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Impact of agriculture on water quality: a brief review

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ABSTRACT

The rapid growth of Brazilian agricultural production is only possible through the use of agricultural inputs, both mechanical (agricultural machinery and tractors) and chemical (pesticides and fertilizers). Unfortunately, agricultural intensification is accompanied by several potential sources of degradation of aquatic ecosystems. Thus, this work aims to present, in the form of a bibliographic review, the impacts that Brazilian aquatic ecosystems have been suffering in recent years, being extremely important to assist river basin managers in decision-making processes, and producers in the best choice of management, thus preserving the quality of Brazilian waters.

KEYWORDS: Watershed Preservation. Conscious Management. Low Impact Agriculture.

1 INTRODUCTION

Brazil contains the largest volume of fresh water in the world. However, this resource is threatened by the increase in water consumption and by the degradation of its quality (MELLO *et al*., 2020). As economic activities and population expand, and climate change alters hydrological cycles, conflicts over the multiple uses of water resources and concerns regarding the decline in water quality increase (MELLO *et al*.,2020).

Changes in land use and occupation are recognized as the main cause of the degradation of water quality. However, different types of land use and occupation affect water quality in different ways. The increase in deforestation, as well as the agricultural and urban expansion in Brazil, stand out as the main degraders (MELLO *et al*, 2020). These mainly cause the increase in the concentration of nutrients, in water temperature and in the sediment loads transported from the drainage basin to the main watercourse (TANIAKI *et al*., 2017). The degradation of water quality also has serious economic consequences, such as the increase in costs related to water treatment (CUNHA *et al*., 2016).

The expansion of agriculture to meet the growing demand for food and the production of biofuels is the main cause of deforestation and changes in land use and occupation, which, according to projections, will increase by at least 50% until 2050 (DEFRIES e ROSENZWEIG, 2010 and TANIAKI *et al*., 2017). The expansion of sugarcane plantations has a significant share of responsibility for this situation, as this is the raw material predominantly planted in the Brazilian territory for the production of biofuels, culminating in the title of second largest producer of ethanol in the world (TANIAKI *et al*., 2017).

Brazil has developed large-scale commercial agriculture, which has gained increasing worldwide recognition. According to the Institute for Applied Economic Research, the Gross Domestic Product of the Agricultural Sector is expected to grow by 3.2% in 2021, with corn and soy standing out, with an estimated growth of 9.1% and 10.5%, respectively (MAPA, 2020a). Forecasts point to an increase of 8% in the Brazilian harvest, and an increase in exports of 5.8% for soy and 13% for corn (MAPA, 2020b).

To reach this level, Brazilian agriculture had to modernize, with the use of industrially produced technological inputs. These are separated into two basic types of technology, namely of a mechanical nature, such as tractors and agricultural machines, and of a chemical nature, such as mineral fertilizers, insecticides, fungicides and herbicides (agricultural inputs) (HOFFMANN, 1992; SOUZA and KHAN, 2001). Consequently, it reached the position of the world's largest consumer of pesticides, representing approximately 20% of the total pesticides consumed in the world (ALBUQUERQUE *et al*., 2016).

Unfortunately, agricultural intensification is often accompanied by several potential sources of negative impacts on soil and freshwater ecosystems. Some examples are displacement and compaction of soil, caused by the use of heavy machinery, and the application of fertilizers and pesticides, with herbicides and insecticides being the most used (ALBUQUERQUE *et al*., 2016 and TANIAKI *et al.*, 2017).

Xie and Ringler (2017) evaluated – according to the supply and demand of food based on the alternative population, economic growth and climate change scenarios – the estimated discharge of nutrients from agricultural activities into water bodies around the world, having concluded that Brazil, China, India and the United States will be responsible for more than half of the global load of Nitrogen and Phosphorus leached into watercourses by 2050.

Different methods of management cause distinct impacts on watercourses, which makes it increasingly important to know the impact caused on the drainage basins regarding each type of planting and management. In this sense, it is necessary to assist the decision-making process carried out by the managers of the drainage basins, as well as by the producers, presenting management strategies that will cause less damage to water bodies. For this reason, this study is characterized by being a literature review of the impact on water quality related to different cultures and management strategies.

2 OBJECTIVES

The main objective of this research is to carry out a brief literature review of studies carried out in recent years regarding the impact of agriculture on water quality. In this way, it is expected to gather in a single document important information to be used as a tool that will help the management agencies of drainage basins and the rural producers.

3 MATERIALS AND METHODS

This study falls into the exploratory and descriptive category, in which information was collected from articles available on platforms such as Scielo and Elsevier, published in the last 5 years. In addition, the theoretical bases that constitute the subject that was intended to be studied were also discussed and analyzed.

4 RESULTS AND DISCUSSION

The main factors that explain the phenomena related to the interaction between water quality and land use for agricultural purposes can be justified by the management systems used. Based on this, it is possible to assess not only the impact on the quality of the water body in a given area, but also the way in which this type of control is carried out, as well as the influence of vegetation cover or the way in which deforestation favors the degradation of that environment.

4.1 Management Systems

Soil management is the set of practices that are applied with the aim of agricultural production, which includes cultivation operations, cultural practices, correction and fertilization practices, among others (LOPES, 2019).

4.1.1 Conventional (Intensive)

The conventional tillage system is a practice that works the soil through plowing, scarification and harrowing, making use of practices such as the intensive cultivation of the soil, the use of chemical fertilizers, the application of pesticides, monoculture, and also the irrigation and genetic manipulation of cultivars. This technique has become, over time, outdated in planting, since, if used incorrectly, it can bring to the soil problems related to physical, chemical and biological degradation (DE PONTI, RIJK e VAN ITTERSUM, 2012; MANFRE *et al*., 2019).

Currently, the machines and implements used in agriculture are increasingly bigger and heavier. With the frequent use of these machines in production systems, soil pressure increased, resulting in accelerated compaction and decreased crop yields, when associated with inadequate use with regard to non-observance of the soil moisture conditions of the crops (CORTEZ *et al*., 2017; FERRARI *et al*., 2018). Soil compaction is characterized by the increase in soil density, by high values of soil resistance to penetration, by the reduction in water infiltration and in the distribution and size of pores in the soil, and by the decrease in gas diffusion and nutrient availability (VALADÃO *et al*., 2015).

Water erosion can occur concurrently with soil compaction, as it is formed by the movement of water over the surface of the soil, in which it cannot infiltrate, thus becoming lost. Erosion manifests itself in different ways, from sheet erosion, in which a more homogeneous removal of a small layer of soil is seen across the entire surface, to its more severe forms, specifically rill erosion, which may evolve into gullies and gully erosion (EMBRAPA, 2020a).

On the other hand, conventional management can also cause high-impact ecological damage to the production area, such as loss of fertility; the change in nutrient availability with the reduction of organic matter; and the contamination of water bodies through the leaching of synthetic compounds (PONISIO *et al.*, 2014).

4.1.2 Reduced Cultivation

It refers to the reduction of one or more tillage operations, when compared to the conventional system. Heavy harrowing can perform all tillage operations in a single operation. Generally speaking, it can be said that the limitations in this system are the same as those presented in the conventional system (SILVA, 2019).

However, the reduced system causes problems related to soil losses, which arise as a result of soil compaction caused by the wheels of the tractors and, later, by the harrow that leaves the surface very pulverized, as its action is more superficial than that of the plow (FERNÁNDEZ, 2016; SILVA, 2019). When other methods are used, this system presents itself as an intermediary between conventional tillage and no-till farming with regard to soil erosion.

4.1.3 No-till farming

The management of the type known as no-till farming emerged in the mid-1970s, being mostly employed in grain crops (MANFRE *et al*., 2019). The cultivation areas where it is applied have been increasing considerably due to the benefits provided (DIAS *et al*., 2015). Studies have shown that the adoption of this management, instead of conventional tillage, contributes to the improvement of the physical, chemical and biological characteristics of the soil. In this way, such improvement can be justified by the application of straw from live and dead plants to the soil, which contributes to the reduction of erosion, minimizing water losses from evaporation, as well as losses of soil and nutrients, in addition to promoting the accumulation of organic material on the soil surface and the reduction of greenhouse gas emissions (FAVARATO *et al*., 2015; OLIVEIRA *et al*., 2015; SANTOS *et al*., 2017; COLOMBO *et al*., 2017).

Despite having several factors that provide a better use of the soil and also a better productivity for the producer, no-till farming has some limitations that must be taken into account. Weed control is usually carried out with the use of herbicides and, therefore, areas with large infestations can be difficult and more costly to control (CERETTA e AITA, 2010). Therefore, the excess of herbicides on the soil can bring several problems related to greater resistance to diseases and pests, as well as the contamination of the soil, water and groundwater (DORES *et al*., 2006).

4.1.4 Agroforestry

It is a form of soil use that combines, in the same area and at a given time, the cultivation of perennial and semi-perennial elements, short cycle elements and also occasional elements (animal husbandry) (EMBRAPA, 2020b).

From the implementation of agroforestry systems, problems related to soil erosion can be minimized, since the application of these systems presents a deliberate combination of woody plants, agricultural crops and/or animals, in sequential or spatial arrangement, which results in benefits to the soil, such as erosion control, the contribution of organic matter and nutrient cycling, in addition to diversifying the production of the farm (PEREIRA *et al*., 2006).

Another extremely relevant factor for the adoption of the agroforestry production system is the significant reduction in both the need to make use of synthetic fertilizers and the use of pesticides. The reason for this is the fact that the system itself has a self-regulatory capacity, that is, it is able to meet its nutritional demands and prevent the incidence of pests.

Santos *et al.* (2019) demonstrated, from several case studies, that, with this system, through the restoration of the hydrological cycle and, consequently, the regularization of rainfall, it is possible to restore extinct water sources, and to recover the soil by inserting organic matter from decaying vegetable matter. Lôbo *et al*. (2021) emphasize that the transition to agroforestry systems provides an increase in biodiversity and soil fertility, the control of erosion and siltation, and the regulation of the hydrological cycle.

As a limiting factor, the management of the agroforestry system can be classified as being the most complex way of operating the system. This is due to the simple fact that it encompasses the practice of soil cover and crop diversification, also taking into account information about natural succession, species ecology and those referring to local specificities. Another factor that can be highlighted is the constant pruning in order to avoid competition between the species of interest and the weeds. In more advanced phases of the system, the concentration of organic matter in selected species may be the management guideline (SIQUEIRA *et al*., 2015).

The managements that can be related to the agroforestry management are the Agroextractive and also the Crop-Livestock-Forestry integration. These types of management even differ from each other, but present solutions close to the objectives of the agroforestry system. In both managements, the conservation and sustainability of the environment is valued, seeking an economical and viable practice for all sectors of agriculture.

4.2 Impacts on Water Quality

Agriculture exerts a great influence on the natural hydrological cycle of drainage basins, resulting from the use of large amounts of water and the contribution to diffuse pollution (MALLMANN, 2018). Soil is a basic natural resource and has important functions, such as storage, drainage and infiltration of surface water, as well as food production. Its degradation can occur due to several phenomena, namely the inadequate use of technologies, the lack of soil conservation practices and the destruction of vegetation cover, among others. As a consequence of the use of degraded soils, several problems for agriculture can occur, such as siltation of water courses, desertification, sandy soil, and others. With this, it is noted that the soils are also linked to the quality and conservation of water and the preservation of its nutrients (MALLMANN, 2018)

Areas with predominantly agricultural uses have a water quality that is different from that of other areas with other types of use and occupation of the soil (OLIVEIRA *et al*., 2017). With regard to agricultural areas, those areas with mechanized irrigation present a water quality that is different from that of non-irrigated areas (OLIVEIRA *et al*., 2017). However, Oliveira *et al.* (2017) found in their study for the Middle São Francisco a similar water quality in irrigated and non-irrigated points, a fact justified by the high self-purification capacity of the São Francisco River. On the other hand, Britto *et al*. (2020) found, for irrigated areas of the Lower São Francisco, agriculture using irrigation as a potential source of contamination of water quality, with high values of salinity, dissolved oxygen, phosphorus, nitrogen and BOD. They also observed points of eutrophication caused by the management of the rice crop, due to the indiscriminate use of nitrogen and phosphorus-based fertilizers (BRITTO *et al*., 2020).

Intensive sugarcane agriculture contributes to increasing nutrient levels in tropical watercourses. Sugarcane production requires an intensive soil management, including soil fertilization and the use of heavy machinery, which are known to increase soil erosion and the loads of nutrients and sediments into watercourses (TANIAKI *et al*., 2017).

With the intensive management of sugarcane, there is a decrease in the conductivity and concentration of dissolved oxygen in the river, with drainage predominantly in the sugarcane fields (TANIAKI *et al*., 2017 and MARTINELLI e FILOSO, 2008). The concentrations of nitrate and suspended solids were up to four times higher in the sugarcane compared to the pasture area, while the water temperature was lower (TANIAKI *et al*., 2017). The high concentrations of fine suspended sediments are a stress factor for aquatic organisms, the high concentrations of nutrients can cause eutrophication of freshwater, and the high levels of nitrate are also considered toxic to the aquatic ecosystem (CAMARGO *et al*., 2005). Queiroz *et al*. (2018) found high trophic levels, which may be related to the interference from sugarcane crops. Dissolved oxygen levels affect not only the composition of freshwater, but also the ability of the ecosystem to process nutrients. The significant reduction in water temperature, after the conversion of pastures into sugarcane crops, may be associated with the increase in the albedo during the sugarcane growing phase (TANIAKI *et al*., 2017).

Regarding family horticulture, the one that offers a better conservation of natural resources (especially water quality) is the organic management, which presents a better environmental performance than conventional management, taking into account physicochemical and biological aspects, visual pollution and the potential for contamination by pesticides (RODRIGUES, 2003).

Aguiar *et al*. (2014) studied, in the state of Pará, the effect of traditional family farming on water quality. In this study, it was observed that this area presents values above the established standard levels. The main characteristic was the increase in the levels of true color, which may be related to the contact of water with decomposed organic materials and the carrying of compost during periods of rain, due to the lack of vegetation cover on the banks, since the color acquired by the water bodies is the result of the leaching of compounds from the vegetal decomposition (SIOLI, 1976).

In a micro basin with economic activity limited to agriculture and livestock, Queiroz *et al*. (2010) found good water quality in terms of physicochemical parameters. This result proves the benefits of proper soil management, with practices of no-till farming and terrace systems, which provide containment and infiltration of rainwater, resulting in a reduction in the dragging of sediments and nutrients to the water bodies.

The practices that follow the removal of natural vegetation tend to produce intense and prolonged degradation of water quality, especially those that do not take conservation practices into account. On the other hand, forest cover is essential for maintaining a good quality water supply, as the vegetation promotes protection against soil erosion, sedimentation and leaching of nutrients (SOPPER, 1975).

In addition, constant monitoring of the quality of water bodies becomes an indispensable instrument for the control and preventive decision-making regarding the use and occupation of the soil.

Andrade *et al*. (2020) suggest the use of bioindicators such as, for example, the BMWP biotic index, which uses benthic macroinvertebrates for the characterization of water quality, as a way to control disturbances in the aquatic environment due to the variation in water composition. Negrão *et al*. (2021) conclude that the biomonitoring of the Cascavel River Basin (PR) from the analysis of samples of macrophyte plants proved to be effective in the environmental assessment of the impacts caused by agricultural, farming and urban occupation in the region.

4.3 Change in Forest Cover

The increase in deforestation with the purpose of making arable lands generates great impacts on water courses. The removal of natural vegetation generates impacts at different spatial scales. At a local scale, erosion of the channel and banks occurs, causing changes in the width and depth of the river, increase in water temperature and flow productivity, and decrease in habitat complexity (PAULA *et al*., 2017). At larger scales, the change in vegetation cover affects the hydrology and water quality, increasing the concentrations of nutrients, dissolved organic carbon and suspended sediment (PAULA *et al*., 2017). Forest cover leads to a reduction in the use of organic and inorganic fertilizers and pesticides, to a reduction in erosion processes and sediment entry into the water, and also leads to general benefits in terms of water quality, resulting from the filtering capacity, or buffering capacity, of riparian areas and wetlands. It is, therefore, vital for the maintenance of water quality and the health of the entire aquatic ecosystem (CUNHA *et al*., 2016).

Ferreira *et al*. (2019) projected the change in the water quality of the Tietê river basin in 2070 and, in general, the deforestation scenario increased the amount of water in the watercourses. Analyzing the conversion of forests into agricultural lands, this can be explained by the reduction in evapotranspiration, a consequence of the removal of tree species and/or replacement by herbaceous species with less transpiration (SCHLESINGER e JASECHKO, 2014 and FERREIRA *et al*., 2019). However, it is important to realize that the increase in the amount of water does not necessarily mean an increase in the availability of water. Poor quality water is actually less available for consumption unless it is treated before consumption (FERREIRA *et al*., 2019).

The reforestation scenario, on the other hand, decreases the amount of water in the basin, however, it has the potential to increase water availability by increasing water quality in most of the basin, dampening the effects of the general decrease in the amount of water. Therefore, the increase in water availability is the greatest benefit of reforestation, a strategy to improve ecosystem services related to water (FERREIRA *et al*., 2019).

5 CONCLUSION

The main responsible for the degradation of water quality is the inadequate management. The adoption of conservation practices is of fundamental importance to minimize the adverse effects on the quality of water resources. In addition, continuous monitoring allows for more effective, and even preventive, control with regard to actions for the preservation of drainage basins. However, there are still gaps in the literature that prevent it from demonstrating more clearly the causal relationship between the improvement of water quality and the use of conservation techniques. Therefore, it is of great importance that research in this regard be further explored.

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