SEVEN publicações acadêmicas

SPATIAL ASSESSMENT OF ENVIRONMENTAL CONTAMINATION BY PESTICIDES IN THE MUNICIPALITY OF PETROLINA-PE – PART II

AVALIAÇÃO ESPACIAL DA CONTAMINAÇÃO AMBIENTAL POR AGROTÓXICOS NO MUNICÍPIO DE PETROLINA-PE – PARTE II

EVALUACIÓN ESPACIAL DE LA CONTAMINACIÓN AMBIENTAL POR PLAGUICIDAS EN EL MUNICIPIO DE PETROLINA-PE – PARTE II

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ABSTRACT

One way to assess the risk of environmental contamination from a pesticide is to consider its physical and chemical properties in terms of soil binding capacity, volatility, leachability, solubility, etc. The GOSS and GUS methods combine this information to create a contaminant profile, serving as a basis for assessing the potential for surface and groundwater contamination by a given pesticide. In this regard, several tools can be used, such as those that consider the combination of these and other models associated with Geographic Information Systems for mapping regions, where soil characteristics and available water resources provide a vulnerability profile for various locations, particularly agricultural producers. The sub-middle São Francisco region is one of Brazil's main fruit producing and exporting hubs, specializing in grape and mango production. The agricultural system implemented in this region requires an assessment of its impacts on the environment, particularly on soil, water, and the atmosphere, through the physical, chemical, and biological characteristics of local natural resources. Controlling pesticide use in this region is a challenge for environmental oversight agencies. This study aims to assess the risk of environmental contamination in the agricultural regions of Petrolina, Pernambuco, based on information generated by a Geographic Information System (GIS). It considers physical aspects of the soil and water compartments, highlighting soil types, hydraulic conductivity potential, and slope, associated with the physicochemical properties of pesticides. These characteristics were found in samples from various crops collected in Petrolina during 2009, 2010, and 2011. Based on the proposed methods (GUS and GOSS), the study revealed high contamination potential for those pesticides that undergo leaching, particularly for azoxystrobin, boscalid, carbendazim, dimethomorph, fenarimol, methomyl, and myclobutanyl thiamethoxam. On the other hand, compounds such as Cyproconazole, Difenoconazole (1,2), Propargite, and Tebuconazole showed a high potential for contaminating surface water. Therefore, leachable pesticides should be avoided in soils with high hydraulic drainage, as well as in soils with relatively steep slopes. The combination of land vulnerability data with pesticide properties showed that it is possible to identify, preliminarily, contamination regions for different pesticides in the municipality of Petrolina. The combination of spatial data with chemical knowledge can point to more rational practices where crop/environment/pesticide should be considered as a whole with interrelationships.

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Keywords: Environmental Contamination. Geographic Information System. Water Resources. Pesticides.

RESUMO
Uma forma de se avaliar o risco de contaminação ambiental por um agrotóxico é considerar suas propriedades físicas e químicas em termos de capacidade de se associar ao solo, volatilidade, lixividade, solubilidade, etc. Os métodos de GOSS e GUS combinam essas informações permitindo criar um perfil do contaminante, servindo como subsidio para avaliar a potencialidade de contaminação dos recursos hídricos superficiais e subterrâneos por um determinado agrotóxicos. Nesse aspecto, várias ferramentas podem ser utilizadas como as que consideram a combinação desses e de outros modelos associados a Sistemas de Informações Geográficas para mapeamento de regiões, em que as características do solo e recursos hídricos disponíveis permitem fornecer um perfil de vulnerabilidade no qual se encontra as diversas localidades, em particular as produtoras agrícolas. A região do sub-médio São Francisco é um dos principais polos produtores e exportadores de frutas do Brasil, sendo especializada na produção de uva e manga. O sistema agrícola implantado nessa região demanda uma avaliação de seus impactos no meio ambiente, notadamente no solo, na água e na atmosfera, através das características físicas, químicas e biológicas dos recursos naturais locais. Controlar o uso de agrotóxicos nessa região é um desafio para os órgãos de fiscalização ambiental. Este trabalho propõe-se a avaliar o risco de contaminação ambiental das regiões agrícolas de Petrolina-PE, baseado em informações construídas a partir de um Sistema de Informações Geográficas, considerando aspectos físicos dos compartimentos solo e água, destacando-se tipos de solo, potencial de condutividade hidráulica e declividade, associados com as propriedades físico-químicas dos agrotóxicos, recorrentes em amostras de diversas culturas coletadas em Petrolina, durante os anos de 2009, 2010 e 2011. Baseado nos métodos propostos (GUS e GOSS), o estudo revelou alto potencial de contaminação para aqueles agrotóxicos que sofrem lixiviação, com destaque para Azoxistrobina, Boscalide, Carbendazim, Dimetomorfe, Fenarimol, Metomil, Miclobutanile Thiamethoxam. Por outro lado, compostos como Cyproconazol, Difenoconazol (1,2), Propargito e Tebuconazol apresentaram alto potencial de contaminação de águas superficiais. Assim sendo os agrotóxicos lixiviáveis devem ser evitados em solos de alta drenagem hidráulica, bem como em solos de relativa declividade. A combinação dos dados de vulnerabilidade das terras com propriedades dos agrotóxicos evidenciou que é possível apontar, de forma preliminar, regiões de contaminação para diferentes agrotóxicos no município de Petrolina. A combinação de dados espaciais com o conhecimento químico pode apontar para práticas mais racionais onde cultura/ambiente/agrotóxico devem ser pensados como um conjunto que estabelece inter-relações.

Palavras-chave: Contaminação Ambiental. Sistema de Informação Geográfica. Recursos Hídricos. Agrotóxicos.

RESUMEN
Una forma de evaluar el riesgo de contaminación ambiental por un plaguicida es considerar sus propiedades físicas y químicas en términos de capacidad de fijación al suelo, volatilidad, lixiviabilidad, solubilidad, etc. Los métodos GOSS y GUS combinan esta información para crear un perfil de contaminantes, que sirve como base para evaluar el potencial de contaminación de aguas superficiales y subterráneas por un plaguicida determinado. En este sentido, se pueden utilizar diversas herramientas, como las que consideran la combinación de estos y otros modelos asociados con los Sistemas de Información Geográfica para el mapeo de regiones, donde las características del suelo y los recursos hídricos disponibles

proporcionan un perfil de vulnerabilidad para diversas localidades, en particular para los productores agrícolas. La región subcentral de São Francisco es uno de los principales centros frutícolas de Brasil, especializado en la producción de uva y mango. El sistema agrícola implementado en esta región requiere una evaluación de sus impactos sobre el medio ambiente, en particular sobre el suelo, el agua y la atmósfera, a través de las características físicas, químicas y biológicas de los recursos naturales locales. Controlar el uso de plaguicidas en esta región representa un desafío para los organismos de supervisión ambiental. Este estudio tiene como objetivo evaluar el riesgo de contaminación ambiental en las regiones agrícolas de Petrolina, Pernambuco, con base en información generada por un Sistema de Información Geográfica (SIG). Considera aspectos físicos de los compartimentos suelo y agua, destacando tipos de suelo, potencial de conductividad hidráulica y pendiente, asociados con las propiedades fisicoquímicas de los plaguicidas. Estas características se encontraron en muestras de varios cultivos colectados en Petrolina durante 2009, 2010 y 2011. Con base en los métodos propuestos (GUS y GOSS), el estudio reveló un alto potencial de contaminación para aquellos plaguicidas que sufren lixiviación, particularmente para azoxistrobina, boscalida, carbendazim, dimetomorf, fenarimol, metomilo y miclobutanil tiametoxam. Por otro lado, compuestos como ciproconazol, difenoconazol (1,2), propargita y tebuconazol mostraron un alto potencial de contaminación de aguas superficiales. Por lo tanto, se debe evitar el uso de plaguicidas lixiviables en suelos con alto drenaje hidráulico, así como en suelos con pendientes relativamente pronunciadas. La combinación de datos sobre la vulnerabilidad del suelo con las propiedades de los plaguicidas mostró que es posible identificar, de forma preliminar, las zonas de contaminación por diferentes plaguicidas en el municipio de Petrolina. La combinación de datos espaciales con el conocimiento químico puede indicar prácticas más racionales donde la relación cultivo/medio ambiente/plaguicida debe considerarse como un todo, con sus interrelaciones.

Palabras clave: Contaminación Ambiental. Sistema de Información Geográfica. Recursos Hídricos. Plaguicidas.

4.2.2 Soil infiltration and runoff profiles

Based on Gomes (1996) and Barbalho (2010), information related to hydraulic conductivity and percentage of soil slope were combined to estimate the infiltration (Table 13) and surface runoff (Table 14) profiles of the different soil types.

Table 13

Infiltration profile as a function of soil slope and hydraulic conductivity

Conductivity	Soil infiltration profile			
	Low Slope (0-6%)	**Gentle Slope (6-12%)**	**Moderate Slope (12-18%)**	**High Slope (18-45%)**
Low	Medium	Low	Low	Low
Average	High	Medium	Low	Low
Discharge	High	High	Medium	Low
Very High	High	High	High	Medium

Source: Barbalho (2010).

Table 14

Surface runoff profile as a function of soil slope and hydraulic conductivity

Conductivity	Soil surface runoff profile			
	Low Slope (0-6%)	**Soft (6-12%)**	**Moderate (12-18%)**	**Discharge (18-45%)**
Low	Medium	High	High	High
Average	Low	Medium	High	High
Discharge	Low	Low	Medium	High
Very High	Low	Low	Low	Medium

Source: Barbalho (2010).

4.2.3 Vulnerability profiles regarding soil classification

The vulnerability profiles regarding the classification of the soils of Petrolina to pesticide contamination were constructed from the combination of the slope profiles of the terrain, hydraulic conductivity, infiltration potential and surface runoff of the water. According to Gomes, Spadotto and Pessoa (2002), the vulnerability profiles were classified as Very Foot-Sick, High, Moderate and Low (Tables 15 and 16).

Table 15

Classification of soil vulnerability profiles to contamination

Slope of the Land	Conductivity	Infiltration Profile of Water	Water Runoff Profile	Vulnerability
Low	Very High	High	Low	Very Afta
Low	Discharge	High	Low	Discharge
Low	Average	High	Medium	Moderate
Low	Low	Medium	Low	Low

Soft	Very High	High	Low	Very Afta
Soft	Discharge	High	Low	Discharge
Soft	Average	Medium	Medium	Moderate
Soft	Low	Low	Low	Low
Moderate	Very High	Discharge	Low	Very Afta
Moderate	Discharge	Medium	Medium	Discharge
Moderate	Moderate	Low	Medium	Moderate
Moderate	Low	Low	Low	Low
Discharge	Very High	Medium	Medium	Moderate
Discharge	Discharge	Low	Medium	Moderate
Discharge	Moderate	Low	High	Low
Discharge	Low	Low	High	Low

Source: Gomes; Spadotto; Pessoa (2002).

Table 16

Classification of soil vulnerability as a function of the integration of information on hydraulic conductivity, terrain slope, infiltration potentials, surface water runoff and depth of the water table

Classe de Solo	Condutividade Hidráulica	Declividade do Terreno	Potencial de Infiltração de Água	Potencial de Escoamento de Água	Profundidade Lençol Freático*	Vulnerabilidade
Latossolos Vermelnos Eutrofórricos e Distrofórricos argissolicos	Média	Suave	Médio	Médio	Profundo a muito profundo	Média
Nitossolos Vermelhos Eutrofórricos latossolicos	Média	Acentuada	Médio	Médio	Profundo	Média
Latossolos Vermelhos Distróficos psamticos	Alta	Suave	Médio/Alto	Médio/Baixo	Profundo	Média/Alta
Latossolos Vermelho-Amarelo Distróficosplanticos	Média	Suave	Médio	Médio	Profundo	Média
Neossolo Quartzarico	Alta	Suave	Alto	Baixo	Profundo a muito profundo	Alta

Source: Gomes; Spadotto; Pessoa (2002).

4.3 CONSTRUCTION OF THE GEOGRAPHIC INFORMATION SYSTEM (GIS)

The construction of the Geographic Information System (GIS) will point out regions vulnerable to contamination by pesticides found in fruit matrices. The following are the steps related to the construction of information that fed the Geographic Information system:

- Step 1: Generation of Map of soil types;
- Stage 2: Generation of a Map of water resources;
- Step 3: Generation of Hydraulic Conductivity Map;
- Stage 4: Generation of a Map of the percentage of soil slope;
- Stage 5: Generation of a map of the potential for contamination by infiltration and surface runoff based on the categorization proposed by Gomes, Spadotto and Barbalho (2002).

All thematic maps were generated at a scale of 1:500,000 from the ArcMap (ArcGIS®) program. The cartographic system defined was the Universal Transverse Projection system of Mercator – UTM, Datum SIRGAS 2000 – Fuso 24S. The files were generated in shapefile format and stored in the project database. The thematic maps were generated using the databases compiled from EMBRAPA, SRHE and IBGE, acquired by ITEP, and converted to the projection and adopted Datum. Based on the digital terrain model obtained from the SRTM (SHUTTLE Radar Topographic Mission), made available by the ITEP Geo Information Unit, and using the slope tool that constitutes the Spatial Analyst Tools, from Arc Map, the slope and hydraulic conductivity maps were generated.

4.4 ENVIRONMENTAL RISK ASSESSMENT: CONTAMINATION OF GROUNDWATER AND SURFACE WATER BY PESTICIDES

To evaluate the potential for contamination of groundwater and surface water by pesticides, the GUS (Groundwater Ubiquity Score) and GOSS indices were used, respectively. These methods are based on the physicochemical properties of pesticides, such as solubility in water (S), coefficient of adsorption to soil organic matter (Koc), in addition to the half-life of the compost in soil (DT50soil) and water (DT50 water).

5 RESULTS AND DISCUSSIONS

In the presentation of the results, it was decided to describe the data necessary for the construction of the Geographic Information System (GIS). The data were divided into the following stages:

- STAGE 1 – Distribution of the structure and soil types, slope of the terrain and water resources in the municipality of Petrolina. The association of these data with the physical and chemical probities of pesticides resulted in the proposition of an index of environmental vulnerability to the contamination of natural resources by these compounds;
- STAGE 2 – Characterization of soil types as to their runoff and drainage potential;
- STAGE 3 – Construction of thematic maps for potential contamination to highlight critical contamination regions

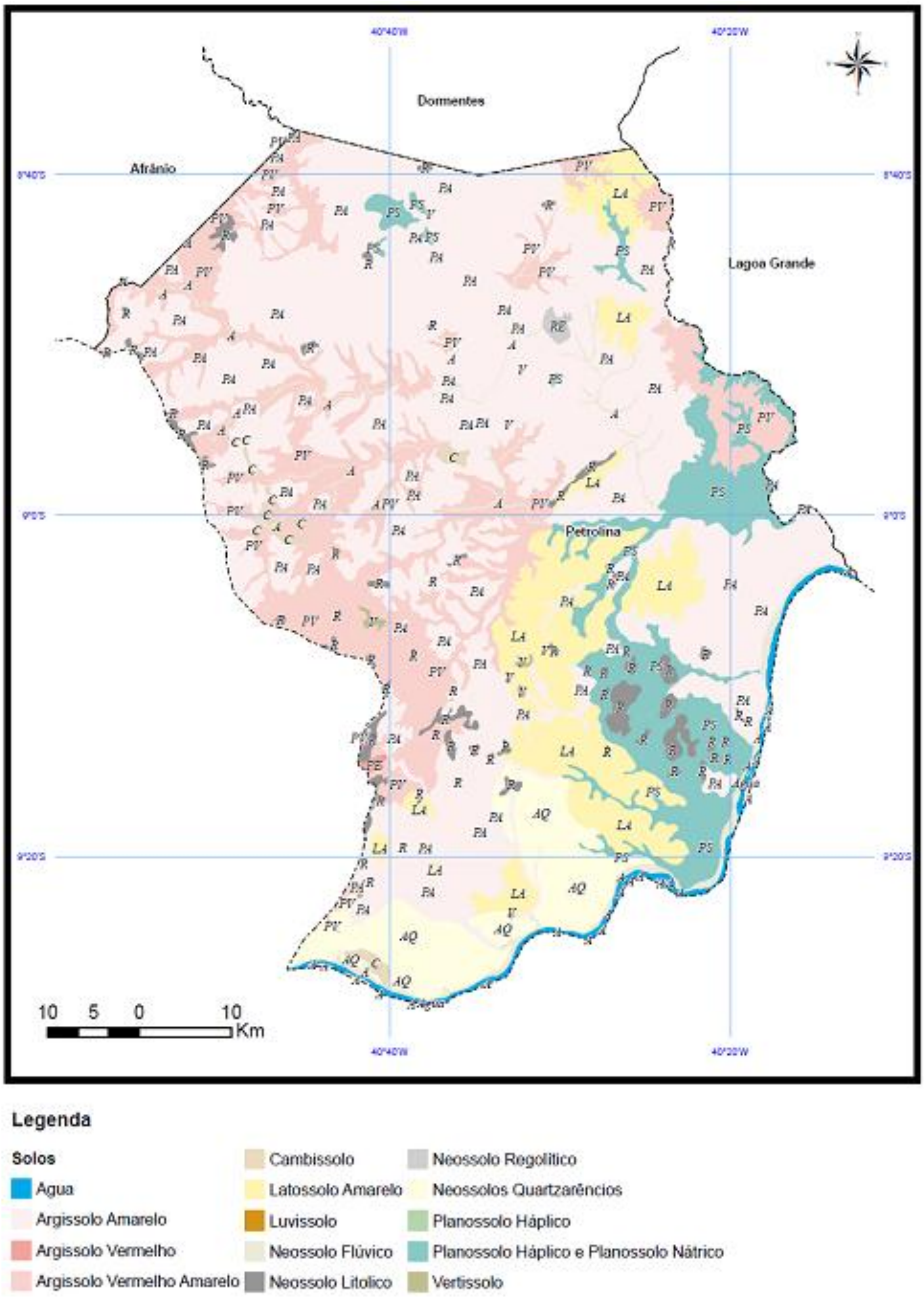
- STEP 4 – Prediction of groundwater and surface water contamination by pesticides;

5.1 STAGE 1 – DISTRIBUTION OF STRUCTURE AND SOIL TYPES, SLOPE OF THE LAND AND WATER RESOURCES IN THE MUNICIPALITY OF PETROLINA

The spatialization of soil types (Yellow Argisol, Red Argisol, Yellow Red Argisol, Cambisol, Yellow Latosol, Luvisol, Fluvic Neosol, Litholic Neosol, Regolitic Neosol, Quartzarenceous Neosols, Haplic Planosol, Haplic Planosol and Nautical and Vertisol Planosol) and water resources found in the municipality of Petrolina subsidized important information about the different runoff and drainage potentials of the terrain (Figure 7 and Figure 8).

Figure 7

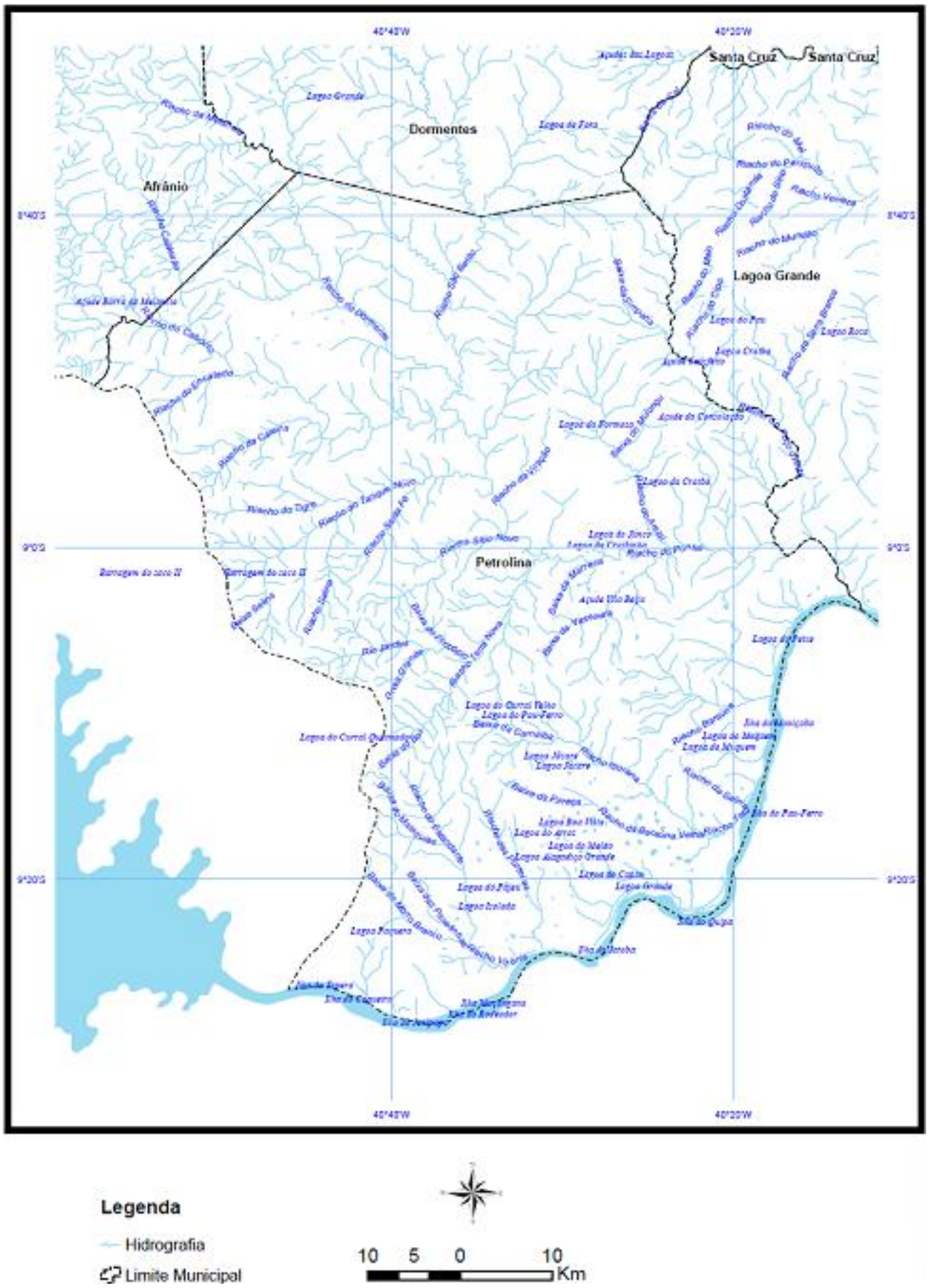
Spatialization of soil types in the municipality of Petrolina-PE



Source: The thematic maps were generated using the databases compiled from EMBRAPA, SRHE and IBGE, acquired by ITEP, and converted to the projection and adopted Datum. Based on the digital model of the terrain obtained from the SRTM (SHUTTLE Radar Topographic Mission), made available by the ITEP Geoinformation Unit.

Figure 8

Distribution of Water Resources in the municipality of Petrolina-PE



Source: The thematic maps were generated using the databases compiled from EMBRAPA, SRHE and IBGE, acquired by ITEP, and converted to the projection and adopted Datum. Based on the digital model of the terrain obtained from the SRTM (SHUTTLE Radar Topographic Mission), made available by the ITEP Geoinformation Unit.

Thus, according to the map, we can highlight the main soil classes found, categorizing each type in particular and categorizing them according to their properties (EMBRAPA, 2002).

Latosols These are soils resulting from energetic transformations of the original material or from pre-weathered sediments where minerals in the last stages of weathering (kaolinites and iron and aluminum oxides) predominate in the clay fraction, with the sand fraction dominated by minerals highly resistant to weathering. They are of variable texture, medium to very clayey, generally very deep, porous, soft and permeable, with a small difference in clay content at depth and, commonly, they are of low natural fertility. In general, its macrostructure is weak or moderate, however, the typical latosolic horizon presents strong microstructuring (pseudosand), a common characteristic in Ferric Red Latosols, soils with high iron oxide content. They are typical of equatorial and tropical regions, distributed mainly on large and ancient erosion surfaces, pediments and ancient river terraces, usually in gently undulating and flat relief. Latosols are the most representative soils in Brazil, occupying 38.7% of the country's total area and are distributed throughout practically the entire national territory. There are several types of Latosols, which are differentiated, among several other attributes, by their color, natural fertility, iron oxide content and texture (EMBRAPA, 2002).

The Ultisols form a very heterogeneous class that, in general, has in common a substantial increase in clay content at depth. They are well structured, have variable depth and predominantly reddish or yellowish colors, texture varying from sandy to clayey in the superficial horizons and from medium to very clayey in the subsurfaces; Its fertility is varied and mineralogy is predominantly kaolinite. Ultisols occupy approximately 20.0% of the country's surface; in terms of geographical extension, they are second only to the Latosols and, similar to these, they are distributed in practically all Brazilian regions. Usually, they occupy terrains with more dissected reliefs when compared to oxisols (EMBRAPA, 2002).

Luvisols These are soils with high natural fertility, endowed with clays with high exchangeable ion retention capacity (high activity clay) and high base saturation (high nutrient retention capacity) in the subsurface horizons, immediately below weak or moderate type A horizons (low organic matter contents, not very thick and low to medium nutrient retention capacity). Expressive areas are found in the Brazilian northeast, where they are distributed mainly in the semi-arid zone (EMBRAPA, 2002).

Neosols are poorly evolved, they present little expression of the processes responsible for their formation, which did not lead, therefore, to significant modifications of the original material. They differ largely by their source material and landscape, such as sedimentary deposits (river plains, marine or non-sandy sediments) and regions of rugged relief. There are four major types of Neosols, which generally have the following characteristics: Litholic Neosols – shallow soils, with a thickness of less than 50 cm, generally having a narrow layer of earthy material on the rock; Regolitic Neosols – deeper soils with a thickness of more than 50 cm and the presence of alterable minerals or rock fragments; Quartzarenic Neosols – deeper soils, with a thickness of more than 50 cm, with an essentially sandy texture throughout the soil and, practically, absence of alterable primary minerals (without nutrient reserve); Fluvic Neosols – soils from alluvial sediments. They usually have a darkened horizon on the surface over stratified layers. Litholic Neosols, in general, are associated with many rock outcrops. On the soil map they are presented as an elongated shape, reflecting the crests and most unstable parts of the landscape. There is no regionalized distribution, occurring throughout the Brazilian territory. Regolitic Neosols are also common in Brazil as a whole. However, extensive areas occur in the semi-arid region of the Northeast. The highest occurrences of Quartzarenic Neosols are in the states of São Paulo, Mato Grosso do Sul, Mato Grosso, west and north of Bahia, south of Pará, south and north of Maranhão, in Piauí and Pernambuco, in predominantly flat relief. Fluvic Neosols rarely occupy appreciable continuous areas, as they are restricted to the banks of watercourses, lagoons and coastal plains where they generally occupy small portions of the floodplains (EMBRAPA, 2002).

They are poorly drained, with a surface horizon with a lighter texture, generally sandy, which contrasts abruptly with the subsurface horizon immediately underlying, dense and extremely hardened when dry, usually with a high concentration of clay, well structured and very slow permeability, showing visible signs of hydromorphism. These soils occur predominantly in areas of flat or smooth undulating relief, widely used with irrigated rice (EMBRAPA, 2002).

Vertosols These are grayish or black soils, with no significant difference in clay content between the superficial and subsurface part of the soil. However, the most important characteristic is the pronounced change in volume with the variation of moisture content due to the high content of expansive clays (high activity clay), having as a characteristic and easily identifiable morphological feature, the presence of wide and deep shrinkage cracks that open from the soil surface in dry periods. They have high chemical fertility, but present physical problems (EMBRAPA, 2002).

Plintosols They have a very large morphological and analytical diversification, however, the most important characteristic of these soils is the presence of reddish spots or mottled (plinthite), usually composing a tangle of colors well contrasting with the soil matrix, which may or may not contain nodules or concretions (petroplintite), which are made up of a mixture of clay, low in organic carbon and rich in iron, or iron and aluminum, with quartz and other materials. They are often acidic and have low nutrient reserves. They are found in flat and smooth undulating relief, in depressed areas, alluvial plains and lower thirds of the slope, situations that imply the slow runoff of water from the soil. Plintosols with a predominance of nodules or concretions (Plintosols, Pétric) (EMBRAPA, 2002).

5.2 STEP 2 - CHARACTERIZATION OF SOIL TYPES AS TO THEIR RUNOFF AND DRAINAGE POTENTIAL

The first soil property considered for the construction of vulnerability profiles was hydraulic conductivity, which can be understood as the ability of the soil to drain any surface water. This property defines the time that pesticides remain in the soil. The greater or lesser speed of water flow leads to the pesticides eventually dissolved in it.

Based on the relationship found by Gomes (1996), Pessoa (2006) and Barbalho (2010) between the types of soil and their potential for hydraulic conductivity, it was possible to categorize the potential for hydraulic conductivity based on the type of soil existing in Petrolina (Table 17).

Table 17

Types of soils found in Petrolina-PE and their potential for hydraulic conductivity

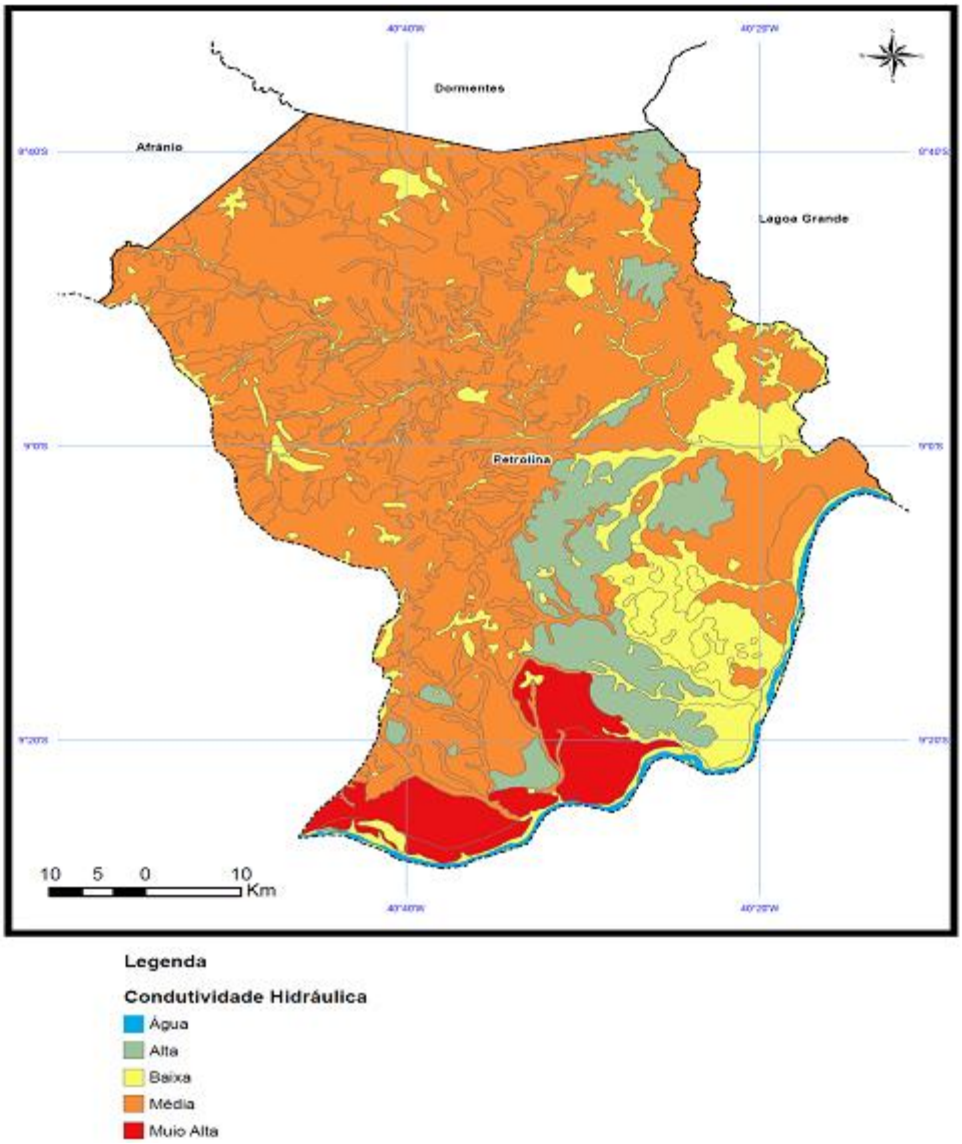
Soil in Petrolina	Hydraulic Conductivity
Yellow Ultisol	Average
Red Ultisol	Average
Yellow Red Ultisol	Average
Cambisol	low
Yellow Latosol	discharge
Luvissolo	low
Fluvic Neosol	low
Lithic Neosol	low
Regolitic Neosol	low
Quartzarencian Neosols	Very high
Haplic Planosol	low
Haplic Planosol and Nautical Planosol	low
Vertisol	low

Source: Gomes (2006); Pessoa (2006); Barbalho (2010).

The typified distribution of the soil in the Petrolina region and its potential for hydraulic drainage is shown in Figure 9. It was possible to observe regions with low, medium to very high predispositions to water transfer towards the local underground aquifer.

Figure 9

Hydraulic Conductivity Potential for the soils of Petrolina-PE



Source: The thematic maps were generated using the databases compiled from EMBRAPA, SRHE and IBGE, acquired by ITEP, and converted to the projection and adopted Datum. Based on the digital model of the terrain obtained from the SRTM (SHUTTLE Radar Topographic Mission), made available by the ITEP Geoinformation Unit.

Most of the soils of Petrolina, represented in orange, presented a medium hydraulic conductivity potential (infiltration), which led to categorizing the region as a medium vulnerability to contamination of groundwater resources.

The regions represented in yellow presented the lowest infiltration potentials and, therefore, would be more protected soils, that is, they do not pose a great danger to the contamination of groundwater resources.

In the case of soils in the southernmost regions of the municipality of Petrolina, represented in red, they were more vulnerable to contamination of groundwater resources, due to their high drainage capacities.

Another important aspect to be considered to predict the potential for contamination of underground aquifers by pesticides is the percentage of soil slope. This percentage can estimate the tendency of pesticide transport from water to the soil, and consequently its diffusion in water bodies.

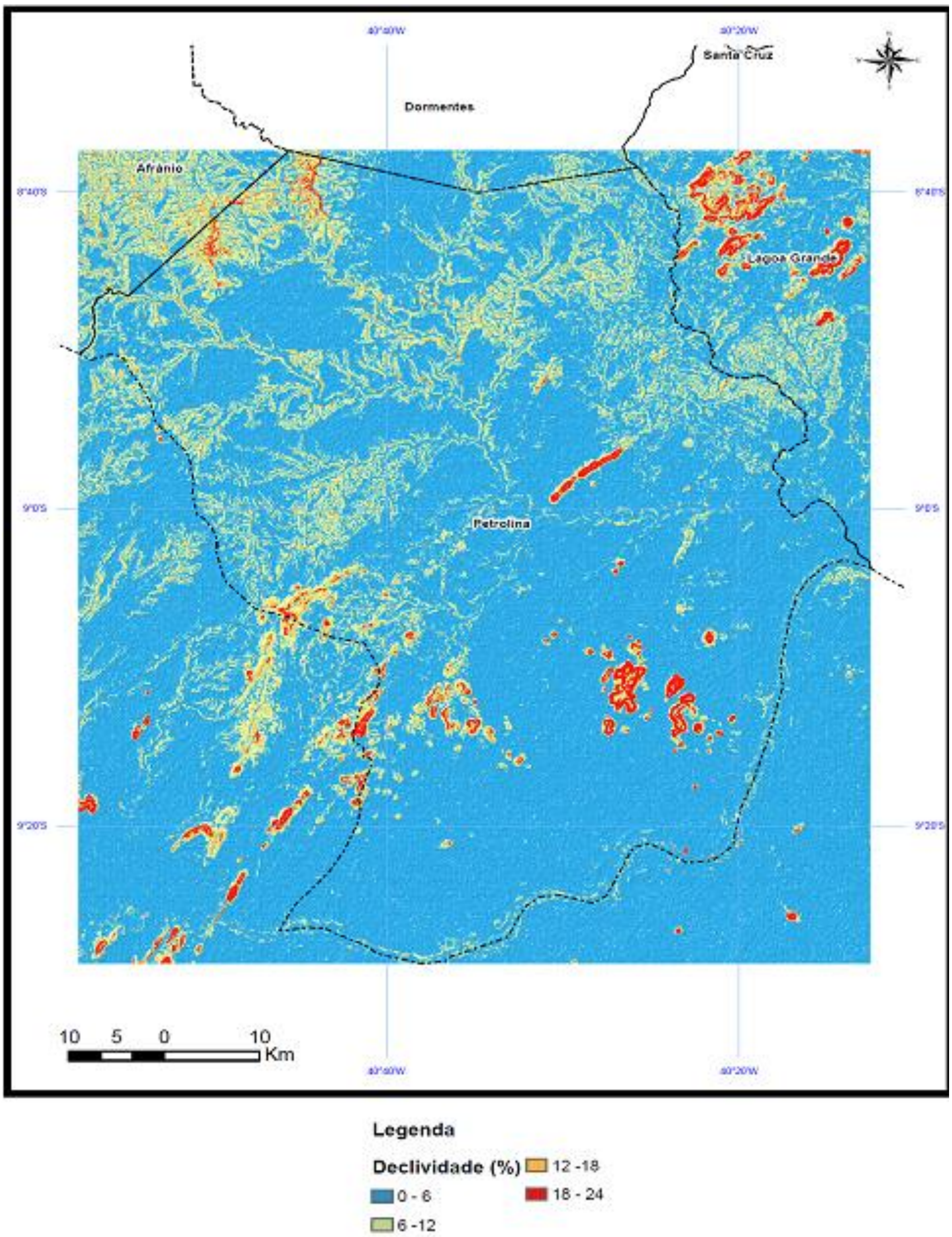
For the Petrolina region, it was possible to point out four categories of soil slopes: a) Soils with low slope (0 to 6%); b) gentle slope soils (6 to 12%); c) soils of moderate slope (12 to 18%); and d) soils with high slope (18 to 45%). This last category is taken as uninteresting, because although they have a high potential for contamination, in this study they would not make a difference since they would hardly be intended for agricultural practices (Figure 10).

The parameters used to create criteria for evaluating the vulnerability of soils to pesticide contamination showed the existence of soils that are more vulnerable to contamination by infiltration and/or surface runoff.

The infiltration potential classified as "high" and "very high" (due to hydraulic conductivity and low slope) indicates high vulnerability of the land to groundwater contamination, with the possibility of the contamination product reaching the deepest water bodies. The runoff potential classified as "very high" and "high" indicates that the lands are more vulnerable to erosion and contamination of surface water bodies. Subsequently, the vulnerability of the land to pesticide contamination was classified due to the integration of information on soil hydraulic conductivity, terrain slope, infiltration potentials and surface water runoff. The vulnerability classes of the established lands were as follows: "very high", "high", "moderate", "low".

Figure 10

Spatialization of soil slope in the municipality of Petrolina-PE



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Two very extreme examples can be used to exemplify such typification:

1) Soils that have high drainage and low slope: In this case, the waters do not runoff due to the low slope of the soil, tending to accumulate on its surface, therefore, due to the high hydraulic conductivity, the tendency is to diffuse into the groundwater, taking with it any residues of dissolved pesticides. The conclusion would be a terrain of high vulnerability to contamination by infiltration;

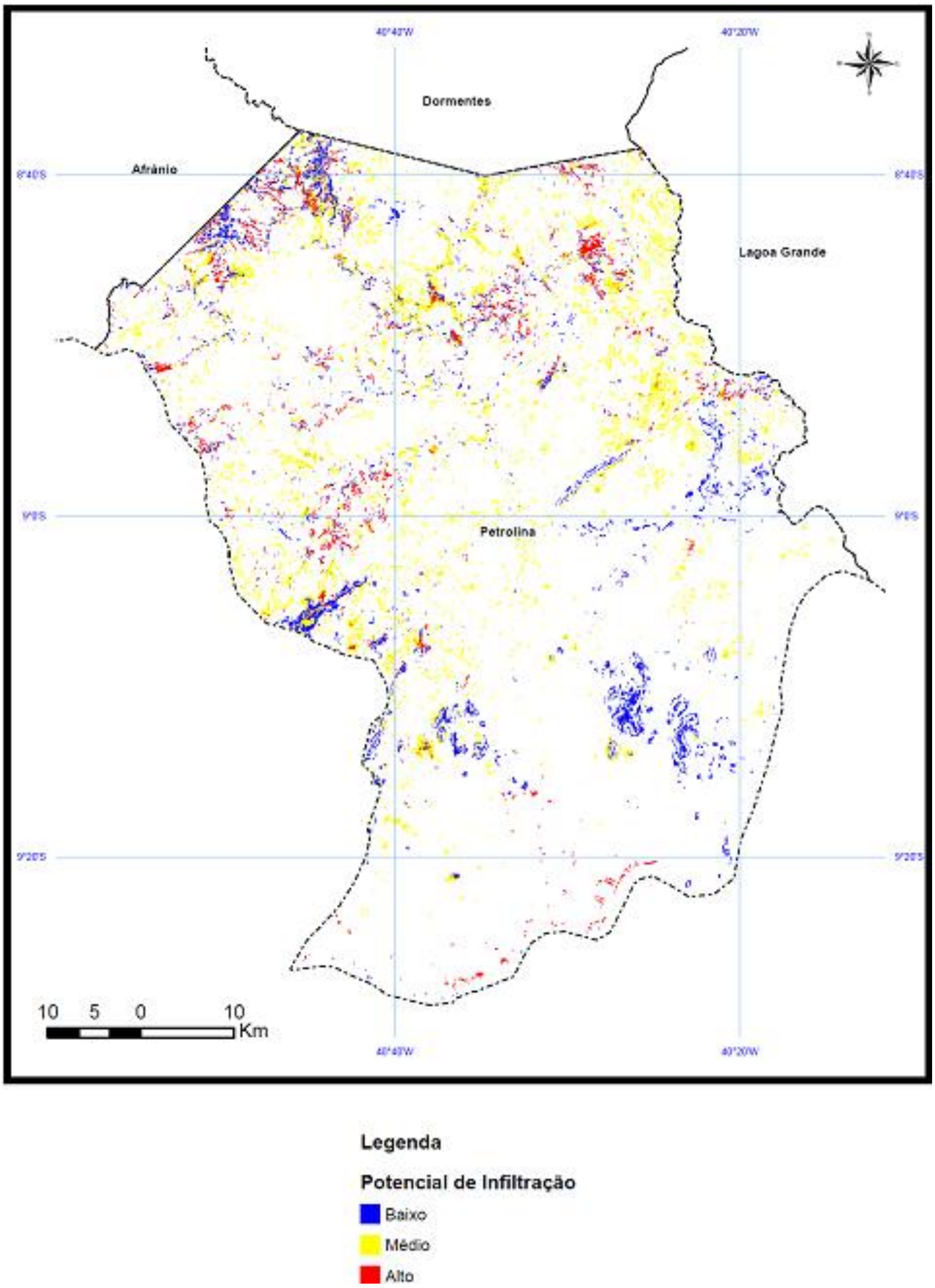
2) Soils that have low drainage and high slope: In this soil profile, the waters do not infiltrate the soil due to low hydraulic capacity, tending to suffer runoff due to its high slope, reaching adjacent water resources such as rivers, streams, dams, etc. They are highly vulnerable to contamination by surface runoff.

5.4 STAGE 3 - CONSTRUCTION OF THEMATIC MAPS FOR POTENTIAL CONTAMINATION TO HIGHLIGHT CRITICAL REGIONS OF CONTAMINATION

Once the soil/water contamination indicators were established, it was possible to point out regions with potential for environmental contamination. The profiles created combining information on slope and soil type, and hydraulic conductivity allowed categorizing regions with high, low and medium potential for contamination of water resources by infiltration (groundwater) and surface runoff (surface water) (Figure 11 and Figure 12).

Figure 11

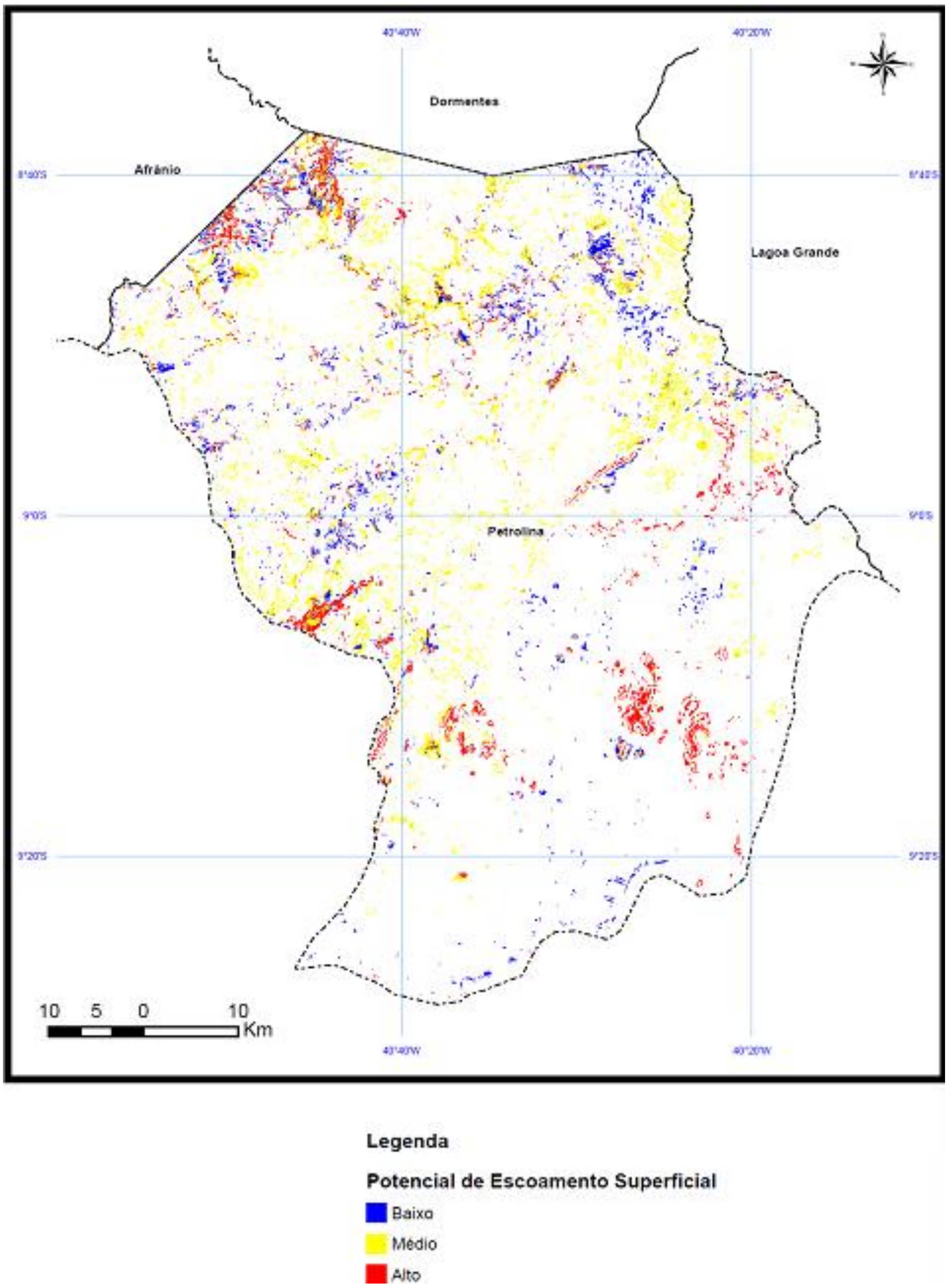
Regions with potential for contamination by infiltration in the municipality of Petrolina-PE



Source: The thematic maps were generated using the databases compiled from EMBRAPA, SRHE and IBGE, acquired by ITEP, and converted to the projection and adopted Datum. Based on the digital model of the terrain obtained from the SRTM (SHUTTLE Radar Topographic Mission), made available by the ITEP Geoinformation Unit.

Figure 12

Regions with potential for contamination by surface runoff in the municipality of Petrolina



Source: The thematic maps were generated using the databases compiled from EMBRAPA, SRHE and IBGE, acquired by ITEP, and converted to the projection and adopted Datum. Based on the digital model of the terrain obtained from the SRTM (SHUTTLE Radar Topographic Mission), made available by the ITEP Geoinformation Unit.

According to Gomes et al. (2002) The infiltration potential classified as high (due to high hydraulic conductivity and the low slope of the area) indicates high vulnerability to contamination of the water compartment of the water table, with the possibility of the contamination product reaching the deepest water bodies or the saturated zone of the aquifer under discussion.

As the water table in this evaluation was replaced by the saturated zone of the Aquifer, this parameter became neutral and the emphasis was transferred to the hydraulic conductivity of the soil and the slope of the terrain. Surface runoff potential classified as high, in turn, indicates that the area is more vulnerable to erosion and contamination of surface water bodies. There will be loss of fertility and removal of pesticides from the soil compartment, via rainwater transport, to waterways.

Maps X and Y show that these soils exhibit higher values of natural vulnerability in relation to the others. This means that when exposed to a certain potentially contaminating load such as pesticides, for example, they can offer some risk of contamination to the aquifer or the water table.

Also according to Gomes et al. (2002), the potential for water infiltration in the soil classified as high indicates an environmental condition of high vulnerability of the soil in the face of the contamination load, which can be understood as a favorable condition, a priori, for the contamination of the water table. For high runoff potential (low vulnerability) the contaminant tends to flow superficially, either in suspension or adsorbed to small aggregates or clods, making the soil less exposed to the contamination condition. In this case, waterways tend to be compromised. The results presented also allow to guide rural management towards the adoption of procedures that avoid risks of contamination of the water table.

Among these procedures are the selection and application of pesticides that, preferably, are retained in the soil and that show rapid degradation. In addition to pesticides, nitrogen fertilizers should be selected, mainly aiming at greater plant efficiency in nitrogen absorption, since this element in its various transformations in the soil can generate compounds that are harmful to the environment (GOMES et al., 2002).

5.5 STEP 4 – PREDICTION OF SOIL CONTAMINATION BY PESTICIDES

Based on the evaluation of the results of pesticide residues in several fruit crops, produced in Petrolina, analyzed between 2009 and 2011, the following pesticides were selected: Acephate, Azoxystrobin, Boscalide, Carbendazin, Carbofuran, Carbosulfan, Cypermethrin, Cyproconazole, Cresoxim-methyl, Cyproconazole, Deltamethrin, Difenoconazole (1,2), Dimethoate, Dimethomorph, Famoxadone, Fenamidone, Phenarimol, Phenpyroximate, Hexitiaxxix, Imidacloprid, Iprodione, Lambda-cyhalothrin, Myclobutanil, Pyraclostrobin, Propagito, Tebuconazole, Tetraconazole, Thiamethoxam, Thiophanate methyl and Zoxamide (Table 17).

The survey found a great diversity of pesticides, with emphasis on Tebuconazole, which had a total of 11 occurrences, followed by carbedazim with 8, lambda-cyhalothrin, and Zoxamide with 7.

The knowledge of the most common pesticides in the region made it possible to know which elements were used in the various crops analyzed. From this information, the survey of their physicochemical properties allowed us to point out which pesticides had the greatest potential contaminants for different types of soil in the municipality studied.

Several studies available in the literature allow us to propose studies to evaluate how pesticides, due to physicochemical properties, can contaminate underground and surface water resources through vulnerable areas of the soil. These studies took into account the GUS and GOSS methods to evaluate the potential for contamination of groundwater and surface water, respectively, which justifies the adoption of these two parameters in the construction of soil/water contamination profiles (FILIZOLA et al., 2005; DOMINGUES, 2010; ANDRADE et al., 2011).

In order to trace the contaminating profile of the recurrent pesticides in the matrices analyzed, a survey of the physicochemical properties of these substances was carried out in terms of: Water solubility, Soil partition coefficient, and soil half-life (Table 18).

The use of these properties used in the elaboration of the GUS and GOSS profiles were discussed in the theoretical framework.

Table 18

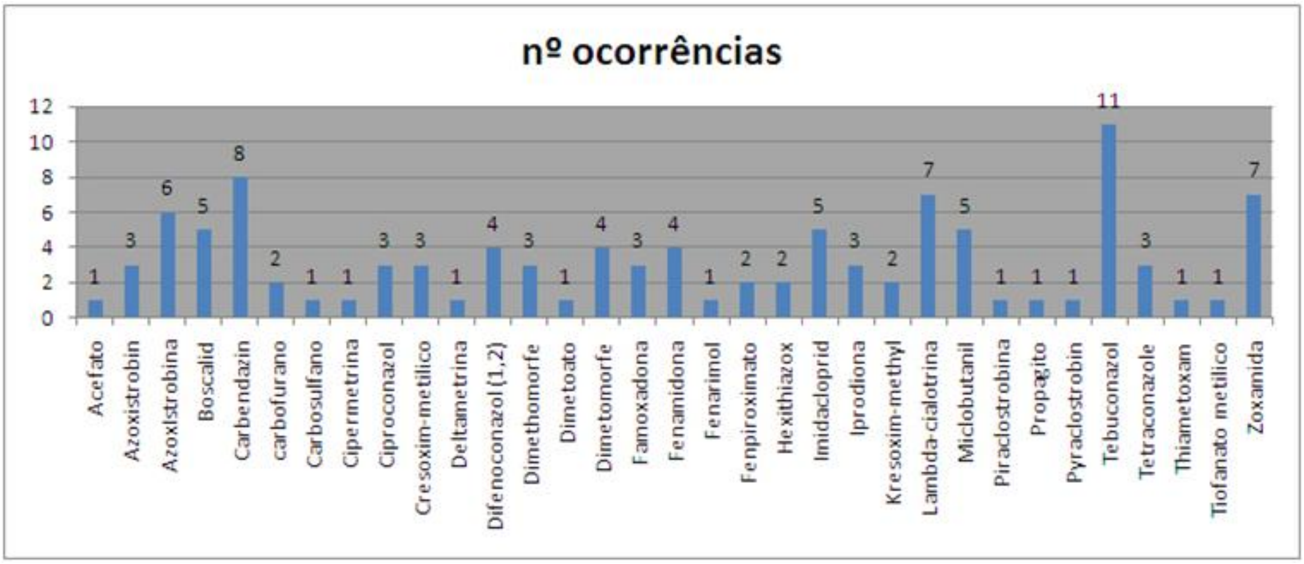
Occurrence and concentrations of recurrent pesticides in fruit samples analyzed in 2009, 2010 and 2011

Matriz	Composto	Concentração mg.kg^{-1}	Matriz	Composto	Concentração mg.kg^{-1}	Matriz	Composto	Concentração mg.kg^{-1}
Acerola	carbofurano	0,02	Uva	Thiametoxam	0,01	Uva	Zoxamida	0,3
Goiaba	Tebuconazol	0,04	Uva	Zoxamide	0,02	Uva	Boscalida	0,01
Goiaba	Cipermetrina	0,1	Uva	Dimethomorph	0,1	Uva	Hexithiazox	0,01
Goiaba	Dimetoato	0,1	Uva	Famoxadone	0,04	Uva	Iprodiona	0,7
Graviola	Carbendazin	0,2	Uva	Piraclostrobina	0,04	Uva	cresoxim-metilico	0,08
Mamão	Carbofurano	0,02	Uva	Tebuconazole	0,02	Uva	Lambda-cialotrina	0,01
Mamão	Carbosulfano	0,01	Uva	Zoxamide	0,02	Uva	Tebuconazol	0,02
Mamão	Imidacloprido	0,02	Uva	Fenamidone	0,02	Uva	Azoxistrobina	0,1
Mamão	Tiofanato metilico	0,01	Uva	Tebuconazole	0,09	Uva	Carbendazin	0,01
Manga	Acefato	0,01	Uva	Azoxistrobina	0,06	Uva	Ciproconazol	0,02
Manga	Carbendazin	0,6	Uva	Dimethomorfe	0,04	Uva	Difenoconazole (1,2)	0,02
Manga	Carbendazin	0,3	Uva	Lambda-cihalotrina	0,03	Uva	Boscalid	0,08
Manga	Carbendazin	0,02	Uva	Zoxamida	0,1	Uva	Fenamidona	0,8
Manga	Azoxystrobin	0,06	Uva	Boscalida	0,02	Uva	Fenarimol	0,01
Manga	Carbendazin	0,04	Uva	Tebuconazol	0,01	Uva	Fenpyroximate	0,01
Manga	Carbendazin	0,07	Uva	Imidacloprido	0,01	Uva	Hexythiazox	0,05
Uva	Famoxadona	0,08	Uva	Azoxistrobina	0,1	Uva	Kresoxim-methyl	0,02
Uva	Difenoconazol (1,2)	0,07	Uva	Boscalida	0,02	Uva	Lambda-cialotrina	0,02
Uva	Dimetomorfe	0,01	Uva	Deltametrina	0,02	Uva	Tebuconazole	0,4
Uva	Iprodione	0,4	Uva	Dimethomorfe	0,01	Uva	Tetraconazole	0,1
Uva	Cresoxim-metilico	0,05	Uva	Famoxadona	0,3	Uva	Azoxistrobin	0,02
Uva	Lambda-cialotrina	0,01	Uva	Fenamidona	0,02	Uva	Boscalid	0,3
Uva	Miclobutanil	0,3	Uva	Imidacloprido	0,01	Uva	Kresoxim-methyl	0,01
Uva	Zoxamida	1,4	Uva	Lambda-cihalotrina	0,04	Uva	Myclobutanil	0,2
Uva	Ciproconazol	0,09	Uva	Miclobutanil	0,05	Uva	Pyraclostrobin	0,02
Uva	Dimetomorfe	0,3	Uva	Zoxamida	0,3	Uva	Tebuconazole	0,07
Uva	Tetraconazole	0,01	Uva	Azoxistrobina	0,1	Uva	Imidacloprid	0,06
Uva	Carbendazin	0,5	Uva	Ciproconazol	0,06	Uva	Myclobutanil	0,04
Uva	Tetraconazole	0,01	Uva	Difenoconazol (1,2)	0,01	Uva	Azoxistrobin	0,01
Uva	Difenoconazole (1,2)	0,02	Uva	Dimetomorfe	0,2	Uva	Tebuconazol	0,01
Uva	Dimetomorfe	0,3	Uva	Fenamidona	0,1	Uva	Zoxamida	0,03
Uva	Lambda-cihalotrina	0,02	Uva	Fenpiroximato	0,01	Uva	Azoxistrobina	0,04
Uva	Miclobutanil	0,02	Uva	Imidacloprido	0,07	Uva	Tebuconazol	0,07
Uva	Tebuconazol	0,1	Uva	Iprodione	0,2	Uva	Cresoxim-metilico	0,01
Uva	Azoxlstrobina	0,06	Uva	Lambda-cyhalotrina	0,02	Uva	Tebuconazol	0,02
Uva	Propagito	0,04						

Source: For this work, data were collected from the analysis of pesticide residues from the main fruit matrices produced in Petrolina between the years 2009, 2010 and 2011, in a total of 107 samples, such as acerola, guava, mango, papaya and grape, analyzed by the Unit of Pesticides and Contaminants in Food and Alcoholic Products – LABTOX, located in Recife-PE, at the Pernambuco Institute of Technology. Labtox receives daily the most diverse fruit matrices produced by the Irrigated Fruit Growing Center of the São Francisco Valley for analysis of about 400 compounds (pesticides).

Figure 13

Frequency of occurrence of pesticides in fruit samples analyzed between 2009 and 2011



Source: Based on and constructed on the data in Table 18.

Table 19

Physicochemical properties of pesticides

Princípio Ativo	Solubilidade em água à 25 °C (mg.L^{-1})	Koc(cm^3.g^{-1})	DT_{50} no solo (dias)	GUS	Potencial de contaminação de águas subterrâneas	GOSS Potencial de contaminação de águas superficiais (Transporte pelo sedimento)	GOSS Potencial de contaminação de águas superficiais(Transporte pela água)
Acefato	818.000	2	3	1,76485721	Não sofre lixiviação	Baixo Potencial	Alto Potencial
Azoxistrobina	6	581	56	2,160452489	Faixa de transição	Médio Potencial	Alto Potencial
Boscalida	6	772	372	2,859427495	Provável lixiviação	Médio Potencial	Alto Potencial
Captana	5,1	200	2,5	0,676088138	Não sofre lixiviação	Baixo Potencial	Alto Potencial
Carbaril	120	300	10	1,522878745	Não sofre lixiviação	Baixo Potencial	Alto Potencial
Carbendazin	8	400	120	2,906570649	Provável lixiviação	Médio Potencial	Alto Potencial
Carbosulfano	0,3	4,41	5	2,345436774	Faixa de transição	Médio Potencial	Alto Potencial
Cpermetrina	0,004	100.000	30	-1,477121255	Não sofre lixiviação	Médio Potencial	Baixo Potencial
Cyproconazole	140	900	129	2,207164999	Faixa de transição	Médio Potencial	Alto Potencial
Ciromazina	136.000	200	150	3,697113776	Provável lixiviação	Médio Potencial	Alto Potencial
Deltametrina	0,2	10.240.000	25	-4,208218747	Não sofre lixiviação	Médio Potencial	Baixo Potencial
Difenoconazol (1, 2)	15	3495	145	0,986778656	Não sofre lixiviação	Alto Potencial	Alto Potencial
Dimetoato	39.800	20	7	2,280894261	Faixa de transição	Baixo Potencial	Alto Potencial
Dimetomorfe	19	402	117	2,886719943	Provável lixiviação	Médio Potencial	Alto Potencial
Fenamidona	7,8	388	8,5	1,311566502	Não sofre lixiviação	Baixo Potencial	Alto Potencial
Fenarimol	14	600	360	3,123415014	Provável lixiviação	Médio Potencial	Alto Potencial
Fenpropatrina	0,33	5000	5	0,210410937	Não sofre lixiviação	Médio Potencial	Baixo Potencial
Fenpiroximato	$1{,}46 \cdot 10^{-2}$	9.995	50	0,000369019	Não sofre lixiviação	Alto Potencial	Alto Potencial
Hexitiazoxe	0,5	6200	30	0,306662648	Não sofre lixiviação	Médio Potencial	Médio Potencial
Imidacloprido	0,61	310	1	0	Não sofre lixiviação	Baixo Potencial	Alto Potencial
Iprodione	13,9	700	14	1,323665515	Não sofre lixiviação	Baixo Potencial	Alto Potencial
Cresoxim-metilico	2	372	1	0	Não sofre lixiviação	Baixo Potencial	Alto Potencial
Lambda-cialotrina	0,005	180.000	30	-1,854189698	Não sofre lixiviação	Médio Potencial	Baixo Potencial
Miclobutanil	142	500	66	2,367281239	Faixa de transição	Médio Potencial	Alto Potencial
Propargito	0,5	4000	56	0,695673959	Não sofre lixiviação	Alto Potencial	Médio Potencial
Praclostrobina	1,9	11.000	32	-0,062302199	Não sofre lixiviação	Médio Potencial	Médio Potencial
Tebuconazol	36	1000	7	0,84509804	Não sofre lixiviação	Médio Potencial	Alto Potencial
Tiabendazol	50	2500	403	1,568549933	Não sofre lixiviação	Alto Potencial	Alto Potencial
Tiametoxan	4100	64	51	3,746101648	Provável lixiviação	Médio Potencial	Alto Potencial
Tiophanate metilico	3,5	1830	10	0,73754891	Não sofre lixiviação	Médio Potencial	Médio Potencial
Zoxamida	0,681	1224	2	0,274605156	Não sofre lixiviação	Médio Potencial	Médio Potencial

T50: half-life; KOC: coefficient of adsorption to organic matter; S: Water solubility
Source: PAN, 2014; EXTOXNET, 2014; NPIC, 2014; EMBRAPA, 2006.

5.5.1 Potential for groundwater contamination – GUS method

The parameter used takes into account two parameters: The half-life of the pesticide in the soil (DT50soil) and the Koc soil sorption coefficient, thus, according to the GUS parameter, the pesticides found in the analyzed crops were categorized in terms of high, low and medium leaching potential and groundwater contamination, They were:

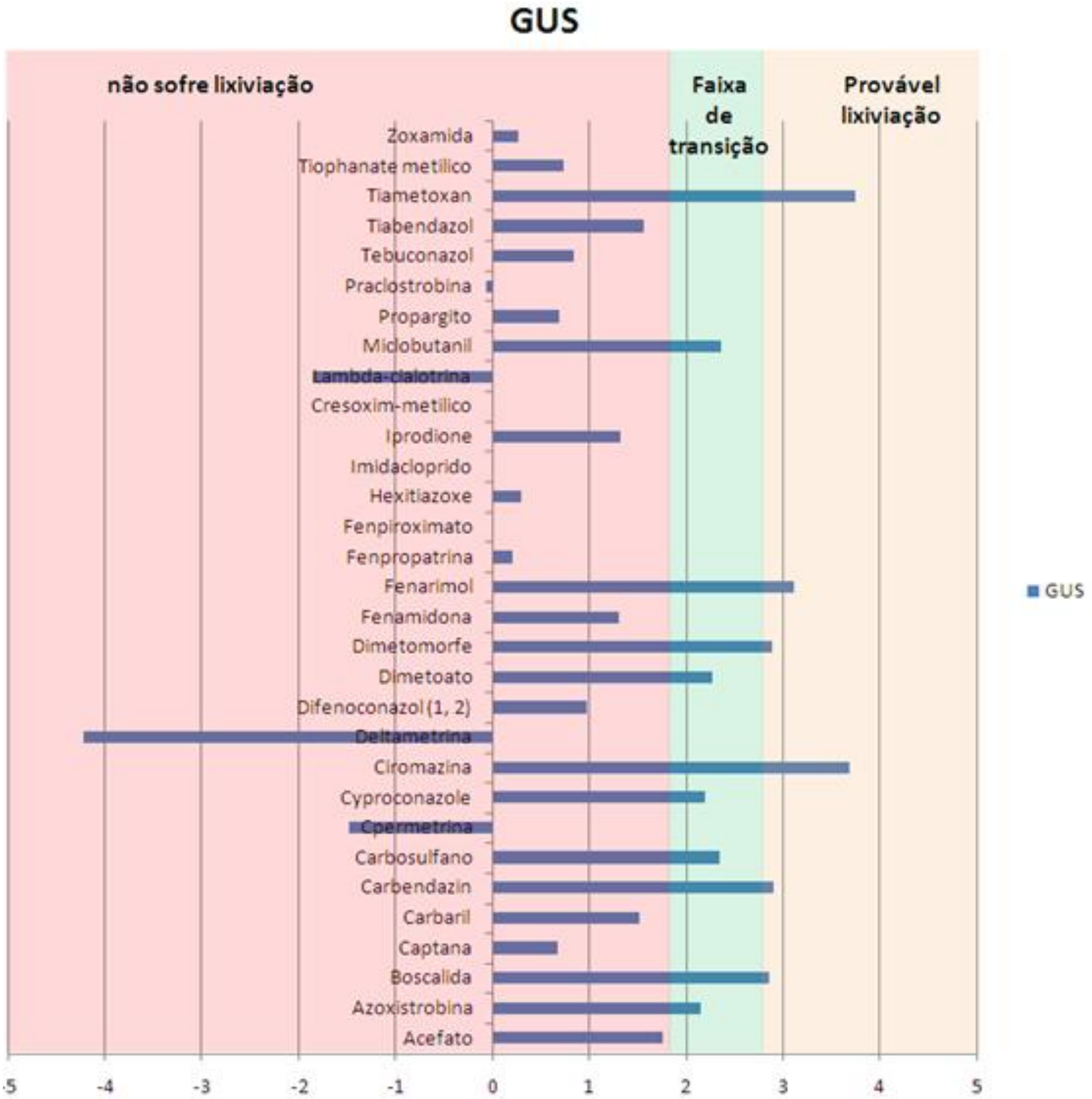
a) High leaching potential: Boscalide, Carbendazin, Dimethomorph, Fenarimol and Thiamethoxam.
b) Medium leaching potential: Azoxystrobin, Dimethoate, carbosulfan, Cyproconazole, Dimethoate, myclobutanil and Propargite.
c) Low leaching potential: Acephate, captan, carbaryl, Cypermethrin, Deltamethrin, Difenoconazole (1,2), Fenamidone, Fenarimol, Phenpropatrin, Phenpyroximate, Hexiathiazoxe, Imidacloprid, Iprodione, Cresoxim-methyl, Lambda-cyhalothrin, Pyraclostrobin, Propagite, Tebuconazole, Thiabendazole, Methyl thiophanate and Zoxamid.

It is noteworthy that although Tebuconazole is the agortoxic with the highest incidence, it has a small potential for contamination of groundwater, although Carbedazin, the second, has a high potential for contamination. The other pesticides that showed high contamination potential Boscalide, Dimethomorph, Fenarimol and Thiamethoxam had few incidences and therefore reflects a probable low contamination even none by these compounds. It should be noted that the indiscriminate use of these compounds, according to the GUS method, will result in a high possibility of contamination of underground aquifers.

Of those with medium potential for contamination, only myclobutanil had a higher incidence (5) the others had a low incidence with only 1 to 3 samples. The following is the graph of the distribution of contaminant ranges according to the GUS method (Figure 14)

Figure 14

Graph with GUS Index for recurrent pesticides in the municipality of Petrolina - PE



Data contained in Table 19
Source: PAN (2014); EXTOXNET (2014); NPIC (2014); EMBRAPA (2006).

5.5.2 Potential for contamination of surface waters – GOSS method

The data in Table 19 were also used to estimate the potential of pesticides to contaminate surface water, whether dissolved or associated with sediment by the GOSS method. In this method, in addition to the properties used in the GUS method, the solubility of the pesticide in water is taken into account. Thus, the classification by the GOSS method follows bands in the properties of the compounds (Table 20). Also according to the method, it should be noted that if the compound is left out of these criteria, it will be considered of medium potential.

Table 20

Pesticides and transport potential associated with sediment and transport dissolved in water

Sediment-associated transport potential				
	DT50solo(d)	**KOC (mL.g-1)**	**S(mg. L-1)**	**Pesticides**
High potential	≥ 40 ≥ 40	≥ 1000 ≥ 500	- ≤ 0,5	Difenoconazole (1,2), Phenopyroximate, Propargite, and Tebuconazole
Medium potential	Do not fall into any of the ranges			Azoxystrobin, Boscalide, Carbendazin, Carbosulfan, Cypermethrin, Cyproconazole, Deltamethrin, Dimethomorph, Phenarimol, Imidacloprid, Hexithiazone, Lambda-Cyhalothrin, Myclobutanil, Pyraclostrobin, Tebuconazole, Thiamethoxan, Thiophanate methyl and Zoxamide.
Low potential	< 1 ≤2 ≤4 ≤ 40 ≤ 40	- ≤ 500 ≤ 900 ≤ 500 ≤ 900	- - ≥ 0,5 ≥ 0,5 ≥2	Acephate, captan, Carbaryl, Cresoxim-methyl, Phenamidone, Dimethoate Imidacloprid and Iprodione.
Transport potential dissolved in water				
	DT50solo(d)	**KOC (mL.g-1)**	**S(mg. L-1)**	**Pesticides**
High potential	> 35 < 35	< 100,000 ≤ 700	≥1 ≥ 10 and ≤ 100	Acephate, Azoxystrobin, Boscalide, Carbendazin, captan, Carbaryl, Carbendazin, carbosulfan, Ciproconazole Difenoconazole(1,2),Dimethoate,Dimethomorph, Fempyroximate,Fenamidone, Phenarimol, Imidacloprid, Iprodione, Cresoxim-methyl,, Myclobutanil, Tebuconazole, Thiabendazole and Thiamethoxam.
Medium potential	Do not fall into any of the ranges			Hexathiazox, Propagito, Pyrostrobin, Methyl Thiophanate and Zoxamide.
Low potential	- ≤1 < 35	≥ 100.000 ≥ 1000 -	- - < 0.5	Carbosulfan, Cypermethrin, Deltamethrin, Lambda-Cyhalothrin, and Phenpropatrine

Source: PAN (2014); EXTOXNET (2014); NPIC, (2014); EMBRAPA, (2006).

From the results presented it can be observed that Tebuconazole presented a high potential for contamination of surface water both in transport associated with sediment and in water, which suggests contamination of exposed aquifers such as rivers, dams, streams, etc. Such a result contradicts its low potential for contamination of groundwater aquifers pointed out by the GUS method.

The second compound in occurrences was carbedazim, which had a medium transport potential associated with the sediment, but high transport in water.

The pesticides with the highest potential for contamination by transport associated with the sediment were: Difenoconazole (1,2), Phenopyroximate, Propargito, all with a low number of occurrences in addition to Tebuconazole. Such deposits must be avoided at all costs in regions vulnerable to contamination by surface runoff.

According to the results, there was a great variability of compounds with high potential for contamination by transport associated with water, which were: Acephate, Azoxystrobin, Boscalide, Carbendazin, captan, Carbaryl, Carbendazin, carbosulfan, Cyproconazole, Difenoconazole (1,2), Dimethoate, Dimethomorph, Fempyroximate, Fenamidone, Phenarimol, Imidacloprid, Iprodione, Cresoxim-methyl, Myclobutanil, Tebuconazole, Thiabendazole and Thiamethoxam. waters contaminating rivers, lakes, etc.

The spatialization of the potential for environmental contamination of the soils of the Petrolina region by infiltration (Figure 13) allowed us to infer that the regions with high infiltration potential consequently presented high vulnerability to the compounds Boscalida, Carbendazin, Dimetomorph, Fenarimol and Thiamethoxam, all with GUS index in the leachable range. These compounds showed a solubility in water between 6 and 19 mg. L-1 and Koc between 400 and 800 cm3/g, except for the compound Thiamethoxam which showed solubility (4100 mg. L-1), above the range found, and Koc of 64 cm3.g-1, below the range for this group of pesticides. Due to the combination of high water solubility and low soil retention, this suggests a high mobility of this compound in soil and water.

On the other hand, the compounds Acephate, captan, carbaryl, Cypermethrin, Deltamethrin, Difenoconazole (1,2), Fenamidone, Phenarimol, Phenpropatrin, Phenpyroximate, Hexiatiazoxe, Imidacloprid, Iprodione, Cresoxim-methyl, Lambda-cyhalothrin, Pyraclostrobin, propagite, Tebuconazole, Thiabendazole, Methyl thiophanate and Zoxamide, all with GUS parameters in the non-leachable range, do not confer contamination potential to regions with high infiltration potential. These compounds presented a wide range of solubility and koc values, from 0.004 to 15 mg. L-1e of 1,200 and 180,000 cm3.g-1, respectively. Regions whose soils presented low hydraulic conductivity and low slope, although not vulnerable to contamination by infiltration, may have contaminated soil, to the extent that, once exposed to pesticides whose profiles associate low solubility in water in addition to high Koc value, which gives them high sorption capacity to the soil, they are not leachable.

The compound Tebuconazole presented solubilities of 36 mg. L-1, above the range found in the group of non-leachable compounds. Tebuconazole showed a 7-day T50 in the soil suggesting rapid degradation.

In the case of Acephate, although it has a very high solubility (S = 818,000 mg. L-1), low sorption potential in the soil (Koc = 2 cm3.g-1) which suggests high mobility in water, its half-life in the soil of the order of 3 days, suggesting that it has a rapid degradation, not presenting a risk of contamination for the water table of the region.

It is also considered that the compounds Azoxystrobin, Dimethoate, carbosulfan, Cyproconazole, Dimethoate, myclobutanil and Propargite have a medium potential for groundwater contamination.

Figure 14 shows regions that may present high surface runoff potentials. In the soils of these regions, the vulnerability to the contaminant points to the pesticides: Difenoconazole (1,2), Phenopyroximate, Propargite and Tebuconazole, suggesting the easy diffusion of these compounds in water bodies, as they have a high potential for contamination whose transport is associated with the sediment. Such behavior can be evidenced by high Koc values of 3495, 9995, 4000 and 14000 cm3. g-1, which can be translated as a greater tendency to attach to sediments. In this way, very leachable soils with a high concentration of organic matter combined with these compounds translate high potential to rivers, streams, dams, etc.

The compounds Acephate, Azoxystrobin, Boscalide, Carbendazin, captan, Carbaryl, Carbendazin, carbosulfan, Cyproconazole, Difenoconazole (1,2), Dimethoate, Dimethomorph, Fempyroximate, Fenamidone, Phenarimol, Imidacloprid, Iprodione, Cresoxim-methyl, Myclobutanil, Tebuconazole, Thiabendazole and Thiamethoxam were categorized using the GOSS method as having a high potential for environmental contamination of surface waters, and transport is associated with water.

Difenoconazole (1,2), Fenpyroximate and Thiabendazole showed a high potential for contamination associated with transport in sediment or water. These pesticides have solubility of 15, 0.0142 and 50 mg. L-1, which is associated with water transport, and Koc of 3495.9995 and 2500 cm3/g, associated with sediment transport. What will define the mechanism of pesticide transport in the environment, in this case will be the soil itself, that is, leachable soils with a high concentration of organic matter will tend to transport pesticides via sediment and poorly leachable soils with low concentration of organic matter should transport these solubilized compounds in water.

The compound Fenpyroximate showed a low solubility in water, suggesting a greater tendency of transport associated with the sediment.

The following compounds presented an average contamination profile: Azoxystrobin, Boscalide, Carbendazin, carbosulfan, Cypermethrin, Cyproconazole, Deltamethrin, dimethomorph, Phenarimol, Imidacloprid, Hexithiazone, Lambda-cyhalothrin, Myclobutanil, Pyraclostrobin, Tebuconazole, Thiamethoxan, Methyl thiophanate and Zoxamide, all with transport associated with the sediment and Hexathiazox, Propagito, Pyraclostrobin, Thiophanate methyl and Zoxamide associated with transport solubilized in the water itself.

The presentation of the contamination profiles by the GOSS method can be interpreted as a portrait of the physicochemical properties of pesticides, therefore, compounds may present different transport profiles of the associated pollutant, either in the sediment or solubilized in the water. An example of this profile is the compound Acephate, which presented low contamination potential, whose transport is associated with sediment, and high contamination potential, whose transport is solubilized in water. An analysis of the compost properties reveals a low Kocsolo value (2cm3.g-1), which can be translated as low ability to associate with the soil and therefore the sediment, as well as a high solubility value (818000g. L-1) suggesting a high solubility in water.

Floods of water in poorly drained soils near surface aquifers combined with pesticides that meet the GOSS criterion result in contaminating conditions of rivers, streams, streams, dams, etc.

The planning of the use of pesticides must take into account the compost itself and the place of use, since the inadequate association of these actors can result in islands of contamination, causing disastrous consequences to the environment.

6 CONCLUSIONS AND FINAL CONSIDERATIONS

1) The analyses presented detected several types of pesticides in different crops, such information demonstrates an agricultural practice with intense and diversified use of these compounds in the municipality of Petrolina;
2) The mere presence of pesticides in crops does not mean that there is local contamination in terms of natural resources, but it can be taken as an indicative parameter;

3) Once evidence of the use of pesticides in agriculture was established, it was possible to diagnose the diffusion of these compounds in the environment. The information on soil types, slope and hydraulic conductivity served to outline a profile of the regions potentially vulnerable to pesticide contamination in the municipality of Petrolina;
4) The survey of physicochemical properties of pesticides were fundamental to establish the mobility behavior of products in natural resources (water and soil) and combined resulted in two theoretical parameters: GUS and GOSS that estimate the potential for contamination of groundwater and surface water respectively;
5) The compounds Boscalide, Carbendazin, Dimethomorph, Fenarimol and Thiamethoxam have a high profile of groundwater contamination, and should be avoided especially in leachable soils with high drainage capacity;
6) The compounds have a high potential for contamination of surface waters: Difenoconazole (1,2), Phenopyroximate, Propargite and Tebuconazole transported associated with the sediment and Acephate, Azoxystrobin, Boscalide, Carbendazin; captan, Carbaryl, Carbendazin, carbosulfan, Cyproconazole, Difenoconazole(1,2), Dimethoate, Dimethomorph, Fempyroximate, Fenamidone, Phenarimol, Imidacloprid, Iprodione, Cresoxim-methyl, Myclobutanil, Tebuconazole, Thiabendazole, and Thiamethoxam whose transport is associated with water. Such compounds should be avoided especially in poorly drained soils with medium to high slope whose regions are close to water resources such as dams, lakes, rivers, etc.;
7) The combination of soil vulnerability data with the properties of pesticides showed that it is possible to point out, in a preliminary way, regions of contamination for different pesticides;
8) The combination of spatial data with chemical properties can point to more rational practices where crop/environment/pesticide should be thought of as a set;
9) The work, although it was a preliminary evaluation not taking into account more specific aspects of the soils such as organic matter, pH, ion exchange, etc., allowed the creation of a database in which it was possible to cross spatial information with physicochemical parameters of pesticides. The result was a

mapping of regions vulnerable to a certain type of compost, and the way in which the contamination will occur (infiltration, surface runoff or soil retention).

Such aspects incorporated into agricultural practices can generate more rational activities in which certain types of pesticides, potentially contaminating, could be replaced according to the geography of the region.

The survey served as a basis for identifying the most recurrent pesticides in various crops in the municipality of Petrolina. Such data can be used in new works, making it gain more information, enriching the Geographic Information System.

Finally, it should be noted that the samples showed a very worrying practice, since the municipality of Petrolina is a reference in fruit production: that there is an intense use and great variability of pesticides and that several water resources/soils may be contaminated, which requires an intense study in order to monitor the resources.

All work to guide planned practices is timely and should be encouraged.

7 SUGGESTIONS FOR FUTURE WORK

1) With the maps generated, study the presence of the pesticides mentioned in surface and underground water resources and in the soil;
2) Study the different types of soil and their organic composition confronting with GUS/GOSS potential data for soil fixation;
3) Studies of each type of soil, deepening aspects of pesticide speciation (ionic form and pH), which will bring more information to the GIS;
4) Monitoring of the waters present in the municipality in terms of contamination by pesticides.

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