Application of indexes to evaluate the water quality of the Continguiba/Pindoba Irrigated Perimeter in Sergipe, Brazil

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Abstract

Irrigation makes food production viable, but the quality and quantity of water may be compromised as a result of inadequate management, which may lead to an increase in the concentration of nutrients, heavy metals and agrochemicals. This study aimed to characterize and monitor the water quality of the Continguiba/Pindoba Irrigated Perimeter in Sergipe, Brazil. Secondary data from the Water Quality Monitoring Program were used through the reports of monitoring campaigns carried out between 2013 and 2014. The Water Quality Index (WQI) and the Trophic State Index (TSI) were used in the water quality assessment. The results showed that there is an influence of seasonality, where the best indices were obtained in the rainy season, with the WQI characterized as regular to good, and the TSI characterized as oligotrophic. There was interference from the drainage of rice lots in the dry season, contributing to the increase of nutrients. There was no spatial influence for WQI, which may be related to the eclipse effect, which attenuated the negative impact of a certain variable given the aggregation of several variables. The TSI suffered spatial influence, the waters added to agricultural and fish lots were classified as oligotrophic or ultraoligotrophic, already in the drainage were found indexes of super-utrophic state.

Keywords: Water resources; irrigated areas; climatic seasonality; anthropic action.

1. Introduction

Water is society's most important natural resource, which is indispensable for its survival (Barros et al. 2011). Water is essential for the survival of all species on the planet and is also the natural resource that faces most problems in terms of quality and quantity (Batista et al. 2014). Water quality reflects the effects of the various processes that have occurred along the way, as well as the influence of the characteristics of the watershed (Massoud 2012).

Changes in water quality can be determined by its physical, chemical and biological characteristics, with a view to characterizing this resource in relation to its different uses and identifying the causes of possible degradation of water resources (Santos et al. 2011).

When the forest is removed giving way to agricultural production systems, or pastures, not only the landscape is altered, but also the water quality of the watershed. Multiple uses and activities in a watershed cause relevant changes in the quality of water resources (Andrietti et al. 2016).

Several countries in the world have faced accelerated eutrophication and degradation of aquatic environments caused mainly by human interference (Bucci and Oliveira 2014).

As a result, the use of water quality indices is a way to monitor surface waters, predict and monitor, through diminished information, the possible deterioration of water resources along the watershed or over time (Blume et al. 2010; Barros et al. 2014).

The use of water quality indicators is of extreme importance for strategy in environmental monitoring and management programs, as it allows for a large amount of information to be converted into an easy to understand concept (Costa et al. 2012). Several researchers have conducted water quality monitoring studies in recent years (Pontes et al. 2012; Verissímo and Ferreira 2013; Bucci and Oliveira 2014; Santos et al. 2018; Carvalho et al. 2019; Carvalho et al. 2020).

When assessing the quality of surface water, it is necessary to employ methods that are easy to understand so that the information can be transmitted to the users of water resources (Ferreira et al., 2015). The water quality index gives relevance to pollution from domestic sewage, which is the main source of pollution in watershed (Alves et al. 2012). The Trophic State Index aims to classify water bodies in different degrees of degradation by surveying concentrations of the limiting nutrient and chlorophyll "a" (Cordeiro et al. 2009).

In view of this, the objective was to investigate the quality of surface waters in the irrigated Cotinguiba/Pindoba perimeter, in the State of Sergipe, Brazil, using the Water Quality Index - WQI and the Trophic State Index - TSI.

2. Material and Methods

2.1 Characterization of the Study Area

The study area corresponded to the Irrigated Perimeter formed by the junction of two villages Cotinguiba and Pindoba, located between geographical coordinates UTM 24L 8868577 m and 8860105 m south latitude and between UTM 24L 740720 m and 750810 m west longitude, with an altitude of approximately 10 m, Figure 1.

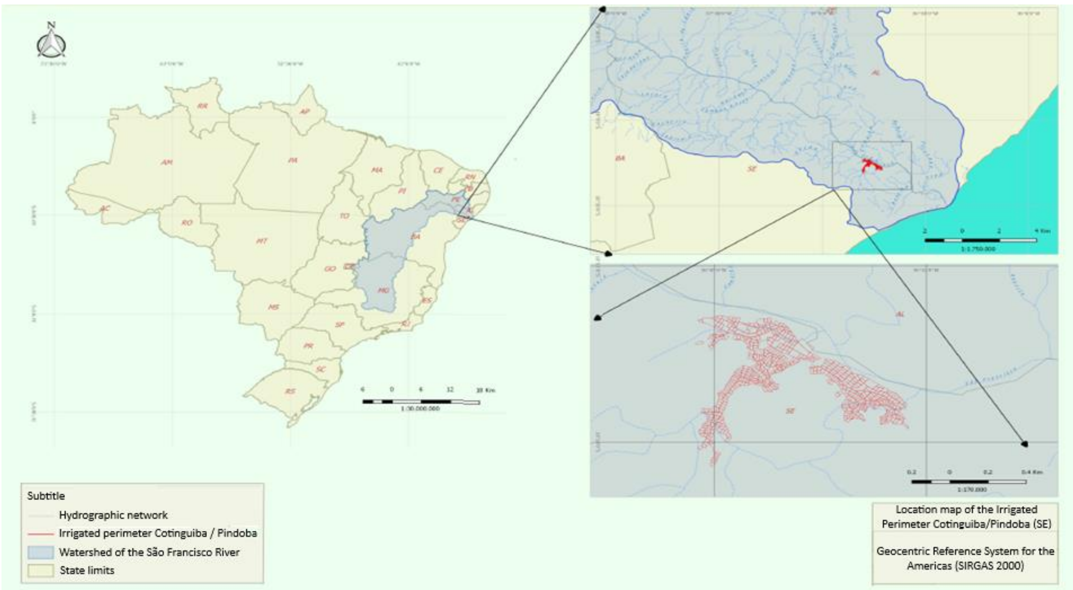

Figure 1. Location Map of the Irrigated Perimeter of Cotinguiba/Pindoba, Sergipe, Brazil.

According to the guidelines of the Land Use Classification System - SCUT, the area under study is characterized by the predominance of more than 90% of Anthropic Agricultural Areas and the second most representative class is water. In this anthropic agricultural area there are important irrigated perimeters that have diversified crops, both temporary and permanent, in a consortium system or single crops, in addition to areas intended for fish farming (IBGE, 2011).

The Cotinguiba/Pindoba Irrigated Perimeter is located on the right bank of the San Francisco River, covering land in the municipalities of Japoatã, Neópolis and Propriá in the State of Sergipe. The perimeter is 112 km from the Sergipe capital, Aracaju, and the SE-200 highway is the main access road that connects the BR-101 to the SE-304 highway.

The Irrigation Project has a total area of 2,215 hectares, 474 agricultural plots, in which 85.9% of the areas are composed of family plots, and 13.2% of business plots (CODEVASF, 2014). The main activities developed are rice growing, polyculture, carciniculture and fish farming. The main crops are rice, green corn, banana and green coconut. Conventional sprinkler and flood irrigation systems are used. As a source of irrigation, the San Francisco River is the main contributor. The streams Pilões, Nossa Senhora, Estiva and Mussuípe also make up the hydrology of the perimeter.

The climate is of the semi-humid type, with rainfall predominating in autumn and winter. The average annual precipitation in the perimeter area is 851 mm, with an annual absolute maximum of 1,074 mm in 1914 and a minimum of 527 mm in 1946 (CODEVASF, 2005). The rains usually occur from March to September, with greater rainfall in the months of April to July, with May being the rainiest month. The dry season occurs from October to February. The average annual temperature is 25.2ºC.

2.2 Data source

This research used secondary data, in the public domain, from the Water Quality Monitoring Program, through the reports of the monitoring campaigns carried out between 2006 and 2014, at the Cotinguiba/Pindoba Irrigated Perimeter. The sampling points can be seen in Figure 2.

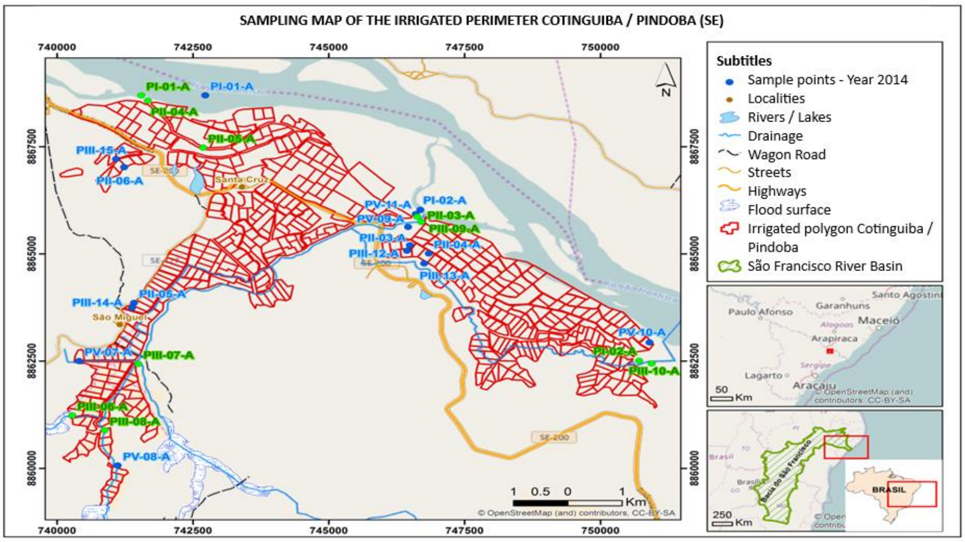

Figure 2. Water quality sampling points at the Cotinguiba/Pindoba Irrigation Perimeter, Sergipe, Brazil.

The monitoring program was intended to characterize the aquatic environment through physical, chemical and biological analysis of water and sediment samples, collected in rainy and dry periods between July 30 and August 7, 2013 and January 4 to 10, 2014 (CODEVASF, 2014).

Samples were collected at 15 (fifteen) distinct sampling stations in 2014 (Table 1), including sampling points in agricultural and fish farming lot drainage. In these stations 41 (forty-one) parameters were analyzed.

Table 1. Description of the sample stations of the surface water quality monitoring network of the Cotinguiba/Pindoba Irrigated Perimeter for the years 2013 and 2014 (CODEVASF, 2014)

Environment	Sample Station	Description	Main feature	Geographic Coordinates 24L UTM (m)	
Primary Source I	PI-01-A	On the riverbed of the San Francisco at least 100 meters upstream of the Pumping Station EB 1204	Water supply to irrigation project	742728	8868696
	PI-02-A	On the riverbed of the San Francisco at least 100 meters upstream of the Pumping Station EB 1204, mixing zone	Water supply to irrigation project	746685	8866026
Multipurpose II	PII-03-A	In the water sluice of lot 394	Water supply for fish farming lot	746494	8865200
	PII-04-A	In the water sluice of lot 400	Water supply for fish farming lot	746839	8865008
	PII-05-A	In the water sluice of lot 337	Water supply for agricultural lot	741415	8863856
	PII-06-A	In the water sluice of lot 495	Water supply for agricultural lot	741233	8867020
Perimeter/collector drainage	PV-07-A	At the entrance of the Estiva creek in the perimeter - lot 357	Drainage of agricultural lot - rice growing	740406	8862502
	PV-08-A	At the entrance of the Pilões creek in the perimeter - lot 389	Drainage of agricultural lot - rice growing	741116	8860068
	PV-09-A	At the entrance of the Mussuípe creek in the perimeter - lot 237	Drainage of agricultural lot - rice growing	746459	8865626
	PV-10-A	In the drainage of the Pumping Station EB 1102 – EBD 01	Perimeter drainage	750903	8862934
	PV-11-A	In the drainage of the Pumping Station EB 1602 – EBD 02	Perimeter drainage	746599	8865926
Drainage of agricultural lot and/or fish farming	PIII-12-A	In the water sluice of lot 394	Drainage of fish farming lot	746438	8865072
	PIII-13-A	In the water sluice of lot 400	Drainage of fish farming lot	746755	8864776
	PIII-14-A	In the water sluice of lot 337	Drainage of agricultural	741376	8863740

Environment	Sample Station	Description	Main feature	Geographic Coordinates 24L UTM (m)	
			lot - rice growing		
	PIII-15-A	In the water sluice of lot 495	Drainage of agricultural lot - rice growing	741084	8867208

2.3 Preliminary evaluation of input data

The preliminary evaluation consisted of organizing and systematizing the database in order to make possible its use in statistical analysis and water quality assessment indices. The secondary data were organized in Excel spreadsheets, for each Sample Station, considering the year of implementation of the monitoring station.

Considering the different rainfall in the sampling months, this study addressed a discussion of seasonal influence, considering a period of drought, with lower rainfall in January 2014 and a rainy period in August 2013.

For spatial analysis of the influence of the irrigation project on water quality in the region under study, monitoring stations were divided by their location, seeking to divide those that do not suffer the interference of the irrigation project, upstream, also called entry stations and the exit stations that are downstream of the project and that have as a basic characteristic the proximity to drainage zones of rice and fish production lots.

2.4 Water Quality Index (WQI)

The variables temperature, hydrogen ion potential (pH), biochemical oxygen demand (BOD), total nitrogen, dissolved oxygen, total solids, total phosphorus, turbidity and thermotolerant coliforms were used for the application of the Water Quality Index (WQI). From the calculation, the value was assigned to the surface water quality, indicated by the WQI on a scale from 0 to 100.

The WQI incorporates nine parameters considered relevant for the assessment of water quality for public supply. The index is calculated by the weighted producer of the water quality corresponding to the variables that make up the index, according to Equation 1.

$$WQI = \prod_{i=1}^{n} q_i^{w_i} \qquad (1)$$

wherein:

WQI = Water Quality Index, scale from 0 to 100;

q_i = quality of parameter i, obtained on the basis of the specific average curve of quality;

w_i = weight attributed to the parameter, according to its importance in quality, between 0 and 1.

The weights of the parameters (w) were attributed considering the importance of the global conformation of water quality, with dissolved oxygen being the variable with the highest weight attributed (0.17) and total solids the one with the lowest weight (0.08). The WQI values were analyzed using classification intervals (Table 2), for which quality levels were defined, and CETESB (2005) also assigns reference colors.

Table 2. Water Quality index (WQI) ranges with respective quality levels and reference colors

WQI ranges	Quality levels	Reference colors
79 < WQI ≤ 100	Great	Blue
51 < WQI ≤ 79	Good	Green
36 < WQI ≤ 51	Regular	Yeloow
19 < WQI ≤ 36	Bad	Red
WQI ≤ 19	Terrible	Purple

The quality indexes were calculated using some variables, but for 2006 it was not possible to evaluate the WQI because in none of the stations were analyzed together the nine necessary parameters: water temperature, pH, dissolved oxygen, biochemical oxygen demand, fecal coliforms, total nitrogen, total phosphorus, total solid and turbidity.

2.5 Trophic State Index (TSI)

The Trophic State Index (TSI) was calculated from the values of phosphorus and chlorophyll-a using the Lamparelli methodology (2004). The TSI, which uses the identified phosphorus concentrations in the water body, could not be verified in 2006, since no phosphorus concentrations were identified in the analyses. Therefore, discussions regarding the WQI and TSI indexes were based on the monitoring campaigns of August 2013 and January 2014.

Equation 2 expresses the TSI calculation for rivers, where total phosphorus (TP) is expressed in µg L^{-1}. Equation 3 expresses the calculation of the TSI for rivers, where chlorophyll-a (CL) is expressed in µg L^{-1}. Discussions on this index were based on the arithmetic mean of the TSI to TP and TSI to CL, which was assigned the term MTSI.

$$TSI_{TP} = 10\ x\ \left(6 - (0.42 - 0.36\ x\ \left(\frac{\ln(TP)}{\ln(2)}\right)\right) - 20 \qquad (2)$$

$$TSI_{CL} = 10\ x\ \left(6 - (0.7 - 0.6\ x\ \left(\frac{\ln(CL)}{\ln(2)}\right)\right) - 20 \qquad (3)$$

The TSI values were obtained through the equations, the classes assigned to each of them and their characteristics (Table 3).

Table 3. Values, classes and characteristics of trophic states

TSI value	**Trophic State Classes**	**C**haracteristics
TSI<47	Ultra-oligotrophic	Clean water bodies, with very low productivity and insignificant concentrations of nutrients that do not cause damage to water uses.
47<TSI≤52	Oligotrophic	Clean, low-productivity water bodies in which there is no undesirable interference with water uses due to the presence of nutrients.

52 <TSI≤59	Mesotropic	Water bodies with intermediate productivity, with possible implications for water quality, but at acceptable levels in most cases.
59<TSI≤63	Eutrophic	Water bodies with high productivity in relation to natural conditions, with reduced transparency, generally affected by anthropic activities, in which undesirable changes in water quality occur due to increased concentration of nutrients and interference in their multiple uses.
63<TSI≤67	Supereutrophic	Water bodies with high productivity in relation to natural conditions, low transparency, generally affected by anthropic activities, in which undesirable changes in water quality frequently occur, such as the occurrence of algae blooms, and interference in their multiple uses
TSI > 67	Hypereutrophic	Water bodies significantly affected by high concentrations of organic matter and nutrients, with marked impairment in their uses, associated with episodes of algae blooms or fish deaths, with undesirable consequences for their multiple uses, including on livestock activities in riverside regions.

Source: Adapted from Lamparelli (2004).

3. Results and Discussion

3.1 Application of the Water Quality Index - WQI

The boxplot of the Water Quality Index was observed in Figure 3, where in the dry period, the index varied from 31.79 to 80.25, classified as bad to good, while in the rainy period it varied from 64.40 to 85.87, classified as regular to good. Considering the seasonal variation it was found that the average WQI for the dry season was regular and in the rainy season it was good.

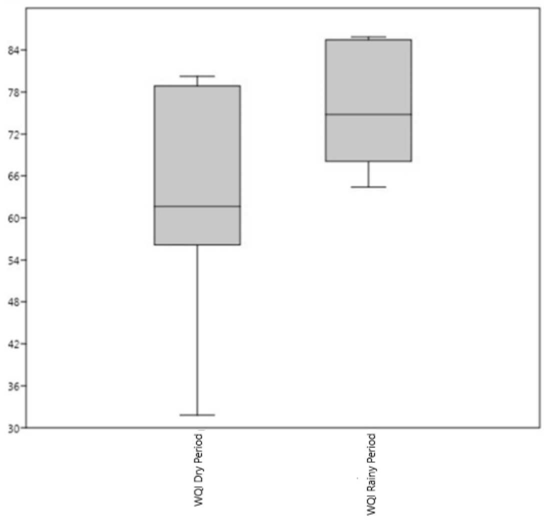

Figure 3. Time variation of WQI at Cotinguiba/Pindoba Irrigated Perimeter.

Barros and Souza (2013) obtained worse results for the Andre stream in Mirassol D'Oeste - MT, because in the dry season the WQI ranged from 37.0 to 56.0 and in the rainy season from 33.78 to 58.27, classifying the water quality as regular in both periods, the authors attributed this level to the disposal of domestic, commercial and agricultural effluents in the stream.

The water quality of the Irrigated Perimeter of Cotinguiba/Pindoba, according to the WQI values, was classified as regular quality, 69.42. Of the fourteen observations, six were regular, seven good and one bad.

Buzelli and Cunha-Santino (2013), when diagnosing the water quality of the Barra Bonita reservoir, SP, classified the water quality of the reservoir as good, for the period from 2007 to 2012, despite the intense anthropic pressures, mainly due to agricultural activities.

Santos et al. (2018) pointed out that the sources of anthropic contamination are still incipient and will probably contribute in the long run to the process of degradation and eutrophication of water bodies in the Sapucaia Coastal watershed in Sergipe, which currently have good quality water and WQI generally classified as good.

The spatial and seasonal variation of WQI can be seen in Figure 4. Only the PI-02-A Station had the index classified as bad during the dry season. This sampling point is located in the San Francisco River bed at least 100 meters upstream of the Pumping Station, it was expected that because it was not influenced by the Irrigation Project the index would not be classified this way.

Figure 4. Seasonal and temporal variation of WQI.

Zanini et al. (2010) inferred that the anthropic activities along the banks of the Rico Stream, in Jaboticabal, SP, reduced the quality of its water during the different periods of the year, showing better quality in the rainy season and lower in the dry season.

In this study, the best rates were obtained in the rainy season, in PI-02-A, PV-09-A, PV-10-A and PV-11-A Stations (Table 4) being the first two of water supply to the lots and the last two of the water drained from the lots. Although the index remains in the same classification does not mean that there was no change in water quality, such classification may be related to the eclipse effect, classic and undesirable in water quality indexes, by aggregating several environmental variables in a single number, which may produce an attenuation of the negative impact of one of the variables against the stable behavior of the others (Silva and Jardim 2006; Verrissimo and Ferreira 2013).

Table 4. Description of the sampling stations with their respective WQI for the dry and rainy periods

Stations	WQI Dry Period	Quality level	WQI Rainy period	Quality level	Characteristic and location of the sampling station
PI-01-A	80.2583	Good	74.7944	Good	Surface Water-Primary Source I-PI-01-A - In the bed of the San Francisco River by the 100 meters the upstream
PI-02-A	31.7983	Bad	85.8715	Good	Surface Water-Primary Source I-PI-02-A - In the bed of the San Francisco River by the 100 meters the upstream da EB01
PV-07-A	57.6643	Regular	68.0815	Regular	Perimeter Drainage/Collector V - At the entrance of the Estiva stream - In Lot 357 - rice growing
PV-08-A	61.6477	Regular	64.4040	Regular	Perimeter Drainage/Collector V - At the entrance of the Pilões stream - In Lot 389 - rice growing
PV-09-A	56.1331	Regular	83.3416	Good	Perimeter Drainage/Collector V - At the entrance of the Mussuípe stream - In Lot 237 - rice growing
PV-10-A	74.7053	Good	85.4674	Good	Perimeter Drainage/Collector V - In Pumping Station Drainage 1102 EBD 01
PV-11-A	78.8751	Good	68.9662	Regular	Perimeter Drainage/Collector V - In Pumping Station Drainage 1602 EBD 02

Simões et al. (2007), when evaluating the WQI in the Assis-SP region, with intense fish farming activity, obtained an indication of good quality, even with the significant change in alkalinity, conductivity and total dissolved solids, observed with the use of Principal Component Analysis. The authors attributed this to the eclipse effect that attenuated one of the variables against the others.

3.2 Application of the Trophic State Index - TSI

The application of TSI assisted in the evaluation of the eutrophication tendency of the hydric bodies under study. There was no significant difference between the median of chlorophyll-a samples ($p>0.05$) by the Kruskal-Wallis test, both for the dry and rainy periods, which demonstrated that there is no influence of seasonality on the data. The total phosphorus variable showed significant difference ($p<0.05$), this parameter varied expressively in each one of the sampling campaigns, that is, there was influence of seasonality. ANOVA statistical evaluations were performed using the PAST - Paleontological STatistics software.

The minimum, maximum, mean and standard deviation of the chlorophyll-a and total phosphorus variables of 15 sampling stations in the rainy and dry season can be observed in Table 5.

Table 5. Descriptive statistics for total phosphorus (TP), chlorophyll-a (CL) and for the Trophic State Index of the Irrigated Perimeter of Cotinguiba/Pindoba, Sergipe, Brazil

Parameter	Minimum	**M**aximum	**Mean**	Standard deviation
CL (μg L^{-1}) | rainy	0.24	13.21	4.028667	3.895484
CL (μg L^{-1}) | dry	0.24	11.77	3.975333	3.624435
TP (mg L^{-1}) | rainy	0.004	0.524	0.0394	0.1340905
TP (mg L^{-1}) | dry	0.012	0.284	0.06813333	0.08812075

In the Water Quality Assessment Program, which comprised two campaigns, dry season and rainy season, CODEVASF (2014) attributes the phosphorus concentrations found in the water to the use of agrochemicals from agricultural areas, which can later be deposited at the bottom of rivers and lakes, which can be released into the water through biochemical processes. Besides this, other sources of phosphorus can be cited, such as the discharge of untreated household effluents from the irrigated perimeter housing plots.

It was found that during the dry season in January 2014, the station with the highest concentration of chlorophyll-a, 11.77 μg L^{-1}, was PIII-13-A Station, which is located in the water sluice of Lot 400 - Drainage of fish farming lot (Figure 5). During the dry season, the PV-09-A Station, drainage of a rice growing lot, had a concentration of 13.21 μg L^{-1}.

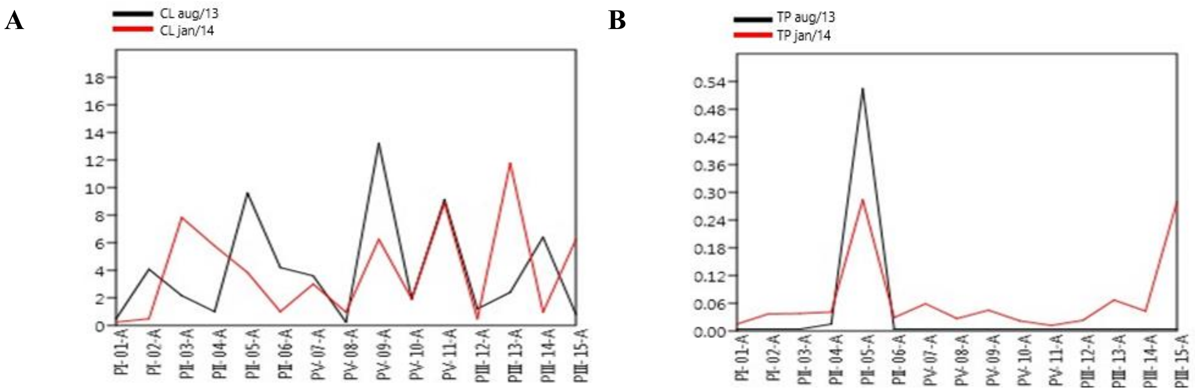

Figure 5. Chlorophyll-a concentrations (μg L^{-1}) at Cotinguiba-Pindoba Irrigated Perimeter sampling stations (A); Total phosphorus concentrations (mg L^{-1}) at Cotinguiba-Pindoba Irrigated Perimeter sampling stations (B).

All stations presented inverse values scale according to seasonality, for chlorophyll-a, with the exception of the PV-11-A Station, with concentration between 8.89 μg L^{-1} and 9.13 μg L^{-1} in the rainy and dry season, respectively. This last station is located in the drainage at the Pumping and Drainage Station02, located on the San Francisco River, which receives influence from all agricultural and fish farming lots.

Total phosphorus concentrations in the rainy season were mostly below 0.004 mg L^{-1}, with the exception of the results in PII-04-A and P-II-05-A stations, the first being fish farming drainage and the second being rice growing. The P-II-05-A Station, during the dry season, also had one of the highest concentrations, 0.284 mg L^{-1}.

The MTSI values can be observed by the Lamparelli methodology (2004) in Figure 6. It was found that in most sampling stations, the MTSI was lower in the rainy season, 2013, compared to the dry season, 2014.

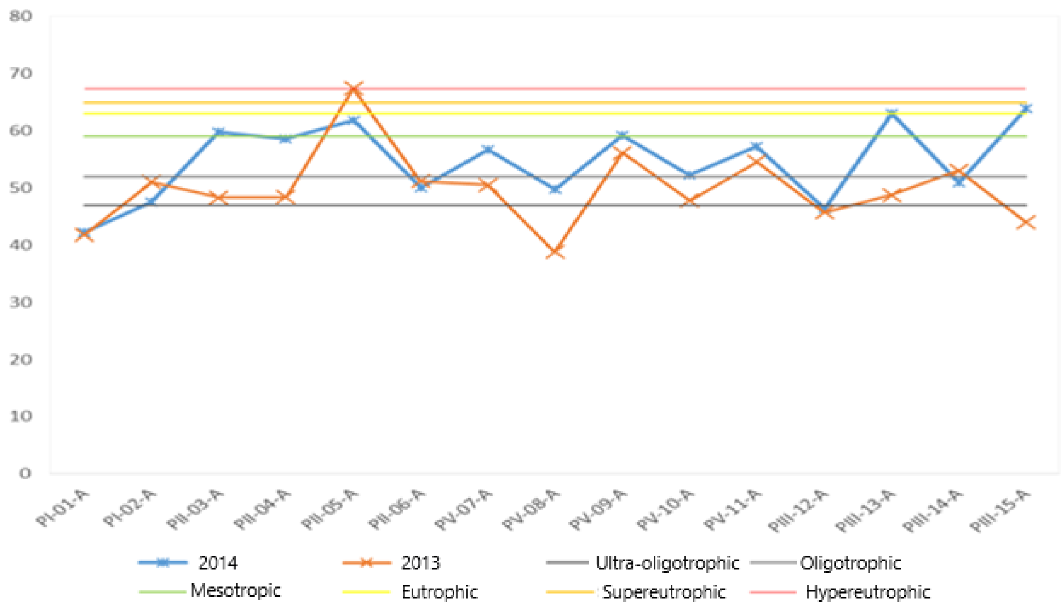

Figure 6. Temporal and spatial analysis of Mean Trophic State Index (MTSI) of Lamparelli (2004) in the Cotinguiba/Pindoba Irrigation Project, Sergipe, Brazil.

Santana et al. (2015) also found higher MTSI values in the dry period than in the rainy period, when analyzing the index in the Pilões, Papagaio and Capivara rivers, in Sergipe State, Brazil. The authors attributed this variation to the increase in temperature and consequently the proliferation of algae.

The maximum MTSI was 63.95 during the dry season, which classifies the water body as super-utrophic, a condition that can cause undesirable changes in water quality, such as the occurrence of episodes of algae blooms and interference in their multiple uses. This condition was observed in PIII-15-A Station, located in drainage of a rice growing lot, as detailed in Table 1.

The maximum value of MTSI was 67.45 in the PII-05-A Station, drainage of rice growing. The other stations presented MTSI values that classified them as mesotrophic, oligotrophic and ultraoligotrophic (Figure 6).

The box-plots of Figure 7 presented a spatial evaluation of the MTSI during the rainy season and the dry season. The MTSI upstream of the irrigation perimeter was lower than the index of the sampling stations located downstream. This demonstrated that the anthropic activities performed in the Cotinguiba/Pindoba Perimeter, mainly agriculture and fish farming, contributed to the increase of the total phosphorus nutrient in the aquatic environment. CODEVASF (2014) reported on the significant presence of macrophytes in the perimeter water drainage.

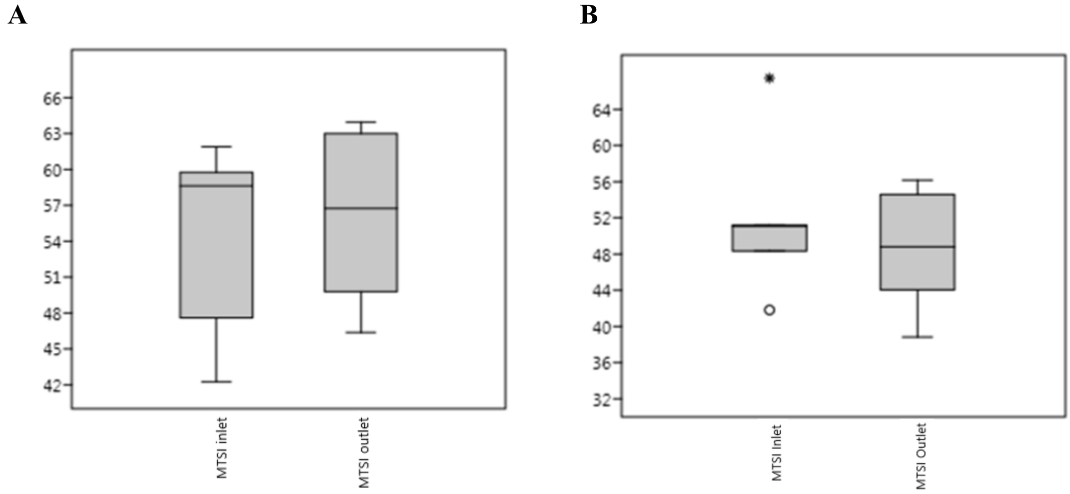

Figure 7. MTSI box-plot with spatial trends, water inlet and outlet stations in the irrigation perimeter, in the rainy season (A) and the dry season (B).

Assessing the box plot quartiles in the rainy period, an atypical value was recorded, 67.45 (hypereutrophic), that significantly departed from the general trend of variation of the other elements of the sample, which may be the result of observations with gross errors or simply the manifestation of very rare events (Naghettini and Pinto 2007).

This value can mean error in sampling, laboratory analysis or a point source of pollution at the time of collection, so it was decided not to remove the sample. In this case, the index value was influenced by the phosphorus concentration, 0.524 mg L^{-1}. In the analyses of the State Water Resources Plan when evaluating physical parameters of water quality, total phosphorus varied from 0.02 to 0.08 mg L^{-1} in the Lower San Francisco region. High phosphorus concentrations may be related to the drainage of nutrient-rich waters that are drained from the lots (Brito et al. 2016).

Considering the arithmetic averages of MTSI (Table 6), the rainy period would be characterized as oligotrophic, condition of clean water bodies, very low productivity and insignificant concentrations of nutrients. The dry season would fit as mesotrophic, a characteristic that attributes to the water body possible implications on water quality, but at acceptable levels in most cases.

Table 6 - Mean Trophic State Index of Lamparelli (2004), description of characteristics and location of sampling stations in the Cotinguiba/Pindoba Perimeter, Sergipe, Brazil

Station	Dry Season	MTSI	Rainy Season	MTSI	Characteristic and location of the sampling station
PI-01-A	42.2557	ultra-oligotrophic	41.8233	ultra-oligotrophic	Surface Water-Primary Source I-PI-01-A - In the bed of the San Francisco River by the 100 meters the upstream
PI-02-A	47.6003	oligotrophic	51.0857	oligotrophic	Surface Water-Primary Source I-PI-02-A - At least 100 meters upstream of the EB01 in the São Francisco Riverbed
PII-03-A	59.7533	eutrophic	48.3330	oligotrophic	In the water sluice of lot 394 – Fish farming
PII-04-A	58.6293	Mesotropic	48.4324	oligotrophic	In the water sluice of lot 400 – Fish farming

PII-05-A	61.8928	eutrophic	67.4537	Hypereutrophic	In the water sluice of lot 337 – rice growing
PII-06-A	50.1443	oligotrophic	51.2111	oligotrophic	In the water sluice of lot 495 – rice growing
PV-07-A	56.7436	Mesotropic	50.5439	oligotrophic	Perimeter Drainage/Collector V - At the entrance of the Estiva stream in Lot 357 rice growing
PV-08-A	49.7821	oligotrophic	38.8233	ultra-oligotrophic	Perimeter Drainage/Collector V - At the entrance of the Pilões stream in Lot 389 – rice growing
PV-09-A	59.2169	eutrophic	56.1706	Mesotropic	Perimeter Drainage/Collector V - At the entrance of the Mussuípe stream in Lot 237 - rice growing
PV-10-A	52.2502	Mesotropic	47.8233	oligotrophic	Perimeter Drainage/Collector V - In Drainage of EB 1102 EBD 01
PV-11-A	57.3094	Mesotropic	54.5718	Mesotropic	Perimeter Drainage/Collector V - In Drainage of EB 1602 EBD 02
PIII-12-A	46.3657	ultra-oligotrophic	45.7891	ultra-oligotrophic	Lot drainage in the water sluice of lot 394 - Fish farming
PIII-13-A	62.9900	eutrophic	48.7891	oligotrophic	Lot Drainage in the water sluice of lot 400 - Fish farming
PIII-14-A	50.9905	oligotrophic	53.0342	Mesotropic	Lot Drainage in the water sluice of lot 337 – rice growing
PIII-15-A	63.9573	Supereutrophic	44.0342	ultra-oligotrophic	Lot Drainage in the water sluice of lot 495 – rice growing

The arithmetic mean of the MTSI both in and out, rainy and dry periods, were similar, fitting as oligotrophic and mesotrophic, respectively. Despite the unstable results that framed the stations in all the trophic state indexes, there was no significant difference (Kruskal-Wallis, $p>0.05$), between the MTSI, for input and output, in the two time periods.

Fia (2009) evaluated the Trophic State Index in the watershed of Lagoa Mirim, RS, Brazil and found that the behavior of this index in the region is unstable, the authors attributed this variability to the diffuse contribution of irrigated rice crops, which return this water to the environment with chemical and organic phosphate fertilizers and also to domestic sewage.

The results obtained by Santos et al. (2018) allowed us to say that the behavior of the TSI along the Sapucaia Coastal watershed in Sergipe is stable, considering the occurrence of periods in which the values achieved become critical, especially for the deterioration in water quality, due to the characteristics of the surrounding water bodies of this watershed.

4. Conclusions

The Water Quality Index (WQI) varied from bad to good during the dry season and from regular to good during the rainy season, proving the seasonal influence.

The arithmetic average of the indices was classified as regular WQI.

No spatial influence on WQI results was evidenced, which may be related to the eclipse effect, attenuation of the negative impact of a certain variable given the aggregation of numerous variables.

The results of the trophic state classification, using the Trophic State Index (TSI) modified by Lamparelli, showed that there is an influence of seasonality, since the best indices were obtained in the rainy season, characterized as oligotrophic.

There was interference from the drainage of rice growing lots in the dry period, contributing to the increase of nutrients, in this period the MTSI was framed in mesotrophic.

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6. References

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