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The English translation aims to inform international audiences about the pesticide exposure issues in the state of Mato Grosso, Brazil—one of the country's and world's largest users of pesticides in volume—and the effects on the region's indigenous populations. The article points out the issues relevant to the problem: violation of human rights and the right to land, health, and food and nutrition security.

Indigenous territories and socio-environmental determination of health: discussing pesticide exposure

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ABSTRACT

The agricultural supply chain stages produce different vulnerabilities among populations, affecting indigenous peoples' health. Pesticide use is intrinsic to monocultures. Exposure to these compounds generates acute and chronic adverse health outcomes for humans and environmental contamination. The text directs the discussions to the state of Mato Grosso (MT) – where several indigenous peoples are facing the production of commodities and pesticide-related health outcomes – to contribute to the public health debate. For that, we resort to the socio-environmental determination of the health-disease process, organizing a matrix of indicators that underscore the choices and omissions of the state in environmental issues, incorporating historicity in the processes of illness. The impacts of the agricultural commodity chain and pesticide exposure in indigenous territories are an intersectoral problem linked to the violation of basic social rights, such as the right to land, health, and food and nutritional security. The answers must take into account the outlooks shared between the economic, political, environmental, and health sectors, with the participation and decision of the indigenous population in all stages of the processes.

KEYWORDS: Social Determination of Health. Agribusiness. Pesticides. Indigenous people.

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Introduction

The intense use of pesticides in agricultural regions is related to the production of grains and fibers, but it is also related to agrarian, political, health, and environmental issues that form a web of direct and indirect routes of exposure, which must be analyzed as a contamination process.[1] The results of pesticide exposure manifest on bodies as skin and eye irritations, headaches, nausea, endocrine disruptions, fetal malformations, miscarriages, genetic mutations, cancers, respiratory disorders, mental disorders (depression and suicide), and exploitation of working conditions,[2,3] affecting the morbidity and mortality profile of populations.

The set of agricultural production operations, known as agribusiness, is legitimized with publicity, public credit policies, tax exemptions, and greater external regulation in management techniques, inputs, and logistics. Its commodities are coordinated by institutions such as the government and future markets, serving a globalized economy, not prioritizing the production of food for domestic supply—the Brazilian population's food sovereignty or food security.[4,5]

The steps that involve the production chain of agricultural commodities (i.e., soy, corn, cotton, and sugarcane) produce different vulnerabilities in populations, affecting the health of indigenous peoples in unfair socio-environmental conflicts, historical processes of discrimination, threats to the integrity of traditional territories, and disruption of native subsistence and self-care systems.[6]

The indigenous policies of past centuries brought the mistaken idea of the transience of the indigenous people, who would become rural workers integrated into 'civilization'.[7] The Indigenous Peoples Protection Service (*Serviço de Proteção aos Índios* – SPI) emerged in this scenario intending to control conflicts over land, transforming the indigenous population into small agricultural producers, settling them in indigenous reserves, and disciplining the access and use of vacant lands. Under the aegis of the tutelary regime, the SPI and Brazil's National Indian Foundation (*Fundação Nacional do Índio* – FUNAI) were essential in shaping the country's existing land ownership model, which remains to this day a nationalized, colonizing, developmental, and exclusionary system.[8]

In Brazil, there are 725 Indigenous Lands (ILs) in different stages of the demarcation process.[9] Each land has sociocultural particularities in which living conditions are related to social, economic, and environmental historical processes.[10] Mato Grosso is one of Brazil's largest producers of agricultural commodities. It is also home to 42 indigenous peoples[9] in 79 recognized ILs.

Thus, this article discusses the pressures of agribusiness and pesticide use on indigenous territories and populations. The text directs the discussions to the state of Mato Grosso to contribute to the public health debate. The state has the second-highest number of recognized ILs in the country,[9] and several of its indigenous peoples are facing agricultural commodity production and adverse pesticide-related health outcomes and mobilizing against them.

Methodology

Franco Netto's analysis model for environmental change[11] uses three interactive groups of socio-environmental determinants. In this study, we expand the explanations through the theoretical perspective of the social determinants of the health-disease process,[12,13] incorporating historicity in the socioeconomic and agro-industrial dimensions, underscoring the choices and omissions of the state in environmental issues and the processes of illness. The information is presented through indicators in each coordinated group but is not limited to the linear casualism between isolated and timely events.[13,14]

The groups of socio-environmental health determinants in indigenous populations are expressed at the following levels:

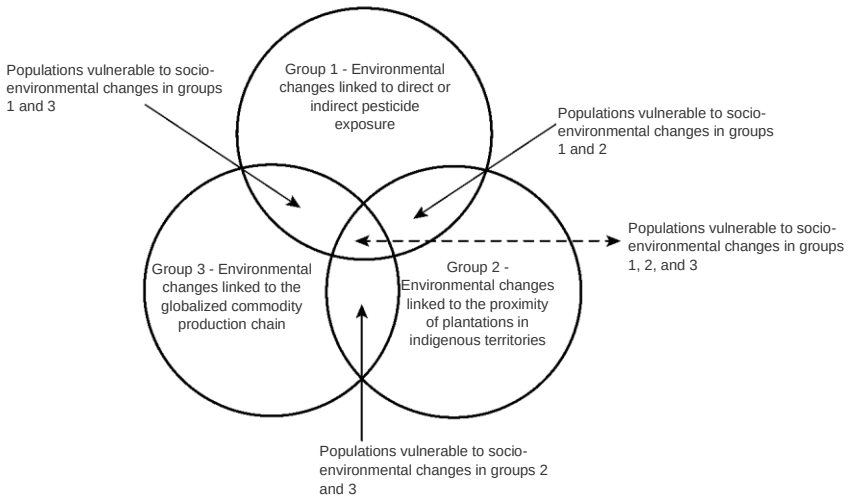
Group 1 - microsocial: linked to multiple exposures directly related to pesticides, their adverse outcomes on the health of populations and the ecosystem of indigenous territories;

Group 2 - intermediate: proximity of ILs to monoculture plantations. Inserted in municipalities with high agricultural productivity and an agro-industrial economy, which generate adverse effects on territories, indigenous health care services, living conditions, food practices (cultivation, hunting, gathering, and fishing), environment (pesticide contamination, deforestation, and slash-and-burns), and traditional healing practices;

Group 3 - macrosocial: a broad dimension of the globalized structure of the agricultural commodity production chain, with transgenic seed cultivation, weak environmental regulations, and disruption of health surveillance. The state encourages production with reduced taxes and legislative changes, and agribusiness has intense publicity and media appeal. Environmental outcomes appear with the expansion of plantations, water use for irrigation, climate change, and epidemics.

The three groups are not isolated. They interact and complement each other and operate in a hierarchy of processes.[14,15] This model is interdisciplinary, with different levels of determinants and a complex relationship between the areas of dialogue. It can stimulate discussions of the vulnerabilities that affect indigenous populations on different temporal and spatial scales (*Figure 1*).

Figura 1. Interaction between hierarchical groups in the socio-environmental determination of the health-disease process in indigenous populations



Source: Franco Netto[11]

Data were obtained from secondary sources in the health and environment sectors and legislation related to the indicators. The economic and environmental data for the year 2018 were: volume of agricultural commodities[16] exported from the municipalities of Querência and Sapezal, the largest producers in the regions of the aforementioned indigenous territories;

Agricultural Gross Domestic Product (GDP); planted area of commodities;[17] estimated pesticide use on commodities;[18] deforestation;[19] slash-and-burns, and fine particulate matter ($PM_{2.5}$).[20] The $PM_{2.5}$ value was obtained for June to November, using the average of the regions' maximum monthly values (*Table 1*).

Health data were obtained from Datasus,[21] using the race/color variable, indigenous category, with no specification of the people. That information is not included in the system, and the Information System for Indigenous Health Care (*Informação da Atenção à Saúde Indígena* – SIASI) restricts that access. Hospitalization rates were calculated from the average values from 2010 to 2018. The calculations were based on the indigenous population residing in the socioeconomic zoning regions (2010 Census, per 10,000 inhabitants).

Two categories were considered when analyzing the health data based on their relation to pesticide exposure: Acute illnesses - the rate of exogenous pesticide poisoning for agricultural, domestic, public health, and rodenticide use (Brazil's Notifiable Diseases Information System of the Unified Health System - SINAN/SUS), and hospitalization rate for respiratory diseases, excluding influenza and tuberculosis (SUS Hospital Information System – SIH/SUS); chronic diseases - hospitalization rate for endocrine, nutritional, and metabolic diseases, chapter IV of the ICD-10.

Table 1. Matrix of indicators used in the socio-environmental determination of the health-disease process in indigenous populations

Levels of socio-environmental determinations	**Indicators**	**Units**	**Sources**	**Year**
Group 3 (macrosocial)- Environmental changes linked to the globalized commodity production chain	Commodity export volume	Tons	Trase	2018
	Agricultural GDP	BRL	SIDRA-IBGE*	2018
	Planted area of commodities	Hectares	SIDRA-IBGE**	2018
	Tax laws	-	DOU***	1997-2020
	Forest Code	-	Law No. 12651	2012
Group 2 (intermediate) - Socio-environmental changes linked to the proximity of agricultural production to indigenous territories	Deforestation	Hectares	INPE[D]	2018
	Slash-and-burns	Absolute number	INPE	2018
	Use of pesticides by municipality	Liters per hectare	Pignati et al., 2017/SIDRA-IBGE	2018
	Particulate matter $PM_{2.5}\mu g/m^3$	Average of maximum values	SISAM[DD]/INPE	2018
	Spraying Distance Act	-	MT[DDD] Decree No. 1651	2013
Group 1 (microsocial)- Environmental changes linked to direct or indirect pesticide exposure	Quality of water and food	Maximum Allowed Value (µg/L) and Maximum Residue Limit (mg/kg)	Ministerial Ordinance GM/MS[€] No. 888/2021 and PARA/MS[€€]	2019-2021
	Exogenous poisoning	Notification	SINAN-DataSUS	2010-2018
	Respiratory disease	Hospitalization	SIH/SIM-DataSUS	2010-2018
	Endocrine, nutritional, and metabolic diseases	Hospitalization	SIH/SIM-DataSUS	2010-2018

Source: Elaborated by author.
*IBGE: Brazilian Institute of Geography and Statistics
**SIDRA-IBGE: IBGE Automatic Recovery System (*Sistema IBGE de Recuperação Automática*)
***DOU: Federal Official Journal (*Diário Oficial da União*)
[D]INPE: The Brazilian Institute of Space Research (*Instituto Nacional de Pesquisas Espaciais*)
[DD]SISAM: The Environmental Health Information System (*Sistema de Informações Ambientais*)
[DDD]MT Decree: Mato Grosso State Decree (*Decreto Estadual do Mato Grosso*)
[€]GM/MS: From the Health Minister's Office (*Gabinete do Ministro*)/(*Ministério de Saude*)
[€€]PARA/MS: Ministry of Health's Analysis Program for Pesticide Residues in Food (*Programa de Análise de Resíduos de Agrotóxicos em Alimentos, do Ministério da Saúde*)

Data from each municipality (environmental, economic, and health) were grouped according to the 12 regions of Mato Grosso's State Socioeconomic Zoning (*Zoneamento Socioeconômico Estadual de Mato Grosso* – ZSEE-MT) to compare land use patterns, the influence of urban centers, and types of production in each region, which supports the state in proposing programs and guiding agribusiness ventures.[22]

Environmental changes related to the globalized commodity production chain

The agricultural model participated with 20% of GDP in state revenue in 2017, behind only the services segment (64%). Among the regions with the highest agricultural GDP in 2018 (gross value of agriculture in thousand reais) is the ZSEE-MT V-Southeast region with BRL 4.3 million, VII-Southwest with BRL 3.9 million, VIII-West with BRL 3.2 million, and III-Northeast with BRL 2.8 million. In 2020, there was a 24.3% increase in national agribusiness GDP over the previous year, reaching almost BRL 2 trillion.[23] It was one of the most profitable sectors during the COVID-19 pandemic.

In 2018, Querência (IV-East region) and Sapezal (VIII-Southwest region) produced 2,411,400 tons of soybeans, among the six largest producers in the state. The state's agricultural commodity production grows yearly, and Querência directs more than 95% of the volume of soybeans, corn, and cotton produced by the municipality to other countries. Sapezal exported 97% of its cotton, 86% of its soybeans, and 54% of its corn.

That production contributed to keeping Sapezal and Querência among 2018's top 50 agricultural GDPs, 3rd and 45th place, respectively. That boosted the input industry (pesticides, fertilizers, and machinery), which grew 6.91% in 2019, with a 23.7% increase in the pesticide industry's invoicing due to the increase in the planted area.[23]

The amount of planted area is guided by the Legal Reserve, established by the Brazilian Forest Code (Law No. 12651/2012, Art. 3, Item III), which provides for maintaining an area with native vegetation as a Legal Reserve corresponding to 80% in properties in the Legal Amazon, 35% in properties in the Cerrado, and 20% in other regions of the country. The largest planted areas of commodities in Mato Grosso – X-Central (3.16 million/ha), V-Southeast (2.73 million/ha), XII-Central-North (1.78 million/ha), and IV-East (1.48 million/ha) – are in the Cerrado, where the forest code allowed more deforestation, provided amnesty for illegal deforestation prior to 2008, and exempted fined areas that should have been reforested.

The agricultural sector also benefits from the exemption of five types of taxes for pesticide purchases. With tax waivers, the country collected BRL 9.8 billion less than it could have in 2017, BRL 6.2 billion of which was just in State Goods and Services Tax (ICMS).[24] Mato Grosso raised BRL 1.3 billion less than they could have that same year. It is estimated that for every USD 1 spent on pesticide purchases, USD 1.28 is spent on health treatments for acute poisoning.[25] Tax exemptions, however, do not account for the external social, environmental, and health factors that impact society.[5,26]

Attempts to expand production occur as the agricultural sector profits and advances over the rights of populations with environmental deregulations that threaten the country's environmental legal protection, indigenous peoples, traditional communities, and their cultures.[27] At the beginning of the COVID-19 pandemic, Supplementary Bill No. 17/2020, drafted by Mato Grosso's governor and approved in the State Legislature, tried to rectify the Rural Environmental Registry (*Cadastro Ambiental Rural* – CAR) of farms overlapping the ILs, a measure that was prevented after the intense social mobilization of indigenous organizations and partner entities, contradicting Art. 231 of Brazil's Federal Constitution of 1988.

According to the Conflicts in the Field[28] document (*Conflitos no Campo*), in 2019,

threats in indigenous territories were linked to logging activities, mining, agricultural expansion of farms, or real estate speculation, accounting for 244 conflicts over land (20% of records), in which one in three families was indigenous. Agricultural production and land expansion strategies do not consider space for the local peoples' social reproduction, transforming the production relations there into exclusionary spaces for the reproduction of capital.[29]

The Southwest ZSEE region and the Haliti-Paresi people

The intersection between socio-environmental determinant groups one and three can be seen in the situation of the Paresi people. They added the Haliti themselves. The Haliti-Paresi people's territory comprises 1.1 million hectares, a population of 2,186 inhabitants, and 64 villages. Historically, some indigenous people enslaved by the pioneers suffered when highway BR-364 opened, lost part of their land, and began to be enticed as pawns on the farms. After mobilization, these people managed to get the federal government to recognize the ILs, but their territories were fragmented, distancing themselves from the traditional means of occupation. Thus, subsistent activities no longer met the needs; one of the strategies was to resort to mechanized agricultural production to establish economic autonomy in the face of the new living conditions imposed by the region, one of the state agribusiness sites.[30]

Since the 1990s, Associação Halitinã and Associação Waymare have managed the mechanized production of soybeans, corn, and beans with local producers in one of the most intensive agricultural production regions in the state. Nine mechanized farming projects with 16,334 (total) hectares planted in two ILs were chosen according to the criteria discussed among indigenous leaders. They also installed a toll on the highway that passes through the IL.

Regardless of this people's choice to produce commodities, legal impasses, and asymmetrical power relations, it is essential to discuss the circumstances and determinations that led to such a decision, as well as the possible conflicts with indigenous rights that have already been promulgated. It is also critical to reflect on whether adopting agriculture, which is pollutive and historically exclusionary, has secured sustainability and subsistence for communities, protected territories, and maintained living conditions. According to reports from the Haliti, fetal malformation cases have increased in recent years, as have concerns about the chemical-dependent agricultural model they have adopted.[30]

Environmental changes from the proximity of agricultural production to indigenous territories

Deforestation in the Legal Amazon continued to grow from 2010 to 2019. The following ZSEE-MT regions were among the highest deforestation rates in 2018: I-Northwest 1 (47,309 ha), IV-East (33,092 ha); XII-Central-North (26,656 ha), and V-Southeast (24,208 ha), showing the Mato Grosso agricultural frontier's expansion routes, totaling 235,140 deforested hectares, 58% of which were in the Amazon and 42% in the Cerrado.

Mato Grosso accounts for the most significant number of slash-and-burns and had 251,835 hotspots from 2010 to 2018, mainly in the dry season. In 2019 and 2020, per INPE, there was an 86% increase in slash-and-burns in the Legal Amazon.[20] These anthropic fires set by agriculturalists are meant to expand pastures for cattle raising and clear areas for planting,[31] and, in some cases, serve to intimidate traditional peoples and small family farmers in an attempt to run them out of their territories. As deforestation and slash-and-burn increase, these areas are turned into pastures or plantations.

Mato Grosso's three biomes totaled 35,122 slash-and-burns in 2018. In the Amazon, there were 17,654 (50.3%); in the Cerrado, 11,653 (33.2%); in the Pantanal, 1,862 (5.3%). In the same year, the ZSEE-MT regions with the

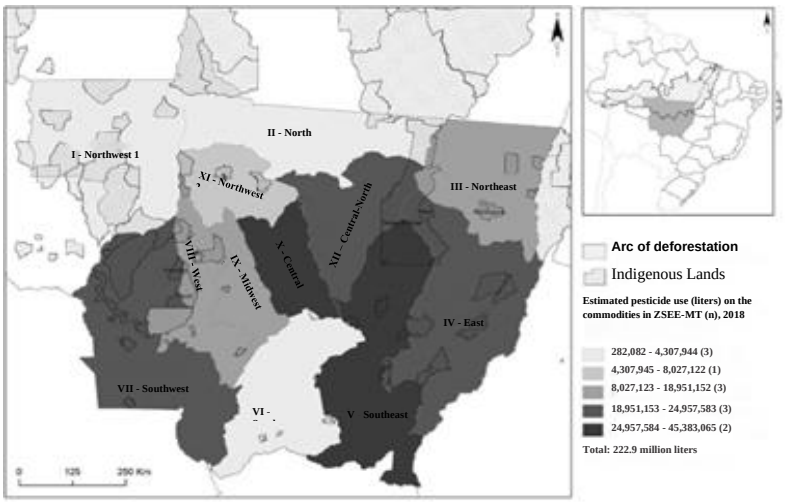
most slash-and-burns were: V-Southeast (19,555), VII-Southwest (3,253), II- North (2,827), and IV-East (2,008). According to the Amazon Environmental Research Institute (*Instituto de Pesquisa Ambiental da Amazônia* – IPAM), the ILs and Conservation Units had the least deforestation and slash-and-burn in 2019.

Solid particles from the fires and liquids (pesticide aerosols) remain in the atmosphere for up to two weeks and are easily inhaled. They are damaging to health, causing illnesses such as respiratory diseases, especially in children and the elderly,[20] increasing their relative risk of hospitalization in the dry season—children by 6% and the elderly by 6.8%.[31]

The ZSEE-MT regions with the highest values of $PM_{2.5}$ particulate matter in the atmosphere in 2018 were II-North (353 μm/m^3 of $PM_{2.5}$), VII-Southwest (308 μm/m^3), XLII-Central-North (283 μm/m^3), and III-Northeast (276 μm/m^3). The areas with the highest $PM_{2.5}$ concentration are not identical to those with the highest number of fires, but some have a higher pesticide use. Brazil's National Environment Council (CONAMA) Resolution No. 491/2018 establishes the concentration of 250 μm/m^3 of $PM_{2.5}$ as the level of attention, and the alert level is 420 μm/m^3 of $PM_{2.5}$ (24-hour average).

In 2018, Mato Grosso commercially used more pesticides than any other state,[32] spraying an estimated 226.4 million liters of pesticides in formulated products that same year, with 222.9 million liters (98.4%) used in soy, corn, cotton, and sugar cane.[18] *Figure 2* presents the regions with the highest pesticide use and the locations of the ILs in the state.

Figure 2. Map of estimated pesticide use by ZSEE regions and the location of indigenous lands (Mato Grosso, 2018)



Source: Elaborated by author, based on IBGE information,[17] Pignati et al.,[18] Seplag-MT.[22]

Based on the figure, we see that the regions that underwent intense colonization by the agricultural expansion fronts and the construction of Highway BR-163 Cuiabá-Santarém in the 1970s have a lower number of ILs (regions II-North; XII-Central-North; X-Central; and VI-South). The V-Southeast region has extensive planted areas for commodities, intense pesticide use, slash-and-burns, and the second-largest agricultural GDP in Mato Grosso. The following regions were among the highest pesticide users in 2018: X-Central (45,383,065 liters), V-Southeast (43,453,597 liters), XII-Central-North (24,957,583 liters), IV-East (23,382,508 liters), and VII-Southwest (21,133,076 liters).

Aerial pesticide spraying is set by Normative Instruction No. 02/2008 of the Ministry of Agriculture, Livestock, and Supply (MAPA), which establishes a minimum spraying distance of 500 meters from homes and 250 meters from water sources. Mato Grosso's guidelines for terrestrial spraying were a minimum distance of 300 meters in areas of villages, water sources, isolated houses, and springs. That distance was reduced to 90 meters from those exact locations under Mato Grosso State Decree No. 1651/2013.

The Resolution of the Collegiate Board of Directors (RDC) No. 294/2019 of ANVISA – (Brazilian Regulatory Health Agency), which approved the new regulatory framework for the toxicological classification of pesticides, based on a global system, reallocated extremely toxic products to other, less-toxic categories,[26] with no further evaluations. That regulatory framework aligns with Bill (PL) No. 6299/2002, which makes the regulatory system for pesticides in Brazil more flexible to reduce costs for the productive sector and forces the hand of health and environmental protection agencies.[24,26,27] It should be noted that the amount of pesticide use continues to climb in Mato Grosso,[18,32] and newly registered pesticides are being released in the country with little or no inspection of use by the state government.

The Southeast and East ZSEE-MT regions and the Xingu Indigenous Territory

In the proposed explanatory model, the intersections between groups two and three result in different vulnerabilities related to the proximity of plantations that use pesticides, driven by the global commodity market. The Southeast and East regions have 20 ILs. Xingu is the largest.

The Xingu Indigenous Territory (TIX) comprises an IL complex: Wawi, Batovi, Pequizal do Naruvôtu, and Xingu Indigenous Park (PIX). The latter has an area of 2.64 million hectares, inhabited by 16 peoples, with a population of 6,090 2013.[9,33] It currently has about 36 indigenous organizations, including the Xingu Indigenous Land Association (*Associação Terra Indígena Xingu* – ATIX), founded in 1995. These associations manage large projects with external non-indigenous institutions on income generation, infrastructure, citizenship, and political representation.

The Xingu leaders have discussed deforestation, the advance of plantations on indigenous territories, deceased fish in rivers near plantations, drifts from spraying pesticides on ILs, and they introduced intersectoral work proposals to ensure compliance with environmental legislation around the territory.[33]

In the Wawi IL of the Khisêtjê people (formerly known as the Suya), the community relocated the village because of the 'smell of poison' coming from the plantations bordering the IL. Deforestation for planting grains increases, and there are reports of health problems, such as fever, headache, itchy skin, and illness among children.[34] A change like that is complex. It involves relocating everyone, obtaining new material resources and infrastructure for building houses, a health center, and schools, adapting new gardens and orchards, and having new routes through the river and by roads. Those routes influence the arrival of materials from outside the village and the shipment of the community's economic production (i.e., pequi oil, honey, pepper, and

artisanal crafts). It also affects health care inside and outside the village, the entry of supplies, mobility of health professionals, and removal of patients for treatments outside the village. The 'smell of poison' is also reported in the Tangurinho village of the Kalapalo people in another region south of the PIX, less than a kilometer from the plantations.

These communities' reports of pesticides in the air indicate the mobility of pesticide residues in the atmosphere. Some of these compounds are volatile and can contaminate clouds and rainwater.[35] Through surface runoff and leaching, they can also contaminate streams, rivers, and the aquatic ecosystem. One example of this is the contamination of *cágados* and *tracajás* (Testudines) evaluated in the Xinguana basin. They showed eight different pesticide residues in concentrations that exceeded the limits established for protein resources for national and international human consumption, affecting the health of the populations that consume these foods.[36]

The outlined context leads us to reflect on the implications of the Proposed Amendment to the Constitution (*Proposta de Emenda à Constituição* – PEC) No. 215/2000 on the right to land for indigenous peoples. That proposal transfers exclusive competence to Brazil's Congress to approve the demarcation of traditionally occupied land and the ratification of the already-approved demarcations, in line with Bill (PL) No. 490/2007, pushed by Brazil's Farm Caucus (*Frente Parlamentar da Agropecuária*), which represents agribusiness in the country's National Congress.

Effects on human health related to pesticides and environmental changes

The microsocial level represents the outcomes linked to pesticides in the health of indigenous populations. In Brazil, 399 active ingredients of agricultural pesticides are approved,[37] of which 120 are related to damaging health, with 67.2% associated with chronic damage. In addition, 80% of the pesticides authorized in Brazil are banned in at least three agricultural-based countries by the Organisation for Economic Co-operation and Development (OECD).[37]

The pesticides glyphosate, 2.4-D, acephate, mancozeb, atrazine, malathion, chlorpyrifos, imidacloprid, paraquat, and carbendazim are among the most used in Mato Grosso. Of these, acephate, malathion, and chlorpyrifos are Organophosphate (OP) insecticides with greater acute toxicity, neurotoxic modes of action, and inhibition of cholinesterase enzyme activity, affecting the central nervous system (CNS), the peripheral nervous system (PNS), and neuromuscular junctions,[3,38] which can lead to respiratory failure in intermediate syndromes.[39] It is noteworthy that the highest hospitalization rate due to respiratory disease was in the VII-Southwest region, the largest producer of cotton, a crop that uses large amounts of chlorpyrifos.

Per SINAN, Brazil had 6,408 cases of glyphosate-related poisonings reported between 2007 and 2016. The highest notifications were in the first and last quarter of each year,[38] following the cultivation of transgenic soy, which is resistant to glyphosate. Of the non-occupational poisonings, 76.7% were consumed, 13% were inhaled, and 5.8% were absorbed by the skin.[40] According to the International Agency for Research on Cancer (IARC/WHO),[3] glyphosate has genotoxic, allergic, and hepatotoxic potential[39] and is in group 2A, a probable human carcinogen.

The 2.4-D herbicide is widely used in soybean cultivation. It is the second most commercially used in the state. It acts as an endocrine disruptor, which affects hormonal processes with estrogenic, androgenic, and antithyroid effects. It also damages the reproductive system, triggering "spontaneous abortions, low birth weight, and skeletal and urogenital malformations."[38(71)] According to IARC/WHO, this herbicide is in group 2B, a possible carcinogen.[3]

ANVISA recently re-evaluated the herbicide paraquat, and its ban was recommended in September 2020 by RDC No. 177/2017, but it is still in use in Brazil. It can be toxic to the liver, kidney, stomach, intestines, and respiratory system.[41]

The most used pesticides in 2018 in Mato

Grosso, which could be quantified per municipality, were the herbicides glyphosate, 2.4-D, and paraquat, common in order of those most used in the X-Central, V-Southeast, IV-East, XII-Central-North, and VIII-West regions. The herbicide atrazine was most used in the X-Central, XII-Central-North, V-Southeast, VIII-West, and VII-Southwest regions. In the V-Southeast, VII-Southwest, X-Central, VIII-West, and IX-Central-West regions, it was the insecticide chlorpyrifos.

The health problems

Table 1 systematizes the socio-environmental changes and health problems per the ZSEE-MT region. There were seven pesticide poisonings among indigenous people from 2010 to 2018, four of them (57%) in 2015. The IV-East and VI-South regions both had two cases. In Mato Grosso, people living close to corn and cotton plantations had almost twice as many acute poisonings as those living elsewhere.[42] However, pesticide poisoning is generally underreported,[5] even more so among indigenous populations.

Table 1. Socio-environmental indicators, health problems related to pesticide exposure per ZSEE-MT region

	2018								Acute illnesses (2010-2018)		Chronic disease (2010-2018)
ZSEE-MT	Agriculture GDP (BRL)	Planted area of commodities (ha)	Deforestation (ha)	Slash-and-burns (each)	Commodity pesticide use (liters) and %		$PM_{2.5}$ Average ($\mu m/m^3$)	Indigenous population (2010 Census)	Indigenous people poisoning rate	Respiratory disease rate in indigenous people	Nutritional disease rate in indigenous people
X - Central	2,001,818	3,163,506	5,471	757	45,383,065	20.4	147	124	0	0	0
V - Southeast	4,322,737	2,737,574	24,208	19,555	43,453,597	19.5	194	4,083	2	14	12
XII - Central-North	1,175,311	1,787,637	26,656	682	24,957,583	11.2	283	1,584	0	11	5
IV - East	2,838,638	1,483,662	33,092	2,008	23,382,508	10.5	206	17,956	1	23	32
VII - Southwest	3,897,390	1,272,977	13,674	3,253	21,133,076	9.5	308	2,559	0	116	19
VIII - West	3,292,312	1,360,135	6,028	925	18,951,152	8.5	149	3,619	3	16	17
IX - Midwest	1,766,669	1,071,844	7,137	1,437	16,281,728	7.3	116	132	0	0	0
III - Northeast	2,840,338	901,446	20,351	1,557	13,218,633	5.9	276	3,519	0	10	10
XI - Northwest 2	506,294	571,515	6,740	261	8,027,122	3.6	95	1,159	0	20	4
II - North	1,872,694	295,441	23,675	2,827	4,307,944	1.9	353	2,414	4	14	11
VI - South	847,932	233,756	20,791	1,073	3,532,054	1.6	236	2,894	7	1	2
I - Northwest 1	321,967	24,946	47,309	787	282,082	0.1	170	2,495	0	25	6
Mato Grosso	25,684,099	14,904,439	235,132	35,122	222,910,544	100	2,532	42,538	2	24	19

A study was done on pesticide use in an IL with the Xukuru people of Pernambuco. Pesticides are historically related to the socioeconomic and industrialization model of this region. For the Xukuru, the use of 'poison' was an alternative to insert themselves into local economic development. They also call the pesticide a medicine, and 46% of the indigenous people interviewed reported headaches, vomiting, dizziness, 'weakness in the body', 'thick tongue', and 'excessive salivation' after the application of pesticides. Ten percent (10%) reported having been poisoned by the product. Respondents also associated an indigenous woman's case of leukemia with pesticide exposure.[43]

The population's respiratory outcomes indicate that exposure to OP insecticides, pyrethroids, and organochlorines is associated with pulmonary diseases.[44,45] Data on respiratory diseases in Mato Grosso's indigenous peoples recorded 905 hospitalizations between 2010 and 2018. The cases varied year to year; the highest record was in 2014, with 149 hospitalizations (16.4%). The highest rates of respiratory diseases (*Table 1*) were in the VII-Southwest (116 admissions per 10,000 inhabitants), I-Northwest 1 (25 per 10,000 inhabitants), and IV-East (23 per 10,000 inhabitants) regions. The VII-Southwest region was the second-highest in $PM_{2.5}$ indicators in the atmosphere, slash-and-burns, and OP chlorpyrifos use. $PM_{2.5}$ from pesticides sprayed into the atmosphere increases nose, throat, eye, and chest irritation.[45] The Pareci people are in the VII-Southwest region and grow soybeans and corn on their land.

Data on endocrine, nutritional, and metabolic diseases show 742 hospitalizations in the indigenous population between 2010 and 2018. The highest record was in 2015, with 93 hospitalizations (13.07%). As hospitalizations vary from year to year, if we consider 2019, the increase was 19.3% in Mato Grosso. The highest hospitalization rates in the period were in the IV-East (32 cases per 10,000 inhabitants), VII-Southwest (19 per 10,000 inhabitants), and VIII-West (17 cases per 10,000 inhabitants) regions. The ZSEE-MT IV-East region had the highest per-hectare deforestation average between 2010 and 2018. It is among the top four regions with the highest number of slash-and-burns that plant the most agricultural commodities and use pesticides such as paraquat. Agricultural production is "predatory to the environment and economic and social relations. It imposes food standards,"[3(252)] and it contravenes Art. 1 of Decree No. 6040/2007 and Art. 4, Item III of the National Food and Nutrition Security Policy (*Política Nacional de Segurança Alimentar e Nutricional* – PNSAN) (Decree No. 7272/2010). The IV-East region is where the Xavante live, traditionally hunters and gatherers, with an intrinsic relationship with the Cerrado.

Imposition and exposure to pesticides in indigenous territories

The IV-East region has the largest indigenous population in the state, composed mainly of the Xavante people. It was the ZSEE-MT region that presented high values for the indicators analyzed in this report. It consistently remained among the top four regions in deforestation, planted area, slash-and-burns, and pesticide use and had higher rates of hospitalizations for respiratory, nutritional, and metabolic diseases.

Among the Xavante ILs, Marãiwatsédé is the only one in the III-Northeast region. However, it merits mentioning due to the research on pesticides between 2013 and 2015 after two children were reported as dying from suspected pesticide poisoning.[46] The historical and productive process of the agricultural-based region traces paths related to this people's multiple social and health outcomes.

In 1966, the Ometto Group exiled the Xavante from their lands to implement agricultural projects. The land was later traded to the Italian holding company, Agip-Petroli do Brasil. Pressured at Eco-92, that company returned the land to the indigenous people, which boosted land-grabbing and invasion activities organized by politicians and public servants in the region. After decades in the possession of non-indigenous people, several legal disputes, and lobbying by lawmakers, the Xavante people's mobilization forced the state's hand to recognize and return their traditional lands—that happened in 2004. However, conflicts continued even after the total "de-intrusion" process in 2013, a period when the territory was used for logging, grazing, livestock, and grain planting,[46,47] and 66.64% of the area was deforested that year.

Active plantations in the southern and central portions of the Marãiwatsédé IL produced soybeans and corn close to the water courses that the Xavante people used. In the Marãiwatsédé village, there were reports of a 'pesticide smell' in the air and symptoms of

dry throat and cough during the agricultural activity period, mentioned since 2013.[46]

During the research, the water was tested for pesticide residues where a new village would be built and where signs and symptoms of nausea and diarrhea were reported (in some cases with blood) after consuming nothing but that water. The water samples were tested for 12 pesticides. It tested positive for permethrin at a concentration of 0.19 µg/L. Although the amount found in the sample was within the Brazilian water potability ordinance, this pesticide has been banned in the European Union since the year 2000 due to its toxicity, rapid oral absorption, irritability of the airways, dermis, and eyes, neurotoxic activity, and for being highly toxic to aquatic communities and bees. The plantations in these territories were fixed sources of environmental pollution and of the water systems that entered the IL.[46]

The dialogue between determination groups one, two, and three, in this case, show that the model of socio-environmental appropriation practiced by agribusiness is systemic and cancels out other possibilities of agricultural, economic, and social production in indigenous territories; characterizing pesticide exposure as an imposition that causes harm to living conditions and social reproduction, disregarding the indigenous peoples' constitutional rights over traditionally occupied lands. Agribusiness intends to expand the area of planted commodities, reducing ILs, quilombola territories, and Conservation Units through PEC No. 215/2000, Bill (PL) No. 490/2007, and Bill (PL) No. 2633/2020. Planted area productivity has also increased through pesticide use, which is intended to be bolstered with Bill (PL) No. 2699/2002. The aerial spraying of pesticides close to or in indigenous territories by rural producers as a strategy to intimidate these peoples and other communities must also be taken into account.

The results presented in this article corroborate the application of such strategies within the state of Mato Grosso. More specifically, like them, they put social, economic, and physical pressure on traditional peoples and communities that are surrounded by agribusiness, primarily indigenous peoples.

Final considerations

The explanatory model sought to identify the pressures of agribusiness and the use of pesticides on indigenous peoples in Mato Grosso, incorporating historicity in the socioeconomic and agro-industrial dimensions that are impacting the environment, with direct or indirect effects on health. Pesticide exposure is one more polluting activity of the agricultural commodity production chain. The selected pesticides represent a fraction of what is used on the state's plantations, mixed with so many other pesticide spray molecules that contaminate the environment, water, biota, and food. There is still little information on pesticide poisoning among indigenous peoples in public databases. Likewise, pesticide-related environmental and health outcomes reported by indigenous communities need to be considered in the assessments because indigenous territories are surrounded by plantations, which are fixed and seasonal sources of pesticide pollution.

Slash-and-burns and deforestation, common in the same ZSEE-MT regions, are also linked to the clearing of new areas for commodity production and extensive livestock farming in the regions surrounding the ILs. They are part of agribusiness's land occupation process. These pressures on indigenous territories intensify land conflicts with attempts to legalize the usurpation of lands through legislative instruments such as Ordinance of the Office of the General Counsel for the Federal Government (*Portaria da Advocacia-Geral da União* – AGU) No. 303/2012 and the others already mentioned, imposing a 'chemical-dependent' agricultural production model. This model can derail ways of life, ecosystem functions, and food self-sufficiency with economic dependence.

The approach used information grouped by

ZSEE-MT regions, which guides agro-industrial enterprises that impact the environment and health. The new zoning is under discussion and should be approved later in 2022, which could have more repercussions for indigenous peoples. The choice of analysis for the socio-environmental determination of the health-disease process in the indigenous population shows that pesticide exposure is a historic, dynamic, and intersectoral problem linked to the violation of human rights and the original right to land, water, health, and food for indigenous people under Brazil's Federal Constitution of 1988. It also presents a hierarchy in the organization of social groups that determines the processes that generate problems in human health.

Research on the adverse effects of pesticides presents challenges to public health because there are disputes in the economic and political fields to maintain the production of agricultural commodities. Studies on pesticides in ILs are scarce in Brazil since the limits imposed by various government bodies stifle access to data production. It is necessary to expand the scope of research based on a socially critical, participatory science that also provides indigenous peoples room for autonomy in their own investigations.

Theoretical models of interdisciplinary reading of territories and work processes in the relationship between health, economic, social, and environmental development transcend the traditional epidemiological view. Agribusiness, pesticide use, territorial conflicts, and health cannot be thought of as dissociated elements. To devise territorial and participatory public surveillance policies in indigenous territories, surveillance of populations exposed to pesticides, intersectoral actions to combat aerial spraying, definitions of pesticide-free areas, and a guarantee of approved and healthy lands for indigenous peoples are some of the challenges posed to public health and included in this study.

Collaborators

Lima FANS (0000-0001-5677-2390)* contributed to the research formulation, data collection and analysis, discussion, writing, and review. Côrrea MLM (0000-0001-7812-0182)* contributed to the research formulation, writing, and review. Gugelmin SA (0000-0002-4818-1344)* contributed to the research formulation, data analysis, discussion, writing, and review.

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