location of the research modules in the Rio Negro Sustainable Development Reserve (RDS Rio Negro) used in this study. IBGE cartographic base 2021. Coordinates (2°56'51.61"S, 60°41'04.01"W). Map produced with Qgis software(QGIS Development Team, 2009)

2.2 DATA COLLECTION

We collected data in two research modules located in the western portion of the Rio Negro RDS. In each module, the data were collected along two straight, parallel 5 km trails connected by 1 km trails at the extremes. The trails were subdivided into 48 segments, each of 500 m (Supplementary material). Trees of timber interest that could be detected from the trail and had a diameter at breast height (DBH) > 7 cm were sampled. We chose this criterion to gather information on areas with future exploitation potential, despite the fact that the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) defines the legal size for timber extraction as 50 cm diameter at breast height (DBH) for all species for which a specific diameter has not been established (BRASIL, 2007).

We collected data from the three main phytophysiognomies present in the research modules: "Iwité" forests, campinarana, and campina. The sites were chosen to represent the main vegetation types in the western part of the reserve. "*Terra-firme*" (Iwité) forests are classified as dense lowland ombrophilous forests with an emergent canopy, occurring on the highest parts of the terrain that are not subject to short-term flooding during the rainy season (Martins, 2012). Campinarana forests have large trees and clusters of palms, while campinas are dominated by a dense cover of shrubs, occasionally interspersed with low trees and herbaceous cover (Martins, 2012). The density of commercially valuable trees along the research trails was estimated using the line-transect technique (Burnham et al., 1980) adapted for sampling commercially valuable trees (Magnusson et al., 2005; 2013), available at https://ppbio.inpa.gov.br/sites/default/files/protocolo_Arvores_comerciais.pdf).

The distinct vegetation associations in the reserve are easily recognized by local inhabitants and identifiable in remote sensing images. Trees with commercial value were identified using vernacular names based on the knowledge of a local community member with extensive experience in logging in the region. However, it is important to emphasize that the species associated with these common names can vary regionally, and often more than one species shares the same vernacular name. In this study, the use of vernacular names was consistent; we relied solely on these names to estimate the distribution of economic value of timber stocks and to compare the compositions of morphologically similar trees among different vegetation associations. The vegetation associations were categorized using field observation data and analysis of forest-cover variation using satellite images in Google Earth Pro (Google Inc., 2023). (Fig. 2).

Figure 2: Association of vegetation photo and satellite images. A - Satellite image of the campina environment. B - Satellite image of the campinarana environment. C - Satellite image of the Iwité environment. D - Photograph of a campina. E - Photograph of a campinarana. F - Photograph of an area of Iwité.

We measured Diameter at Breast Height (DBH) with a tape measure graduated in mm, measured and tree height with electronic hypsometer. Using binoculars, we examined the trees to determine the presence or absence of cavities that could be used by vertebrates. To identify individuals that produce non-timber extractive products, we conducted a bibliographic survey and information based on traditional knowledge of Jânio Silva about these morphospecies.

2.3 DATA ANALYSIS

Vegetation associations have distinct structures, so simple counts may not be comparable. To correct the estimate of the density of trees of timber interest in each vegetation association, we used the probability of detection in different phytophysiognomies. This correction was calculated using the "distance sampling" package (Buckland et al., 2005) in RStudio (R Core Team, 2015). The half-normal detection probability model was used to estimate the distribution in the campinas environments, and the hazard-rate model with a simple polynomial fit for the campinarana and Iwité environments (Tab. 2). To investigate whether the morphospecies commonly exploited by loggers varied between vegetation associations, we analyzed the distribution of corrected morphospecies abundance.

The wood-volume data for each individual were derived from the product of its height (h) and the area calculated from the diameter (r * 2) measured at 130 cm from the ground, with values substituted into the equation $V = \pi \times r^2 \times h$. Due to resource constraints, tree height could only be estimated for a sub-sample of one-third of the individuals using a hypsometer. For unmeasured individuals, heights were estimated based on the average height of trees of the same morphospecies in the same vegetation association in each trail segment.

The economic value of the wood was estimated as 35% of the volume of each individual's wood stock, according to the Coefficient of Volumetric Yield (CRV) and Resolution No. 474 of the National Environment Council (CONAMA, 2009). For this estimate, only trees identified by local experts as suitable for sale were considered. Individuals with a DBH of less than 13 cm, those with twisted or crooked trunks less than 8 meters high, and/or individuals with forked trunks less than 13 meters high were classified as having no economic value. Our estimates were based on the volume of each individual suitable for trading, multiplied by the commercial value per cubic meter of its species.

To assess spatial autocorrelation, we calculated Moran's I index for each variable (Supplementary material). As no variable showed autocorrelation, we did not adjust for spatial dependence in subsequent analyses. Multivariate models were adjusted based on the abundance of morphospecies commonly exploited by loggers, adapted to the nature of each data set. The fit of the models was assessed using residual analysis, employing the "Logit" link function to relate the vegetation types (i.e. campina, campinarana or Iwité) as predictors of the response variables.

We modeled the relationship between timber stock, economic value of timber, non-timber extractive products (NTEPs) and cavities individually using generalized linear models. Altitude and linear distance from the nearest watercourse were included as additional predictors. For timber stock and economic value, the response variables were considered to follow the Gaussian distribution family and to normalize the distribution and improve the fit of the models, the data were log-transformed. The non-timber extractive-product model used the Poisson distribution family, while the cavity model used the negative binomial distribution family, both adjusted for zero inflation and outliers.

All analyses were conducted in R version 2023.12.1+402 (R Core Team, 2015) using the packages mvabund version 4.2.1 (Wang et al., 2012) and glmmTBM version 4.2.1 (Magnusson et al., 2017; Brooks et al., 2023). All the data and metadata utilized in the analyses are available in the supplementary material.

3. RESULTS

The abundance of morphospecies commonly exploited by loggers varied between vegetation types (Tab. 2). The campinarana and campina vegetation contained a subset of the morphospecies found in "Iwité" (Fig. 4, Tab. 2), and all the morphospecies found in these environments were also recorded in "Iwité".
With a few exceptions (e.g., "Macucu" - Fig. 4), most were also more abundant in "Iwité". The Table 1 lists the names of species from the Amazon region associated with the vernacular names used in identification, the type of vegetation association where the morphospecies were found, and their types of use (Tab. 1).

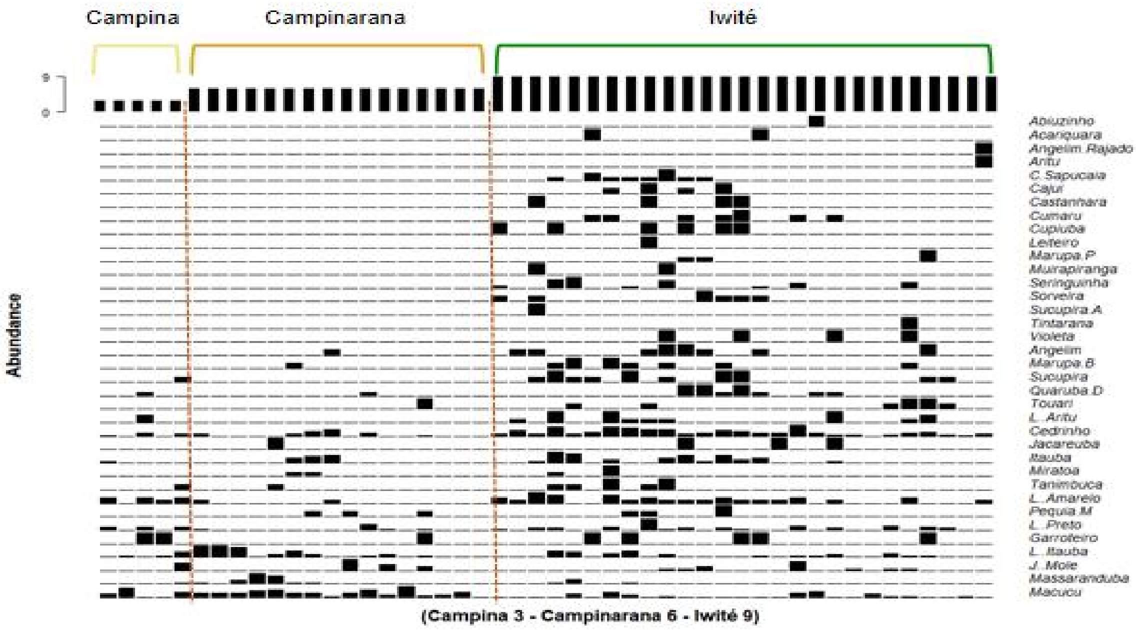

Figure 3 - Distribution of morphospecies among vegetation associations

After including altitude and distance from watercourses, vegetation type still contributed significantly to the model (Tab. 4, Fig. 4). Economic value of the wood stock was related to distance from the watercourse, but the distribution of resources was mainly affected by vegetation type. The only variable that was not related to wood stock and economic value was altitude (Tab 4). The number of cavities in the morphospecies showed no significant relationship with the environmental variables in our analysis (Tab 4). The models that did not show significant results are available in the supplementary material.

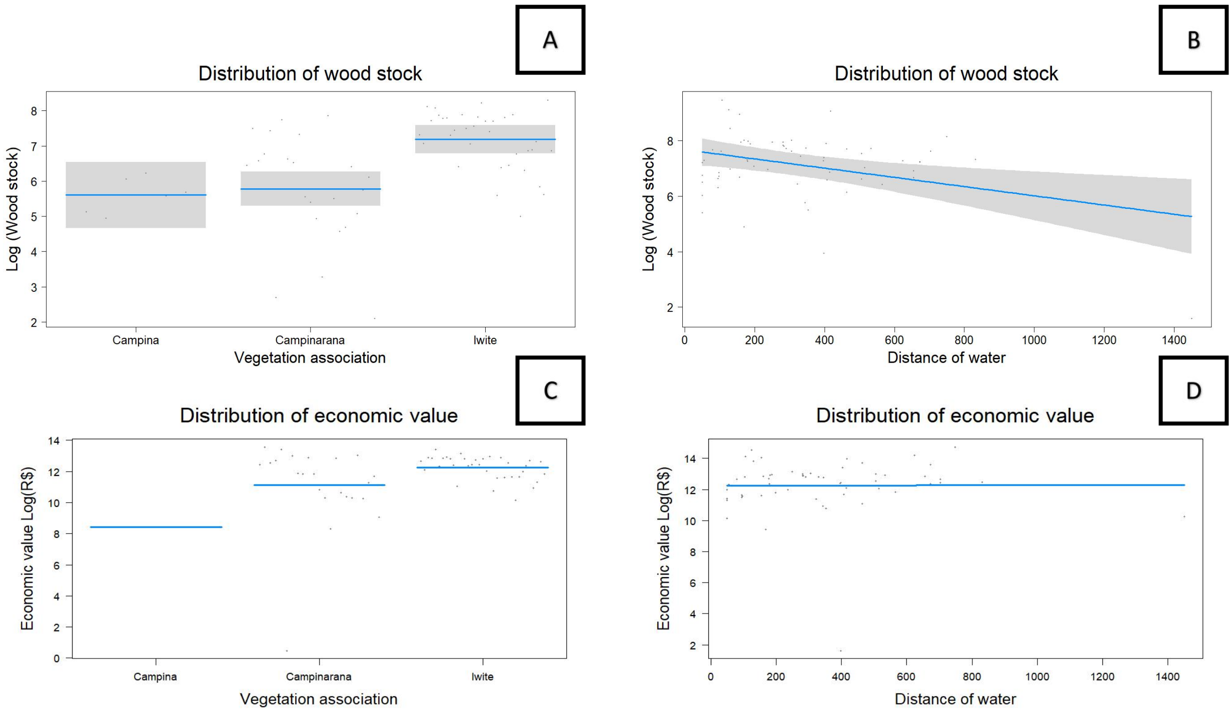

Figure 4. A - Distribution of wood stock (m³) among vegetation associations. B - Distribution of wood stock (m³) in relation to distance from watercourses. C - Distribution of economic value in vegetation associations. D - Distribution of economic value in relation to distance from watercourses.

4. DISCUSSION

Trees of timber interest in the Rio Negro RDS occur mainly in the Iwité forests. These areas concentrate the largest number of morphospecies of commercial interest, timber stock and economic value. Consequently, they are the areas of greatest interest for timber extraction. Campinas and Campinaranas cannot be considered sanctuaries for most of the species exploited in the reserve, as they contain only a subset of the morphospecies of commercial value. Campina has few morphospecies of commercial value and, even when they belong to morphospecies that are used for timber in other areas, the trees have low structure, deformed trunks and the low vegetation is generally not characterized as forest (SNIF, 2009). Although timber resources that are not available for timber supply have no economic value, these resources meet the definition of environmental assets and can provide social benefits (Nascimento and Góes, 2016).

Despite the differences in composition, there was little difference in the abundance of commercially valuable species that provide non-timber extractive products and cavities among the vegetation associations. Although these services did not vary between vegetation associations, it is not known how relevant this is for fauna. Integrated studies of fauna and flora distributions will be necessary to understand the complementarity of vegetation associations in the reserve in terms of resources for fauna. In addition, the model showed a significant relationship between the distribution of wood volume and economic value in relation to distance from watercourses. Trees close to the stream and water table tend to be exceptionally well-favored, with high growth rates and better form than trees further away, which means that these areas have greater commercial value (Bren 1993). Therefore, these areas can be considered of high commercial interest and consequently susceptible to logging impacts.

The removal of individuals of timber interest can also lead to the local extinction of species that are commonly associated with others due to similar characteristics and economic usefulness. Certain ecological characteristics predispose some timber species to population decline under logging pressure (Martini et al., 1994). This is the case of Massaranduba, a morphospecies of high commercial value that includes at least 8 species of the genus Manilkara (Rodrigues et al., 2017). These species show different rates of abundance and population growth (Gayot and Sist, 2004). In addition, logging can cause around a quarter of all trees to die or be damaged during the extraction process (Uhl and Vieira, 1989). This results in the unnecessary death of hundreds of trees of intermediate size and affects individuals that are not targeted by the market.

The economic benefits of logging tend to be short-term and generally favor external actors, while the negative impacts of this activity are concentrated locally, creating social injustices (Shanley and Medina, 2005; Lapola et al., 2023). Reducing tropical deforestation to almost zero is necessary for biodiversity conservation, the provision of ecosystem services, and, to a certain extent, climate mitigation by reducing emissions (Nobre, 2016). Forest management must go beyond simple carbon-stock considerations. The benefit of forest management depends heavily on long-term sustainability (Romero et al., 2020). Natural-resource management is only sustainable if there is knowledge to assess the costs and benefits of exploitation through ecological, economic, and cultural information based on the context in which it will be applied. Not removing these trees promotes the maintenance of these resources and helps to preserve the socio-cultural integrity of the communities that live and depend on forest resources (Alexiades and Shanley, 2000).

Identifying patterns in the distribution of natural resources is a promising and efficient strategy for monitoring, helping to preserve forest resources and identify the places most susceptible to anthropogenic impacts. In the case of the Rio Negro RDS, the concentration of commercially valuable morphotypes in "Iwité" forests indicates that control operations do not need to be concentrated throughout the reserve, but could be focused mainly on sites that give access to these areas. In addition, many commercially exploited species also have ecological value that is not captured by market prices and is not recorded in timber resource asset accounts in monetary terms (Toledo, 2018; Nascimento and Góes, 2016). It is therefore important to broaden our understanding of the various ecological contributions of timber species to the overall economy as well.

5. CONCLUSION

Most of the morphospecies of trees of value to the timber industry in the Rio Negro Sustainable Development Reserve are concentrated on more clayey soils (Iwité vegetation) and are not found in campina and campinarana, so areas with these vegetation associations do not serve as refuges the species. The wood value of trees is as high or higher near streams as in areas distant from watercourses, so there is economic incentive for loggers to degrade riparian areas. There is need to control illegal logging in the reserve to product non-timber resources, such as fruits and tree hollows.

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8. TABLES

Vernacular names	Scientific names related	Vegetation type	Types of use
Abiuzinho	*Pouteria sp.*[18]	Iwité	Timber
Acariquara	*Minquartia guianensis Aubl.*[19,8,2]	Iwité	Medicinal, Fruit and Timber
Angelim Pedra or Angelim	*Dinizia excelsa Ducke* [10,6,,13] *Hymenolobium modestum Ducke* [10,2] *Hymenolobium petraeum Ducke* [10,12,2]	Iwité	Timber
Angelim Rajado	*Zygia racemosa (*Ducke*) Barneby & J.W.Grimes* [19,1]	Iwité	Timber
Aritu	*Nomenclature not found in bibliographic material*	Iwité	Timber
Burra leiteira da folha miúda or Leiteiro	*Sapium glandulatum (L.) Morong* [4,2]	Campinarana	vegetable milk (Food e medicinal) and Timber

Castanha Sapucaia	*Lecythis pisonis Cambess.*[6] *Lecythis pisonis subsp. usitata (Miers) S.A.Mori & Pranche* [2]	Iwité	Timber
Cajuí	*Anacardium giganteum J.Hancock ex Engl.*[2,1] *Anacardium spruceanum Benth. ex Engl.* *Anacardium parvifolium Ducke* [1]	Iwité	Fruit and Timber
Castanharana	*Eschweilera odorata*[2]	Iwité	Oil, nuts, fibras, medicinal, cosmetic and Timber
Cedrinho	*Voshysia sp*[2]	Iwité Campinarana	Timber
Cumaru	*Dipteryx odorata (Aubl.) Forsyth f.*[19,12,14,5,1,6,13,2] *or* *Coumarouna odorata Aubl.*[19,14,6]	Iwité	Oil, nuts, fibras, craftwork, medicinal, cosmetic and Timber
Cupiuba	*Goupia glabra Aubl.*[1,13]	Iwité	Timber
Itaúba	*Mezilaurus duckei van der Werff* [7] *Mezilaurus lindaviana Schwacke & Mez* *Mezilaurus itauba (Meisn.) Taub. ex Mez* [1,5,13,2] *Octea agyrophylla duke* [7]	Iwité	Timber
João Mole	*Neea divaricata*[2]	Iwité Campinarana	Timber
Jacareúba	*Calophyllum brasilienses* [1,2]	Iwité Campinarana	Timber

Louro Amarelo	*Licaria pachycarpa (Meisn.)Kosterm*[7] *Aniba panurensis (Meisn.) MezLicaria*[1] *Licaria chrysophylla (Meisn.) Kosterm.* [7]	Iwité Campinarana	Food and Timber
Louro Aritu	*Licaria guianensis Aubl. or Licaria aritu Ducke*[2,19] *Licaria martiniana (Mez) Kosterm.* [7]	Iwité	Timber
Louro Itauba	*Mezilaurus synandra (Mez) Kosterm*[7] *Mezilaurus itauba (Meisn.) Taub. ex Mez* [7]	Iwité Campina	Food
Louro Preto	*Dicypellium manausense W.A.Rodrigues* [1] *Ocotea neesiana (Miq.) Kosterm.*[2]	Campinarana	Food
Macucu	*Aldina heterophylla Spruce ex Benth.*[13]	Iwité Campina Campinarana	Medicinal and Timber
Marupa Branco or Parapará	*Jacaranda copaia* (Aubl.) *D.Don*[12,2] *Simarouba amara* Aubl.[6,12]	Iwité	Timber
Marupa Preto	*Simarouba amara* Aubl.[12,2,3]	Iwité	Timber
Massaranduba	*Manilkara elata* (Allemão ex Miq.) *Monach.*[15] *or Manilkara huberi* Ducke [12,13] *Manilkara inundata* Ducke[15] *Manilkara bidentata (A.DC.) A.*Chev.[15]	Iwité Campina Campinarana	Fruit, vegetable milk (Food) and Timber
Miratoá	*Apuleia leiocarpa* (Vogel) J.F.Macbr.[19,2]	Iwité	Timber
Muirapiranga	*Ormosia sp.*[2]	Iwité	Timber
Piquiá Marfim	*Aspidosperma desmanthum* Benth. ex Müll.Arg.[17]	Campinarana	Timber
Quaruba Dura	*Vochysia guianensis* Aubl.[13,2]	Iwité	Timber

Seringuinha	*Allophylus sp.*[2]	Iwité	Latex and Timber
Sorveira or Sorva Grande	*Couma macrocarpa Barb.Rodr.*[9] *Couma utilis* Müll.Arg.	Iwité	Fruit , vegetable milk and Timber
Sucupira	*Bowdichia virgilioides Kunth*[13]	Iwité	Timber
Sucupira Amarela	*Vatairea sericea (Ducke) Ducke*[2]	Iwité	Medicinal
Tanimbuca	*Terminalia sp*[2]	Campinarana	Timber
Tauari	*Couratari macrosperma A.C.Sm.*[12,2] *Couratari multiflora (Sm.) Eyma*[12]	Iwité	Timber
Tintarana or Tinteiro	*Miconia sp.*[1]	Iwité	Timber
Violeta	*Platumiscium duckei Hub.*[2]	Iwité	Timber
Rouxinho or Pau Roxo	*Peltogyne sp.*[12,2]	Iwité	Timber

Table 1 - Scientific names associated with the vernacular names of morphospecies recorded in the vegetation types of the RDS Rio Negro and the different types of uses of each morphospecies found in the RDS of Rio Negro

Vegetation Association	No. of individuals	No. of morphospecies	No. of individuals (NETP)	Morphospecies NTEP
Campina	94	4	91	3
Campinarana	310	11	287	5
Iwité	866	36	391	20
Total	1270	36	769	20

Table 2 - Overall distribution of trees with different characteristics in the vegetation associations of the western part of the RDS Rio Negro.

Vegetation Association	No. of individuals found	Number of individuals expected	Probability of detection
Campina	94	222	P = 0.45
Campinarana	310	910	P = 0.31
Iwité	866	1938	P = 0.31

Table 3- Probability of detection based on distance sampling used to adjusting the density estimate.

Environmental variables	Morphospecies	NETP	Wood stock	Economic value	Cavities
Vegetation Association	P = 0.02	P = 0.5	P < 0.01	P < 0.01	P = 0.2
Altitude	P = 0.9	P = 0.3	P = 0.8	P = 0.8	P = 0.6
Watercourses	P = 0.02	P = 0.6	P < 0.01	P < 0.01	P = 0.4

Table 4- Results of Generalized Linear Models

8.1 REFERENCES TABLE 1

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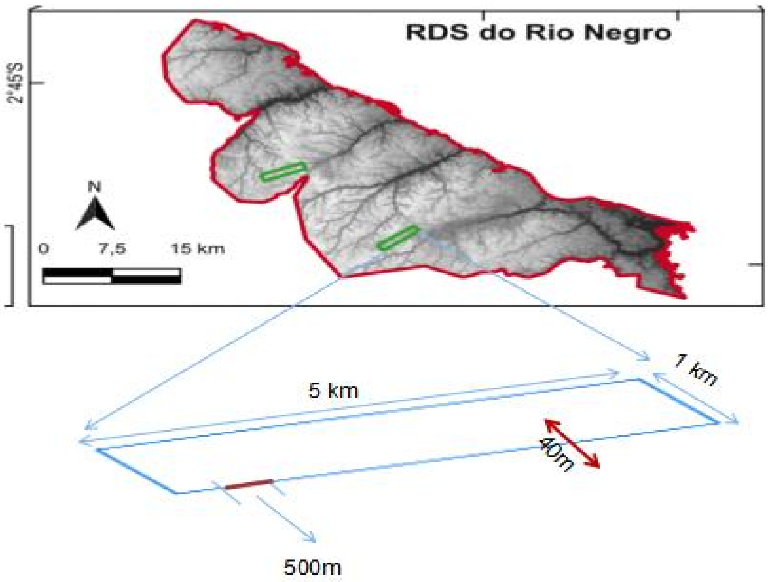
9. SUPPLEMENTARY MATERIAL



Dimensions of the two research modules of the Rio Negro RDS and The trails subdivided into segments, each of 500 m. IBGE cartographic base 2021.

Variable	standard deviate	P_value	Expectation	Variance
M³	3.6662e-09	0.5	-0.02127660	2.238877e-17
NETP	7.5455e-10	0.5	-0.02127660	2.114194e-17
Valor	-1.4718e-09	0.5	-0.02127660	2.222614e-17
Cavidade	-7.5262e-10	0.5	-0.02127660	2.125036e-17

Results of the Moran's I test for the spatial autocorrelation of the m3, NETP, value and CAV variables. The Moran's I statistic, expectation, variance, standard deviation and p-value are presented.

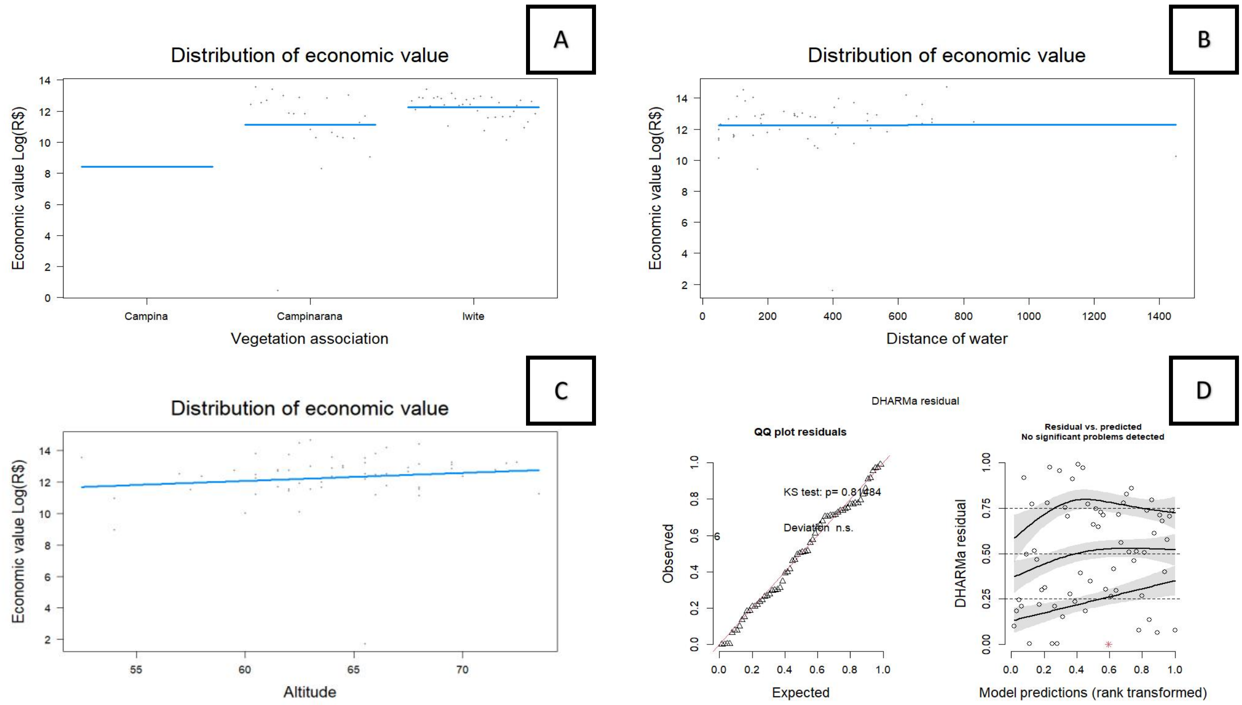


Figure 1. A - Distribution of economic value in vegetation associations. B - Distribution of economic value by distance from water. C - Distribution of economic value by altitude. D - GLM model residuals for distribution of economic value .

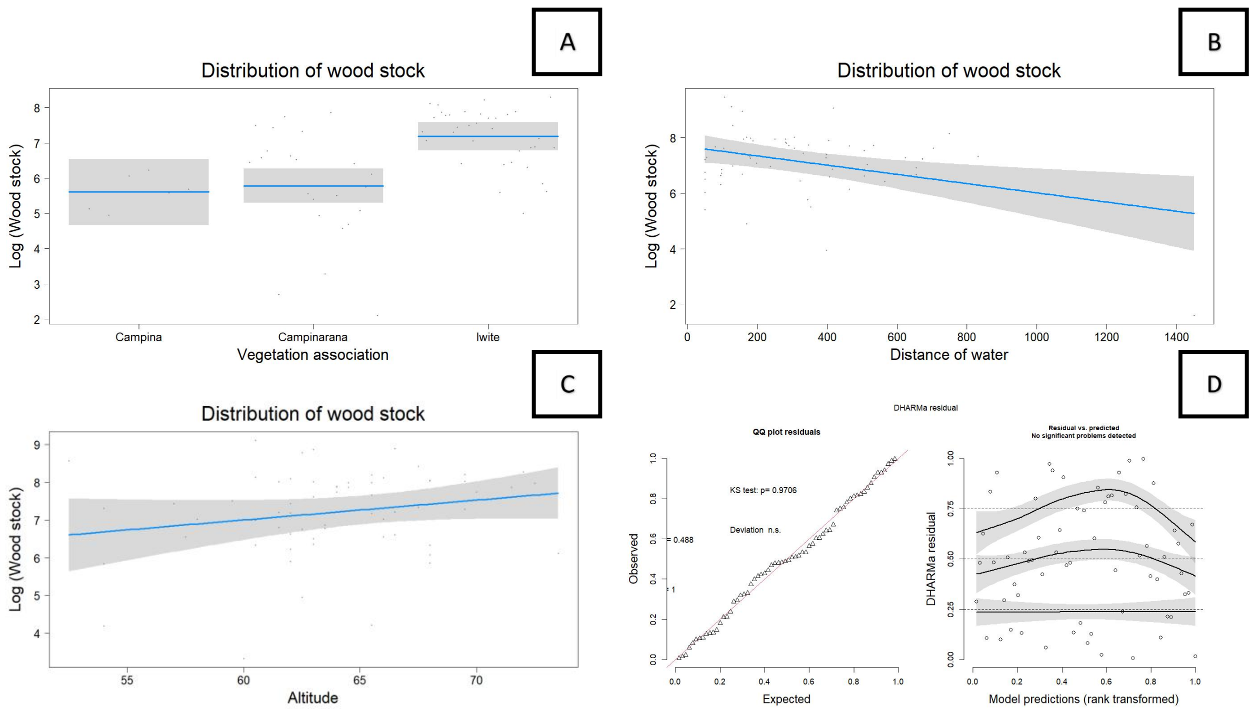


Figure 2. 2.A - Distribution of wood stock in vegetation associations. 2.B - Distribution of wood stock by distance from water. 2.C - Distribution of wood stock by altitude. 2.D - GLM model residuals for distribution of wood stock .

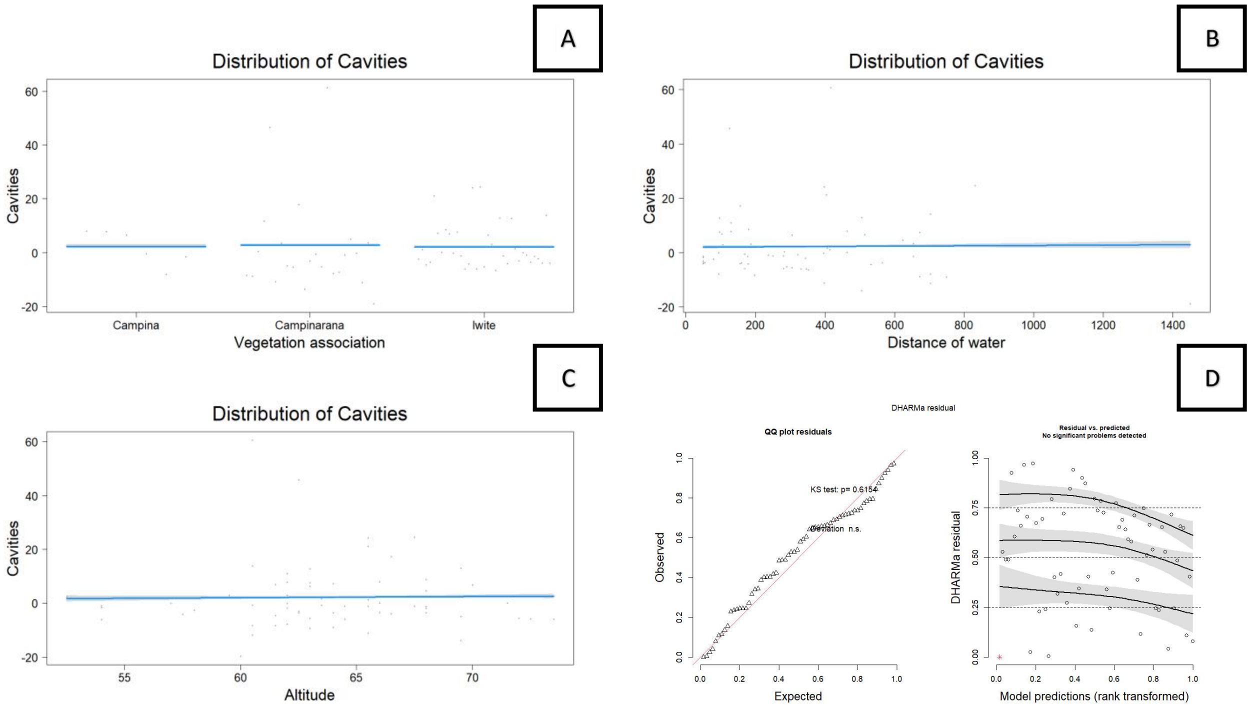


Figure 3 - 3.A Distribution of cavities in vegetation associations. 3.B- Distribution of cavities by distance from water. 3.C - Distribution of cavities by altitude. 3.D - GLM model residuals for distribution of cavities.

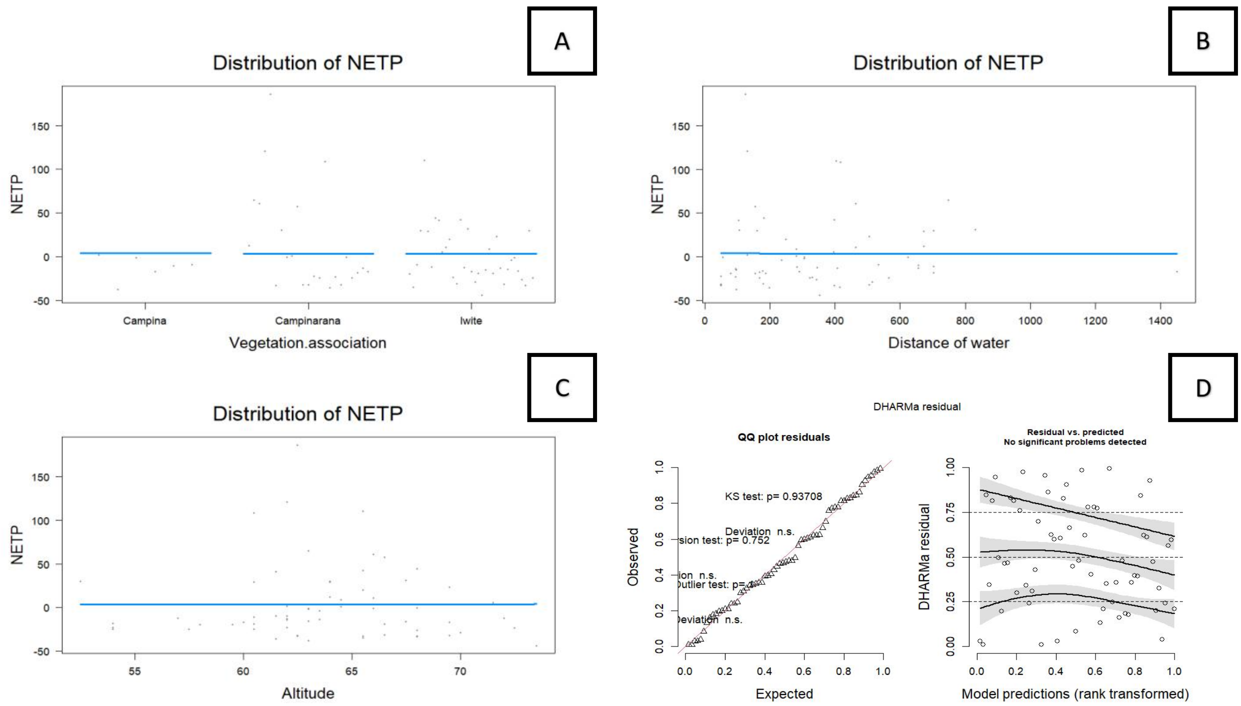


Figure 4. A - Distribution of NETP among vegetation associations. B - Distribution of NETP by distance from water. C - Distribution of NETP by altitude. D - GLM model residuals for distribution of NETP.