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Assessment of conflicts between mangroves and human occupation in Subaé river outfall between the years 1988 to 2017.

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Abstract

Coastal zones fulfill important ecological, social and economic functions. Because soil flooded by tidal variations and due to great variation in salinity. Mangroves cover these regions. They are also a tropical coastal ecological system, always in the lowlands, at the mouths of rivers and estuaries. Despite their important environmental role, mangrove areas have been continuously decreasing worldwide, with an average reduction of 30% in the last 30 years. Thus, this research sought to determine land use and land cover change in low Subaé. With emphasis on Mangrove areas and urban occupation. We used supervised classifications of satellite images to evaluate the changes. We chose images from 1988, 2003, and 2017. And used images from the Landsat series (30m) and an image from the PlanetScope satellite (3m). We validated classifications through the Tau and Geographical Simultaneity concordance measures. We observed that performing the spatio-temporal analysis observing only the variation of areas may not represent the phenomena that occurred. The overall Tau index calculation for the ratings was 0.89. During the period 1988-

2017 there was a significant reduction in Agricultural areas, corresponding to around 15% of the study area. Meanwhile, growth of pasture from 24km² to 48Km² and the Urban Zone, occurred over all classes, including mangroves.

Keywords: Mangroves; Land Use and Land Cover; Baía de Todos os Santos; Socioenvironmental conflicts.

1. Introduction

Coastal zones fulfill important ecological, social and economic functions, occupied by marine engineering works, ports, navigable canals, dredging and artificial landfills (PRIMAVERA, et al., 2019). They are affected by the damming of rivers, facilities for leisure areas, tourism, and urbanization, among other interventions. All of that resulted in rapid changes in local environmental characteristics (SANTOS, 2011; ONYENA & SAM, 2020).

The mangrove areas are considered a tropical coastal ecological system. They are located in border areas between the continent and the sea, along the coast, always in low terrain, at deltas and estuaries, having soil flooded by tidal and widely salinity variations (CORREIA and SOVIERZOSKI, 2005). These areas are important and have fundamental functions such as: maintaining water quality, sediment fixation, providing primary production and maintaining biodiversity (MITRA,2020). Converting them in a relevant nursery and refuge area for several species of commercial interest (WORTHINGTON, et al., 2020).

Despite their important environmental role, mangrove areas have been steadily decreasing worldwide. Many authors report an average reduction of 30% in the last 30 years. The main cause is due to social and economic pressures (KANNIAH et al., 2015; CARNEY et al., 2014; LEMARIE et al., 2006; RUBÉN et al., 2002).

The understanding the urban growth pattern and the resulting forms of impact represents important information in the decision making processes regarding environmental planning (MARTINS and WANDERLEY, 2009). That spontaneous growth of urban areas and their polluting activities, in addition to environmental and climatic changes, directly affect the conservation status of coastal environments. Thus, in order to help their preservation, it is important to highlight any research aimed to understand and modify, if necessary, their dynamics (WORTHINGTON, et al., 2020; HIMES).

In this sense, geotechnologies appear as a possible option for monitoring and research in these areas, both in operational and cost terms (MOURA and CANDEIAS, 2011). Geotechnologies Provides efficient and agile ways to characterize land use. This method eases the acquisition and manipulation of data, allows repetition in the collection of information, and constant updates of the analyzed areas (MAURYA et al., 2021). Thus, this research sought to determine spatio-temporal changes. Demonstrating loss and gain relationships between classes in the low Subaé, with an emphasis on the areas of mangrove and urban occupation.

2. Methodology

The study area is located in Baixo Subaé, located in the Northern Reconcavo of the state of Bahia (Figure 1).

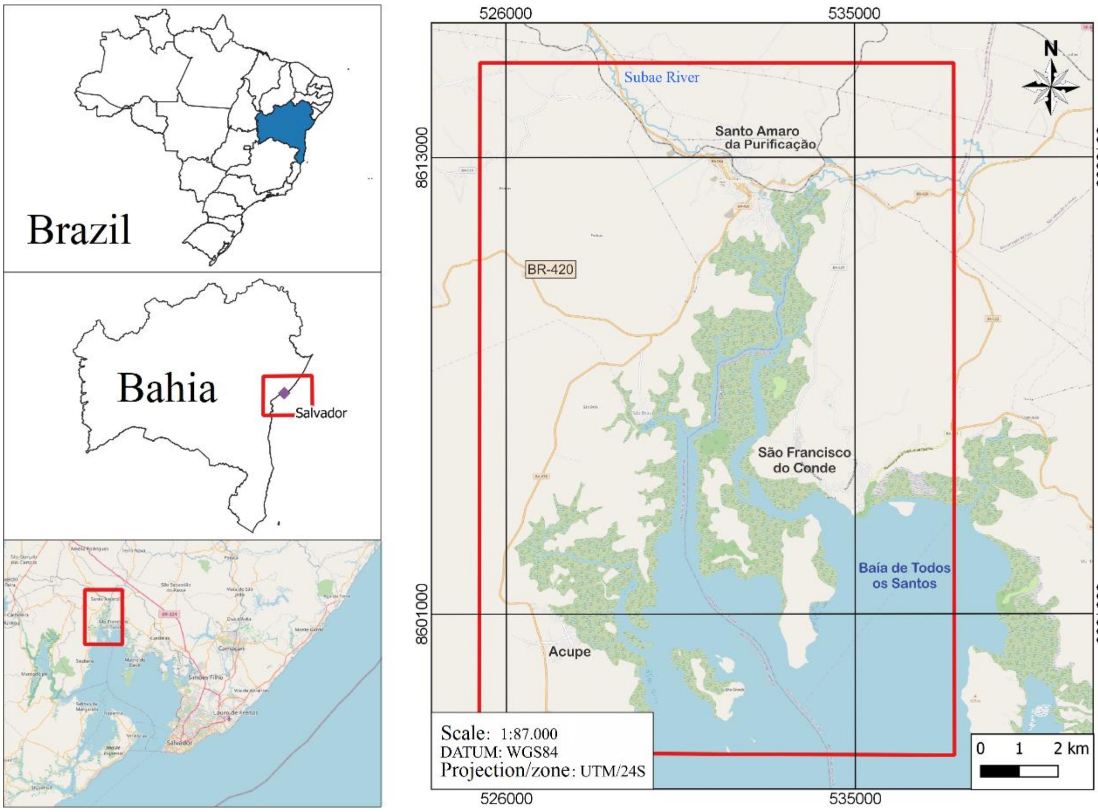


Figure 1 - Location of the study area

Satellite images from the Landsat Series (30m) were used for temporal evaluation of the mangrove areas. And, an image from the PlanetScope satellite (3m) was used to determine the accuracy of the classifications.

To allow comparison between maps with different spatial resolutions, we created a vector file with 5000 points of random location in the map area. This vector received the classes values in both images. We arrange the data in a Confusion Matrix. And, calculated the Tau and Geographic Simultaneity (GS) (SILVA et al., 2017) indices, which were classified according to Silva (2018). The methodological steps are shown in Figure 2.

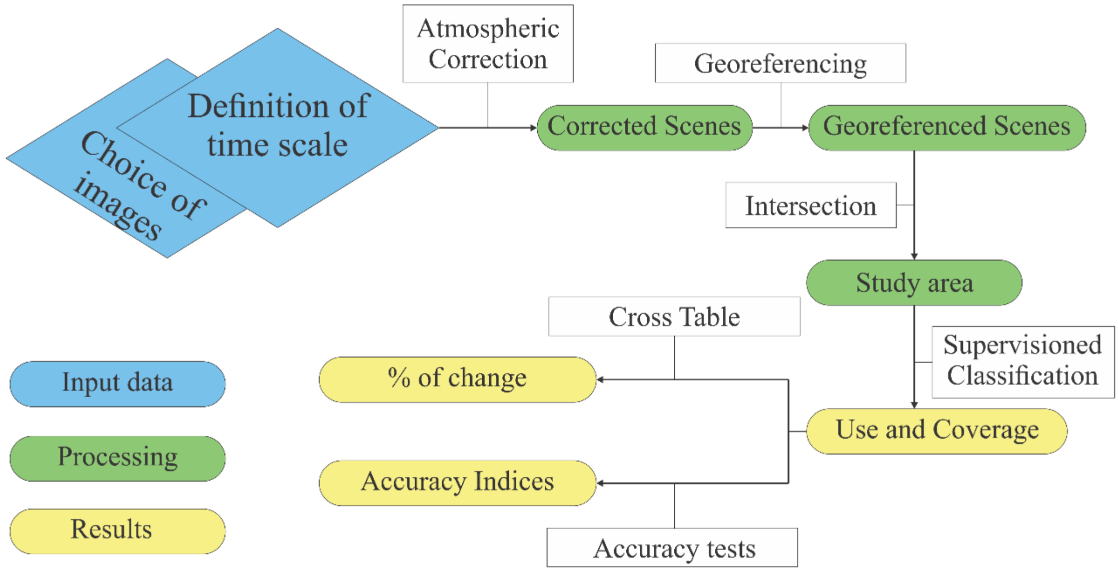


Figure 2 - Flowchart: Modeling Mangrove Space-Time Alteration.

3. Results and discussion

The results of the classifications are shown in Table 1

Table 1– Classes of Use and coverage for the years studied (Km²).

Satellite / Year	Mangrove	Arboreal Vegetation	Agriculture	Exposed soil	Urban	Water	Pasture
L5/1988	25.89	66.76	44.35	12.56	2.79	44.78	23.14
L7/2003	27.24	50.13	13.57	20.28	4.53	48.09	56.43
L8/2017	27.10	73.63	6.91	7.96	6.05	49.92	48.72
PS/ 2017	28.32	68.13	9.92	8.91	7.43	49.16	48.56

The comparison of the data obtained between the classification of the image of the Planet Scope satellite, and the classification of Landsat8 of June 2017, allowed the accomplishment of the concordance measures. At the intersection between point vectors and the classified images (Table 2), the classes numbers from 1 to 7 correspond to: Mangroves, Tree vegetation, Agriculture, Exposed soil, Urban area, Water bodies and Pasture, respectively.

Table 2 - Confusion Matrix for Concordance Measures.

Class	1	2	3	4	5	6	7	Total PS*
1	615	18	1	6	0	29	8	677
2	9	1501	8	7	3	2	81	1611
3	1	29	136	0	1	0	24	191
4	0	8	5	123	0	1	16	153
5	5	5	0	6	119	2	18	155
6	8	1	0	0	0	1130	0	1139
7	11	109	6	23	8	2	911	1070
Total L8	649	1671	156	165	131	1166	1058	4996

The general Tau index for the classifications was 0.89, considered Almost Perfect (SILVA, 2018). Evaluating the agreement indexes for each category (Table 3). It can be seen that classes 1,2,6 and 7 obtained an Excellent and Almost Perfect classification for the Geographic Simultaneity and Tau indices, respectively. Class 5 was Almost Perfect for Tau, but it only Very Good for GS. Class 3 and 4 were Very Good (SG) and Substantial (Tau).

Table 3 - Concordance indices.

Class	Geographic Simultaneity	Tau
1	1.856031	0.91653
2	1.829984	0.872978
3	1.583837	0.776168
4	1.549376	0.766153
5	1.676139	0.827258
6	1.961224	0.974624
7	1.71246	0.817293

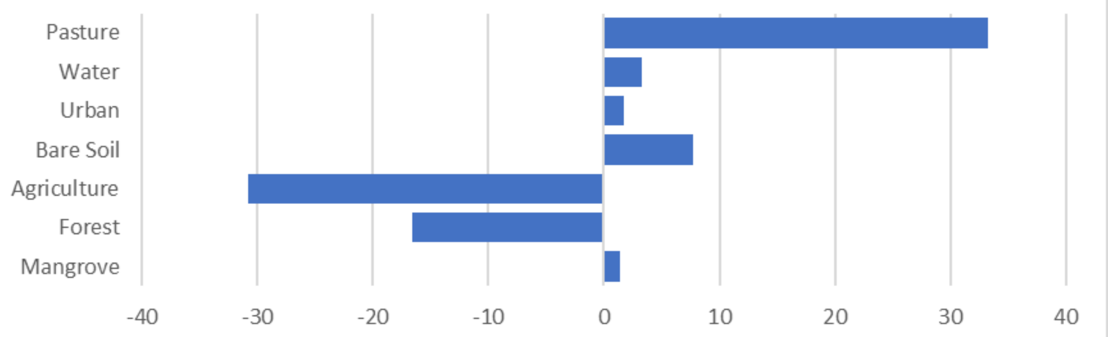
The following cross-table shows the changes that occurred (in pixels) between 1988 and 2003 (Table 4).

Table 4 - Confusion Matrix between the years 1988 and 2003 (in pixels).

Class	1	2	3	4	5	6	7	Total 2003
1	24927	751	103	4039	27	313	109	30269
2	674	39615	11407	287	53	11	3656	55703
3	17	2816	11044	913	0	0	290	15080
4	792	5717	4779	3964	404	218	6659	22533
5	182	368	443	626	2484	5	923	5031
6	1604	63	33	2465	1	49210	53	53429

7	566	24848	21466	1662	134	2	14025	62703
Total 1988	28762	74178	49275	13956	3103	49759	25715	244748

The processing of changes between the periods from 1988 to 2003, allowed us to infer that there was a significant increase in using pasture in the same order as the reduction in agriculture (around 30 km²), and the tree vegetation that had a reduction of 15km², approximately (Figure 3). These results are compatible with the report of the SEI (2012) which highlighted the state of natural vegetation in this region, which was practically devastated because of the rise to productive activities. Pasture, agriculture and forestry activities were the main responsible for the suppression of natural vegetation



	Mangrove	Forest	Agriculture	Bare Soil	Urban	Water	Pasture
Change	1.36	-16.63	-30.79	7.72	1.74	3.3	33.31

Figure 3 - Variation by Category between 1988 and 2003

When looking at total gains and losses (Figure 4), one can see the growth of the urban area without loss of area. Similarly, there was an increase in the class of water bodies. However, this fact may be related to tides' variation, considering that it was low in 1988 (FOLHA DE SÃO PAULO, 1988) and high in 2003 (O GLOBO, 2003). It was also observed that the greatest loss of mangrove area was related to the increase in the water class.

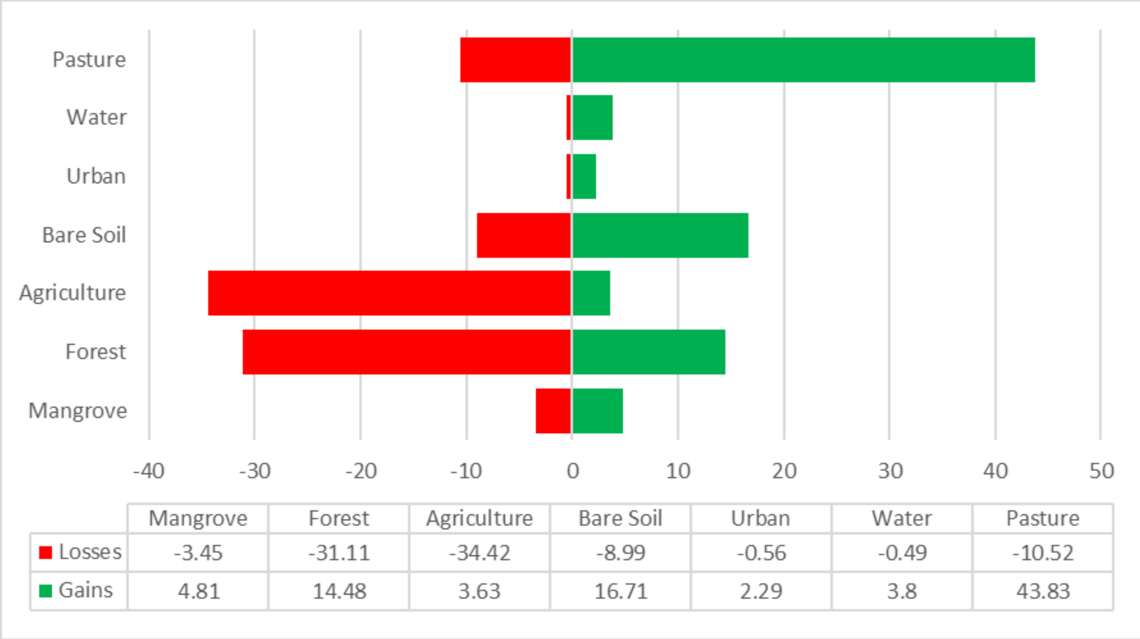


Figure 4 - Losses and gains between 1988 and 2003

Analyzing only the growth of the urban area (Figures 5 and 7A), the biggest growth was in pasture, followed by the classes of agriculture and tree vegetation. On the other hand, were a small reduction, 0.56 km² in urban class, following the same line in the variation of tides. Considering that most of the urban areas are on the coast.

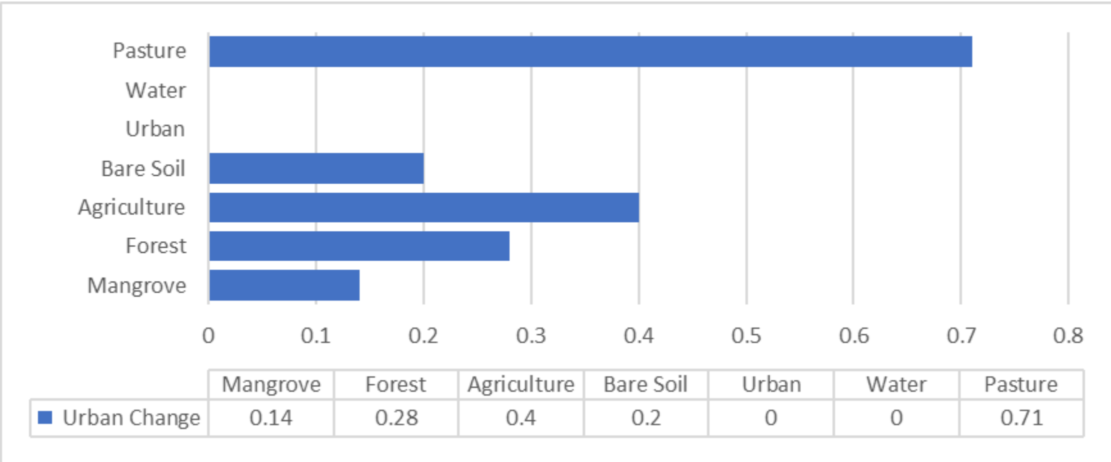
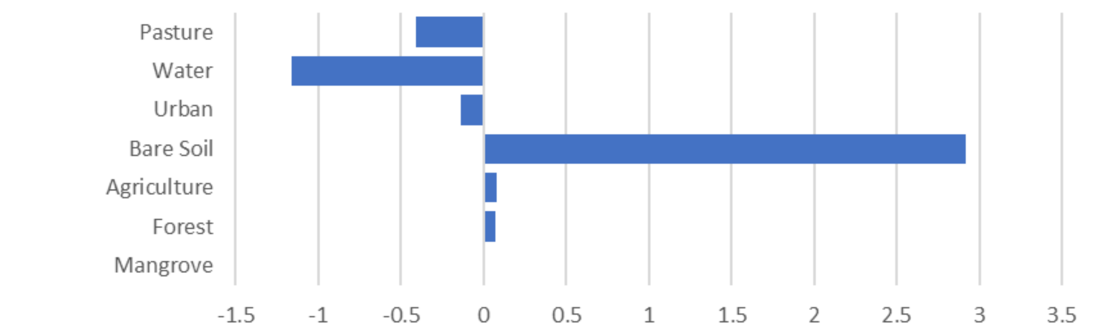


Figure 5 - Contributions in the variation of the Urban Zone between 1988 and 2003

Observing the behavior of mangroves, it was observed a 3 km^2 growth over areas that were previously bare soil. A priori, this growth occurred in an area close to the urban area of Santo Amaro (Figures 6 and 7B). Originally, mangroves occupied this area, but between 1973 and 1976, this area was devastated. There is a few data regarding the causes mortality in the literature, probably because of the military dictatorship in the period when this happened. And it is worth mentioning that factors such as sedimentation rate, sediment subsidence, fluvial discharge, tides, and changes in sea level, have a direct influence on the growth and survival of mangroves (LIMA and TOGNELLA, 2012).



	Mangrove	Forest	Agriculture	Bare Soil	Urban	Water	Pasture
Mangrove Change	0	0.07	0.08	2.92	-0.14	-1.16	-0.41

Figure 6- Contributions to the variation of mangroves between 1988 and 2003

There is no precise information about mangroves'mortality in Subaé's delta. Among the causes that may have contributed to this situation, is the contamination of the area by heavy metals. The first evidence of contamination in the area emerged precisely in 1975. Researchers related rates up to sixty times higher than those established by the World Health Organization, for lead (0.1 mg / kg) (Lyrio and Garrido 2019). The excessive concentration of metals in mangrove plants can lead to adverse effects such as cell damage, reduced growth and increased mortality (Barros et al. 2012).

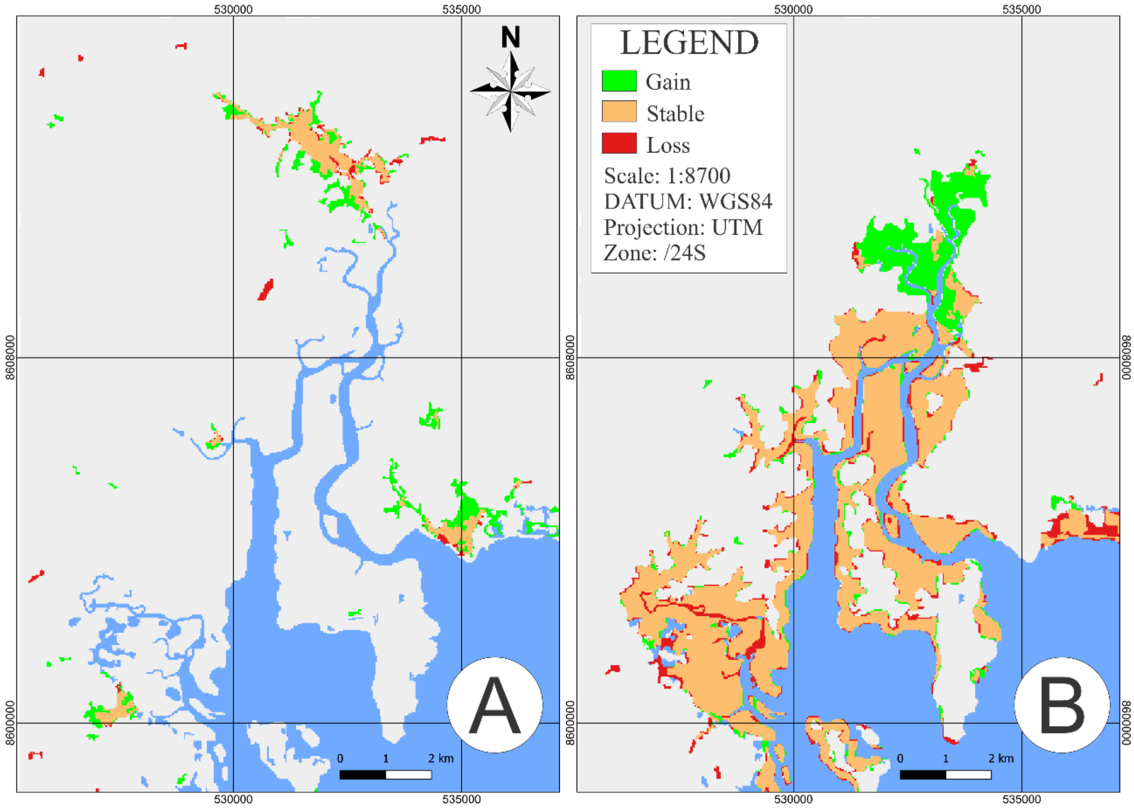


Figure 7 - Losses and gains Urban class 1988-2003 (A) and losses and gains Mangrove 1988-2003 (B).

Analyzing the data on the temporal variation for each class between the periods of 2003 and 2017 (Table 5), there were no transitions between the agriculture class for the urban classes and water bodies, as well as there was no assignment of land from the water bodies class to the agriculture class.

Table 5 - Confusion Matrix between the years 2003 and 2017.

Class	1	2	3	4	5	6	7	Total 2017
1	26920	936	24	597	55	718	856	30106
2	366	43848	2838	6375	109	52	28225	81813
3	18	569	6407	121	0	0	559	7674
4	974	799	790	2536	300	335	3110	8844
5	84	222	44	1155	4046	9	1161	6721
6	1703	75	0	1182	121	52280	101	55462
7	204	9254	4977	10567	400	35	28691	54128
Total 2003	30269	55703	15080	22533	5031	53429	62703	244748

In Figure 8, it is possible to observe that there was a great variation in losses and gains in pasture class. This class has gone through losses and gains greater than 20 km². On the other hand, the classes Mangrove, Urban and Water Body showed only small variations. The greatest growth is related to the class Arboreal vegetation. On the other hand, the class that lost the most area was Pasture, which may be related to the implantation of forestry areas (JESUS, 2018).

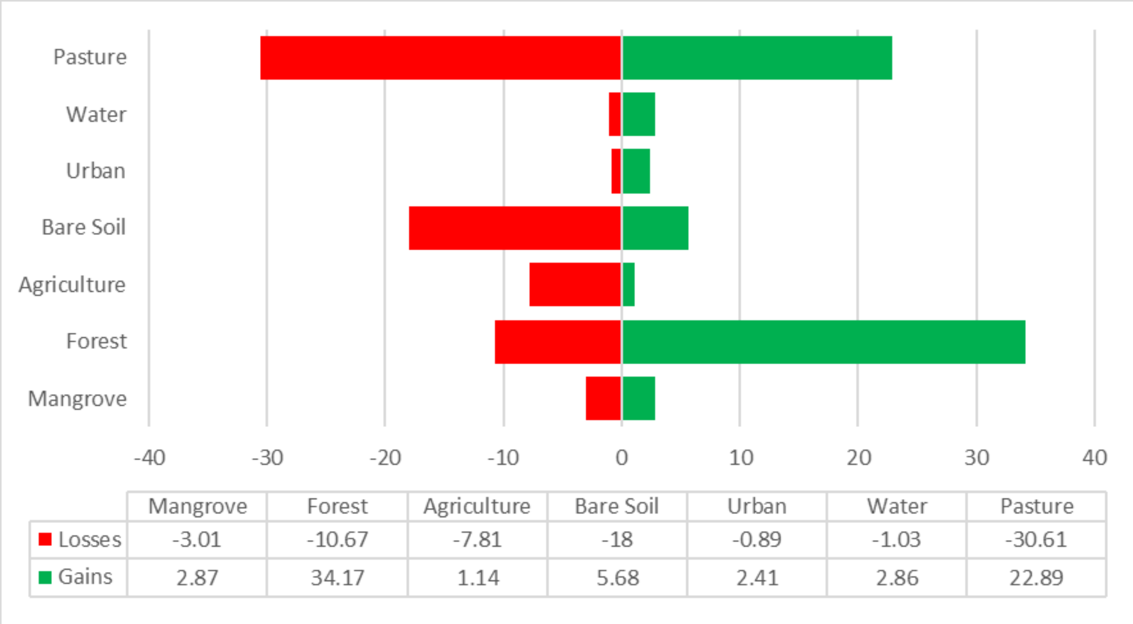


Figure 8 - Losses and gains between 2003 and 2017.

Evaluating only the variation in area (Figure 9), it can be seen that the class with the greatest loss of area is that of exposed soil, followed by Pasture and Agriculture, while the Water and Urban classes, obtained a small area gain. This variation between classes may be seasonal. Images from December/2003 and June/2017, indicates summer and winter, respectively. Another factor is the temporary peanut, bean, and corn crops grown in Santo Amaro (BAHIA, 2011).

The mangrove class did not show significant variation, considering that the gains and losses were of the same order. This effect emphasizes the importance of observing the geographic location of these changes, since the losses and gains cancel each other out in the area variations.

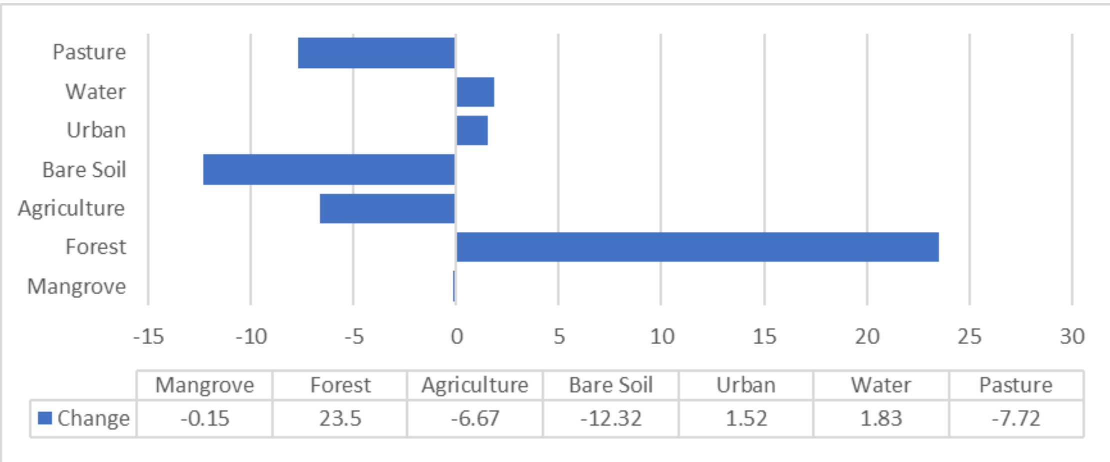
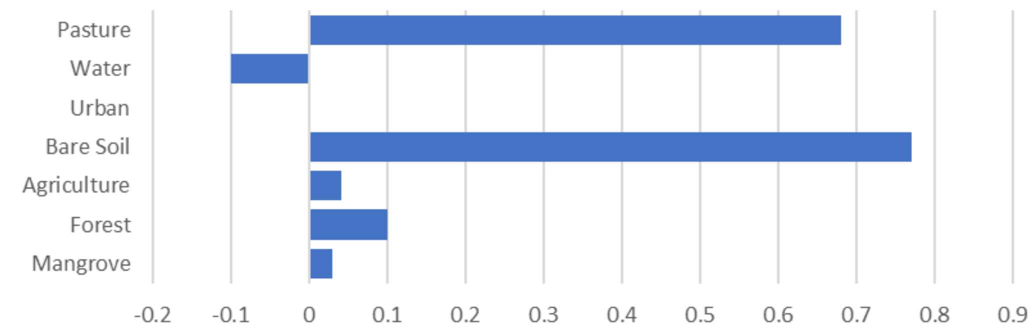


Figure 9 - Variation by Category between 2003 and 2017

Regarding the urban class, when detailed, we inferred that the loss of area is related to the water class (Figure

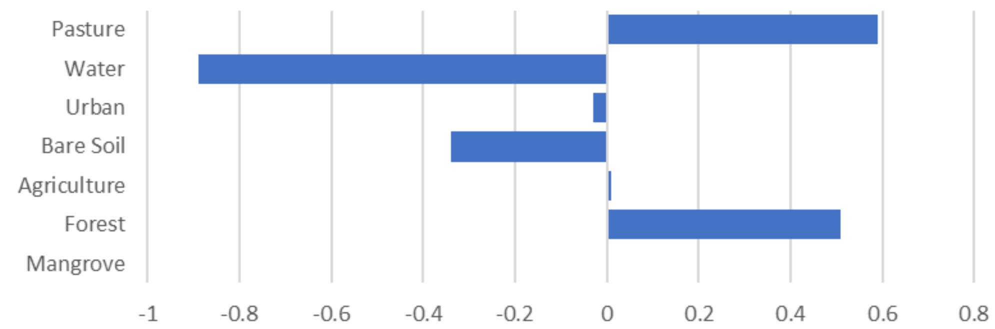
10 and 12A). This behavior may be related to difficulties in discerning the exposed soil class and the urban area. Most of the growth occurs on areas of exposed soil and pasture, followed by tree vegetation, agriculture and mangroves, on a smaller scale.



	Mangrove	Forest	Agriculture	Bare Soil	Urban	Water	Pasture
Urban Change	0.03	0.1	0.04	0.77	0	-0.1	0.68

Figure 10 - Contributions in the variation of the Urban Zone between 2003 and 2017.

Like the urban class, there are losses of the mangrove class to water (Figures 11 and 12B). Observing the tide tables, we noted that despite the high tide on both days, the tide height was 1.2m, in 2003 (MESQUITA, 2003), while in 2017 this value was 2.3 m (MOURA, 2019). The losses to exposed soil and urban areas are more visible when observing geographic locations.



	Mangrove	Forest	Agriculture	Bare Soil	Urban	Water	Pasture
Mangrove Change	0	0.51	0.01	-0.34	-0.03	-0.89	0.59

Figure 11 - Contributions to the variation of the mangrove between 2003 and 2017.

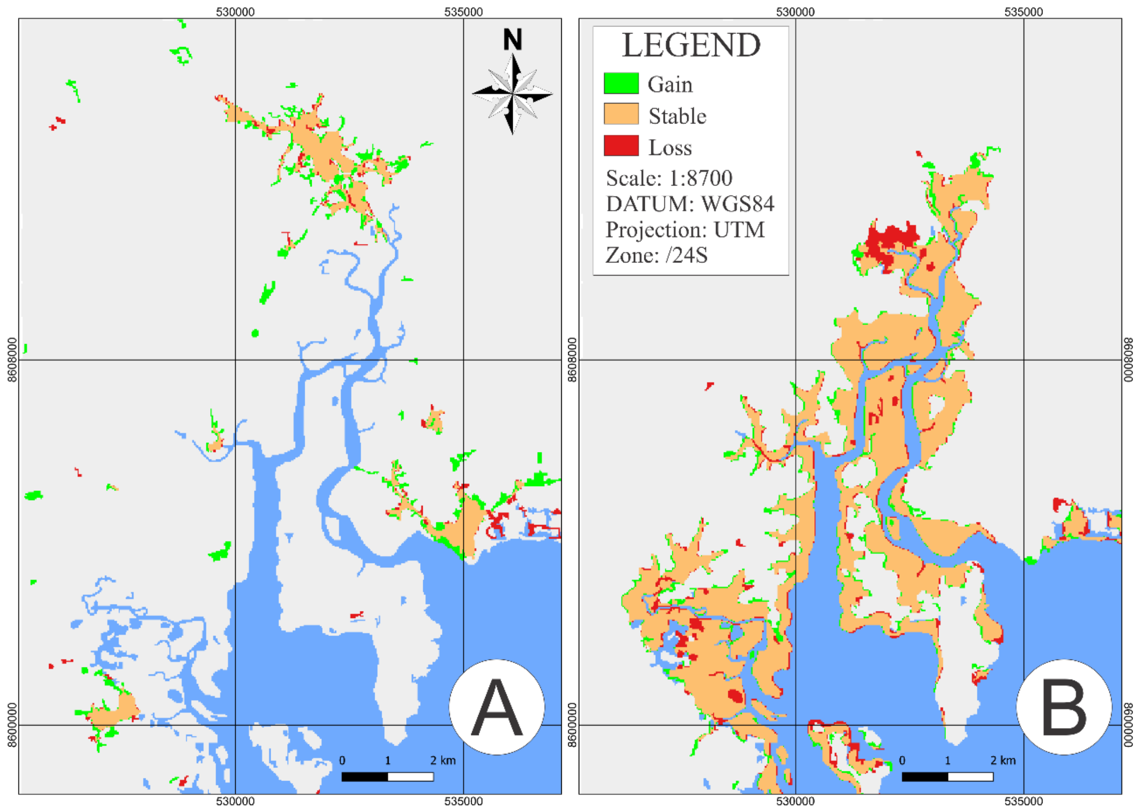


Figure 12 - Losses and gains Urban class 2003-2017 (A) and Losses and gains Mangrove 2003-2017 (B).

Table 6 shows the area values for class transitions during the period between 1988 and 2017.

Table 6 - Confusion Matrix between the years 1988 and 2017.

Class	1	2	3	4	5	6	7	Total 2017
1	24618	1266	101	3509	25	256	331	30106
2	427	49596	20145	1023	69	7	10546	81813
3	9	1042	5610	857	0	0	156	7674
4	480	2238	2563	2197	145	195	1026	8844
5	75	702	996	645	2702	2	1599	6721
6	2898	166	28	2919	0	49299	152	55462
7	255	19168	19832	2806	162	0	11905	54128
Total 1988	28762	74178	49275	13956	3103	49759	25715	244748

Analyzing the losses and gains for the complete temporal extension of the study (Figure 13), we found the major changes in area for the Pasture, Agriculture, and Vegetation classes, with transitions of 40km², 50Km² and 50Km², respectively. When considering the total variation as the sum between losses and gains, there is also growth, with insignificant losses, in water and urban classes. On the other hand, the agriculture class had the lowest growth at the expense of a large loss of area.

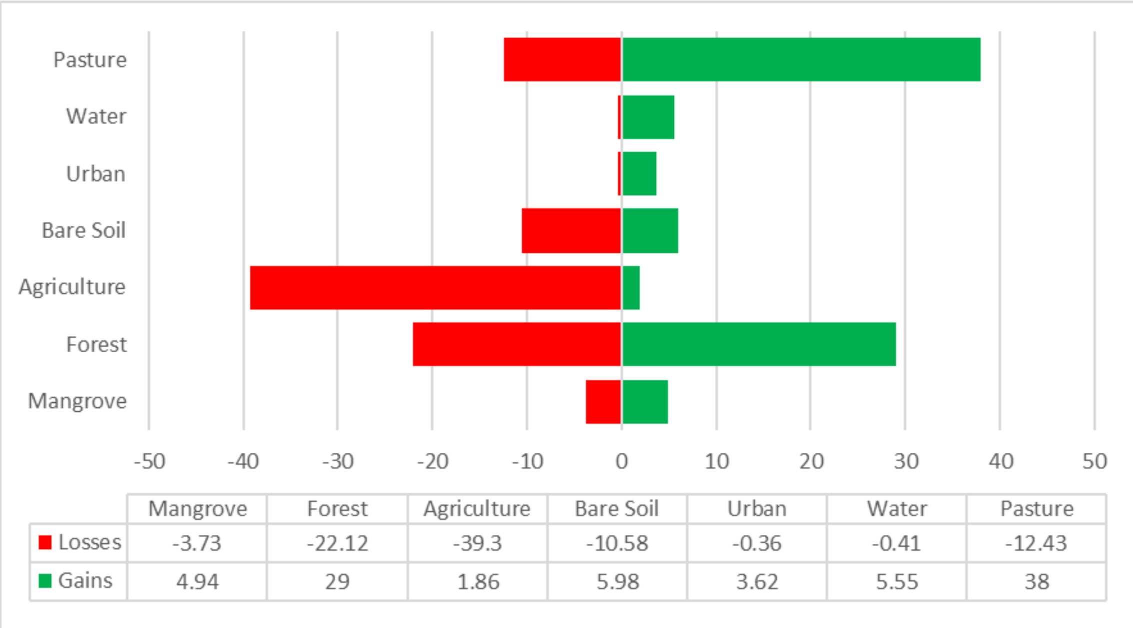


Figure 13 - Losses and gains between 1988 and 2017.

Recognizing the difference between losses and gains, it is possible to see a significant reduction in agricultural areas. This reduction corresponds to 15% of the study area, approximately. In the same way, but with less intensity, there is a reduction in exposed soil areas.

The growth of pasture from 24km² to 48Km² is also notable, being the second largest class found in the area. The most abundant class is Arboreal Vegetation, mainly because it makes no difference between the Atlantic Forest, Secondary Forest, or Silviculture. In this case, it is possible to explain that the growth of this class was probably driven by the production of eucalyptus (JESUS, 2018) (Figure 14).

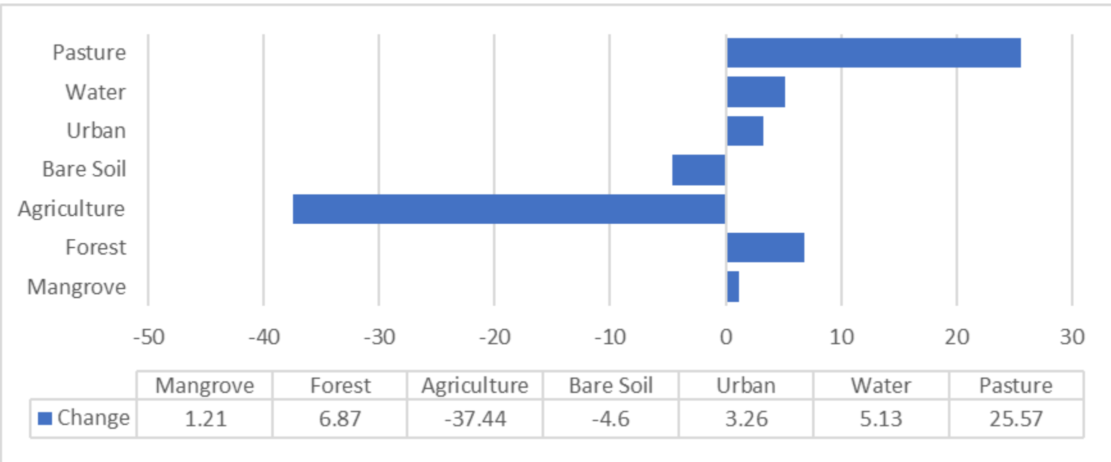
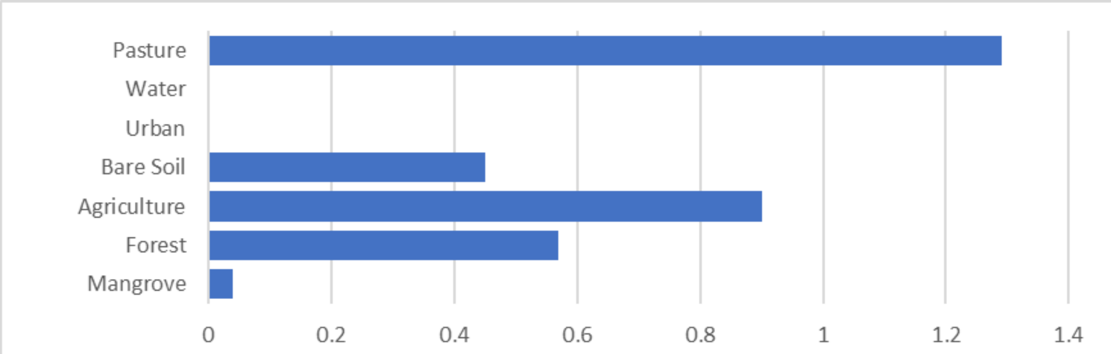


Figure 14 - Variation by Category between 1988 and 2017.

Considering the variations that occurred in the Urban Zone during this interstice (Figures 15 and 18A), there is a notable growth in area gain over all classes, except water bodies. The most affected classes, for this growth, were Pasture, Agriculture, and Urban Vegetation.



	Mangrove	Forest	Agriculture	Bare Soil	Urban	Water	Pasture
Urban Change	0.04	0.57	0.9	0.45	0	0	1.29

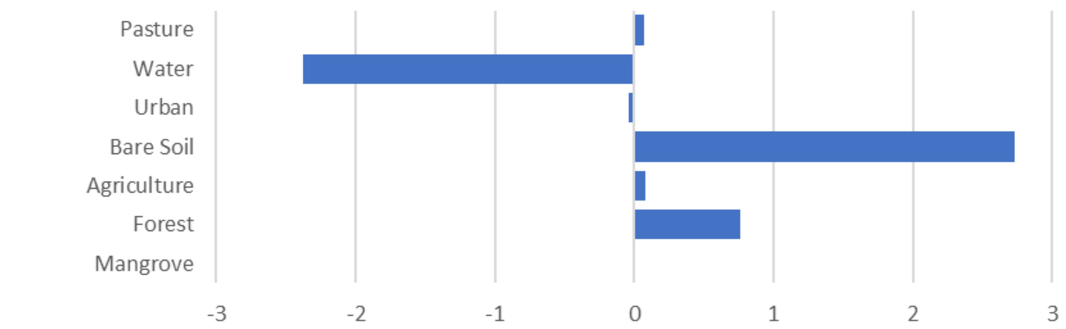
Figure 15 - Contributions in the variation of the Urban Zone between 1988 and 2017.

Notwithstanding the growth over other classes, the urban class also advanced over the mangrove areas. Only the seasonality and the instability of the land acted as limitations for this growth. Despite the environmental importance, only in 2006 mangroves were legally cited, as part of the Atlantic Forest (BRASIL, 2006). However, was in 2012 that the Brazilian recognized mangroves as a permanent preservation area (BRASIL, 2012). Although this recognition, population growth continues to pressure mangroves, as seen in Santo Amaro da Purificação (Figure 16, 17 and 18A).

Figure 16 - Urban Occupation of Santo Amaro da Purificação.

Another significant changes in the mangrove class is the growth over the Exposed Soil. Alike the transition to 2003, by the recovery of the area previously deforested in Santo Amaro da Purificação (Figures 17 and 18B).

The loss of area for the Water class is related to the variation in tides, low in 1988 and high in 2017. The sea level in 2017 was even higher than in 2003 (MESQUITA, 2003; MOURA, 2019).



	Mangrove	Forest	Agriculture	Bare Soil	Urban	Water	Pasture
Mangrove Change	0	0.76	0.08	2.73	-0.04	-2.38	0.07

Figure 17 - Contributions to the variation of the Mangrove between 1988 and 2017.

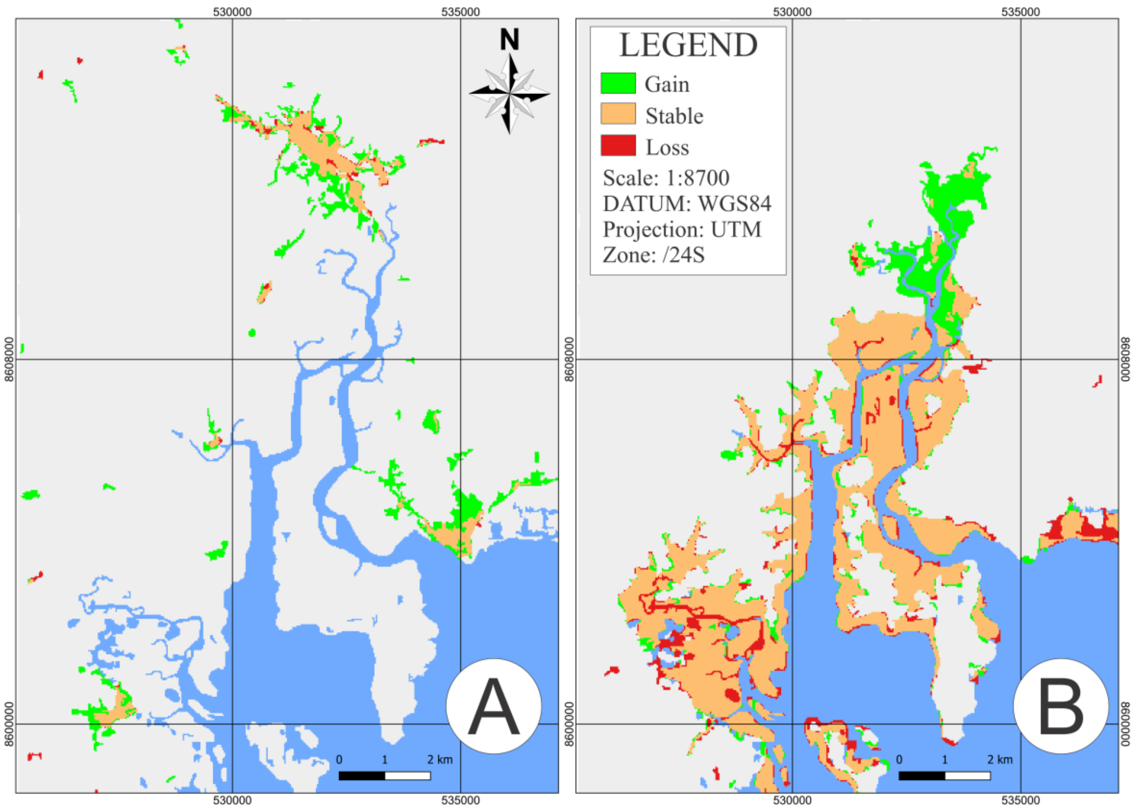


Figure 18 - Urban Area Losses and Gains 1988-2017 (A) and Mangrove Losses and Gains 1988-2017 (B).

4. Conclusions

Calculating the general Tau index for the classifications was 0.89, considered to be almost perfect. Class 1, 2, 6, and 7 obtained an Excellent and Almost Perfect classification for the Geographic Simultaneity and Tau indices, respectively. Class 5 was also considered to be Almost Perfect for Tau, but rated as Very Good for SG. Classes 3 and 4 were considered Very Good (SG) and Substantial (Tau).

Carrying out the spatio-temporal analysis observing only the variation of areas may not represent the phenomena that occurred. The result for a class that did not vary over time may indicate two things. First, that there were no changes in this local. Second, it may indicate that a substantial increase was suppressed by a loss of equal magnitude.

During the period 1988-2017 there was a significant reduction in agricultural areas, corresponding to approximately 15% of the study area. The pasture expanded from $24km^2$ to $48Km^2$ and urban area growth occurred across all classes, including mangroves. The mangroves expansion over areas that were previously bare soil, is related to the incident between 1973, and 1976.

5. Acknowledgment

This work was carried out in partnership with the Technology, Engineering, Robotics and Physics Group (G-TERF), from Federal University of Recôncavo da Bahia (UFRB) and was part of the project: Development of the Quality Index of Mangrove forests in Todos Santos Bay (BTS), Bahia. Call MCTIC/CNPq - No. 21/20170 (Process: 441389/2017-1).

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