DOI: 10.1590/1413-812320172210.17742017

ARTICLE

Spatial distribution of pesticide use in Brazil: a strategy for Health Surveillance

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Abstract *The intensive use of pesticides in Brazilian agriculture is a public health issue due to contamination of the environment, food and human health poisoning. The study aimed to show the spatial distribution of the planted area of agricultural crops, the use of pesticides and related health problems, as a Health Surveillance strategy. We obtained data from the planted area of 21 predominant crops, indicators of the consumption of pesticides per hectare for each crop and health problems. The amount of pesticides used in the Brazilian municipalities was spatially distributed and correlated with the incidence of pesticides poisoning: acute, sub-acute and chronic. There was a predominance of soybean, corn and sugar cane crops, which together accounted for 76% of the area planted in Brazil in 2015. Some 899 million liters of pesticides were sprayed in these crops, and Mato Grosso, Paraná and Rio Grande Sul used the largest quantities, respectively. The health problems showed positive and significant correlations with pesticide use. The methodological strategy facilitated the identification of priority municipalities for Health Surveillance and the development of intersectoral actions to prevent and mitigate the impacts of pesticides on health and the environment.*

Key words *Spatial distribution, Pesticides, Agribusiness, Health Surveillance*

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Introduction

Brazil is one of the largest agricultural producers in the world and the second largest country exporting these products, playing an important role in the Brazilian economy. To keep up this production, this sector uses intensively transgenic seeds and chemical inputs, such as fertilizers and pesticides. Brazil's extensive planting area has made the country the largest consumer of pesticides in the world. The imposition of the Green Revolution Policy, transgenic crops, increased crop pests, subsidized agricultural credits and tax exemption are factors that have contributed to the increased consumption of pesticides[1]. In addition to these factors are weaknesses in state surveillance over their use and the lack of policies that curb the use of pesticides and encourage agroecological production.

In large areas of monocultures, these poison syrups are sprayed by tractors and airplanes over crops, which affect not only "pests" in plants, but also environmental matrices such as soil, surface water, air, rain and food. These are intentional pollutions, since spraying targets insects, fungi or "weeds", and in this process, plantations and environmental matrices are contaminated, as well as workers, dwellers of the surroundings and other animals. This production model generates complex risk situations and "rural accidents" that challenge health surveillance actions and their methodologies. These events have been denounced by social movements and evidenced by the society that coexists in this model of agricultural production[2,3]. However, there are few records of acute, sub-acute and chronic poisoning related to the use of pesticides.

The lack of data on the consumption of pesticides, their types and volumes used in Brazilian municipalities, the lack of knowledge about their toxic potential and of laboratory diagnoses and the pressure/harassment of agribusiness farmers who hold public positions favor concealment and invisibility of this important public health issue[4,5].

In this setting, public institutions, researchers, health professionals and society face difficulties in obtaining total/real data on the volume and types of pesticides used in a given farm or region, contravening Law Nº 12.527/2011[6] on access to information. In addition, the Agricultural Census, which is an important and useful source of information on agriculture in the country, was not performed in 2016.

Considering the need for greater technical support for the implantation and implementation of the Health Surveillance of Populations Exposed to Pesticides in the national territory, this paper aims to show the spatial distribution of the planted area of agricultural crops, to generate estimates of the use of pesticides and associate the consumption of pesticides with indicators of acute, sub-acute and chronic poisoning by these substances in Brazilian municipalities. This methodological strategy aims to identify priority regions for promotion, prevention and precaution actions related to health problems and environmental damage.

Methodology

This is an ecological epidemiological study. We carried out the spatial distribution of environmental indicators (planted area and consumption of pesticides) and the correlation with health indicators (acute, sub-acute and chronic poisoning), considering as a possible cause the toxicity of pesticides from human exposure and occupational, environmental and food contamination.

In order to establish correlations, the municipalities of Mato Grosso State were used to exemplify the usefulness of this methodological strategy for surveillance actions in Brazilian municipalities.

Environmental indicators

We retrieved data of crops planted area from the Municipal Agricultural Production (PAM) of the IBGE Automatic Retrieval System of the Brazilian Institute of Geography and Statistics (IBGE-SIDRA) for the year 2015[7]. We opted for the variable planted area to the harvest, in hectares of temporary and permanent crops and defined the use of pesticides sprayed according to crop type, "pests" to be combated and amount of hectares planted[8].

This study used 21 varieties of predominant crops in the Brazilian territory dependent on chemical inputs, among the 66 crops available in IBGE-SIDRA. We selected the crops of pineapple, cotton, rice, sugar cane, beans, tobacco, sunflower, watermelon, melon, corn, soybean, tomato and wheat in the temporary crop. Permanent crops were banana, coffee, papaya, mango, grape and citrus fruits (sum of orange, lemon and mandarin).

In order to estimate the consumption of pesticides, the methodology of Pignati et al.[8] proposed indicators of mean amount of pesticides

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used per hectare for four agricultural crops (cotton, sugar cane, corn and soybean) in Mato Grosso, formulated from the Mato Grosso Agricultural Defense Institute (INDEA-MT)[9] database, which aggregated information on agronomic prescriptions containing the use of pesticides by municipality, volume (liters) used, size of the treated area and type of "pest" to be combated.

Based on this database and methodology, the mean amount of pesticide used per hectare was generated for other 17 crops and the estimated values for soybean, sugar cane, corn and cotton crops were updated based on consultancies with agronomists and farmers during research carried out by the Center for Environmental Studies and Workers' Health (NEAST). Literature that quantified mean pesticide used per hectare in some crops was also used[10,11].

The types of active ingredients frequently used in Mato Grosso's crops were adapted from three sources. The first one, by Pignati et al.[8], which listed the most used active ingredients in 2012 and their respective volumes per hectare in Mato Grosso; the second, from the 2014 sales data made available by IBAMA; the third, from research projects conducted by NEAST of the Federal University of Mato Grosso (UFMT) for 2016, which includes agronomic prescription data from the second, third and eleventh largest municipal pesticide users in Mato Grosso in the 2014/2015 harvest.

The calculation to estimate the use of pesticides in the municipalities was based on the multiplication of indicators (mean amount of pesticides used per hectare of a given crop) by the hectares planted in the 21 agricultural crops studied. Subsequently, we added the total amount of liters of pesticides obtained from all agricultural crops for each municipality, obtaining the total estimate of pesticide use by Brazilian municipality. We listed the most used active ingredients in Mato Grosso and their respective volumes used in soybean, corn, sugar cane and cotton crops and potential health problems that each product may cause[8].

Health indicators

We obtained health data from the Department of Information Technology of the Unified Health System (DATASUS) of the Ministry of Health[12]. We selected a health indicator of each poisoning type with probable cause of occupational, food and environmental exposure to the use of pesticides: acute (pesticide poisoning), sub-acute (fetal malformations) and chronic (childhood and juvenile cancer).

Data on poisoning by pesticides for agricultural, veterinary and rat poison use, by place of residence were retrieved from the Notifiable Diseases Information System (SINAN). Fetal malformation data were acquired from the Live Birth Information System (SINASC), referring to the evidence of congenital anomalies by mother's place of residence. Scientific evidence shows a higher occurrence of malformation in mothers living in rural areas, where mother exposure and mother/father occupational exposure[13,14] to pesticides is found.

Cancer data were obtained from the Mortality Information System (SIM), referring to cancer deaths in the 0-19 age group, characterized as childhood cancer, following the 10th International Classification of Diseases (ICD-10)), Codes C00 to C97, by place of residence. The children and adolescents group was chosen due to the susceptibility to environmental exposure to chemicals and since most cases of cancer (80%) are environment-related[15].

From the health data, mean coefficients of each health indicator were generated by municipality of Mato Grosso, represented by the following calculation: we added the number of disease/death cases from 2012 to 2014. Then, the arithmetic mean was calculated by the number of years studied (5 years). The arithmetic mean was used in the numerator and the 2013 population was used as denominator, referring to half of the period, and later, the value found was multiplied by the standardized constant for each indicator[16]. Thus, we obtained the 2013 population estimate in DATASUS. These are negative indicators, because the higher their value, the greater the risk of occurrence and deaths in the population.

Statistical review

Excel 2010 software was used for the elaboration of tables and Esri's ArcGis 10.1 was used to make thematic maps. Environmental indicators were classified in geometric intervals of eight classes for the municipalities of Brazil and five classes for the municipalities of Mato Grosso, and later, the environmental information was spatialized so that the darker shades represented the largest amount of planted area and consumption of pesticides.

The Mato Grosso environment and health indicators were analyzed in the SPSS program, version 20[17]. The association of indicators was estimated using Spearman's correlation test, considering non-parametric data distribution, as indicated by the Kolmogorov-Smirnov test. The correlation matrix was constructed between the amount of liters of pesticides consumed (independent variable) and the mean coefficient of acute, sub-acute and chronic poisoning by pesticides (dependent variables) in the 141 municipalities of Mato Grosso.

The discussion about statistical significance was expanded, which in this study, in addition to the p-value of 5%, a p-value of less than 20% was considered significant, based on the precautionary principle that seeks to avoid damage due to scientific uncertainty on its impact[18], so that this proposal becomes relevant for the implementation of actions of Health Surveillance of Populations Exposed to Pesticides. The approach shown is also based on the perspective of Critical Epidemiology, proposed by Breilh[19] that emphasizes participatory monitoring, based on situations of exposure and imposition of pesticides observed in reality, in a dialectical, critical and reflexive way.

Results

In 2015, Brazil planted 71.2 million hectares of crops in the 21 crops analyzed, and among them, soybean accounted for 42% of the country's total planted area (32.2 million hectares), followed by corn with 21% (15.8 million hectares) and sugar cane with 13% (10.1 million hectares). Together, these three crops accounted for 76% of Brazil's total planted area and were the ones that consumed pesticides the most, corresponding to 82% of all Brazilian consumption in 2015 (Table 1). An estimated total of 899 million liters of pesticides formulated products were sprayed on the 21 types of Brazilian crops that year.

Soybean was the crop that most used pesticides in Brazil, accounting for 63% of the total, followed by corn (13%) and sugar cane (5%). Tobacco was the crop with the highest mean amount of liters of pesticides per hectare with 60 l/ha. Cotton came second, consuming 28.6 l/ha, followed by citrus fruits (23 l/ha), tomato (20 l/ha), soybean (17.7 l/ha), grape (12 l/ha), banana (10 l/ha), rice (10 l/ha), wheat (10 l/ha), papaya (10 l/ha), corn (7.4 l/ha) and sunflower (7.4 l/ha). Other crops used less than five liters per planted hectare.

According to analyzed crops, Mato Grosso planted 13.9 million hectares and consumed 207 million liters of pesticides, followed by Paraná, with 10.2 million planted hectares, consuming 135 million liters of pesticides and Rio Grande do Sul, with 8.5 million planted hectares, using 134 million liters of pesticides (Table 2).

The amount of planted area of monocultures was spatialized by Brazilian municipalities as shown in Figure 1, facilitating the identification of the regions with the largest planted areas.

Likewise, the municipalities that obtained the largest quantities of planted area were also the ones that used the most pesticides, as shown in Figure 2.

The ten municipalities that used the most pesticides in liters in Brazil were: Sorriso-MT (14.6 million), Sapezal-MT (11.1 million), São Desidério-BA (10.2 million), Campo Novo do Parecis-MT (9.1 million), Nova Mutum-MT (9.0 million), Formosa do Rio Preto-BA (8.1 million), Nova Ubiratã-MT (8.0 million), Diamantino-MT (7.6 million), Rio Verde-GO (7.3 million), Campo Verde-MT (6.7million). In 2015, 24 municipalities used between 4.1 and 14.6 million liters of pesticides, 111 municipalities used 1.1 million to 4.1 million liters, 404 used 334,000 to 1.7 million liters, 912 municipalities used between 94,400 and 334,000 liters, 1,249 municipalities used between 26,300 to 94,400 liters, 1,272 municipalities used between 7,000 and 26,300 liters, 998 municipalities used between 1,500 and 7,000 liters and 600 municipalities under 1,500 liters.

Information on the type of pesticides (herbicides, insecticides or fungicides) and active ingredients used in the municipalities' crops is fundamental to the association with the most frequent health effects in the population of predominantly agricultural municipalities.

The 20 most frequently used active ingredients in the period 2012-2016 were Glyphosate (herbicide), Chlorpyrifos (insecticide), 2.4-D (herbicide), Atrazine (herbicide), mineral oil (adjuvant), Mancozeb (fungicide), Methoxyfenozide (Insecticide), Acephate (insecticide), Haloxyfop-P-methyl (herbicide), Lactofen (herbicide), Methomyl (insecticide), Diquat (herbicide), Picoxystrobin (fungicide), Flumetsulam (herbicide), Teflubenzuron (insecticide), Imidacloprid (insecticide), Lambda-cyhalothrin (insecticide), Imazethapyr (herbicide), Azoxystrobin (Fungicide) and Flutriafol (Fungicide). Of these 15% are extremely toxic, 25% highly toxic, 35% moderately toxic, and 25% are poorly toxic in the toxicological classification for humans.

Regarding agricultural crops, the active ingredients most frequently used in soybeans were glyphosate, with about 5.5 liters per hectare (l/

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Table 1. Planted area, mean use per hectare and total pesticides by type of crop in Brazil, 2015.

Crop	Planted area (hectares)	Mean use of pesticides (liters/hectares)	Pesticides consumption (liters)
Soybean	32,206,787	17.7	570,060,129.90
Corn	15,846,517	7.4	117,264,225.80
Sugar cane	10,161,622	4.8	48,775,785.60
Cotton	1,047,622	28.6	29,961,989.20
Wheat	2,490,115	10	24,901,150.00
Tobacco	406,377	60	24,382,620.00
Rice	2,162,178	10	21,621,780.00
Coffee	1,988,272	10	19,882,720.00
Citrus fruits	766,516	23	17,629,868.00
Bean	3,130,036	5	15,650,180.00
Banana	484,430	10	4,844,300.00
Tomato	63,626	20	1,272,520.00
Grape	78,026	12	936,312.00
Sunflower	111,843	7.4	827,638.20
Papaya	30,445	10	304,450.00
Watermelon	97,910	3	293,730.00
Pineapple	69,565	3	208,695.00
Mango	64,412	3	193,236.00
Melon	20,837	3	62,511.00
Total	**71,227,136**	-	**899,073,840.70**

Source: IBGE-SIDRA[20]; Pignati et al.[8]

ha), 2.4-D (1.0 l/ha), Metolachlor (0.7 l/ha), Tebuthiuron (0.6 l/ha), Trifluralin (0.4 l/ha), Paraquat (0.3 l/ha), Flutriafol (0.25 l/ha), Carbofuran (0.2 l/h) and others. In corn crops, active ingredients were Atrazine (3.55 l/ha), Glyphosate (0.4 l/ha), Chlorpyrifos (0.25 l/ha), Methomyl (0.2 l/ha), Tebuthiuron (2.0 l/ha) and others. In cotton crops, active ingredients were Chlorpyrifos (6.25 l/ha), Clomazone (3.8 l/ha), Trifluralin (2.6 l/ha), Methomyl (1.35 l/ha), Diuron 1.2 l/ha), Ethephon (1.0 l/ha) and others. In sugar cane crops, active ingredients were Glyphosate (1.3 l/ha), Metribuzin (0.5 l/ha), Trifluralin (0.5 l/ha), 2.4-D (0.25 l/ha), Tebuconazole (0.4 l/ha), Diuron (0.45 l/ha), MSMA (0.25 l/ha), Carbofuran (0.2 l/ha) and others.

The following health indicators were selected from the acute and chronic diseases described in scientific literature[8,21] related to exposure to pesticides: acute poisoning by pesticides, incidence of fetal malformation (sub-acute poisoning) and childhood cancer mortality (chronic poisoning).

Figure 3 shows, as an example, the spatial distribution thematic map, with the environmental and health indicators for the state of Mato Grosso. However, maps can be built for all Brazilian states through this methodology.

The mean coefficients of health indicators were concentrated in the municipalities of central and southern Mato Grosso, accompanying the municipalities with the highest consumption of pesticides. These indicators were correlated to the environmental indicator of consumption of pesticides by municipality of Mato Grosso.

Spearman's correlation coefficient between pesticide use (liters) in 2015 and the mean acute poisoning coefficient (2012-2014) was 13.2% for a p-value of 0.11. In addition, Spearman's correlation coefficient between consumption of pesticides (liters) in 2015 and the mean coefficient of incidence of fetal malformation (2012-2014) was 14% for a p-value of 0.09. Finally, Spearman's correlation coefficient between consumption of pesticides (liters) in 2015 and the mean coefficient of childhood cancer mortality (2012-2014) was 17% for a p-value of 0.04.

It is observed that both health indicators showed a positive correlation with the environmental indicator, indicating that insofar as consumption of pesticides increases, the mean coefficient of acute, sub-acute (fetal malformation) and chronic (childhood cancer) poisoning also increases.

Table 2. Planted area of the analyzed crops, their respective consumption of pesticides and predominance of agricultural crops by Federated Unit, Brazil, 2015.

Federated Unit	Studied crops planted area (hectare)	%*	Consumption of pesticides (liters)	Crop predominance in the Federated Units
MT	13,980,996	98.7	207,735,607	Soybean (63%), corn (25%), cotton (4%), sugar cane (2%), bean (2%), rice (1%), sunflower (1%)
PR	10,255,468	96.3	135,470,543	Soybean (49%), corn (23%), wheat (12%), sugar cane (6%) bean (4%), tobacco (1%)
RS	8,543,105	95.3	133,788,693	Soybean (59%), rice (13%), wheat (10%), corn (10%), tobacco (2%), bean (1%), grape (1%)
SP	8,136,504	96	61,797,269	Sugar cane (66%), corn (10%), soybean (9%), citrus fruits (5%), wheat (1%), bean (1%), banana (1%)
GO	5,830,192	95.5	75,135,233	Soybean (53%), corn (23%), sugar cane (15%), bean (2%), cotton (1%)
MG	5,130,624	94.5	52,731,202	Soybean and corn (24%), coffee (18%), sugar cane (17%), bean (6%)
MS	4,665,446	98.2	58,029,601	Soybean (49%), corn (35%), sugar cane (11%), cotton (1%)
BA	3,643,888	72.9	49,108,595	Soybean (29%), corn (16%), bean (11%), cotton (11%), coffee (3%), sugar cane (2%), banana (2%), citrus fruits (1%)
MA	1,627,532	88.9	20,649,982	Soybean (42%), corn (25%), Rice (13%), Bean (5%), sugar cane (3%), cotton (1%)
SC	1,481,843	93	23,918,055	Soybean (38%), corn (25%), rice (9%), tobacco (7%), bean (5%), wheat (5%), banana (2%), sugar cane (1%)
PI	1,416,818	90.8	17,358,130	Soybean (43%), corn (26%), bean (14%), rice (6%) sugar cane and cotton (1%)
TO	1,173,302	97.7	17,403,387	Soybean (69%), corn (13%), rice (10%), sugar cane (3%) watermelon (1%), bean (1%)
CE	997,257	66.1	6,551,303	Corn (33%), bean (27%), banana (3%), sugar cane (1%), rice (1%)
PE	763,751	91.4	4,490,610	Sugar cane (38%), corn and bean (23%), banana (4%), mango (1%), grape (1%)
PA	762,574	57.2	9,443,170	Soybean (25%), corn (17%), rice (5%), banana (3%), bean (3%), citrus fruits (1%), sugar cane (1%), pineapple (1%)
ES	593,627	91	5,456,549	Coffee (68%), sugar cane (12%), banana (4%), corn (3%), bean (2%), papaya (1%)
RO	568,795	92.7	6,910,076	Soybean (38%), corn (29%), coffee (13%), rice (7%), bean (4%), banana (1%)
AL	417,845	90.3	2,755,645	Sugar cane (67%), bean (11%), corn (7%), tobacco (2%) citrus fruits (1%), banana (1%), rice (1%), pineapple (1%)

it continues

Discussion

The results showed the predominance of planted area of soybean, corn and sugar cane crops in the country. This reflects the Brazilian development-oriented policy focused mainly on the production of primary goods for export. This "commoditization" generates impacts on public health, affects vast territories and involves different population groups when compared to peasant, agroecological and family agriculture[1]. Regional discrepancies in agricultural production are accompanied by a technological and tax incentive process for land exploitation and use

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Table 2. continuation

Federated Unit	Studied crops planted area (hectare)	%*	Consumption of pesticides (liters)	Crop predominance in the Federated Units
SE	308,188	81.1	2,922,050	Corn (46%), sugar cane (15%), citrus fruits (13%), bean (4%), rice (1%), banana (1%)
PB	278,061	85.2	1,631,397	Sugar cane (37%), corn and bean (20%), banana and pineapple (3%) citrus fruits (1%)
RN	175,913	56.7	986,017	Sugar cane (19%), bean and corn (14%), Melon (3%), banana (2%), watermelon (2%), mango (1%), pineapple (1%), papaya (1%)
DF	154,322	95.8	1,838,655	Soybean (43%), corn (41%), bean (10%), wheat (1%), citrus fruits (1%)
RJ	133,257	88.5	1,014,804	Sugar cane (53%), banana (13%), coffee (10%), citrus fruits (6%), pineapple (2%), tomato (2%), corn (2%), bean (1%)
AC	73,363	62.9	584,454	Corn (36%), banana (8%), bean (7%), rice (5%), sugar cane (3%), coffee (1%), watermelon (1%), citrus fruits (1%)
RR	56,806	87.4	763,059	Soybean (37%), banana (17%), rice (12%), corn (8%), bean (4%), citrus fruits (4%), watermelon (2%) cotton (1%), papaya (1%)
AM	36,145	29	306,916	Corn and banana (5%), watermelon (4%), citrus fruits (3%), sugar cane (3%) and pineapple (3%), bean (2%), rice (2%), coffee (1%) and papaya (1%)
AP	21,514	62.4	292,838	Soybean (33%), banana (6%), corn and rice (5%), pineapple (3%), citrus fruits (3%), bean (3%), watermelon (2%)
Total	**71,227,136**	**92.7**	**899,073,840,70**	**Soybean (42%), corn (21%), sugar cane (13%), bean (4%), wheat (3%), rice (3%) and coffee (3%), cotton (1%), citrus fruits (1%), banana (1%), tobacco (1%)**

* In reference to the 66 crops offered by IBGE-SIDRA.

Source: IBGE-SIDRA[20]; Pignati et al.[8]

that continues to coexist with fragilities in environmental legislation, social control, and policies that favor this chemical-dependent model.

Bombardi[22] says that the high agricultural productivity of Brazilian agribusiness is responsible, in total terms, for the greater consumption of pesticides, so that soybean, corn and sugar cane crops together account for almost 70% of all the use of pesticides in Brazil. This study found that these three crops accounted for 82% of the total volume of pesticides used in the country in 2015, indicating a trend of increased use in these crops.

For Altieri[23], transgenic monocultures may influence the upswing of pesticide use, such as the glyphosate herbicide used in RR (Roundap Ready) soybean tolerant to this pesticide. This would entail the emergence of pest resistance, also increasing the consumption of other types of pesticides. In face of the findings of phytosanitary emergencies, pesticides previously banned by regulatory agencies and which are proven to be toxic to living organisms, such as insecticide Emamectin benzoate[24] will be authorized. The falling prices of more toxic pesticides and some tax exemptions also lead to an increased amount of pesticides used, exposing the population to higher chemical loads, as well as to multiple exposure to different classes of use and types of pesticides[1,8].

The use of maps such as those shown in this study facilitates the highlight of the potential environmental pollution sites, which are propor-

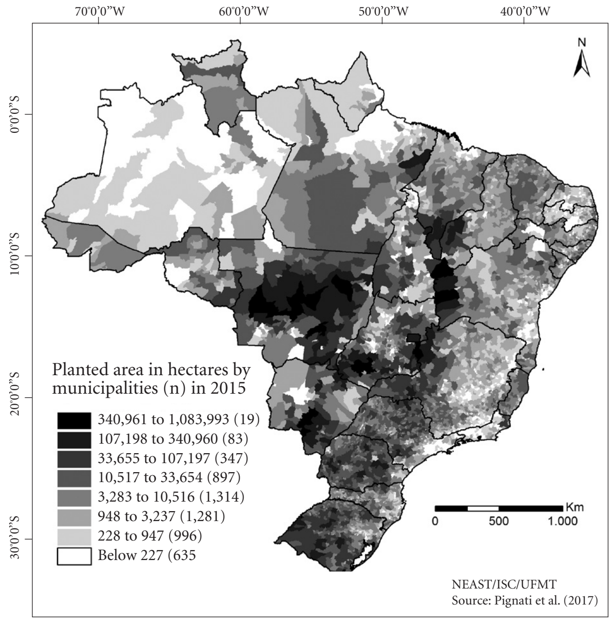

Figure 1. Total planted area of crops studied, by Brazilian municipality, 2015.

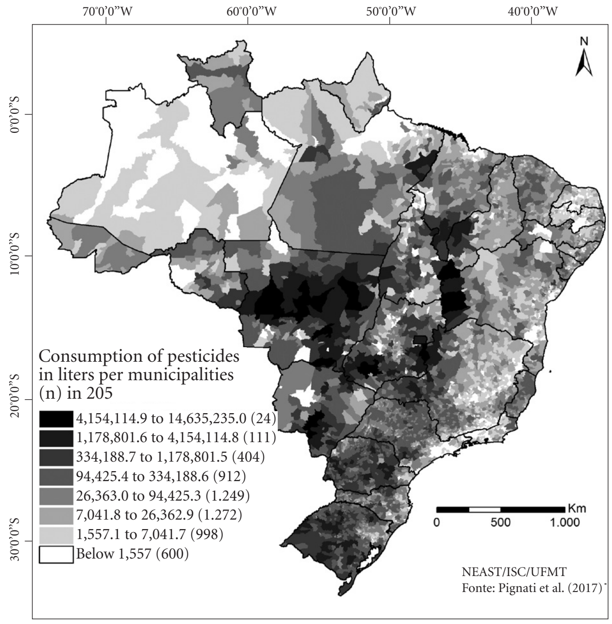

Figure 2. Estimated consumption of pesticides used in crops studied by Brazilian municipality, 2015.

tional to the intensity of agricultural production and pesticide use. In addition, maps allow us to determine the locations that should be a priority for the prevention of risks related to contamination in water, rain, air, food, workers, exposed populations and animals, among others[25-27], an important tool for participatory and precautionary surveillance.

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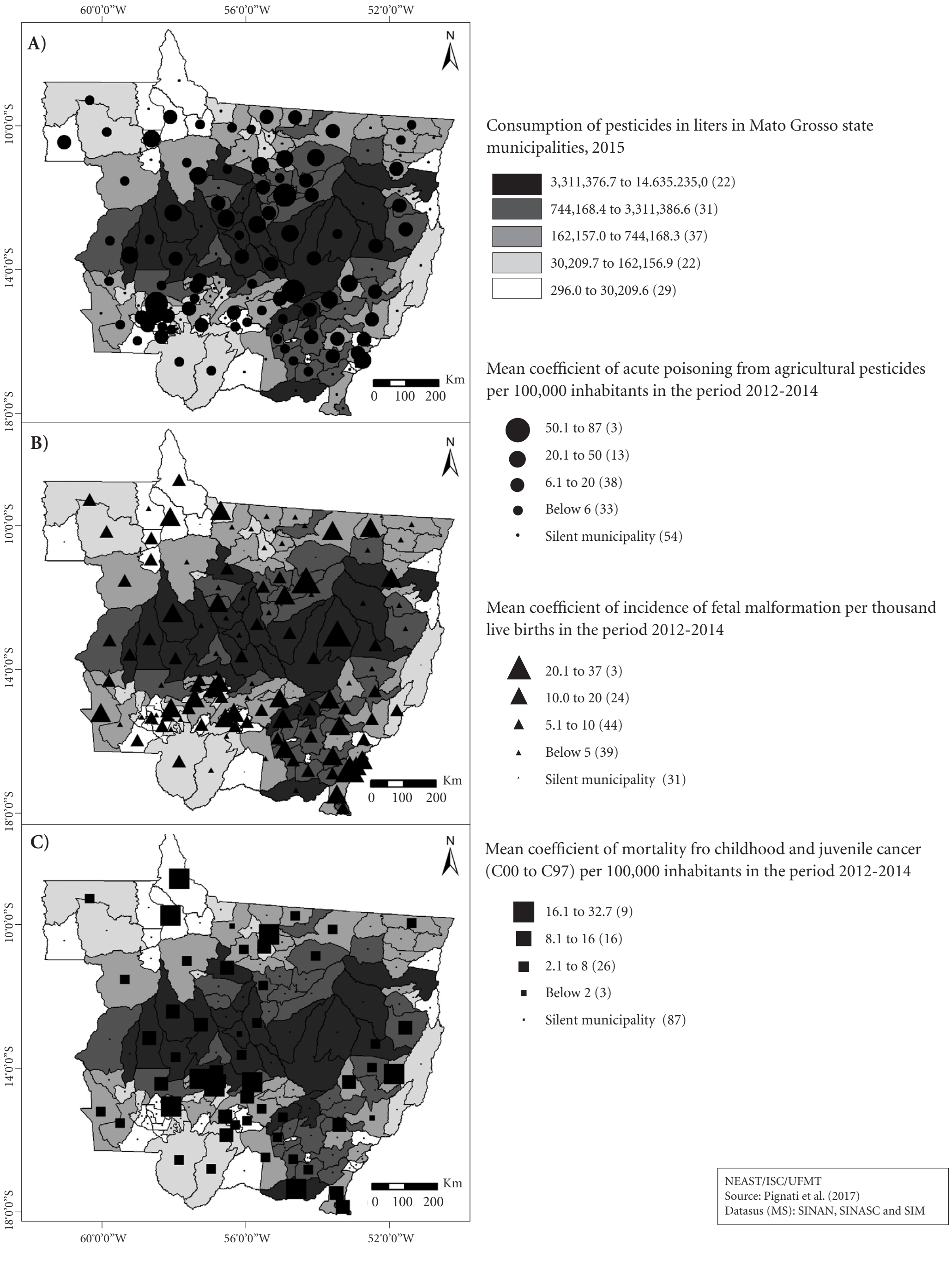

Figure 3. Consumption of pesticides and coefficients of acute (a), sub-acute (b) and chronic (c) poisoning by pesticides in the municipalities of Mato Grosso, 2015.

The extensive areas of high pesticide consumption monocultures are mainly located in the Cerrado (type of savanna) biome. According to the Brazilian forest code (Law Nº 12.651/2012), the preservation of 35% of legal reserve with native vegetation is allocated to this biome and, consequently, 65% of the area is cleared for deforestation. This makes the Cerrado one of the most deforested biomes in the country and with a high probability of contamination of pesticides in its watersheds and aquifers. The remaining portions of the Cerrado are also directed towards the expanded agricultural border by the National Institute of Colonization and Agrarian Reform (Incra) and the Brazilian Agricultural Research Corporation (Embrapa) in a project for the states of Maranhão, Tocantins, Piauí and Bahia (acronym Matopiba), as observed in Figure 1.

In these regions of high and medium pesticide use, it will be necessary to prioritize the implementation of the Health Surveillance of Populations Exposed to Pesticides (VSPEA). These methodological strategies add important aspects to the operationalization of the guidelines of the National Worker Health Policy, environmental health and population exposed to pesticides. Knowledge of these territories, their productive activities, social movements and operating institutions, the morbidity and mortality indicators of the municipality are fundamental for the implementation of a more effective Health Surveillance process enhanced by Participatory Monitoring[19].

The spatial distribution of the use of pesticides and health diseases can also assist exploratory analyses, generation of hypotheses and territorial associations, which can later be confirmed in statistical tests[28]. At the municipal level, environmental contamination and human poisoning estimates may be inferred according to the type of predominant crop in the municipality, the types of pesticides used and their toxicological characteristics (such as toxicodynamics and toxicokinetics), serving as a warning to health professionals to subsidize Health Surveillance actions.

There is a high consumption of pesticides and health indicators do not show a significant correlation in some municipalities shown on the map. The political factors of domination and/or harassment of agribusiness institutions over municipal governments may interfere with the non-notification of cases, as observed by Nasrala Neto et al.[4] and Onishi[5], generating an "intentional invisibility" of those diseases.

The formulation of health indicators with pesticide poisoning data is also a challenge due to thigh underreporting of these diseases. For each reported case of acute poisoning, another 50 are not reported or are underestimated as a public health problem, interfering with the governmental information-decision-making-action process[29,30].

Prolonged exposure to pesticides and acute poisoning cycles may lead to sub-acute and chronic poisoning with irreversible damage. Some pesticides may have effects on human development, such as fetal malformations. Literature indicates that mothers' environmental exposure to pesticides was associated with a higher occurrence of fetal malformation in municipalities with high pesticide use, in all quarters of pregnancy in Mato Grosso[13]. Studies associate father or mother occupational exposure to pesticides with the occurrence of fetal malformation[14,31].

Exposure to chemical substances (pesticides) in regions of medium and high agricultural production has been identified as potential causal factors for cancers, since the International Agency for Research on Cancer (IARC/WHO) has classified pesticides frequently used in crops as potentially carcinogenic, for example, glyphosate[32].

Childhood cancer is an important indicator of environmental vulnerability and is the second cause of death of the population aged 0-19 years in Brazil. One of the limitations pointed out in literature regarding the study of childhood cancer mortality is the lack of reliable records for all cancer-related deaths in this age group[33]. Literature points to a higher incidence of leukemia and lymphoma in the central and southern regions of the state of Mato Grosso, which correspond to regions with high agricultural production[34,35]. It is also observed that hospitalizations for childhood cancer in the Cancer Hospital of Mato Grosso and the higher prevalence is of users coming from regions with high agricultural production[34,36].

Thus, from the results of this study, we can observe that health indicators (acute poisoning, incidence of fetal malformation and childhood cancer mortality) showed a positive correlation with the environmental indicator (consumption of pesticides), indicating an association between the increased consumption of pesticides and the mean coefficients of health indicators. It is possible to identify the concentration of pesticide consumption in the municipalities of the Midwest (3.3 to 14.6 million liters) and South (744 thousand to 3.3 million liters) of the state of Mato Grosso, where agricultural production is more intense.

Thus, it is possible to establish statistical correlations and visualize the pressures from a spatial and ecological perspective, contributing with analyses of the Brazilian agricultural municipalities, especially of the human and environmental exposure to pesticides, because of the agricultural model, in addition to the adoption of analytical perspectives that contribute to health surveillance and incorporate new methods aiming at prevention and development of collective

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actions, overcoming the reduced linear causality model and incorporating integrated approaches to health surveillance.

Conclusions

The effectiveness of health surveillance actions in Brazil depends on interinstitutional and participatory processes and practices that incorporate information on social, environmental and health impacts related to the agricultural production process and to occupational, food, environmental and population exposure to pesticides.

The methodological strategy shown in this paper contributes to the collectivization of crucial information for the knowledge and action of the sectors, institutions and stakeholders central to health surveillance actions, especially considering the relationship between the production processes and people's health-disease process.

This methodology can be used in Brazilian municipalities or health regions and/or regions, based on data from agricultural production, average amount of pesticides used per hectare of crops and some diseases related to their acute, sub-chronic or chronic impacts on human health. The spatial distribution of information allows us to identify patterns of consumption and priority areas with greater exposure to pesticides and generate exploratory analysis and statistical, spatial and visual correlations.

The information produced is important for the processes of health education among exposed populations, workers and entities that are part of social control, aiming at strengthening surveillance actions, as well as integrated actions of agriculture, environment, labor and health inspection agencies.

This methodology can help in the formation of health promotion networks, besides motivating health surveillance actions aimed at transforming the current agricultural production process, replacing pesticides and chemical fertilizers with other food production practices and control of agricultural diseases such as agroecology.

Collaborations

WA Pignati participated in the paper's concept and design, data discussion and interpretation and critical review. FANS Lima and SS Lara participated in the design, data analysis, collection and interpretation and in the writing, critical review and approval of the version to be published. MLM Corrêa participated in data interpretation and discussion, in the writing, critical review and approval of the version to be published. JR Barbosa participated in data interpretation and critical contributions to the text. LHC Leão participated in the interpretation and discussion of results, critical contributions to the text and approval of the version to be published. MG Pignati participated in the critical review of the text and approval of the version to be published.

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Article submitted 30/05/2017
Approved 26/06/2017
Final version submitted 17/07/2017