Twelve years of soil preservation and rehabilitation at Rio do Peixe watershed, promoting conservation agriculture

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Abstract

This work aimed to test innovations for the diagnosis of agricultural properties at Rio do Peixe Watershed, to locate erosions and to correct them by changing soil management, aiming at recovering degraded areas, rehabilitating them and promoting conservation agriculture, evaluating the results by remote sensing and water quality indicators. In 2019, it turned twelve years of inspection/monitoring at Rio do Peixe Watershed. From 2007 to 2017, using the Conventional CDA methodology, 14,076 ha were inspected at Vera Cruz sector, 94 properties were notified and in Ocauçu, 82 properties, located in 9,027 ha. As a work strategy, in Marília, the Innovative CDA Methodology was used, which allowed the inspection and rehabilitation of 52 properties in 27,775 ha, from 2017 to 2018. After the notifications, the owners presented the conservationist technical projects for each property, which were implemented, using conservation practices such as improving vegetation cover and crop rotation to control laminar erosion and agricultural terracing, divergent channels and containment basin to control gullies erosions. This work promoted a transformation from degrading agriculture to conservation agriculture, having degraded pastures transformed into an agricultural area, implementing the No-tillage system. Pastures were recovered by implementing the Integrated Crop-Livestock System; it was possible to increase the occupancy rate by 31% comparing to the original situation. This is a great work that benefits Watershed farmers, increasing productivity and consequently the profit, as well as for the local people improving the quality of water that supplies the region of Marília.

1 INTRODUCTION

Aiming to regulate the use and conservation of soil, to combat soil erosion, São Paulo State Secretariat for Agriculture and Supply, through the Coordination of Agricultural Defense (CDA), is responsible for applying the Law on Use, Conservation and Preservation of Agricultural Soil - State Law nº. 6.171 / 88 - (São Paulo, State, 1988) to monitor and discipline the soil use and conservation to fight soil erosion and has been carrying out this work for 20 years with very positive results, mainly in inspections carried out at Watersheds.

The area of the state occupied by agriculture has approximately 18 million hectares, with 330 thousand agricultural properties. During that period, 772,000 hectares were already worked at 19,846 agricultural properties that were notified and rehabilitated agroecologically (Vischi Filho et al., 2019).

The CDA Diagnostic methodology uses conservation law as a tool and considers the watershed as the ideal work unit for carrying out this type of activity. The watersheds have an important function of regulating the water balance, as well as housing agricultural production and promoting the storage of rainwater, which seeps into the soil and are available to rivers throughout the year (Lal, 1994; Vischi Filho et al., 2018 and 2019).

Degradation of the watershed is related to the lack or deficiency of vegetal cover of cultures that occupy the soil and has consequently the erosive processes that cause the silting of the watershed water network, interfering in the quantity and quality of the water (Rodrigues et al., 2015). The first principle of soil conservation is soil cover, whether vegetable or mulch. The use of practices, such as the use of varieties that provide bigger vegetal coverage of the soil, reducing the direct impact of raindrops on the soil surface, reduces the soil losses, water, organic matter, and nutrients because of water erosion (Silva et al., 2005; Rodrigues et al., 2015; Merten et al., 2016).

The inappropriate use of agricultural soils causes the gradual loss of its productive capacity and the contamination of water resources by sediments, resulting from the erosion process (Araujo, et al., 2007; Lelis & Calijuri, 2010). The last decades have been characterized by drastic changes in land use and occupation in the region, which for Zalidis et al. (2002) represented one of the main driving forces for environmental degradation, especially on soil and water. This occurs because of the inexistence, or of the erroneous adoption of conservationist practices in the cultivation areas of agricultural properties, a fact commonly verified in Brazil, mainly in pasture areas (Menezes et al., 2009).

Irrational soil management makes production unfeasible and compromises the balance of ecosystems and soil cover (Santos et al., 2007), which is a form of management for a specific crop, in a management system and specific locations, represent a joint effect in reducing water erosion (Silva et al., 2009).

The second principle of soil conservation is to avoid that the surface run-off regime goes from laminar to turbulent and, for that, the construction of an agricultural terracing system is carried out, which has the function of sectioning the length of the ramp and promoting the infiltration of soil water. According to Pruski (2006), the more the soil surface is protected by vegetation cover, against the rain action, lower the propensity for erosion to occur. Studies by Minella et al. (2007) to identify the origin of sediments at watersheds concluded that the areas of crops are the main sources of sediments and suggested that programs for the implementation of conservationist management of soil practices are essential. By adopting proper management and mitigating actions to recover the impacted areas, there will be an improvement in water quality at the watersheds (Araújo et al., 2009). As a final product of soil conservation, its contribution to minimizing floods during periods of heavy rainfall and increased availability of water in the dry period of the year is considered.

In this work on the inspection of Rio do Peixe watershed, the type of intervention aimed at transforming conventional and soil-degrading agriculture into conservationist agriculture, implementing conservationist technical projects that contemplated this novelty. Conservation Agriculture is an agricultural system that promotes the maintenance of permanent soil cover, minimal soil disturbance or no-tillage and the diversification of plant species. It increases biodiversity and natural biological processes below and on the soil surface, which contributes to increasing the efficiency use of water and nutrients, to improve and sustain agricultural production (FAO, 2019).

In 2019, it turned twelve years of activities to inspect the use and conservation of soil at Rio do Peixe watershed, in sections I, II and III, located in Vera Cruz, Ocauçu and Marília cities. This work aimed to test innovations for diagnosis of agricultural properties, to locate erosions and to correct them with changes in the ways of soil management, aiming at transforming the degraded agricultural properties at Rio do Peixe watershed into rehabilitated properties, promoting conservationist agriculture and evaluating the results through remote sensing and water quality indicators.

2 MATERIALS AND METHODS

This work was carried out in the sections of Rio do Peixe Watershed, located in Vera Cruz, Ocauçu and Marília cities, SP, Brazil, at coordinates S22° 14'52.68 ", W49° 44'59.97", start and end at coordinates S22° 18'13.28 ", W50° 2'54.22", Datum WGS 84 (Figure 1).

The climate of the region is humid subtropical of Cwa type, according to Köppen-Geiger classification, having temperatures in the warmest month above 29.7°C and the coldest month, below 10.6°C, average annual rainfall of 1,193 mm.

Predominant soils are Red-Yellow Ultisol Abrupt, moderate horizon A, sandy/medium texture and Litolic Entisol, eutrophic (Santos et al., 2018). Geological formation consists of rocks from the Bauru Group, covered by neocenozoic sediments (Bezerra et al., 2009). Predominant relief is the smooth undulating, in the western plateau of São Paulo and, in the depression, strongly undulating in the escarpments (Itambé) that separate the plateau from the depression.

CDA inspection/diagnosis methodology (conventional) was developed from 1999 on, by the technical staff of Agronomist Engineers, published in 2003 and it was improved in 2017, receiving the name of Innovative CDA Diagnostic Methodology (Vischi Filho et al., 2019). This happened because action strategies needed to be created to streamline all of this demand. Several options for technological innovations were tested, including the use of model aircraft, helicopter, and drone; however, the results were only favourable when this new method of work was developed. The CDA Innovative pilot project was carried out at Rio do Peixe Watershed, on a 53 thousand hectare stretch, located in Vera Cruz, Ocauçu and Marília cities.

Inspection and agro-environmental rehabilitation work at Rio do Peixe Watershed started on June 15, 2007, and it has been currently happening (from 2007 to 2020). Inspections are carried out at all properties that compose these three sectors of Watershed. CDA Conventional methodology was applied, which consists of preparing an action with the delimitation of Watershed in a topographic map scale 1:50.000, elaborating a mosaic of aerial images, which will be used in the field, "in loco" to help in the localization strategy and, also in the visit to all Watershed properties. Subsequently, the properties are visited using the "checklist" (official CDA document for Soils), in which erosions and other forms of degradation are included, in compliance with conservation legislation (São Paulo State, 1988).

Erosions are georeferenced using a Global Positioning System (GPS) receiver, classified, photographed (photos that will compose a photographic report) and noted in the "checklist" leading to the data generated in the diagnosis that will be used to compose the processes relevant to each agricultural property visited and based on the information contained in the diagnosis database. The owner of the area hires an Agronomist Engineer who will prepare a technical conservation project for the recovery of the degraded area, respecting the projects, the class of land use capacity (Lepsch et al., 2015), for this property.

The conservation project is analyzed by the CDA Staff, who approves it or not, sending it for corrections if necessary (physical project, on paper) and if it is approved, it goes to the implantation stage, by the farmer, correcting and remedying soil damage and erosion at that location. The CDA Staff, in this work, is composed of four Agronomist Engineers who work for a week, monthly. They visited each property two to five times during the implementation of the project, the first time during the diagnosis, monitoring the execution of the technical project, and on the property release after the works. After the project was implemented, the soil was preserved and the property became more profitable, increasing productivity. This methodology was applied to two sections of this Watershed, defined as, section I, located in Vera Cruz, SP, Brazil, with an area of 14,076 ha (period of work from 2007 to 2011) and section II, located in Ocaucu, SP, Brazil, with an area of 9,027 ha (from 2011 to 2015).

In this CDA activity, as well as in other works distributed throughout the territory of the State of Sao Paulo, having difficulty of traversing the 330 thousand agricultural properties in the state. A strategy needed to be developed and a new methodology for inspection was adopted, it was the Innovated CDA Methodology, which was applied in Watershed section III, in Marilia with an area of 27,775 ha (from 2017 to 2018).

The methodology consists of making the diagnosis in the office using the databases of Rural Environmental Registry (CAR, 2017), opening and saving the georeferenced "shapefile" with the property limit. To learn about the owner and property information, we used data from the Animal and Plant Defence Management System (GEDAVE, 2017). The CAR and GEDAVE information are specialized in Google Earth(r) Pro, (current aerial images), promoting an interface of this information with databases, performing diagnosis and inspection by remote sensing. Within the property perimeter, whose shapefile was imported into Google Earth(r), the diagnosis begins visualizing the erosions, insertion of a georeferenced GPS point on this erosion, drawing a polygon of this erosion contour, classifying the erosion according to soil conservation legislation

(Sao Paulo State, 1988). Also, elaborating an Excel(r) spreadsheet containing the following information: the number of georeferenced GPS points, the type of erosion, description of it (Table 2), and erosion area (ha). This work is carried out throughout the property's perimeter.

After the diagnosis by remote sensing is completed, a colour aerial image is saved in JPEG format and spreadsheet in Excel(r), and they are made available to the CDA Staff who will visit the property and go straight to the erosion site, as it is geo-referenced, not needing to be looking for erosion. It is checked whether the erosion of that point exists or not and if it exists, whether it is according to what was described for that point in the Excel(r) spreadsheet. If the erosions are according to the data in the spreadsheet, the information is maintained and if they are divergent, this information is corrected on the spreadsheet. After visiting all points on the spreadsheet, obtaining photos of the erosions, we have real data on the soil situation of the agricultural property. The data is placed in documents that will be handed in to the notified owner. After this stage, the procedures are identical to the conventional CDA methodology: the owner of the area hires an Agronomist Engineer who will prepare a technical conservation project to recover the degraded area.

To validate the new methodology, some indicators were used to evaluate the results obtained with the implementation of soil conservation. Through the vegetation cover improvement, resulting from changes in soil and water management practices that were proven by comparing the state of the art (before evaluation/work - T1) with the results obtained (after the implementation of technical projects - T2). Using Google Earth(r) Pro images, through the historic images tool (years: 2002, 2006, 2012, 2013, 2017 and 2018) to evaluate the post-agro-environmental rehabilitation of properties (Figure 2).

The measurement of soil losses and sediment input to the river, due to the action of soil erosion, were evaluated by the water quality indicators evaluated by the Turbidity analysed by the Standard Methods for the Examination of Water and Wastewater - 2130 B method (SMWW a). Suspended Solids were analysed according to the 2540 D method (SMWW b). The Phosphorus were analysed according to the United States Environmental Protection Agency, EPA 6010D method (USEPA). Organic Carbon were analysed according to 5310 C method (SMWW c), which was measured from periodic analyses of Rio do Peixe water.

The samples were obtained from the watercourse, at a station located downstream from the areas where the watershed has the highest concentrations of cultivated areas, and they are collected by Sao Paulo Environmental Company (CETESB, 2020), once a month, in February, October, and December. According to method 1060 and 9060 of Standard Methods for the Examination of Water and Wastewater (SMWW d), at the collection point code 00SP21438PEIX02100 / UGRHI 21 (coordinates: S22deg18'13.62" - W50deg2'53.62").

These indicators were chosen because turbidity shows the sediment input in the water body due to erosion and the transport of these particles to it. The months were defined, as there is a higher probability of erosion, according to rainfall data, considered as the highest rainfall averages, the months of February, October, and December, which were the months that sampled and analysed the water. To subsidize the turbidity and suspended solids assessments in water, the information of Setzer (1985) has used as a comparison.

The data were obtained in two periods, considered as treatments, being: T1 - data referring to the period called BEFORE the working diagnosis and erosion control, considering the information from 2000 to 2007 and T2 - data referring to the period named AFTER the working diagnosis and erosion control, considering the information from 2008 to 2018. The improvement in water quality was assessed by determining the indicators that were tabulated and compared through graphics prepared for each indicator for the T1 and T2 treatments (Figure 3).

3 RESULTS

The work carried out by Sao Paulo State Secretariat of Agriculture to apply the legislation, dealt with erosions diagnosis and correction at agricultural properties located at Rio do Peixe watershed, sections of Vera Cruz, Ocaucu and Marilia, which correspond to 53 thousand hectares. A great work that "Cares for the Well-Being of Society" and brings benefits to the farmers of Rio do Peixe Watershed. Especially to the entire local people that have benefited from its development, including on improving the quality of water that supplies cities, mainly Marilia (216,684 inhabitants) and Presidente Prudente (227,072 inhabitants) that collect waters from Rio do Peixe for public supply.

From 2000 through 2007, Rio do Peixe watershed water was monitored with the respective sample collections and the performance of analyzes that functioned as a control (T1) of the two treatments used.

From 2007 to 2011, 14,076 ha were diagnosed in Vera Cruz city. From 2011 to 2015, 9,027 ha were worked in Ocaucu, totalizing 23,103 ha, in these two sections (I and II), that is, 224 ha per month, the work was carried out by four Agronomist Engineers who worked one week, monthly, for 103 months. In Marilia, in 2017, 27,775 ha were diagnosed, which were worked on in 2018, implementing conservation projects on 52 agricultural properties.

In section I, in Vera Cruz, 94 agricultural properties were notified, out of a total of 176 properties. They implemented conservation projects, predicting innovative measures such as improving the vegetation cover of pastures using Integrated Crop-Livestock Systems in the rebuild of them, in crops, adoption of No-tillage and bioengineering, in addition to the usual practices, such as agricultural terracing, containment basins and road readjustment (Figure 2).

In the Ocaucu section II, 82 agricultural properties were notified and in Marilia, section III, using the Innovative CDA Methodology (Vischi Filho et al. 2017 and 2018), in just nine months, 20 large agricultural properties and 32 small properties were inspected, with a total area approximately 27.7 thousand hectares. It was diagnosed and evaluated from January to November 2017, in just 9 months of work, 27,775 ha or 3,086 ha per month. This methodology allows the strategy of evaluating, in detail, an area, which, according to the old methodology, would take 103 months to be carried out (8 years and 7 months) and in just nine months the work was accomplished generating time - saving.

Erosions and other soil degradation processes are reported in Table 2. These inspections already carried out received the conservation technical projects for the areas and were implemented.

The results obtained with the changes in soil and conservation management practices of water regarding the improvement of vegetation cover were confirmed by the evaluation of aerial images before the work was carried out – 2002. After the work was carried out - 2013, 2017, 2018 and 2019 - (Figure 2) that is, after the conservationist projects have been implemented, with the areas already recovered and the erosions controlled, starting to adopt conservationist practices that transform soil management, aiming at Conservation Agriculture.

The conservationist practices adopted were improvement of vegetation cover by adopting a system of direct planting in the straw or by improving the management of pastures by correcting and fertilizing the soil, crop rotation, adoption of the Integrated Crop-Livestock System and bioengineering. Mechanical practices were also implanted, such as agricultural terracing, containment basins and divergent channels for the conduction of runoff to the drainage channels and bottom drain, for the control of gully erosion. Disciplinary measures, such as capture, conduction and dissipation for rainwater contributions from dirt roads (Figure 2). It is important to highlight that after the notifications of the farmers, there was an awareness that they started to worry and make conservation practices a preventive and routine action on the properties. This work to inspect the use and conservation of the soil is important not only for the soil and water preservation, however, also for the rural producer to earn more money with his activity, a fact that can be proven by analysing Table 3. Where in most of the agricultural properties worked with the recovery of pastures, farmers had an increase of 31% in the occupation rates of these areas and with this, they will have a higher income and a greater profit in their activity.

The results of the "in loco" survey for land use and occupation (Table 2) show that the following crops predominate at the Watershed are pastures with 30,472 ha, coffee with an area of 2,798 ha, fruit (mango, coconut, and citrus) with 136 ha, eucalyptus with 95 ha, vegetables with 60 ha, passion fruit with 15 ha, crops of the annual cycle (corn and beans) with 181 ha, sugar cane with 37 ha, and in the environmental condition, natural forest, with 10,606 ha that cover the slopes of the formation known as ”Itambe”.

The improvement in water quality caused by the control/minimization of erosive processes and sediments carried to the watercourse were confirmed by the water quality indicators: Turbidity, Suspended Solids, Phosphorus and Organic Carbon, analyzing the representative graphics of these analyses (Figure 3).

The Turbidity of the water evaluated from 2000 to 2007, considered as before the work was carried out (BEFORE - T1), presented average values of 192 NUT (Nephelometric Units of Turbidity), against the average values of 102 NUT, evaluated from 2008 to 2018, considered as after the completion of the work (AFTER - T2), a decrease of 53% in the average values. For the T1 treatment, the values were higher than the Conama standard (Conama, 1986), which is 100 NUT (Figure 3A), in the average of February and December. In T2 treatment, the average values were 102 NUT, except for February 2009, 2014, 2017 and 2018; October 2009, 2012 and 2018; December 2009 and 2015 (Figure 3B).

The suspended solids evaluated from 2000 to 2007 (T1), presented average values of 297 mg l-1 (milligrams per litre), against the average values of 132 mg l-1, evaluated from 2008 to 2018 (T2), a 44% drop in average values.

The phosphorus evaluated from 2000 to 2007 (T1), presented average values of 0.18 mg l-1 (milligrams per litre), against the average values of 0.14 mg l-1, evaluated from 2008 to 2018 (T2), a 78% drop in average values.

The Organic Carbon evaluated from 2000 to 2007 (T1), presented average values of 9.60 mg l-1 (milligrams per litre), against the average values of 5.19 mg l-1, evaluated from 2008 to 2018 (T2), with a 59% drop in average values.

4 DISCUSSION

4.1 Land Use and Occupation

The following crops predominate in these sections of Watershed were Pasture, Natural Forest and Coffee. The natural forest, considered the best vegetation cover, is present in an area corresponding to 21.16% of the area of this stretch of Rio do Peixe Watershed. Santos et al. (2014) evaluating a watershed with 11,000 ha, located in Botucatu, in relief conditions similar to Rio do Peixe watershed, in terms of land use and occupation found 1,109 ha of natural forest, corresponding to 9.95% of the watershed area, a situation that corresponds to less than half of the result found in the present work, showing that in this stretch of Rio do Peixe Watershed, the forest is more preserved.

As for the pasture area, there is an occupation in the studied section of 30,472 ha, representing 60.81% of the total area of the Watershed (Table 1). The results found are similar to those of Lima et al. (2004) who evaluated 43,228 ha of pasture area in a watershed in Ilha Solteira, SP, which represents 66.79% of the total area. In this work, one of the positive examples was the transformation of a property, with agricultural area, located in Ocaucu city, SP, with a degraded pasture area of 500 ha. After carrying out this work, these 500 ha were transformed into an agricultural area with no-tillage system, intended for annual crops, with rotation: brachiaria straw, soybeans, corn and wheat in winter (crop change and soil management). A new conservationist technology that was implemented in the region.

Using the images from the Google Earth(r) Pro to verify the effectiveness of the works implanted in the pasture area having an erosive process (Figure 2A and 2B). Action of agri-environmental adequacy to contain the erosive processes was implemented and the control of the erosion in the area was accomplished with the construction of containment basins on areas with pastures. There was an improvement in the visual aspect of the area compared to soil conservation, in which case it was proven that pasture management with the use of containment basins favored the restoration of the area and the return of potential soil productivity.

Analysing Figures 2C, 2D, 2L, and 2M, it can be seen that the change in management in coffee culture provided a positive change in the landscape, inferring that in addition to improving the landscape with more intense vegetation cover (Figures 2D and 2M), there was an improvement in potential crop productivity. In the coffee culture, what contributed to the improvement of the soil conditions was the adequacy of the crop following the level of the ground and recovery of soil fertility. The soil conservation techniques applied in this case were sufficient to control erosive processes.

In Figures 2E and 2G, using the image comparison method, it can be seen that the agricultural terracing built in the area in question was efficient in controlling erosion processes at the property. According to Araujo et al. (2009) the use of appropriate management measures and erosion mitigating actions, with the recovery of the impacted areas, there will be an improvement in water quality and control of sediment production, minimizing silting and consequently, there will be an almost complete environmental rehabilitation.

The comparison between aerial images from before (T1) and after (T2) was used to assess the efficiency of the results obtained, a method that was also used by Bezerra et al. (2012) who evaluated by photocomparation the vegetation cover and the potential of water in the soil aiming at the monitoring and recovery of degraded areas, considered that the photocomparation with the supervised classification allowed to follow the development of the vegetation cover with grasses, as well as their relation to soil water potential. According to Menezes et al. (2009) using remote sensing, it was possible to verify the presence of areas already affected by inadequate management on areas with degraded pastures. These authors also highlighted the fact that native vegetation has been largely converted into pasture. Figures 2K and 2O, show the mechanical control of erosions with the construction of dams and terraces that altered the landscape of the place, previously degraded, into a pasture with productive capacity (Figures 2J and 2N). Figure 2J shows an old and eroded road that carried sediments to the bed of Rio do Peixe and which was corrected by building terraces (Figure 2K).

It is important to observe the fact that there are practices focused on the conservation, which represents a large part of the Rio do Peixe Watershed section, besides promoting important benefits for soil conservation, it can be another factor that stimulates the increase in income for producers, once, with conserved pasture, there is a higher volume of biomass and, consequently, the possibility of higher animal density. An example of this statement is the pasture areas recovered with the adoption of the Integrated Crop-Livestock Systems (LIS), where the management of these pastures has changed, replacing the grass variety and providing pasture with good vegetal mass during the dry periods. This resulted in an occupancy rate of five Animal Units (AUs) per ha, as evidenced by the evaluation of 10 properties, where there was an average growth of 31% in the occupancy rate, compared to the original situation found before carrying out the inspection work. It corroborates with this information the study of Albernaz & Lima (2007) who evaluated two sub-watersheds, in Lavras, MG, occupied by pastures, according to conservationist practices: level planting, terracing, containment basins, liming maintenance and inferred that at Ribeirao Santa Cruz sub-watershed (SW) more conservation practices are adopted than at SW Agua Limpa and the exposure of the soil to degradation was bigger at SW Agua Limpa. A similar result was observed by Zolin et al. (2011) stating that the biggest relative reductions in soil loss occurred on scenarios with conserved pasture, indicating that the optimization of soil conservation can be accomplished by adopting conservationist management practices for pasture recovery. According to Rodrigues et al. (2015) who analysed the role of vegetation in water interception and erosion control, at Rio Paraiso Watershed, in Sao Manuel, SP, and the uncovered soil showed a 98.09% increase in sediment production, when compared to soils with vegetation cover.

4.2 Water Quality Indicators (WQI)

4.2.1 Turbidity

Analysing the turbidity data, suspended solids, phosphorus and dissolved organic carbon (Figures: 3 - A, B, C, and D), it ensures that the data from treatment T2 are more uniform or stable than in T1 for these indicators. When analysing Figures 3A and 3B, related to water turbidity, in previous years the implementation of the work (T1) and after the implementation of the work (T2), it observes that, on average, water turbidity was lower in February and December when we compare (T2) with the situation before the implementation of the work (T1). This difference seen in T2 can be explained by the decrease in the supply of sediments in the watercourse. It happened because of the effects of the change in soil management with the adoption of conservationist practices and erosion control through the implementation of technical projects at the 228 properties that were recovered with conservationist agriculture, through the work performed (Figures 2B, 2D, 2E, 2G, 2I, 2K, 2M and 2O).

A similar result was found by Souza & Gastaldini (2014), who observed that land use significantly influenced the water quality parameters. In areas considered to have a higher percentage of agriculture and with problems related to erosion, the situation of the area before the implementation of constructions, the parameters of turbidity, suspended solids are higher. This land use, without adopting conservationist practices, can be considered as having the biggest potential for erosion.

4.2.2 Suspended Solids

As for suspended solids, the highest values were recorded in T1 treatment (Figure 3C) compared to T2 (Figure 3D), in February all values were bigger than 100 mg l-1 (milligrams per litre), with an average of 252 mg l-1 for that month. The same happened with the values of October 222 mg l-1 and in December with an average of 416 mg l-1. In T2, the values were more uniform, with averages of 126, 163 and 107 mg l-1, only with a peak of 696 mg l-1 observed in October 2012 (Figure 3D), however, it was still below the peaks recorded in the T1 in October 2006, which was 884 mg l-1 and the peak observed in December 2003 with 1850 mg l-1 (Figure 3C).

The results of suspended solids for the rainy season were lower than those described by Setzer (1985) who evaluated soil losses and their relation to turbidity and water parameters in several watershed in the state of Sao Paulo and inferred that the averages annual rates for suspended solids in the rivers of Sao Paulo are slightly less than 150 mg l-1, rising to almost 300 mg l-1 in the rainiest months and lowering to less than 50 mg l-1 in the driest months.

The results of the work show that there was a significant decrease in suspended solids after the adoption of conservationist practices and the rehabilitation of agricultural properties. Rodrigues et al. (2015) evaluated that the runoff coefficient was low in the presence of vegetation resulting in bigger infiltration and better flow regularity and that erosion and carried sediments increased on unprotected soils, changing the dynamics of water on the soil.

4.2.3 Total Phosphorus

The total phosphorus dissolved in water in T1 (Figure 3E), presented values higher than those recommended by CONAMA Resolution 20/86, which is 0.025 mg l-1), compared to T2 (Figure 3F). The values of phosphorus for T2 of 0.10, 0.16 and 0.16 mg l-1, for February, October, and December, respectively, were below the values of 0.21, 0.13 and 0, 21 mg l-1, except for October, the values observed in T1 were higher than those recorded in T2, except for the peaks recorded in December 2010 and October 2009 and 2012, which reached more than 0.30 mg l-1, even below the peaks that occurred in T1 in 2001, 2002, 2003 and 2005, which reached 0.50 mg l-1, in December 2005 (Figure 3E).

The results show lower values than the values obtained by Donadio et al. (2005) who evaluated the water quality in a Watershed in Taquaritinga, SP, whose predominant soil is the Ultisol and the average values of phosphorus in the water for the dry period of the year was 1.58 mg l-1and for the rainy season was 4.32 mg l-1.

The results of phosphorus, found by Pinheiro et al. (2014), who studied the use and occupation of soil and the relation to water quality in two sub-areas of Rio Duas Mamas Watershed in Santa Catarina, were 27.3 and 41.6 mg l-1 and, were higher than the results found in the present study. This was because in SW2 there were banana cultivation and cultivation areas for annual cycle crops, despite the large percentage of remaining natural forest, in both cases.

4.2.4 Organic Carbon

As for the organic carbon dissolved in water (C), the data were higher in T1 with averages of 9.76, 10.50 and 8.55 mg 1^{-1}, in February, October and December respectively, reaching values of C above 19 mg 1^{-1} in

2000. In treatment T2, the average carbon values of 6.25, 5.88 and 4.90 mg 1^{-1}, for the same months, were between 4.9 and 6,2 mg 1^{-1} (Figure 3H) while at T1, they were between 8.5 and 10.5 mg 1^{-1}(Figure 3G).

It ensures that the amount of C in the water after the implementation of the project was lower than the situation before the implementation of the project, in this case, the conservationist practices implemented contributed to a smaller amount of eroded sediments, a result that corroborates with Silva et al. (2005) that in their study the organic C was the constituent found in bigger quantity in eroded sediments, emphasizing the need for conservationist practices that reduce the erosive action of rain, maintaining this organic fraction in the soil.

5 CONCLUSIONS

The inspection of Rio do Peixe Watershed, carried out from 2007 to 2019, having inspections, diagnostics, and rehabilitation of agricultural properties, is transforming them into conservationists, preserving the soil and water, taking care of the well-being of the local society.

Implementation of the Integrated Crop-Livestock Systems, with the change in soil and pasture management, increased the occupation rate of areas with pastures, by 31%, compared to the original situation.

The Innovated CDA Methodology presents a positive yield of 1377% in comparison to the conventional CDA Methodology, saving capital and the human resources of Agricultural Defense.

In these twelve years of work at Rio do Peixe Watershed, new technologies have been developed for the site, such as Bioengineering, No-Tillage, and Integrated Crop-Livestock Systems, a fact that has changed the habit of how to treat natural resources of large farmers in the region.

The agri-environmental monitoring and rehabilitation methodology is feasible and can contribute to the management and monitoring of the watersheds, in addition to transforming conventional, degrading agriculture into conservation agriculture.

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Figure 1. Study site at Rio do Peixe Watershed. Brazil, Sao Paulo State. Rio do Peixe Watershed and Watershed Sections

Figure 2. Images of the work area before the project implementation (A, C, F, H, J, L, N - images of 12/05/2002 Google Earth(r)) and after the implementation of soil conservation practices (B (year 2013), D (2013), E (2019), G (2017), I (2018), M (2017) e O (2019), images of Google Earth(r)). A, erosion in a very deep furrow (gully); B, erosion controlled with the construction of containment basins; C, incorrect management of coffee crop; D, with the change of management, transformation of the landscape; E, erosion controlled with construction of terraces; F, erosion in very deep furrow (gully); G, transformation of the landscape, with gully control; H, erosion and silted river; I, landscape transformation, by crop management change that decreases the river silting (detail); J, path with erosion, very deep furrow (gully); K, erosion control with construction of terraces; L, incorrect management of coffee crop, with several erosion (detail); M, control of gullies with the change of coffee management (detail). N, Large erosion gully. O, gully controlled with the construction of terraces (Adapted from Vischi Filho et al., 2016).

Figure 3. Turbidity (A, B, Conama 100 NUT standard), suspended solids (C, D), phosphorus (E, F, Cetesb standard 0.025 mg l-1) and organic carbon (G, H) in water collected in Rio do Peixe, considering the years

2000-2007 (before), and subsequent to the implementation of the project from 2008-2018 (after) (Adapted from Vischi Filho et al., 2016).

Table 1. Erosions and other soil degradation found at Rio do Peixe watershed during diagnosis

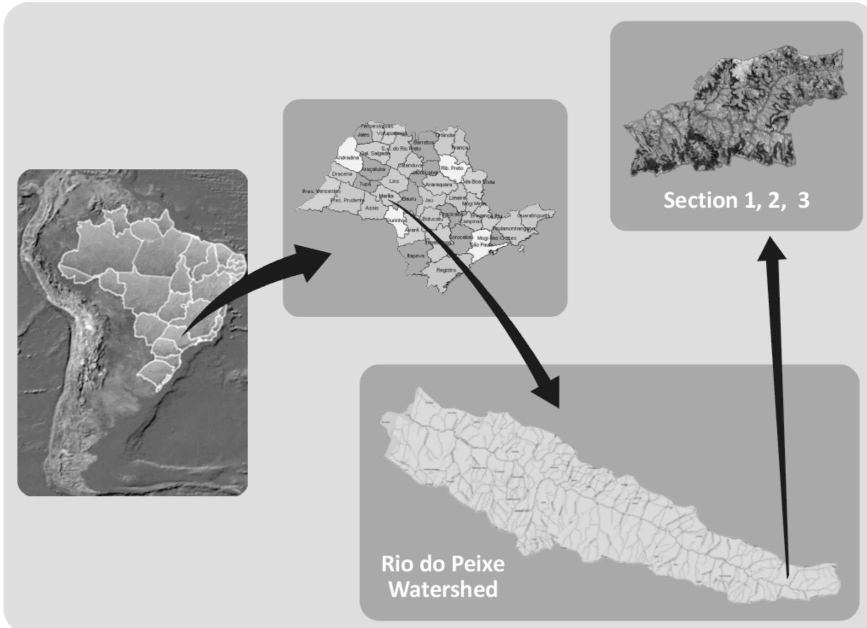
Municipality	**Vera Cruz**	**Ocauçu**	**Marília**
Erosion Type	**Area (ha)**	**Area (ha)**	**Area (ha)**
Laminar Erosion	1270	2035	880
Ravine	259	76	57
Gully	263	106	245
Physical, Chemical and Biological Soil Degradation	1	5	13
Drainage meadow construction	70	73	85
Total Area (ha)	**1862**	**2294**	**1282**

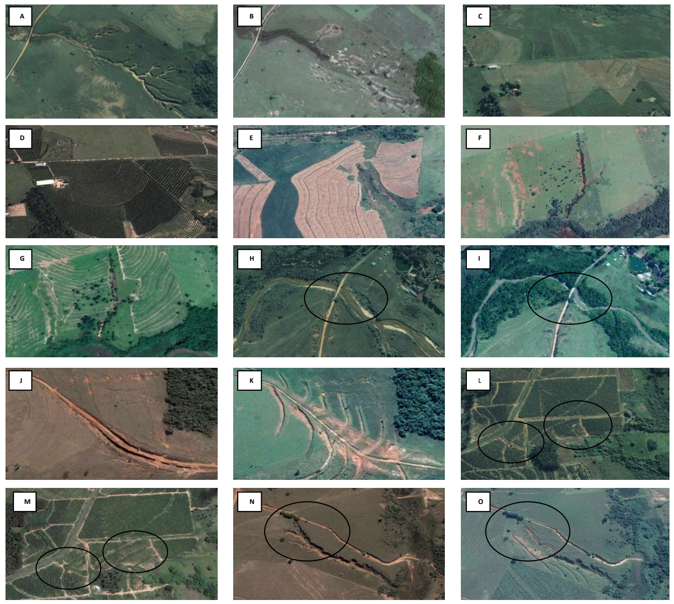
Table 2. Land Use and Occupation in Rio do Peixe Watershed

Municipality	**Vera Cruz**	**Ocauçu**	**Marília**
Crops Grown	**Area (ha)**	**Area (ha)**	**Area (ha)**
Coffee	2232	521	45
Pasture	9799	5726	14947
Vegetables +	14	36	10
Annual crops ++	12	69	100
Passion fruit	13	11	1
Eucalyptus	41	33	21
Sugar cane	8	26	3
Fruit trees	106	25	5
Manioc	20	312	939
Natural Forest	1214	1745	7647
APP §	449	408	3836
Others ¶	168	115	221
Watershed Area	**14076**	**9027**	**27775**

+ Vegetables: pumpkin, lettuce, cabbage, parsley, chive. ++ Annual crops: corn, soybean, wheat. § Permanent Preservation Area. ¶ Others: roads, rivers, farms improvements, warehouse.

Table 3. Cattle herd evolution in Rio do Peixe Watershed. 2009/2010 prior to the work completion. 2016/2017 after pastures recovery


Section 1, 2, 3
Rio do Peixe
Watershed


A
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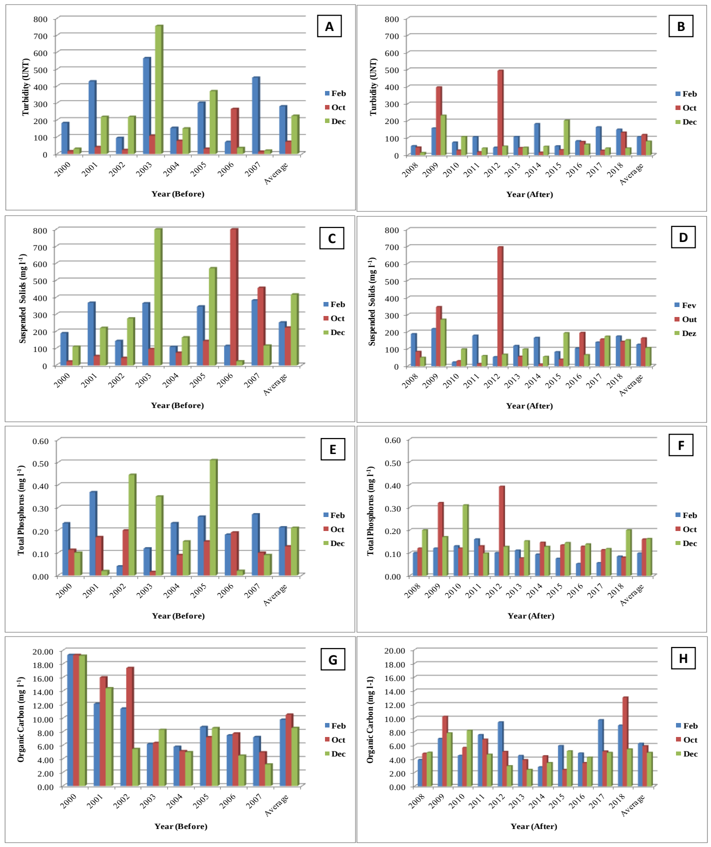
A
Turbidity (UNT)
Year (Before)
Feb
Oct
Dec
B
Turbidity (UNT)
Year (After)
Feb
Oct
Dec
C
Suspended Solids (mg l-1)
Year (Before)
Feb
Oct
Dec
D
Suspended Solids (mg l-1)
Year (After)
Fev
Out
Dez
E
Total Phosphorus (mg l-1)
Year (Before)
Feb
Oct
Dec
F
Total Phosphorus (mg l-1)
Year (After)
Feb
Oct
Dec
G
Organic Carbon (mg l-1)
Year (Before)
Feb
Oct
Dec
H
Organic Carbon (mg l-1)
Year (After)
Feb
Oct
Dec
Average