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USE OF MOHID PLATFORM IN THE SIMULATION OF THE WATER TRANSPORT OF CONTAMINANTS IN THE CORN PLANTATION IN VARRE-SAI, RJ

USO DA PLATAFORMA MOHID NA SIMULAÇÃO DO TRANSPORTE HÍDRICO DE CONTAMINANTES NO CULTIVO DE MILHO EM VARRE-SAI, RJ

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ABSTRACT

Seeking to increase agricultural production and, at the same time, concern for the environment, this work seeks to use the MOHID Land platform coupled with the SWAT model to demonstrate the feasibility of applying such software to study the transport of contaminants in water environments. To this end, a simulation of a corn plantation was developed at the Panorama site, in the municipality of Varre-Sai, Rio de Janeiro. It was concluded that the MOHID Land platform can be used to study the transport of contaminants in water bodies, being a management tool and decision-making aid for engineers and public entities seeking to adopt measures to control pollution in the environment.

Keywords: Agriculture; corn; pollution.

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RESUMO

Buscando o aumento da produção agrícola e, ao mesmo tempo, a preocupação com o meio ambiente, esse trabalho busca utilizar a plataforma MOHID Land acoplada ao modelo SWAT para demostrar viabilidade de aplicação de tais softwares no estudo do transporte de contaminantes em meios hídricos. Para isso, foi desenvolvida uma simulação de uma plantação de milho no sítio Panorama, região do município de Varre-Sai, Rio de Janeiro. Concluiu-se que a plataforma MOHID Land pode ser utilizada para o estudo do transporte de contaminantes nos corpos hídricos, sendo uma ferramenta de gestão e auxílio a tomada de decisão para engenheiros e entidades públicas que buscam adotar medidas de controle da poluição ao meio ambiente

Palavras-chave: Agricultura; milho; poluição.

1. INTRODUCTION

It is a challenge faced across the world in diverse river basins meeting society's growing food production needs while maintaining or improving water quality. In many nations, the agricultural norm is for farmers to dictate what, when, and where to plant based on market demand and the most economically efficient use of land resources for each individual agricultural enterprise (Jiang, 2021).

Brazil is one of the largest agricultural exporters in the world, and also the world's main exporter of soybeans, orange juice, sugar, meat, coffee, tobacco and ethanol. It is also the second largest exporter of corn and the third of cotton. The Brazilian agricultural system was oriented towards the acquisition of machinery and equipment, and the stimulation of the use of modern inputs. There was major investment in innovative agricultural research. This allowed the country to meet a broad export demand, while still supplying the domestic market (Luna; Klein, 2019).

Because of the modernization of practices and the increase in plantations, the use of fertilizers has increased, which can generate pollution in the soil and water resources. To maintain production and reduce the use of fertilizers in the soil, software-based simulation techniques can be used. These can predict the behavior of plantation growth and harvest cycles, and the movement of water resources in the soil, which carry agricultural inputs. With this resource, it is possible to create solutions for the pollution of water resources and the transport of contaminants, as well as understanding the water consumption by the vegetation.

Acidification and contamination of water resources by ammonia are currently recognized as serious environmental problems (Longhini *et al*., 2024; Mazur et al., 2016; Rodhe, 1989). In particular, concentrations of ammonium nitrate have already been observed in river water, in non-compliance with class 02, which is defined for surface water resources with fresh waters, with salinity equal to or less than 0.5‰ (percent per thousand) destined supply for human consumption, after conventional treatment (CONAMA, 2005; Gomes; Barizon, 2014). It is noteworthy that pollution of surface and groundwater caused by agriculture is a global problem (Sandu *et al*., 2022; Zhang et al., 2017), but this ammonia pollution is also observed in saline waters (Asih et al., 2022).

Among the objectives for sustainable development, of the United Nations, number 6, “Drinking water and sanitation”, seeks the equal availability of clean water and basic sanitation among all populations on the planet. In order to meet this objective, by 2030, investment will be necessary to promote the maintenance and restoration of water quality (UN, 2015).

According to the UN (2024), currently, 2.4 billion people live in countries with water stress, a fact worsened by the pollution of water resources, and communities around the world are looking for ways to manage water in a more sustainable way and find new sources, in a context of climate change that increases the incidence of drought.

2. MODELLING SYSTEM: SOFTWARES TO SIMULATE SCENARIOS

Among many software that can be used to simulate the pollution of water resources, we can mention the MOHID Modeling System, which is a state-of-the-art integrated modular system, composed of a series of models that simulate surface water bodies, streams and river basins. The development of the MOHID code follows a methodology that improves its robustness in relation to programming errors. MOHID is written in ANSI FORTRAN 95, taking advantage of all of its new features, including the ability to produce object-oriented code even though it is not an object-oriented language. Includes object-oriented features. This results in a series of object-oriented models to simulate the water cycle that integrate several different scales and processes (Chambel-Leitão et al., 2007).

The MOHID platform has been developed for oceanic and hydrological applications since 1985. It is possible to carry out hydrodynamic and transport simulations in the ocean using MOHID Water and hydrological simulations on the continent using MOHID Land. The platform is offered as an open and free programming code, being produced at MARETEC at the Instituto Superior of the University of Lisbon. Currently, the MOHID programming code is sold commercially by Bentley® through the OpenFlows® Flood® interface. One of the MOHID platform interfaces was developed by Bentley® and is called OpenFlows Flood®. The OpenFlows Flood® system is commercial software that consists of an interface that allows: (i) to easily create a model using the MOHID platform codes; (ii) run the simulations and; (iii) visualize the results obtained.

The MOHID Land model simulates crop development and biomass growth, which can potentially be used to estimate ecosystem stocking rates and prevent soil degradation (Simionesei et al., 2018).

Another software used to simulate scenarios involving agricultural pollution is the Soil & Water Assessment Tool (SWAT), which consists of a model for river basins. This software requires specific information about climate, soil properties, topography, vegetation and land management practices in the basin to directly simulate physical processes associated with water movement, sediment movement, crop growth, nutrient cycling, among others. In SWAT, a basin is divided into sub-basins using topographic information. Sub-basins, in turn, are subdivided into hydrological response units, which represent a unique combination of land use, soil type and slope (Alemayehu et al., 2017; Neitsch et al., 2011).

SWAT incorporates features from several others with improvements, such as: a) simultaneous calculations in several sub-basins to predict water production in the basin; b) a groundwater component or return flow; c) a reservoir storage component to calculate the effect of agricultural ponds and reservoirs on water and sediment production; d) a meteorological simulation model incorporating precipitation, solar radiation and temperature data to facilitate long-term simulations and provide temporally and spatially representative meteorological conditions; e) improves the method for predicting runoff peaks; f) the crop growth model to account for annual variation in growth; g) a simple flood routing component; h) sediment transport components to simulate the movement of sediments through ponds, reservoirs, streams and valleys; i) calculation of transmission losses; j) the target component of a pesticide; h) SCS technology, popularly known as Curve Number, optional for estimating peak flow rates and; c) recently developed sediment production equations. These modifications expanded the model's ability to address a wide variety of watershed management problems (Neitsch et al., 2011).

It is also worth mentioning that SWAT presents a soil cover and plant growth database, which contains information necessary to simulate the planting of a specific soil cover. These parameters in the database define plant growth under ideal conditions and quantify the impact of some stresses on crop development (Neitsch, 2012). SWAT has already been used to simulate plantations in several regions, such as Ghana (Worqlul et al., 2018), Ethiopia (Wabela et al., 2022), and Kenya (Alemayehu et al., 2017).

In the integration of MOHID and SWAT, the SWAT source code was partially modified, particularly in the inputs and outputs of the model, using the MOHID code and programming philosophy. These changes maintained the integrity of the original model, thus ensuring that the results remain the same as the original version of SWAT. This allowed the results to be output in the MOHID format, enabling immediate processing with the MOHID data visualization and analysis tools (Chambel-Leitão et al., 2007).

In view of the above, the study area is Sítio Panorama, located in the municipality of Varre Sai, in the Northwest of Rio de Janeiro, Brazil, it was used as a reference for this study, as it is a property that has many bibliographic data available in function of carrying out studies and research already developed (Zanetti, 2007). The property has corn crops, even though this is not the major plantation (Maciel et al., 2012). Among the crops available in the region, corn is the one with the most studies available in MOHID Land (Ramos et al., 2018), which is why this crop was used in this work. To estimate the amount of grain in the corn harvest, it is possible to adopt the same proportion used by Song et al. (2017), that is, for every 1 unit of biomass, there are 0.8 units of grains. For calculation purposes, it can be considered that 20% of the amount of biomass would be considered as planting productivity, which would be sold for Rio de Janeiro internal food supply.

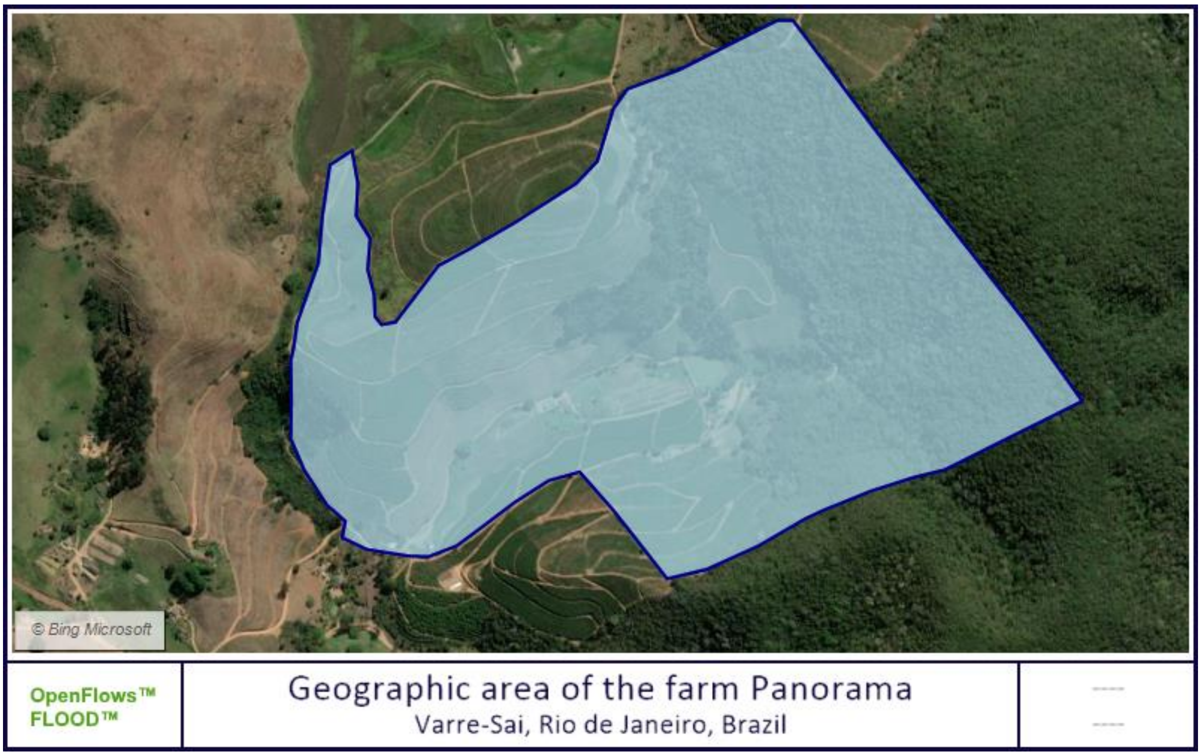
3. OBJECTIVES

The objective of this work is to understand how modeling technologies can assist engineers in contaminant management, based on the analysis of an agricultural model for corn planting formulated on the MOHID Land Platform in the municipality of Varre-Sai, Rio de Janeiro, Brazil.

4. METHODOLOGICAL PROCEDURES

Initially, it was used the website of the National Rural Environmental Registry System - SICAR (< https://www.car.gov.br/publico/imoveis/index >) to download the limits of the Panorama site in the municipality of Varre-Sai, as shown in Figure 1.

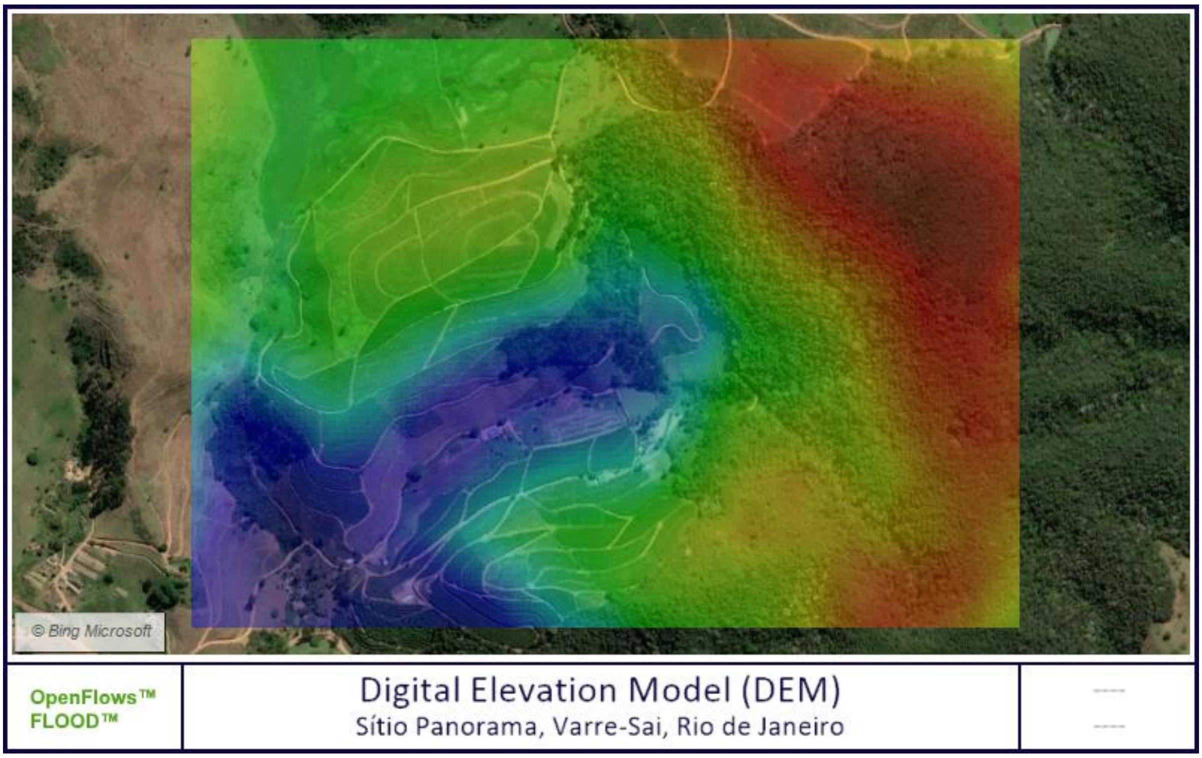
Figure 1: Geographic area of the Panorama site in Varre-Sai, Rio de Janeiro, Brazil.



Source: Authors.

Then, to download topographic points, it was accessed the TOPODATA website (<http://www.dsr.inpe.br/topodata/acesso.php>). Files of type "xyz" (longitude, latitude, elevation) were selected, which are available in "ASCII" format, with ".txt" extension, and the file referring to the study site was downloaded, whose location is indicated by the number "20s42". With this, it was possible to develop in MOHID, the Digital Elevation Model (DEM) of the terrain, in English Digital Elevation Model (DEM), as shown in Figure 2.

Figure 2: Digital Elevation Model of the Panorama site, Varre-Sai, Rio de Janeiro.



Source: Authors.

In the soil data used in MOHID Land to represent the Varre Sai site, in Rio de Janeiro, 8 soil layers were adopted, 12cm, 12cm, 27cm, 30cm, 33cm, 18cm, 115cm and 65cm. The first five (5) layers of soils were defined following the percentages and depths defined by Mendes et al. (2014), the first layer had 57.9% of clay, 10.6% of silt, 31.5% of clay and a density of 1.28g/cm3, the second one had 57.9% of clay, 12.9% of silt, 29.2% of clay, the third layer had 27.1% of sand, 10.9% of silt, 62% of clay and 1.22 g/cm3 density, the fourth layer had 25.3% of sand, 10.9% of silt, 63.8% of clay, and 1.26g/cm3 density, the fifth layer had 24.4% of sand, 9.9% of silt, and 65.7% of clay. The percentage values of the soil composition were used to fill in the Rosetta table (https://www.handbook60.org/rosetta/), where the necessary data to fill in the soil characteristic in the MOHID was obtained.

It fills in the soil saturation coefficient (Ksat), it was necessary to switch to the meter per second (m/s) unit as Rosetta provides the result in the centimeter per day (cm/day) unit. Mendes et al. (2014) consider three more soil layers with similar characteristics, however, they do not define their composition measurements in percentages. In these last three layers, from 6 to 8, the same characteristics were adopted, and their value was based on the soil that is already filled in the MOHID Land model.

For experimental purposes, and due to the choice of the month of October, which is sunny, a radiation of 1000W/m2 was adopted. The simulated time was 19 (nineteen) days, and on days 01, 06, 10, 14 and 17, a constant rain of 3 millimeters (mm) was adopted every 15 minutes until completing 8 hours, after which there was an interval without rain , after 24 hours, another 3 mm of rain occurs. On the 2nd, 4th, 7th, 11th, 15th and 18th it didn't rain. On the 3rd, 8th, 12th, 16th and 19th there was a rainfall of 3 mm on the day. The objective was to vary rainfall conditions to verify the simulated results. For this simulation, the MOHID modules used were: Atmosphere, Basin, Basin Geometry, Drainage Network, Geometry, Model, Porus Media, Porus Media Properties, Runoff, Runoff Properties, Sediment Quality, Vegetation and Water Quality. It was important to activate the “Continuos” command in the modules so that they continued to chain the simulations in sequence.

Although MOHID has formulations on soil data, some commands are not previously filled in in the MOHID modules. Therefore, to simulate the transport of contaminants in the soil, it was necessary to increase the modules below the MOHID commands and which activate the Platform's previous formulations.

In the Vegetation module, the command that triggers corn cultivation was inserted, and some characteristics of the cultivation: total plant biomass, total plant nitrogen, total plant phosphorus, root biomass, canopy height, specific leaf storage, crop coefficient (plant transpiration coefficient), root depth, leaf area index.

The following lines of code were inserted in the Drainage Network module: cohesive sediment, temperature, salinity, nitrate, nitrite, ammonia, dissolved refractory organic nitrogen, dissolved non-refractory organic nitrogen, particulate organic nitrogen, phytoplankton, zooplankton, oxygen, inorganic phosphorus, fecal coliforms, dissolved refractory organic phosphorus, dissolved non-refractory organic phosphorus, particulate organic phosphorus, grossprod, light limitation factor, temperature limitation factor, nitrogen limitation factor, phosphorus limitation factor, phytoplankton grown excretion respiration mortality, zooplankton grown excretion respiration mortality, zooplankton grazed by zoo, phytoplankton assimilation and excretion of inorganic phosphorus, phytoplankton assimilation and excretion of ammonia, phytoplankton assimilation and excretion of nitrate.

The commands were inserted in the Runoff Properties module: critical shear for erosion, critical shear for deposition, erosion coefficient for shear, cohesive sediment, temperature, salinity, nitrate, nitrite, ammonia, dissolved refractory organic nitrogen, dissolved non-refractory organic nitrogen, particulate organic nitrogen, phytoplankton, zooplankton, oxygen, inorganic phosphorus, fecal coliforms, dissolved refractory organic phosphorus dissolved non-refractory organic phosphorus, particulate organic phosphorus.

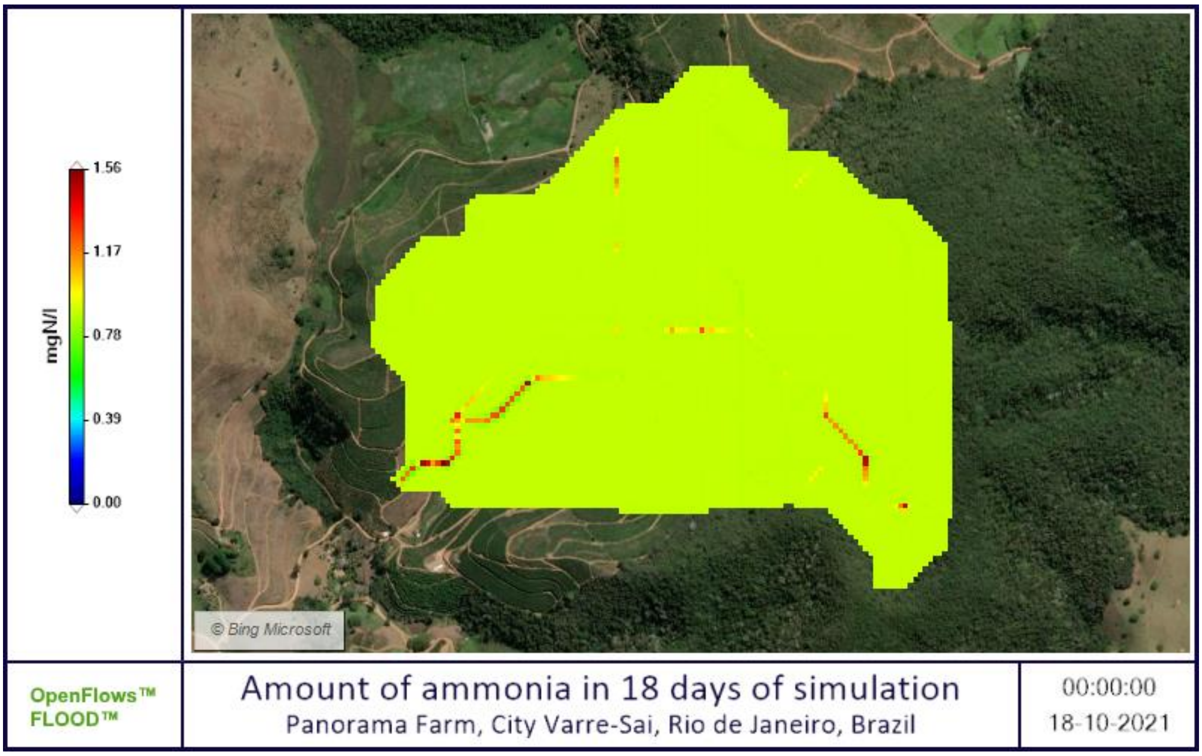
In the Porus Media Properties module it was necessary to include data from: temperature, nitrate, nitrite, inorganic phosphorus, particulate inorganic phosphorus, ammonia, soil dry density, particulated refractory organic carbon, particulate labile organic carbon, particulated refractory organic nitrogen, dissolved refractory organic nitrogen, dissolved non-refractory organic nitrogen, particulate organic nitrogen, particulated refractory organic phosphorus, dissolved refractory organic phosphorus, dissolved non-refractory organic phosphorus, particulate organic phosphorus, nitrogen gas, heterotrophic microorganism nitrogen, autotrophic microorganism nitrogen, anaerobic microorganism nitrogen, urea, heterotrophic microorganism carbon, autotrophic microorganism carbon, anaerobic microorganism carbon,

carbon dioxide, heterotrophic microorganism phosphorus, autotrophic microorganism phosphorus, anaerobic microorganism phosphorus, oxygen, salinity, fecal coliforms, PH, ionic strength, phosphorus adsortion index, heterotrophic microorganism population, autotrophic microorganism population, anaerobic microorganism population.

5. APPLICATIONS

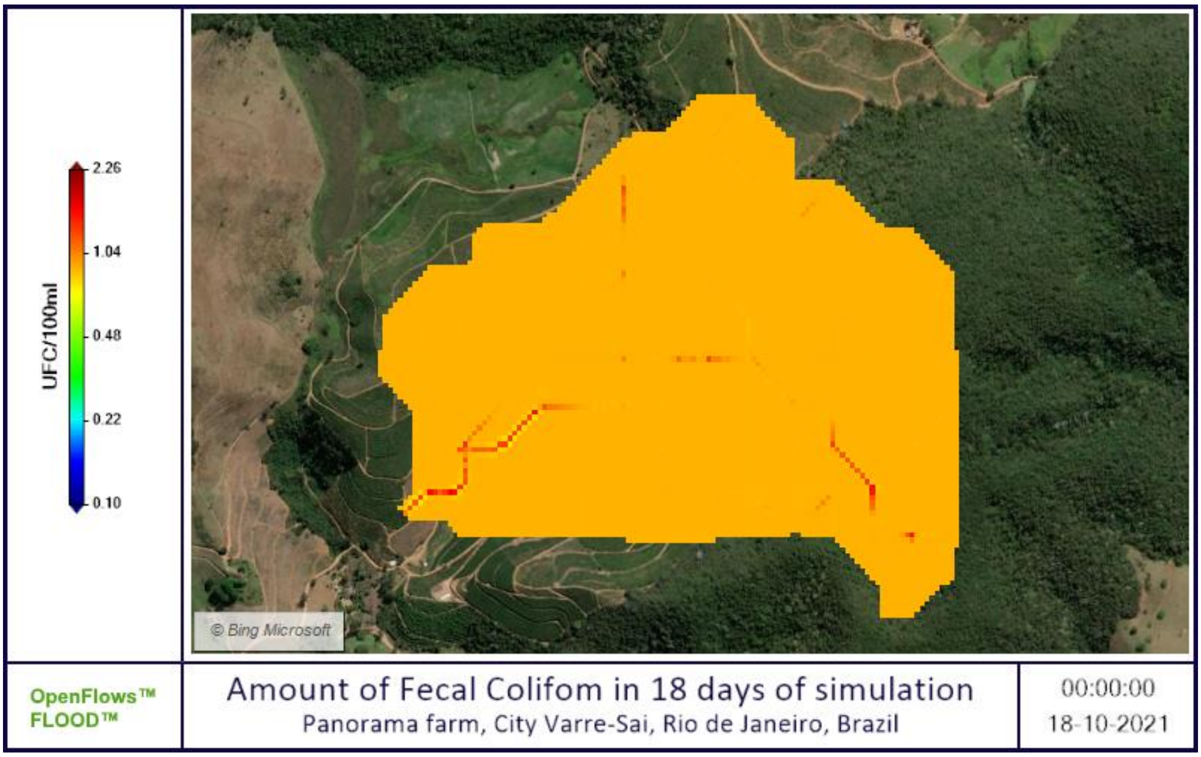
The application of the simulation results aimed at studying the transport of contaminants in water bodies. This is because it obtains estimated data on the route of substances found in agriculture, which can pose a risk to water bodies, when leached into rivers and/or nearby underground galleries, among them, we can mention Ammonia, Figure 3, and Coliforms thermotolerant (subgroup of bacteria from the coliform group that ferment lactose at 44.5 ± 0.2°C in 24 hours), Figure 4. Since ammonia is probably the result of the use of nitrogen fertilizers applied in the area, while thermotolerant coliforms are originating from homeothermic feces also used in soil fertilization.

Figure 3: Water flow measuring milligrams of ammonia nitrogen per liter of water.



Source: Authors.

Figure 4: Water flow with measurement of Fecal Coliform Units per 100ml of water.



Source: Authors.

6. DISCUSSIONS

MOHID Land has good sensitivity to climatic conditions, making it possible to carry out simulations with variable periods of rain, however, for the simulation of weeks and months, due to the amount of data processed, soil, radiation, wind, rain, fertilizers, pesticides, among others, used as input, there is a considerable delay in analyzing the results, and/or greater possibility of errors in programming. Many data are linked and dependent on each other, which requires an in-depth study of the characteristics of the plantation, the region's soil and the characteristics of the agricultural inputs adopted to fill gaps in the program.

According to the Brazilian National Environmental Consul – i*n portuguese Conselho Nacional do Meio Ambiente* - CONAMA (2005), a limit of 200 thermotolerant coliforms per 100 milliliters for Class 02 waters should not be exceeded, which meets the unit found in Figure 3. In addition, in Figure 4 there is a value below of 3.7 mg of ammonia nitrogen per liter, which is permitted for Class 01 fresh waters, with a pH less than or equal to 7.5.

7. CONCLUSION

It is considered that the objective of the work was achieved, since it was possible to simulate a corn plantation for 19 (nineteen) days at the Panorama site in the municipality of Varre-Sai, in Rio de Janeiro, and after 18 (eighteen) days, it was

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already It is possible to visualize the path of ammonia nitrogen and thermotolerant coliforms in the program. This visualization already allows conclusions to be drawn about the quantity permitted by CONAMA (2005) of these components.

With this research, it was concluded that the MOHID Land platform can be used to study the transport of contaminants in water bodies, being a management tool and decision-making aid for engineers and public entities seeking to adopt water control measures. pollution to the environment.

It is expected that this work will contribute to the understanding of the functionalities of MOHID Land, so that, combined with good modeling techniques, it will help predict water contamination, support planning, make it possible to guarantee public safety and create an environment that minimizes harmful effects of agriculture on water resources.

In the future, other agricultural components that are used in plantations and their concentration in water resources can be analyzed. In addition, it is suggested to monitor the entire growth of a plantation in MOHID Land, aiming, with the simulation of a longer planting period, to guarantee a more sustainable harvest, one that maintains production and harms the environment as little as possible.

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