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EMERGENCE OF MALARIA IN THE AMAZON REGION AND ITS RELATION TO ENVIRONMENTAL AND HEALTH SCENARIOS

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ABSTRACT

Objective: To analyze the epidemiological profile of malaria in the Amazon region and its relationship with environmental, social and health indicators, between 2007 and 2021. **Methods:** Observational study of incidence rate, lethality and mortality from malaria in the Amazon region and environmental indicators, social and health. **Results:** Regarding the variation of malaria in the environmental and health scenario, there was an increase in the last 5 years for incidence (10.4%), lethality (38.5%), IPA (10.4), deforestation (44.5%) and fires (17.5%), with 86.1% of cases for P. vivax and 5442.9% of lethality for P. malariae. In deforested areas, Pará (44,972.09km²) and Mato Grosso (20,490.06km²) stand out, with fires between 575.539/PA - 477.707/MT and a higher incidence of malaria in Acre (49791.6/100mil) and Roraima/RR (38154.8/100mil), especially in indigenous areas, which comprise larger deforested areas considering only RR. In the Amazon social view, 77.7% of the states have low income (< R$980), high Gini index (0.5-0.6) and HDI between 0.639-0.729; to the coverage of Basic Care and sanitation, households registered in UBS between 43.8-88.6%, low health plan (<58%); visit of ACE (39.5-78.6%); inadequate sanitary sewage (<64%) and low drainage system (< 70%). To IPA, 55.6% of the states showed an increase (2016-2020), with risk classification in medium and low in 2020 and frequency for agriculture activity. **Conclusion:** There was an increase in health indicators in the last 5 years and, concomitantly, elevation of deforestation and fires, and incipient social indicators and sanitation, therefore, inferring contributions of these indicators to the elevation of malaria cases in the Amazon region and the hyperendemic state.

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INTRODUCTION

Malaria is a major public health problem worldwide, with more than 241 million cases and 627 thousand deaths in 2020 alone, registering an increase compared to 2019 (227 million and 558 thousand deaths); this increase being attributed, especially, to the emergence of *Severe Acute Respiratory Syndrome Coronavirus 2* (SARS-CoV-2), where two thirds of the deaths were due to the disruptions of services and health surveillance during the pandemic of coronavirus disease 2019 (COVID-19) and the remaining cases to recent changes in the methods of quantification of death and mortality rate by the World Health Organization, especially, applied to sub-Saharan African countries that hold approximately 93% of deaths (WHO, 2022).

By definition, malaria is a protozoa, with acute febrile clinic, transmitted through the bite of the female mosquito of the genus *Anopheles,* caused by four species; *Plasmodium ovale, P. malariae, P. vivax, P. falciparum,* the last two being of greater global burden, with *P. falciparum* predominant mainly in the African region, Southeast Asia, Eastern Mediterranean and Western Pacific in over 60% of cases, and *P.vivax*with 74.1% in the Americas region (BRAZIL, 2020; 2022; Pereira *et al*, 2021; Bissoli *et al*., 2022; WHO, 2022). Although sub-Saharan African countries have the highest number of cases and deaths, countries located in the Americas emerge with potential for malaria transmission, with about 18 endemic countries registering more than 600,000 cases in 2020 alone. In this scenario, Brazil stands out, with about 99% of autochthonous cases recorded in the Amazon region, thus highlighting its hyperendemic character, mostly associated with economic activities such as agriculture and mining, and migration, in addition to factors related to services and incipient health actions, social and health disparity, and environmental degradation, thus jeopardizing the efforts agreed in plans and strategies for malaria control and elimination (Grilo *et al*, 2020; Brazil, 2022; Buck and Finnigan, 2022; WHO, 2022). At the budgetary level applied to malaria control and elimination, in 2017, more than US$ 3.1 billion were spent worldwide; however, the economic impact is even greater when considering the outcomes left by the disease, health care, hospitalizations, and work disabilities due to sequelae due to lesions in multiple organs, especially the brain; Besides leaving indirect consequences with low local development where, according to reports by Souza *et al* (2021), the health-social cycle *is* strongly associated with poverty - Malaria *generates poverty and poverty generates Malaria* - (Multini, 2017; Souza, 2021; Barreto *et al*., 2022; OMS, 2022). Thus, among the main factors of malaria endemicity in the Amazon, there is literary consistency directed to environmental factors, especially economic activities that directly involve environmental changes with the exploitation of natural resources, especially deforestation (Chaves *et al* (2020; 2021; Pereira *et al*., 2021; Pontes, 2021; Junior *et al*., 2022). According to the National Institute for Space Research - INPE, the Amazon region presents high annual deforestation rates and consecutive growth since 2017, reaching 10,362km² of forest destruction only in 2021, presented by 29% higher than the year 2020, this being the worst scenario in a decade (Imazon, 2021; 2022; INPE, 2021). Thus, such aspects directly impact the local ecology and, consequently, alter the frequency and intensity of rainfall and loss of biodiversity that directly imply the *Plasmodium cycle*; therefore, considering deforestation as one of the main factors associated with malaria, the public neglect of the disease emergency and its consequences is explicit (Lana *et al*., 2017; Barlow *et al*., 2020; Laporta *et al*., 2021; Brazil, 2022; Souza *et al*., 2022).

Moreover, considering social, sanitary and health aspects as facilitators to the incidence of cases, the high frequency and maintenance of cases in the region exposes the vulnerability of the population in the face of social disparity between states and municipalities, and the incipient control measures and prophylactic actions implemented so far in Brazil. Thus, in view of the favorable scenario for the dissemination of malaria, epidemiological surveillance emerges as a key measure for the analysis, organization, knowledge and implementation of plans for the prevention and control of malaria, contributing to the situational diagnosis in different territories of the Amazon and serving as technical support to the federative entities regarding the implementation of actions and services and the allocation of resources in the health system in order to reflect the health indicators attributable to malaria. From this, the present work assumes its essentiality based on surveillance with the objective of analyzing the epidemiological profile of malaria in the Amazon region and its relationship with environmental, social, and health indicators between 2007 and 2021.

MATERIAL AND METHODS

This is an observational study, with descriptive aspect, based on the quantitative analysis of the time series referring to the incidence rate of malaria (100,000 or 1,000 inhabitants), malaria lethality and mortality in the Amazon region per 100,000 inhabitants, its Annual Parasite Incidence rate (API) per 1,000 inhabitants, economic activity exercised by those affected (%), registered parasite species (%), environmental, social and health characteristics, in the period from 2007 to 2021. The data referring to cases were obtained from the Sistema de Informação de Agravos de Notificação - Sinan and Sivep/Malaria, with the Incidence Rate being calculated following the pattern with the population estimate from the Instituto Brasileiro de Geografia e Estatística - IBGE, by the equation:

$$\textbf{\textit{Incidence Rate}} = \frac{\text{Number of cases}}{\text{Population quantily}} \times 100.000 \text{or } 1.000$$

For mortality rate, the same equation pattern is followed, and for lethality, the number of deaths by the number of infected people x 100,000:

$$\textbf{\textit{Mortality Rate}} = \frac{\text{Number of deaths}}{\text{Population quantily}} \times 100.000$$

$$\textbf{\textit{Lethality Rate}} = \frac{\text{Number of deaths}}{\text{Number of infected (confirmed cases)}} \times 100.000$$

For the calculation regarding IPA, the number of positive exams / population x 1,000 inhabitants was considered; and, for interpretation, the classification of transmission risks was established according to the Ministry of Health, as:

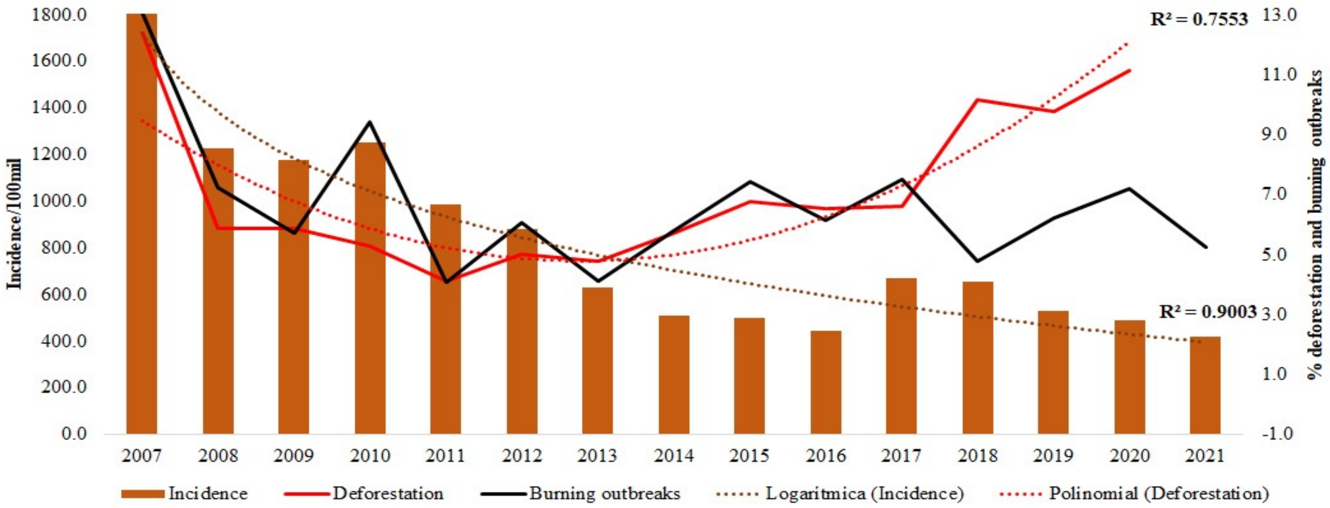
TRANSMISSION RISK RATING	
High Risk	>49,9/1.000
Mediumrisk	10 e 49,9/1.000
Lowrisk	0,1 - 9,9/1.000
No risk of malaria transmission	0

Furthermore, regarding environmental aspects, the absolute (n) and relative (%) frequency of deforestation (Km²) and fires in the period from 2007 to 2021 were considered, with data obtained from the National Institute for Space Research - INPE and IBGE. The social, health, and sanitation variables considered were:Gini Index, Human Development Index (HDI), percentage coverage of households enrolled in the Family Health Unit (USF), health plan coverage, coverage of visits by the Endemic Control Agent (ACE), sanitary sewage coverage, and drainage system obtained from IBGE. For all study variables, the mean and annual variation between 2007-2020 (14 years) and 2016-2020 (5 years) were calculated. In order to facilitate the analysis of health indicators (total number of cases and incidence; deforestation and fires) in the Amazon region, mapping was performed with the aid of GIS Quantum GIS (QGIS), version 3.16.9, according to the official geocentric reference standard for Brazil (SIRGAS 2000). Moreover, for the formation of graphs and tables, the *Microsoft* Excel 2016 program was used.

RESULTS AND DISCUSSION

According to data obtained from Sinan and Sivep/Malaria, in a temporal trend referring to the incidence rate for Malaria in the Amazon region (100,000 inhabitants) between 2007 and 2021, oscillation was observed throughout the period, ranging from 1.811.8/100mil inhabitants in 2007 to 418/100mil in 2021, with a trend line expressing a decrease, having a coefficient of determination (R^2) of 0.9; however, presenting peaks in 2010 (1,251.1/100mil) and 2017 (668.8/100mil) (Figure 1/A, B). To mortality, it stands at 0.3/100mil (2007) and 0.1/100mil (2020), and for lethality, 17.6/100mil (2007) and 22.3/100mil (2020); the Annual Parasite Incidence (API) was 18.1/1,000 (2007) and 4.9/1,000 (2020), with peaks in 2010 (12.5/1,000) and 2017 (6.7/1,000). The parasite species follow an annual pattern with higher mean frequency for *Plasmodium vivax* (86.1%) followed by *P. falciparum (*13%) (Figure 1/B). Regarding the deforestation percentile, the variation was 5.9% (2007) and 11.1% (2020), exposing the increasing annual trend and consecutive from 2013, with R^2 of 0.7; to the fires, it presents oscillation and peaks in 2010 (9.4%), 2012 (6.1%), 2015 (7.4%) and 2017 (7.5%) and 2020 (7.2%) (Figure 1/A). Analyzing the annual variation between 2007 and 2020, it was observed a decrease in almost all parameters (except lethality) being 73% for incidence, 66.7% for mortality, 72.9% IPA, 21.05% deforestation (Km²) and 0.28 for fires; however, when evaluating the last 5 years, there was an increase of 10.4% for incidence, 38.5% for lethality, 10.4/1,000 of IPA, 44.5% deforestation and 17.5% fires (Figure 1/B). According to the Ministry of Health/MS (Brazil, 2022), although mortality has decreased over the years, as expressed in the data of Figure 1/B, lethality remains a challenge and possibly a reflection of negligence of timely diagnosis and adequate treatment Fig. 1B.

A



B	Health Indicators (100,000 inhab)			IPA*	% parasite species				Lethality/parasiticspecies (100,000hab)			Environmental indicators
Years	Incidence	Mortality	Lethality		*P. vivax*	*P. falciparum*	*P. malariae*	*P. vivax*	*P. falciparum*	*P. malariae*	Deforestation (Km²)	Burningoutbreaks (n°)
2007	1811.81	0,3	17.6	18.1	79.9	19.1	1.0	5.8	49.0	757.6	-	186480
2008	1225.48	0,2	18.1	12.3	84.8	14.3	0.9	8.0	43.0	0.0	13.300,67	103453
2009	1176.91	0,3	22.5	11.8	84.1	15.0	0.9	9.8	44.2	4878.0	6.309,08	81682
2010	1251.10	0,2	19.3	12.5	85.3	13.7	1.0	7.9	55.9	699.3	6.291,95	134614
2011	988.18	0,2	19.2	9.9	87.3	11.5	1.1	11.4	43.5	775.2	5.692,05	58186
2012	879.74	0,2	22.1	8.8	86.0	12.5	1.5	10.4	50.9	0.0	4.429,46	86719
2013	628.37	0,1	17.7	6.3	83.3	15.4	1.2	12.7	26.7	0.0	5.396,84	58688
2014	509.49	0,1	15.8	5.1	84.0	15.3	0.7	10.2	47.0	0.0	5.115,03	82553
2015	499.03	0,1	17.4	5.0	88.8	10.7	0.5	10.6	81.2	0.0	6.117,63	106438
2016	443.03	0,1	16.1	4.4	88.9	10.6	0.5	13.6	68.4	0.0	7.268,86	87761
2017	668.78	0,1	14.8	6.7	89.6	9.8	0.5	6.5	59.1	0.0	6.999,58	107439
2018	654.17	0,1	20.3	6.5	89.8	9.5	0.7	13.7	73.4	9090.9	7.091,40	68345
2019	528.49	0,1	17.0	5.3	89.3	9.9	0.8	15.3	19.8	0.0	10.897,39	89176
2020	489.04	0,1	22.3	4.9	83.6	15.0	1.4	23.4	46.7	60000.0	10.501,46	103161
Var¹	-73.0	-66,7	27.0	-73.0	-	-	-	3.0	-0.04	78.1	-21.05	-0.28
Var²	10.4	0	38.5	10.4	-	-	-	0.7	-0.3	100	44.5	17.5
Average	839.5	0,2	18.6	8.4	86.1	13.0	0.9	11.4	50.6	5442.9	7.339,3	96764

Legend: *Annual Parasite Incidence (API) - number of positive tests/population x 1,000mil hab; Var % ¹ - Percentage variation in the comparison of 2007 vs 2020; Var % ² - Percentage variation in the comparison of 2016 vs 2020 (5 years); - Not applicable; Source: IBGE (2020); INPE (2020); SINAN (2020); SIVEP/MALARIA (2020).

Figure 1. Trend of malaria and health and environmental indicators in the Amazon region, between 2007-2021. Where A, incidence rate (100mil), frequency of deforestation and fires; B, health indicators; IPA; frequency of parasite species and environmental indicators, considering average and annual variation

In agreement, Souza (2021) reports that, although initiatives to control malaria, the improvement of diagnostic techniques and treatment on an adequate basis to reduce morbidity and mortality, the disease remains a major public health problem with occasional failures, especially in surveillance, because there is no universal action that covers all endemic areas, which reflects, therefore, in the disparity of indicators and high rates of lethality. According to the Epidemiological Bulletin of the MS (2020), the lethality rate in the extra-Amazon region is 123 times higher compared to the Amazon region due to the delay in suspecting malaria, given the non-endemic scenario that consequently leads to worsening and death. Following this survey regarding the gaps in surveillance and based on the data exposed in this study, where the year 2020 was responsible for the highest lethality rate considering the previous 10 years (2010-2019), this scenario is affirmed and, to this, the extensive literature affirms this failure as a setback and a result of the context of the emergence of SARS-CoV-2 in which surveillance was shown to be incipient to malaria with low notification of cases and increased lethality, thus, also exposing impediments in the treatment and the lack of efforts and reinforcements to the existing surveillance system (Multini, 2017; Souza, 2021; Gandra, 2022). Thus, for MS (2020), timely treatment results in cure, reduction of the time of disability and interruption of the chain of transmission, however, for Lana *et al* (2017) and Souza (2021), one of the challenges that plague the country include the higher prevalence of the parasitic species *P. vivax* and its character of rapid development of gametocytes, asymptomatic profile, latency stage (weeks to months), microscopy of difficult detection and refractory potential to standard treatment and, as about 86.1% of cases in the Amazon region belong to this species, the control is even more challenging, however, the authors argue that whatever the parasitic species, the correct and timely treatment is a determining factor to survival.

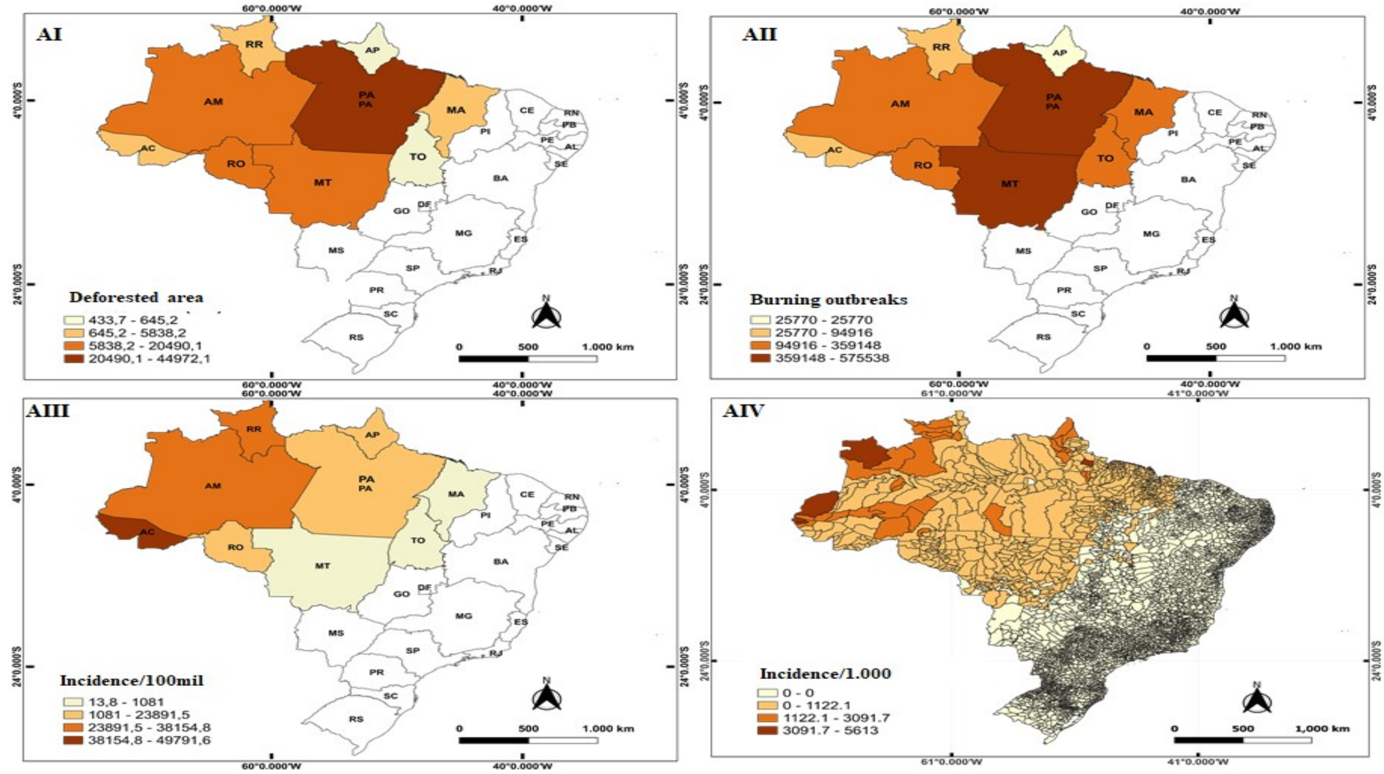
Given the high lethality, it is noteworthy that although the prevalence of *P. vivax,* most deaths are recorded for *P. malariae*and *P. falciparum,* demonstrating the severity of these species. Such information is consistent with the literature and, specifically for *P. malariae,* despite the lower frequency of cases (between 0.5 and 1.5%) and clinical picture similar to *P. vivax,* the lethality is alarming and holds potential for relapse in the long term, which implies, therefore, in morbidity and mortality; moreover, for *P. falciparum,* its lethal potential is well recognized with shorter duration of the tissue cycle, rapid multiplication in the bloodstream, higher production and merozoites (in tissue and erythrocyte schizogony), high destruction of erythrocytes, ability to form clots which gives rise to problems such as thrombosis and among others being, therefore, the only one to produce changes in microcirculation and greater sequelae establishes, as soon, its severity; thus, it is emphasized an adequate attention to these cases (Gomes *et al*, 2019; Brazil, 2020; WHO, 2021; Pereira *et al*.,2021; Souza, 2021). Beyond these aspects, according to Padilha (2018), the paradigm involves deforestation and its correlation with the decline or not of malaria generates debates and, according to the author, depending on the location, such relationship is linked to the dynamics of the deforested area and local transmission, therefore, not being uniform and/or linear, because it depends on the overall proportion of forest cover. By taking into account such fact, the non-linear model of deforestation and incidence exposed in the present study transcends Padillha's (2018) survey, however, in consideration the occurrences of peaks and the percentage comparisons of annual variations expressed in the last 5 years (2016-2020), with an increase of 44.5% in deforestation, 10.4% in incidence and 10.4% in IPA, one can infer a certain relationship between such factors and, as soon, go in consensus with recent studies that punctuate the pathology as a burden and resulting, above all, from anthropic actions.

In a study conducted Loaiza *et al* (2019) aiming to explore possible changes in hematophagous insect communities as a function of forest disturbance, the Dilution Effect Hypothesis (DEH) was raised where it holds that high biodiversity dilutes sources of infections, these being represented by reservoir species, and reduces the risk of human infections, however, the authors translate their findings from the higher entomological risk for mosquito-borne infections when in forest disturbance, where they present abundance of mosquito species and lower reservoir. Complementing the findings of Loaiza *et al* (2019), Chaves *et al* (2021) recall that the *anopheles (Nyssorhynchus) darlingi*mosquito is the main malaria vector in the Amazon; in their study, its frequency was 46.6% in field collections in 12 Amazonian municipalities, this prevalence being a result of changes in the vegetation of the Amazon Rainforest caused by human action causing, therefore, a decrease in mosquito biodiversity and, in areas of deforestation and/or fragmented areas, the abundance of this species was significant ($P = 0.03$), thus, favoring the risks to the disease. For Laporta *et al* (2021), in 12 cities in four states in the Amazon region, *Ny. Darlingi*was prevalent (86%) with an overall *Plasmodium* infection rate of 1.04%, with municipalities showing up to 3.7%; cumulative deforestation ranged from 9.9 to 89% (mean 50.2) and, in a confirmatory analysis of infected anopheline incidence and deforestation, there was a significant relationship ($P < 0.001$), that is, degraded and newly degraded sites showed higher risks of exposure to malaria, being considerably high in sites with more than 50% deforested area. Similarly, MacDonald and Mordecai (2019), Barlow *et al* (2020) and Chaves *et al* (2020; 2021) point out that the combination of malaria and deforestation has a spatial and temporal relationship, indicating that peaks of the disease occur according to anthropogenic actions; above this, the exposed data corroborate this burden given the concomitant peaks between malaria, IPA and fires in 2010 (1251.1/100mil; 12.5/1.000; 9.4%), 2012 (879.7/100mil; 8.8/1,000; 6.1%), and 2017 (668.8/100mil; 6.7/1,000; 7.5%), with an average deforestation of 69,206 km² in this period. According to these authors, this relationship is based on several factors, such as: with environmental degradation, there is a greater likelihood of invasion of species and hematophagous insects into new ecological niches; loss of biodiversity, thus decreasing the DEH leading to diffuse competition; increase in local temperature and reduced time for larval to adult development; and the development of ecotone and the displacement of vector species to other locations.

Thus, as the life cycle of *Plasmodium sp.* depends on human-mosquito interrelationships, deforestation and fires are fundamental to the dynamics of infection based on the ease of proliferation and dispersal of the species under these conditions. Although the relationship is widely described in the literature, this subject is still neglected, disposed of leniency and permeated by dismantling in public policies; based on this, Barlow *et al* (2020), Massad *et al* (2020), and Laporta *et al* (2021) warn the importance of political and media attention on the cause and the essentiality of economic development projects that consider the environment and its preservation to, as soon, shape the worrisome scenario of vector-borne infectious diseases, especially malaria. From the social, demographic, and quality of health services (Basic Care/AB and basic sanitation) point of view, authors infer a relationship with the malaria endemic and epidemic. Above that, initially it was performed mapping of the areas of the Amazon region as to the occurrence of the disease and environmental issues (deforestation and fires) with accumulated data between 2007 and 2021, and it reaffirms the non-occurrence of a pattern, as raised by Padilha (2019) and Laporta *et al* (2021); where the largest areas of deforestation are centered in Pará/PA (44,972.09km²), followed by Mato Grosso/ MT (20.490,06Km²), Rondônia/RO (14.057,07Km²) and Amazonas/AM (12.305,26 Km²) (Figure 2/AI); with fires in PA (575.539) and MT (477.707) (Figure 2/AII) and, paradoxically, a higher incidence of malaria in Acre/AC (49.791.6/100mil), Roraima/RR (38.154.8/100mil) and AM (33.155.9/100mil) (Figure 2/AIII); by municipality, the highest registers per 1,000 inhabitants are concentrated in Acre: Mâncio Lima (5613.0), Rodrigues Alves (4481.5); Amazonas: Atalaia do Norte (3364.9) and São Gabriel da Cachoeira (3091.7); Pará: Anajás (5536.8) (Figure 2/AIV). In the social view, 77.7% of the states present income below R$ 980, being Maranhão/MA, PA, AM, AC, Amapá/AP, Tocantins/TO, RO; Gini index between 0.5 and 0.6 and Human Development Index/HDI between 0.639 (MA) and 0.729 (MT). Regarding basic health and sanitation, the frequency of households registered in UnidadesBásicas de Saúde/UBS (Basic Health Units) is between 43.8% in AP and 88.6% in TO; the coverage of health insurance is below 58% in all the

UF; The frequency of visits by the Agente de Combate a Endemias/ACE is between 39.5% in RO and 78.6% in MT; adequate sanitation between 6.7% (RO) and 63.2% (RR), and exclusive drainage system between 11.5 (MA) and 69.2% (MT) (Figure Tabela 2/B).

when considering proportionality to the territory and, among its municipalities, Feijó and Mâncio Lima emerge in the ranking of the 10 most critical. Furthermore, according to data from Boletins Epidemiológicos (2021), approximately 70% to 67.4% of the cases in Acre registered in 2020/2021 were in rural areas and, considering the



UF	Social Indicators, AB and sanitation								
	Incidence (100,000)	Income (R$)	Gini	HDI	% Households registered in the FHU¹	% Health insurancecoverage	% Visitfrom ACE¹	% Sanitarysewage	% Drainage system
TO	13,8	935	0,5	0,699	88.6	39.5	71,1	31,9	20,2
RR	38154,8	1026	0,6	0,707	51.6	28.8	64,7	63,2	42,9
RO	20576,4	980	0,5	0,690	51.2	41.3	39,5	6,7	54,1
PA	9844,8	754	0,5	0,646	61.3	52.5	65,4	13,6	28,1
MT	1081,0	1237	0,5	0,729	73	55.6	78,6	35,8	69,2
MA	296,7	580	0,5	0,639	65.8	21.6	64,3	13,8	11,5
AP	23891,5	863	0,6	0,708	43.8	46.5	51	6,9	37,5
AM	33155,9	795	0,6	0,674	54.9	58	52,2	13,7	38,5
AC	49791,6	810	0,6	0,663	52.4	30.9	66,4	11,4	14,3

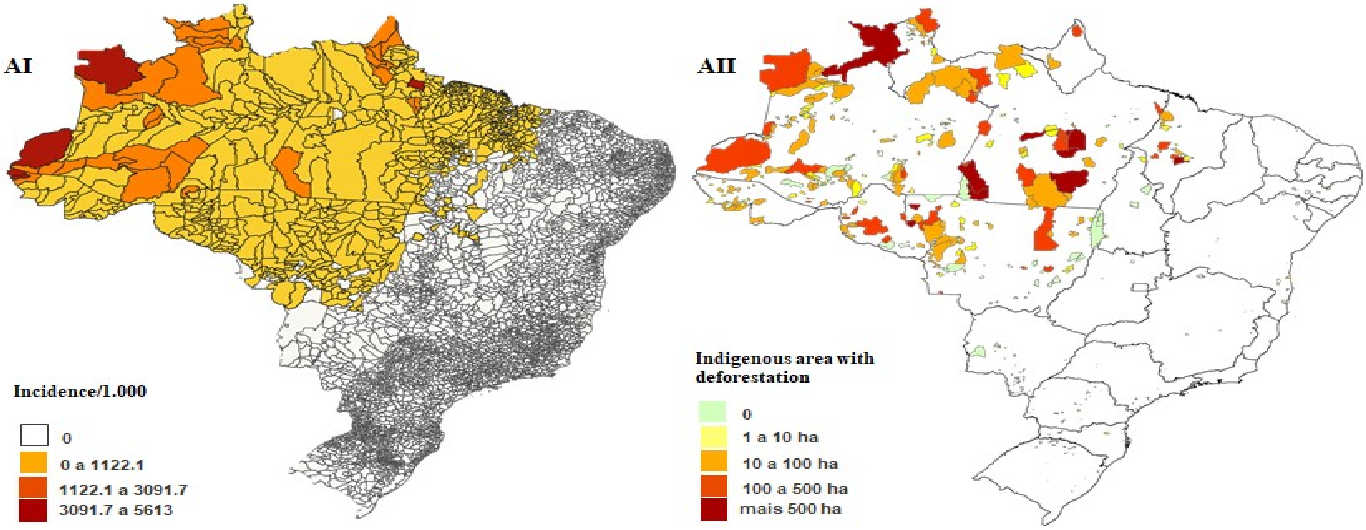
Legend: ¹Domiciles registered in Family Health Unit (Thousand households); ²Health Plan (medical or dental), considering total of 59.7 million people; ³Endemic Disease Control Agent.

Source: IBGE/PNS (2019; 2020); SNIS (2020); INPE (2020); SIVEP/MALARIA (2020).

Figure 2. Spatial trend of malaria according to social, health and sanitation indicators in the Federal Units (UF) of the Amazon region. Where A: distribution of deforested areas (Km²), fires (n°) and incidence of malaria (100 thousand inhabitants); B: social, health and sanitation characteristics, between 2007-2021

In accordance with a study by Padilha (2019), the deforestation-malaria paradox was exposed in the present study; for the author, areas with less degradation, such as Acre, exposed higher malaria cases and, in Rondônia, with one of the highest rates of deforestation, demonstrated lower incidence rates going, therefore, in conformities with data from the present study; corroborating, again, the non-uniformity of these variables and the need for a qualified look at local dynamics and evaluations considering the deforested territorial extension before the totality. According to the 2021 Epidemiological Bulletin, among 22 municipalities in Acre, Cruzeiro do Sul and Rodrigues Alves account for 80% of the total number of cases and, according to Oliveira *et al* (2021), in an indirect analysis of deforestation based on climate modeling, these municipalities have the largest abrupt changes in deforested areas. Thus, according to the Amazon Environmental Research Institute (IPAM, 2022) and the Deforestation Alert System (SAD, 2022), the State of Acre presents a worrying degradation dynamic, with gradual annual growth and a 36% increase in the deforested area only between June (2021) and July (2022), being the state with the greatest loss of forested areas

data from the present study where approximately 48.5% of those affected have agricultural activities, this fact is corroborated. According to the last Agricultural Census (IBGE, 2017), Acre and Amazonas have farming as one of their main activities and, according to Duarte *et al* (2020), this practice was responsible for a 55% increase in deforestation in Acre in 2019 alone; for Pontes (2021), with the agribusiness project called Amacro (union between 3 Amazônia, Acre and Rondônia), deforestation reaches 30% cumulative and 47% of the total deforested only in 2018, therefore, justifying the dynamics of malaria transmission in these states and the contribution of human actions without proper control. Following this same line, the literature draws attention to the highest cases of malaria in Roraima, with an incidence of 38154.8/100mil in the present study; this position can be justified by the greater activity in timber exploitation with a large presence of the local logging industry. According to a report by the Institute of Man and Environment of the Amazon (Imazon, 2022), Roraima held a larger area of illegal exploitation with the equivalent of 5 thousand soccer fields between August 2019 and July 2020, with about 9,458 hectares of exploited



Source: INPE (2020); SIVEP/MALARIA (2020).

Figure 3. Spatial trend of malaria and deforested area in the Amazon Region. Where A, distribution of cumulative malaria cases in municipalities between 2007 and 2020; B, distribution of deforested indigenous areas (hectares) in 2020

forests, 55% without authorization from the State Foundation of Environment and Water Resources of the State (Femarh/RR), in this sense, according to Pereira *et al* (2021), the higher incidence may be associated with human actions with clear consequences to the proliferation and dispersion of mosquito species. Another strong point to be listed in Amazonas and Roraima with high contribution to the dynamics/incidence of malaria, refers to the largest contributions of deforestation and fires, although not significantly explicit in Figure 2/AI and II especially in indigenous areas; and to this, one can attribute the prevalence of mining activity in these locations, which has enormous environmental impact. Analyzing this scenario in detail at the level of municipalities, data expressed in Figure 3 considering the territorial extension of these two states, deforestation is alarming, with most of the areas representing hectares between 10 and >500 deforested only in 2020.000/hab), especially in the municipalities of São Gabriel da Cachoeira, Atalaia do Norte (AM) and parts of Amajari and Alto Alegre (RR), coinciding with indigenous reserve areas, especially, Yanomami and Homoxi (AM/RR) and Alto Rio Negro (AM); besides indigenous areas located in Pará (Apytereua, ItunaItatá and Kayapó). According to data from the BoletimEpidemiológico (2021), about 80% of malaria cases in Roraima are distributed in 7 municipalities, especially in Alto Alegre and Amajari, with about 58.4% of the cases in indigenous communities and 22.2% attributed to the mining sectors. According to a report by Instituto Socioambiental/ISA (2022), illegal mining is one of the main activities in the state, with a direct and predominant impact on the Yanomami Indigenous Land which, in the last five years, has shown a forest degradation curve rising 3350%, with an impacted area of 3,272 hectares only in 2021 and, from this practice, with deforestation and residual pools left, mosquitoes find a suitable environment for their evolutionary cycle (Brazil, 2020; Machado *et al*., 2020). In the analysis by Health District of the Yanomami indigenous areas, of the 37 existing poles, 18 (48.6%) have records of deforestation related to mining observed by satellite. However, this data is underestimated because if the analysis were to expand beyond satellite data to include poles using information regarding the activities of floating dredges (rafts) and mining groups, the number would expand to 24 poles (64.9%). In this line, authors emphasize public health problems, especially the increase in local malaria cases, where about 95% of the 790 inhabitants had the disease, and the increase in occurrences in urban areas imported from the mining areas (Machado *et al*., 2020; ISA, 2022). Also according to the report, a problem involving the minimum record of deforestation in Roraima when considering its totality and the non-uniformity of the degraded area, refers to the existing gaps in analysis methods where, for example, activities performed with rafts are not measurable by remote sensing methods, this being widely used in various regions, thus exposing a smaller record of environmental degradation in this state. As a model, authors transcribe the use of rafts near the mouth of the Igarapé Xeriana and in the Novo River, with the occurrence of underground mines which, however, are not yet visible by satellites; corroborating the low local scarcity in the face of the high activity of miners and, consequently, deforestation. With this problematic underdiagnosis of deforested areas, this same scenario can be inferred for the state of Acre and, therefore, strengthen a qualified evaluation in the Amazon and the relevance of joint actions against this cause in order to enact the real scenario of economic activities carried out locally, deforestation and its impact on public health (Machado *et al*., 2020; ISA, 2022; Junior *et al*., 2022). In 2021, the Amazon presented more than 300 unlicensed rafts, with about 94% of mining area in Brazil, more than 50% being illegal, especially in indigenous areas and Conservation Units; in Pará, this reality is similar (Brazil, 2020; Diniz, 2021; Fellows, 2021). According to Ellwanger *et al* (2020) and Junior *et al* (2022), the anthropic actions in the Amazon and the impunity of such actions considered illegal are the main challenges in the country. Moreover, this neglect of environmental issues has gained greater visibility in the current government (2019-2022), where deforestation and environmental degradation is seen as a culture, reflected by political negligence through budgetary reduction of environmental agencies, the dismantling in 2019 of the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (created in 2004) and changes in processes expected to ensure and assign responsibilities to violators and, consequently, a decrease in infraction notices in the region, therefore, promoting the wave of deforestation, exploitation, and burning in the Amazon forest. Specifically to the attribution of responsibilities, Prizibisczki (2022) reports changes in the rules for applying fines that, in short, inspectors will have, in addition to everything else, to prove or not the violator's intention of damage when practicing deforestation to then apply punishments; therefore, serving as another challenge to the complex sanctioning process.

Nevertheless, issues involving environmental impacts related to infectious diseases are not current and, in the case of malaria, where its manifestation does not occur eventually, the extent of the impacts previously described modulates the transmission and distribution of the disease, therefore, reflecting on the health indicators, which together result from socioeconomic aspects, demographic aspects and the quality of basic health services that, although recognized as determinants of health status and direct relationship to the health-disease process, are incipient in the Amazon region, especially due to the disparity between states, as expressed in the study where the Gini index is between 0.5-0.6, thus corroborating its strict relationship with poverty and social inequality (Castro *et al*., 2019; Chaves *et al*., 2021). In this sense, according to the Ministry of Health (Brazil, 2022), malaria is strongly related to social vulnerability and it is estimated that higher proportions of cases and deaths occur in places with lower income and low HDI; this scenario can be observed in the region where about 88.9% of the states have income below one minimum wage (except MT), when considering the year 2021 (R$ 1,100.00 by Law 14.158/2021) and 66.7% with medium HDI. Furthermore, as widely reported, aspects involving basic care and adequate sanitation, especially the ACE view, sanitary sewage, and rainwater drainage are key to preventive actions, surveillance, and control of malaria; however, when evaluating the current scenario, the occurrences of the disease are expected, given the lower adequacy of these indicators in all states of the region (Figure 2/B). Referring to the households registered in UBS and the health insurance coverage, they present low coverage in 55.6% of the states (UBS <60%) and 100% of the states with coverage below 60% for health insurance, thus favoring vulnerability, indicating gaps in the health care model, which may infer the high lethality rates during the analyzed period. Thus, when taking into account the social, health and sanitation indicators previously exposed, the rainfall and temperature of the region (data not exposed), together with aspects involving deforestation and fires, the massive proliferation of mosquitoes is a reality from an environment conducive to the development of breeding sites and natural and anthropogenic water bodies, formation of small rivers and stagnant water without proper management that influence the dynamics and seasonality of the disease, creating a perfect condition for the permanence of endemicity with high epidemic potential in the Amazon region (Barlow *et al*., 2020; Johansen *et al*., 2020; Laporta *et al*., 2021).

However, between 2016-2020, 55.6% of the states showed an increase in IPA, ranging from 327.8% (RR) and 10.8% (AM). In the year 2020, RR (46.6), AM (14) and AC (13) were classified with medium transmission risk (between 10 and 49.9/1,000) and the others with low risk (0.1 - 9.9/1,000), except TO with no risk (Table 1). Regarding the activities of those affected, there was frequency for agriculture in PA (60.4%), AM (58.7%), AC (48.5%), PA (38.7%), MT (37.4%), MA (35.8%) and RO (32.6%) and mining for TO (47.7%) and RR (41.4%) (Tabela 1). According to the MS, IPA is an important tool to assist in comparative analyses of the disease situation in different locations and time, and serves as a basis for planning and managing public policies and health services related to malaria. In this sense, in this study, its assessment emerged as support for the characterization of risks by state and, from the data, where 55.6% of states showed an increase in IPA, it is notable the need for public health policies and awareness in these states, especially in RR, AM and AC, given their classification with medium risk of transmission (between 10 and 49.9/1,000) and the dynamics and factors previously known and contributing to the transmission of the disease. In a recent study, Grilo *et al* (2020) shows that, in 2017, the PAI was higher in CA 43.4/1,000, RR 21.4/1,000 and AM 20.4/1,000, therefore, medium risk of transmission; thus, in agreement with the data from this study, the continuity of the chaotic state during different periods is demonstrated, characterizing, then, these areas as hyperendemic and the public neglect of the current situation that, according to the author, comes from the encouragement of economic activities of high environmental impact as demonstrated above. This reality can be exposed by the higher infection in individual with garimpagem activity in TO and RR and, although raised the relevance of illegal garimpo in RR, AM and PA, specifically in TO, this activity presents huge social and environmental damage with large machinery and minimal use of personal protective equipment, both for risks of occupational accidents and infectious diseases (Pimentel, 2019; Brazil, 2020). In a study by Bissoli *et al* (2022), between 2003 and 2017, the IPA showed oscillation in the Amazon region, going from high and medium risk of transmission and, although most states have shown a decrease in this period, AC and RR maintained high rates. For the authors, this variation focused on the reduction of cases is due to the actions taken in certain periods, however, with the maintenance and peaks of cases and IPA, one can cogitate a lack of integration between the different spheres focused on controlling the disease and gaps in the actions to combat endemics due, above all, to the lack of a qualified and broad look at the factors that corroborate the incidence of malaria.

Table 1. Variation of Annual Parasite Incidence (API) according to interpretation and economic activity profile of the affected population in the Amazon region, between 2007-2020

UF	IPA**						
	2007	2011	2016	2020	Var¹	Var²	IPA Interpretation (transmissionrisks)
TO	0,04	0,005	0,003	0	-100,0	-100,0	High risk (>49.9/1,000); medium risk (10 and 49.9/1,000); low risk (0.1 - 9.9/1,000); no risk of malaria transmission (0)
RR	19,9	25,3	10,9	46,6	133,8	327,8	
RO	23,0	18,3	4,0	6,6	-71,4	65,5	
PA	182,3	14,8	1,8	2,8	-98,5	59,0	
MT	1,1	0,5	0,2	1,0	-4,4	50,4	
MA	7,8	0,3	0,02	0,01	-99,9	-50,0	
AP	12,7	24,1	14,6	3,8	-69,7	-73,7	
AM	31,4	16,5	12,6	14,0	-55,3	10,8	
AC	16,5	28,6	40,7	13,0	-21,0	-68,1	

UF	% Activity									
	Traveler	Mining	Construction	Hunting / Fishing	Vegetal Exploration	Mining	Tourism	Domestic	Livestock	Agriculture
TO	3,1	1,2	0,9	5,7	10,2	47,7	0,9	9,0	2,3	18,9
RR	1,3	0,5	0,7	11,2	0,8	41,4	0,6	8,8	1,2	33,5
RO	7,9	1,7	3,8	8,9	2,4	26,7	2,1	7,6	6,4	32,6
PA	2,3	0,9	0,6	3,2	2,3	31,1	1,0	19,1	0,9	38,7
MT	2,0	0,4	0,3	6,8	7,1	23,3	0,7	20,8	1,1	37,4
MA	3,8	0,4	0,4	16,2	0,5	30,2	0,8	10,8	1,1	35,8
AP	3,4	0,1	0,6	6,9	1,5	1,7	1,3	23,3	0,9	60,4
AM	2,2	0,1	0,2	1,1	0,5	0,04	0,9	35,4	1,0	58,7
AC	1,3	0,9	2,3	2,7	2,3	5,8	4,6	29,6	2,0	48,5

Legend: * Annual Parasite Incidence (API) - number of positive examinations/population x 1,000mil hab;
Var % ¹ - Percentage variation in the comparison of 2020 vs 2007;
Var % ² - Percentage variation in the comparison of 2020 vs 2016 (5 years);
Source: SINAN (2020); SIVEP/MALARIA (2020).

Nevertheless, analyzing the states in isolation, unlike Roraima, Acre, Amazonas and Pará, the states of Tocantins, Maranhão and Mato Grosso showed lower incidence for malaria, with 13.8/100mil, 296.7/100mil and 1081/100mil, respectively (Figure 2A; B). However, recent literature highlights an extremely relevant factor to be pointed out regarding the maintenance of native vegetation cover that, although TO, MA and MT are part of the legal Amazon, the cover is not arranged in its entirety and there are transition zones between biomes (cerrado and pantanal) and differences in local temperature with an impact on the mosquito cycle and its lower prevalence and, therefore, reveals lower susceptibility in some areas (Couto *et al*., 2020; Ferreira *et al*, 2021; Gandour, 2021).In addition, to corroborate the data, the Annual Parasite Incidence (API) was calculated followed by its interpretation as to the risks of transmission, thus, it was observed variation of this rate during the period, being exposed a reduction of API between 2007-2021 for 88.9% of the UF (except RR), with greater decreases in TO (100%), MA (99.9%) and PA (98.5%) the others between 71.4% - 4.4%).

Moreover, another aspect considered by Samesima (2019) and Johansen *et al* (2020) and previously raised is that, although most studies translate the risks of transmission related to environmental and economic activities, the household and peridomicile characteristics contribute significantly to the proliferation of the vector and increase of cases, in addition to the contribution of work activities developed as a risk factor for infection. Thus, in a study by Johansen *et al* (2020), the characterization of the population in different localities of the municipality of Mâncio Lima/AC, with an average of 1 to 1,714 malaria cases, corresponds to 55.7% of individuals with informal activity in agriculture, low-income localities, 16.8% of individuals with multisited households (urban and rural) and about three-quarters of the 24 localities with very intense malaria transmission (≥ 500) with peri-urban agricultural settlements within a radius of 20km. This reality is not restricted to CA, as 77.8% of the states have the same profile, especially Amapá with more than 60% of cases. Added to this, Grilo *et al* (2020) contributes with arguments regarding the fish farming activity as a probable larval habitat and, therefore, a rich potential that relates to abandonment, lack of cleaning and maintenance of fishponds, thus contributing to the proliferation of *A. darlingi*and*,* when considering the state of Acre with the highest rates of tank construction, Roraima and Amazonas as this type of activity more profitable and expanding, and the scenario of higher transmission risks in these areas, this relationship can be raised. With this profile, the authors transcribe the erroneous perception regarding malaria as a disease isolated to the Amazon rainforest and that private and household characteristics contribute to the burden of the disease. In agreement with the author, where the largest cases are found in individuals with subsistence or commercial agriculture activities in peri-urban settlements, the greater vulnerability of this population is corroborated and, in the study, findings are raised regarding the urban-rural mobility of these workers, especially during the overnight stay, which demonstrates a continuous risk of exposure to the mosquito (Johansen *et al*., 2020). For Pereira *et al* (2021), 47.71% of the occupations of those affected was as a farmer in municipalities of the state of Pará and, to this, the authors translate the practice of labor activities without the proper use of personal and collective protection equipment, therefore, demonstrates a relationship as malaria and activities developed; after all, associate it as a work-related disease is to ensure a qualified look at the dynamics of malaria. From this outlined profile, it is observed a greater social vulnerability of this population and, therefore, to take actions based on social and educational development in health in order to minimize exposure is to allow control and reduction in the incidence of the disease.

CONCLUSION

From the data, it was possible to observe an increase in cases and lethality of malaria and ALI in the last 5 years (2016-2020), concomitantly with an increase in deforestation rates and fires, thus inferring the contribution of anthropic actions based on forest disturbance to the increase of cases in the Amazon region. In an isolated analysis, the highest incidence of the disease is centered in Acre, Roraima, and Amazonas, especially in indigenous locations, which, added to the others, have incipient social, health, and sanitation indicators, especially the frequency of households registered in the USF, This favors the hyperendemic scenario of the region and thus corroborates the increase in the rates of IPF and, consequently, the medium risk profile for transmission, especially in individuals who work in agriculture. In this scenario, we highlight the need for qualified malaria surveillance measures with a broad perspective due to its multifactorial character, implementation and practical monitoring of public policies for environmental prevention and control, deconstructing environmental degradation as a culture in the country, and assigning responsibility to offenders, the participation of different entities in the development of a comprehensive health care service aimed at timely diagnosis and treatment with an impact on the reduction of lethality rates, especially in endemic areas and, in addition, provides basic support for the adequacy of social indicators and health education for the most vulnerable population, thus ensuring the prevention of this public.

REFERENCES

Barlow, J *et al*. 2020. Clarifying Amazonia's burning crisis. Glob. Change Biol. 26, 319–321.

Barreto, T. M. A. C *et al*. 2022. Hospital costs of diseases attributable to environmental factors among Boa Vista residents and the increments of care for Venezuelan migrants. Cad Saúde Colet, 2022

Bissoli, L *et al*. 2022. Spatial and Temporal Distribution of Annual Parasite Incidence of Malaria in Brazil: A Case Study of Acre Between 2003 and 2017. *Journal Between Places*, 13(25), 153–173.

Brazil 2020. Federal Public Ministry. Sobre a evolução tecnológica da atividade garimpeira e a consequente intensificação de seus impactos: Illegalgold mining in theAmazon: legal frameworks and controversial issues - Brasília, MPF, 2020.

Brazil 2020. MinistérioPúblico Federal. Illegal gold mining in the Amazon: legal frameworks and controversial issues. Brasília.

Brazil 2020. Ministry of Health. BoletimEpidemiológico: número especial.

Brazil 2020. Ministry of Health. Annual Parasite Incidence (IPA) Malaria Qualification Form.

Brazil 2022. Ministry of Health. Malaria.

Bridges, A 2021. Amacro: the new (old) frontier of deforestation in the Amazon. Environmental Journalism.

Buck, E., Finnigan, N. A 2022. Malaria. StatPearls [Internet]. Treasure Island (FL).

Castro, M. C *et al*. 2019. Development, environmental degradation, and disease spread in the Brazilian Amazon. PLoS Biol. 17.

Chaves, L. S. M *et al*. 2020. Global consumption and international trade in deforestation-associated commodities could influence malaria risk. *Nat Commun* 11, 1258.

Chaves, L. S. M *et al*. 2021. Anthropogenic landscape decreases mosquito biodiversity and drives malaria vector proliferation in the Amazon rainforest. PLOS ONE.

Couto, B. W *et al*. 2020. Seasonal pattern of malaria cases and the relationship with hydrologic variability in Amazonas State, Brazil. *Rev Bras Epidemiol.*

Diniz, C. 2021. Technical Note on Garimpo in Rio Madeira. o MapBioma

Duarte, M. L *et al*. 2020. Patterns and causes of deforestation in Baixo Acre, western region of the Brazilian Amazon. Journal of Environmental Analysis and Progress, 5(1), 117-127.

Ellwanger, J. H *et al.* 2020. Beyond diversity loss and climate change: Impacts of Amazon deforestation on infectious diseases and public health. An Acad Bras Cienc.

Fellows, M. 2021. Amazonia on Fire: Deforestation and Fire on Indigenous Lands. Granda, A. 2022. Death rate from neglected diseases increases during pandemic. AgênciaBrasil.

Ferreira, M. N *et al*. 2021. Drivers and causes of zoonotic diseases: an overview. Parks.

Gandour, C. 2021. Public Policies for the Protection of the Amazon Forest. PUC - Rio de Janeiro.

Grilo, F *et al*. 2020. The Annual Parasite Incidence of Malaria in the Legal Amazon in 2017 With Focus on the State of Acre. EmAmb-USP.

Institute of Man and Environment of the Amazon - Imazon 2021. Logging Monitoring System (Simex): Mapping of logging in Roraima - August 2019 to July 2020.

Institute of Man and Environment of the Amazon - Imazon. Deforestation Alert System (2022). Report.

Instituto de Pesquisa Ambiental da Amazônia 2022. Report: Deforestation in the Amazon.

Instituto Socioambiental 2022. Report: Scars in the Forest Evolution of illegal mining in the Yanomami Indigenous Territory in 2020

Instituto Socioambiental 2022. Report: Yanomami Under Attack.

Johansen, I *et al*. 2020. Human mobility and urban malaria risk in the main transmission hotspot of Amazonian Brazil. PlosOne.

Junior, E. A *et al*. 2022. Unmasking the impunity of illegal deforestation in the Brazilian Amazon: a call for enforcement and accountability. Environ. Res. Lett.

Lana, R.M *et al*. 2017. Socioeconomic and demographic characterization of an endemic malaria region in Brazil by multiple correspondence analysis. *Malar J* 16, 397.

Loaiza, J. R *et al.* 2019. Forest disturbance and vector transmitted diseases in the lowland tropical rainforest of central Panama. *Tropical Medicine & International Health.* 2019.

MacDonald, A. J., Mordecai, E. A. 2019. Amazon deforestation drives malaria transmission, and malaria burden reduces forest clearing: a retrospective study. The Lancet Planetary Health. 3: S13.

Machado, A. M. 2020. Xawara: traces of Covid-19 in the Yanomami Indigenous Land and the omission of the State. São Paulo, Instituto Socioambiental.

Massad, E *et al.* 2020. The risk of malaria infection for travelers visiting the Brazilian Amazonian region: a mathematical modeling approach. Travel Med. Infect. Dis.

Multini, L (2017). Economic Impact of Malaria. 2017.

National Research Institute - INPE (2021). Estimated deforestation by clear cutting in the Legal Amazon for 2021 is 13,235 km2.

Oliveira, A. B.F *et al* (2021). Deforestation and climate change are projected to increase heat stress risk in the Brazilian Amazon. Commun Earth Environ 2, 207.

Padilha, M (2019). Comparison of malaria incidence rates and socioeconomic-environmental factors between the states of Acre and Rondônia: a spatio-temporal modelling study. *Malaria Journal*.

Pereira, A. L. R *et al.* 2021. The socioenvironmental production of malaria in three municipalities of the Carajás region, Pará, Brazil. Rev Saude Publica.55:73.

Pimentel, F. P. 2019. GARIMPO DE DIAMANTES DE RIBAMAR FIQUENE: In short/ a story of lovers. Monograph (Bachelor in Humanities). Imperatriz, Maranhão.

Samesima, C, 2019. Analysis of socioeconomic effects on malaria in Legal Amazon, Brazil [dissertation]. São Paulo: Faculty of Public Health, University of São Paulo.

Santos, R. R. V. 2020. A piscicultura no contexto amazônica: evolução e especialização produtiva no estado do Pará. Dissertation. Belém, Pará.

Souza, B. V. 2021. History of epidemiological aspects and analysis of effective public health interventions in malaria control in Brazil. *Brazilian Journal of Health Review,* 4(1).

Viana, J. 2019. Fish farming in Roraima. Amazoom.

World Health Organization - WHO 2022. World Health Statistics - Malaria.

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