Salinity and Sediment Issues in the backwaters of Mangrove Forests

Measuring of the Sediment Depths and Electrical Conductivity in the Mangrove Forests of Lac Bay, Bonaire

BSc thesis by < Rik van der Meulen >

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Salinity and Sediment Issues in the backwaters of Mangrove Forests: Measuring of the Sediment Depths and Electrical Conductivity in the Mangrove Forests of Lac Bay, Bonaire

Bachelor thesis Soil Physics and Land Management Group submitted in partial fulfillment of the degree of Bachelor of Science in International Land and Water Management at Wageningen University, the Netherlands

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Abstract

Mangrove forests are among the most productive ecosystems on the planet. However, the global mangrove area is decreasing annually by 0.7% - 3%. For mangrove areas in semi-arid to arid climates, salinity is one of the causes for a decrease in mangrove canopy and tree die-off. This process occurs in mangrove forests and the backwaters near the main land. Because of their location and the presence of sediments, water circulation from the seaside becomes limited. The backwaters near the mainland become shallow, warmer and isolated compared to the rest of the seawater, which results in increasing evapotranspiration and salinity rates. Lac Bay on Bonaire is a place where the salinity of the backwaters increase and where sediments limit the water circulation. In this case study, the electrical conductivity (EC) and sediment depths (SD) are measured to assess the current situation concerning the EC and SD variety in the backwaters of the mangrove forest at Lac Bay. This is done in two different areas in the backwaters: Area 1 and Area 2. In addition, the EC is measured twice to see if the EC changes over time and a third area is used as a reference site. The results show that the measured range of the EC in Area 1 and Area 2 is between 85 mS/cm - 128 mS/cm. The measured range of the sediment depths in Area 1 and Area 2 is between 1 cm – 379 cm. Furthermore, the EC values change over time and, with some exceptions, the greatest values are found the furthest from the feeder channels, which provide water from Lac Bay towards the backwaters. The tides are also a possible factor for the water to flow over a broader mangrove area towards the backwaters. This causes exceptions on the general pattern where EC increases with distance to feeder channels. Overall, the SD gradually increases with distance to the mainland. Some local exceptions from this pattern were measured in Area 2 and could be possible due to irregularities in the underlaying bedrock. In addition, the sediment inflow in the northern part of Area 1 causes some greater values than the surround areas.

These results and conclusions provide a baseline for follow-up research. This follow-up research should focus on factors which will prevent sediment inflow and help to reduce the EC values to make it possible to restore the previous state of the mangroves.

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Introduction

Location and Characteristics of Mangrove Forests

Mangrove forests can be found in tropical and subtropical regions, across 112 countries (Alvarenga et al., 2015). The forests are located along coastlines where salinity and tides fluctuate (Feller et al., 2010). Mangroves have a range of adaptations (Parida & Jha., 2010) to handle the salinity fluctuations (Agoramoorthy et al., 2008). However, different salinity tolerances occur with different species of mangrove trees. (Parida & Jha., 2010) The aerial roots of mangrove trees provide oxygen to the roots (Kothamasi et al., 2006) and make it possible for mangrove trees to cope with the tidal differences (Feller et al., 2010).

The Beneficial Aspects of Mangrove Forests

The benefits of mangrove forests cover a variety of fields. From an ecological point of view, mangrove forests are a habitat for a diversity of species (Bernardino et al., 2022). Furthermore, the mangroves play a part as breeding area for waterbirds (Mardiastuti et al., 2018) and serve as breeding areas for other ecosystems. Coral reefs rely on mangrove forests to function as breeding and nursery areas for fish. In a later stage, the fish will migrate to nearby located coral reefs (Hylkema et al., 2015).

Mangrove forests provide economic benefits as well. The extraction of natural resources and tourism can serve as a source of income (Spalding & Parrett., 2019). Fishermen living nearby or in mangrove forests rely on the area for food and income (Rachel et al., 2021). In addition to fishermen, other people living along the coast are dependent on mangroves. They depend on the mangrove forests to form a natural barrier and protect coastal areas against natural hazards, such as tropical storms, hurricanes and flooding (Alvarenga et al., 2015). Because of climate change, natural hazards are expected to become more extreme and will affect larger areas (Torresan et al., 2012). This can increase the significance of the role that mangrove forests play in coastal protection management.

Furthermore, mangrove areas can play a role in combatting climate change. The trees can absorb CO_2 out of the air and store it in biomass (Agoramoorthy et al., 2008). As a result of the anaerobic state of the waterlogged soils, sediments storage vast amounts of the absorbed carbon originating from the trees (Tue et al., 2020). Therefore, mangrove areas are effective in storing carbon and have some of the highest quantities of carbon among the different tropical forest types (Adame et al., 2021).

The Loss of Mangrove Forests

Although mangrove forests are among the most important biological and productive ecosystems (Srikanth et al., 2016), vast areas of mangroves have been threatened in the past decades (Osland et al., 2018). The global area of mangrove forests decreased by an estimated 20% in the period between 1980 - 2005 (Perdomo et al., 2021) and the global mangrove area is still decreasing with a yearly rate of 0.7% - 3% (Alvarenga et al., 2015).
This is mostly due to anthropogenic activities (Hayashi et al., 2019), which change the mangrove areas as well as the surrounding areas. Toxic pollutants, expansion of urban and agricultural areas are all causing direct and indirect losses of mangrove forests (Agoramoorthy et al., 2008: Godoy et al., 2018).

Problems in the Backlands of Mangroves

Several problems can arise in the backwaters of mangroves. As a result of the complex root systems of mangroves, accumulation of sediments takes place (Luom et al., 2021). These sediments can originate from the mainland or can be supplied from the seaside due to tidal processes (Perillo, 2019). The sediment inflow from the mainland is caused by erosion and the erosion rate differs per land use type, soil types and slopes. Urbanization and agricultural influences can increase the erosion rate and together with the produced and accumulated organic matter of the mangroves (Borboza et al., 2014), the surface level increases.

This surface level increase causes a decrease in tidal inflow towards the backwaters, as it forms barriers for water inflow and takes up volume what was originally filled with water (Hylkema et al., 2015). The decrease of tidal inflow is influential to the salinity levels of the water. Factors such as precipitation, seepage water and the presence of a freshwater discharge can decrease the salinity levels. However, when these fresh water inflows are not present or exceeded by evapotranspiration, the salinity level increases. Because of this, salinity levels in the backwaters can differ from the salinity levels of seawater.

With an increase of salinity, mangrove canopy can decrease and tree die-off can occur (Peters et al., 2021). The loss of canopy and the tree die-off varies as salt tolerances differ among mangrove species (Chen & Twilley, 1998). Furthermore, mangrove areas in arid regions are expected to be more vulnerable to this phenomenon, as they are expected to become dryer due to climate change (Alongi, 2015).

Bonaire as a Case Study

Bonaire gives a practical example of sedimentation and salinity issues in the backwaters of mangrove forests. Up to the present, little information is available on sediment depths and salinity levels in these backwaters. Therefore, this case study will focus on mapping the current state of the sediment depths (SD) and mapping of the electrical conductivity (EC) in the backwaters of Lac Bay. As salinity levels are correlated to EC, it can be used as an indicator for salinity (Sahana et al., 2021). The measured electrical conductivities are the foundation for this research to gain insight into the salinity variety in the backwaters. This leads to the following general research question and the related specific research questions:

"What are the values of the two factors, electrical conductivity (EC) and sediment depth (SD), in the backlands of Lac Bay, Bonaire?"

Specific research question 1**:** *"What are the EC values in the backlands of Lac Bay?"*

Specific research question 2: **"***What are the SD values in the backlands of Lac Bay?"*

Methodology

Study Area

Bonaire is an island located in the Southern Caribbean Sea. The smaller island, called "Klein Bonaire", is located at the west side of the main island. Both are visible in *figure 1,* together with the different land use types on Bonaire. The island has an approximate area of 288km² (Elmar et al., 2019). The climate is categorized as semi-arid to arid climate (Crews et al., 2019) with an annual rainfall of 463 mm per year and a potential of 8.4 mm per day can be evaporated (Freitas, 2005).

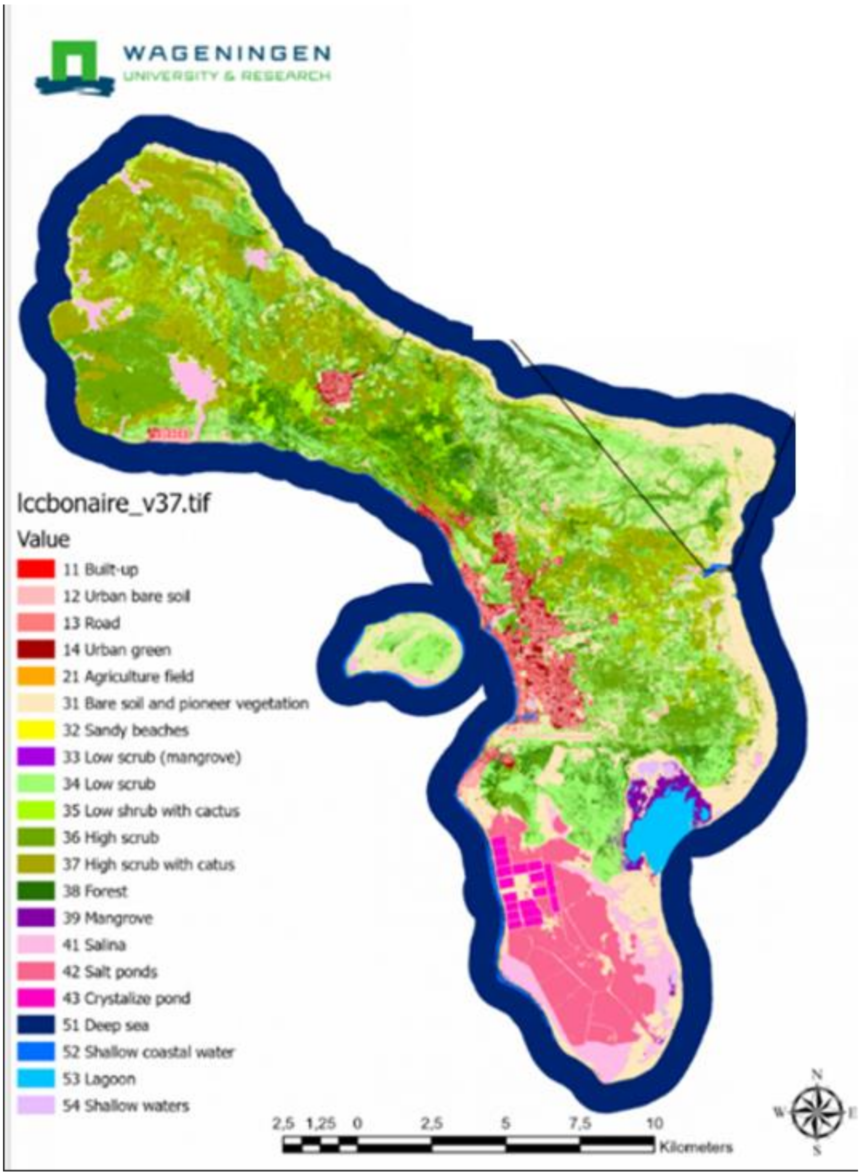

Figure 1: *Land use map of Bonaire* (Mücher & Verweij, 2020).

Figure 1 shows that most of the mangroves are in Lac Bay, which is located at the South-East coast of Bonaire. The research location is in the northern part of this bay. There are three different mangrove species on Bonaire, the red mangroves: Rhizophora mangle, the black mangroves: Avicennia germinans and the white mangroves: Laguncularia racemose (Senger et al., 2021).

However, the mangrove area in Lac Bay consists mostly out of black mangroves and red mangroves. (Davaasuren & Meesters, 2012) For this research, three different areas are investigated, which are all visible in *figure 2.* The main focus of this research is on Area 1 and Area 2. Area 3 functions as the reference site for the EC values of Area 1 and Area 2.

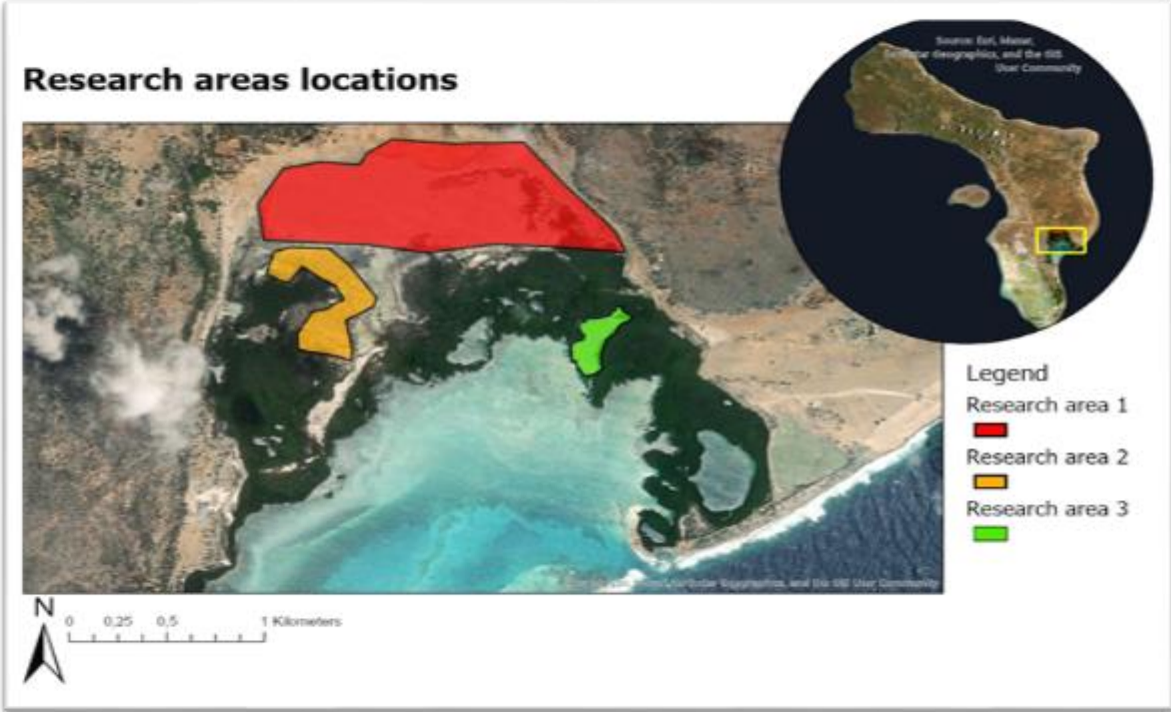

Figure 2: *The research areas in Lac Bay and in the top right corner the location of Lac Bay on Bonaire* (Esri, 2022).

Area 1 is an area which used to be covered with mangroves (*annex I*). Only some black mangrove trees remain together with some young trees of red mangroves in the most eastern part of the area. The waterbody of Area 1 is separated from the rest of the bay by mangrove forest and a few small islands (*figure 3a*. The area is 0,78 km².

Area 2 is an area where in the period of 2014-2020 a lot of mangrove trees died, which is visible in *annex XVIII***,** and is characterized by dead trees, as is visible in *figure 3b*. Furthermore, the measured water depths did not exceed 0.65 meter and 122 out of 133 measured water depths in area 2 did not exceed 0,30 meter (*annex II*). The area is 0.16 km².

Area 3 is a waterbody surrounded with red mangrove forests and is in direct contact with the rest of Lac Bay. The area is 0.056 km² and is used as the reference site for EC values of water which is surrounded with relatively healthy mangrove forests (*figure 3c)*.

Figure 3a: *Photo of Area 1.*

Figure 3b: P*hoto of Area 2.*

Figure 3c: *Photo of Area 3.*

Data Collection and Instruments

Collection Method and Instruments for the Electrical Conductivity

To answer specific research question 1**:** *"What are the EC values in the backlands of Lac Bay?"* water samples were taken. These samples were diluted and the EC values of these dilutions were measured in mS/cm. In addition, the original EC was calculated from these dilutions and processed in ArcGIS Pro. *Annex III* shows an extensive overview of the mentioned executed steps for measuring the EC values. The steps used in ArcGIS Pro are presented in *annex IV.* Areas 1 and Area 2 were sampled two times at the same sample points. This is done at different moments in time. Area 3 was only sampled once as a reference site for EC values. The internal validity for measuring the EC can be found in *annex III* and the used equipment for sampling and processing of the water samples can be found in *annex V.*

Data Collection Method and Instruments for Sediment Depths

To answer specific research question 2: ***"What are the depths of the sediments layers in the backlands of Lac Bay?"***, the SD was measured in cm. The measured SD was processed in ARCGIS PRO. *Annex* VI Shows an extensive overview of the execution of measuring and processing the SD. The steps used in ArcGIS pro are presented in *annex IV*. All of the sample points were measured once for Area 1 and Area 2. However, Area 3 is not measured, as this area is only used as a reference site for EC. The internal validity for the method used to measure the SD can be found in *annex VI* and the used equipment for sampling and processing of the measured SD can be found in *annex VII.*

Results

Results of the Electrical Conductivity

The sample points for measuring the EC values are visible in *figure 4*. Furthermore, Area 1, Area 2 and Area 3 are shown as well *figure 4*. In addition, the feeder channels close to the areas are shown together with the water entrances, where water can flow from the bay into the mangrove forests. The two green feeder channels on the left side are connected to the bay, but the entry points are not visible in *figure 4.* The coordinates and the codes of the EC sample points are shown in *annex VIII – annex XII*.

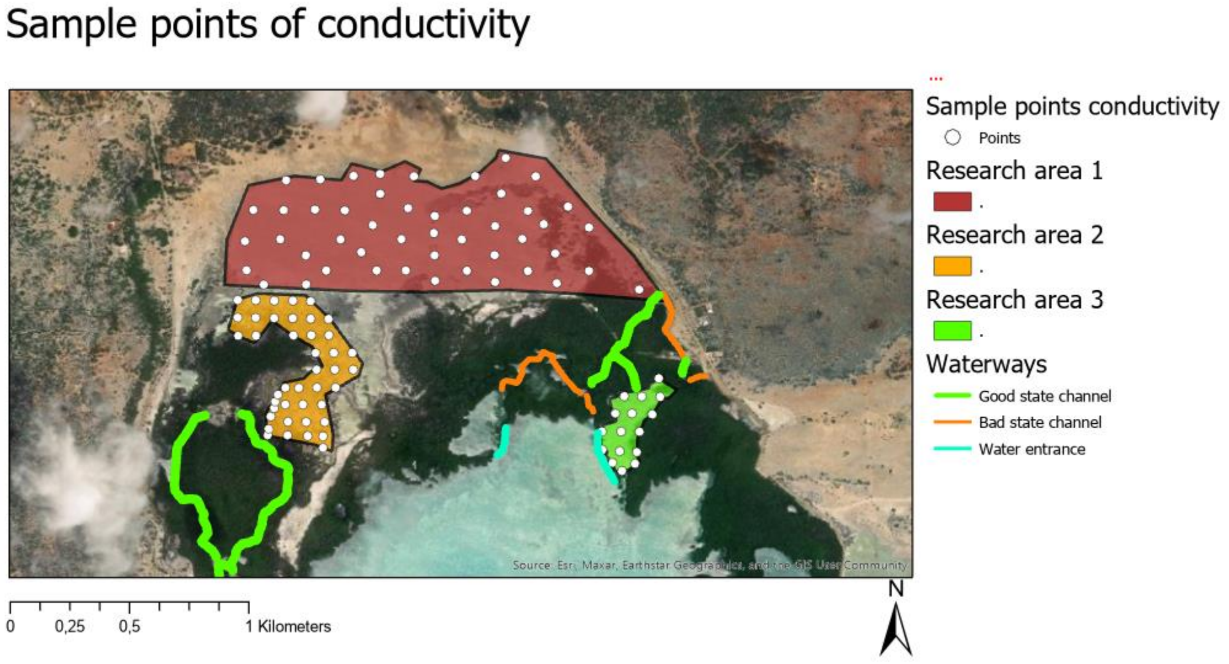

Figure 4: *The EC sample locations, together with the research areas and the locations of the feeder channels* (Esri, 2022).

The sample points in Area 1 and Area are measured twice at different intervals. Both of the sample intervals were during a three-day survey. All of the sample points of Area 3 are measured once on the same date. The end result of the method mentioned in *"Data collection method and instruments for the electrical conductivity"* and *annex III using the steps in ArcGIS Pro in annex IV* is visible in *figure 5* and *figure 6.*

Electrical Conductivity First Interval

Figure 5 shows the interpolated EC values of the first intervals. The ranges of the calculated EC values and EC classes are shown in *table 1.*

Area 1 is measured from 21-05-2022 up till and including 23-05-2022. In *table 2*, it is visible when the samples were taken during the tides in Area 1. The exact time of a measurement at a sample point is shown in *annex XIII***.** Area 2 is measured from 10-05-2022 up till and including 12-05-2022. In *table 3***,** it is shown when the samples were taken during the tides in Area 2. All of the sample points are taken around the low tide with the least value. The exact time of measuring at a sample point is shown in *annex IX***.** Area 3 is measured on 13-06-2022. In *table 4*, it is shown when the samples were taken during the tides. To see per sample point when a sample was taken, see *annex X***.**

Table 1: *The ranges of the measured EC values and EC classes from the first interval for Area 1, Area 2 and Area 3.*

Area	Measured range of EC values (mS/cm)	Range of EC value classes (mS/cm)
1	87 – 110	≤87 - ≤111
2	93 – 128	≤95 - ≤131
3	75 – 82	≤79 - ≤83

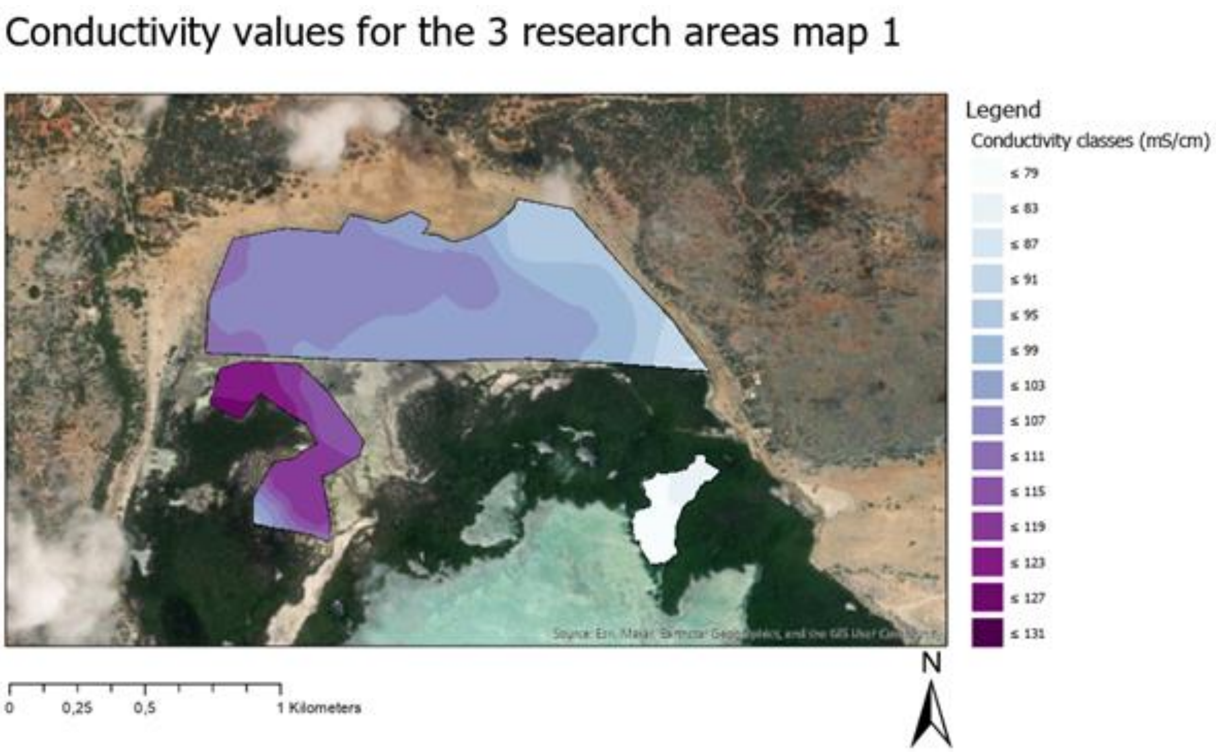

Figure 5: *Interpolated EC values of the first interval (Esri, 2022).*

Table 2: *Tides during the collecting of the EC samples of Area 1, first interval (Tide-forecast.com, 2022).*

Tides	Time and date	Tidal height (m)	Time interval of measuring
High	4:59 AM(Sat 21 May)	0.6	1:30 pm – 2:10 pm
Low	2:10 PM(Sat 21 May)	0.21	2:10 pm - 3:48 pm
High	6:01 AM(Sun 22 May)	0.57	2:05 pm – 2:42 pm
Low	2:42 PM(Sun 22 May)	0.23	2:42 pm - 4:20 pm
High	7:02 AM (Mon 23 May)	0.52	
Low	3:07 PM (Mon 23 May)	0.26	3:08 pm - 5:16 pm
High	10:00PM (Mon 23 May)	0.45	

Table 3: *Tides during the collecting of the EC samples of Area 2, first interval (Tide-forecast.com, 2022).*

Tides	Time and date	Tidal height (m)	Time interval of measuring
High	7:58 AM(Tue 10 May)	0.5	
Low	3:44 PM(Tue 10 May)	0.29	3:47 pm - 4:42 pm
High	10:12 PM(Tue 10 May)	0.44	
Low	3:13 AM(Wed 11 May)	0.41	
High	8:47 AM(Wed 11 May)	0.47	
Low	3:38 PM(Wed 11 May)	0.31	4:04 pm - 5:57 pm
High	10:24 PM(Wed 11 May)	0.47	
Low	4:57 AM(Thu 12 May)	0.38	
High	9:40 AM(Thu 12 May)	0.43	
Low	3:23 PM(Thu 12 May)	0.32	3:59 pm - 5:42 pm
High	10:46 PM(Thu 12 May)	0.51	

Table 4: *Tides during the collecting of the EC samples of Area 3 (Tide-forecast.com, 2022).*

Tides	Time and date	Tidal height (m)	Time interval of measuring
High	Not retrievable	Not retrievable	8:35 AM – 8:59 AM
Low	8:59 AM (Mon 13 June)	0.22	8:59 AM - 10:45 AM
High	12:05 AM (Tuesday 14 June)	0.67	

Electrical Conductivity Second Interval

Figure 6 shows the interpolated data of the second time interval survey. The ranges of the calculated EC values and EC classes are shown in *table 5.* Area 1 is measured from 21-06-2022 up till and including 23-06-2022. In *table 6*, it is shown when during the tides the samples were taken in Area 1. To see per sample point when a sample was taken, see *annex XI***.** Area 2 from 18-06-2022 up till and including 20-06-2022. In *table 7*, it is shown when during the tides the samples were taken in Area 2. All of the sample points are taken around the low tide with the least value To see per sample point when a sample was taken, see *annex XII***.** Area 3 is measured once, so the same data is used for the EC values in *figure 5* and *figure 6*. Thus, Area 3 in *figure 6* is measured on 13-06-2022 as well and the tidal information of *table 4* is the same as in *table 8*. The exact time of taking an individual sample can also be found in *annex X***.**

Table 5: *The ranges of the measured EC values and EC classes from the second interval for Area 1, Area 2 and Area 3.*

Area	Measured range of EC values (mS/cm)	Range of EC value classes (mS/cm)
1	99- 112	≤99 - ≤ 111
2	85 – 110	≤ 87 - ≤ 111
3	75 – 82	≤79 - ≤83

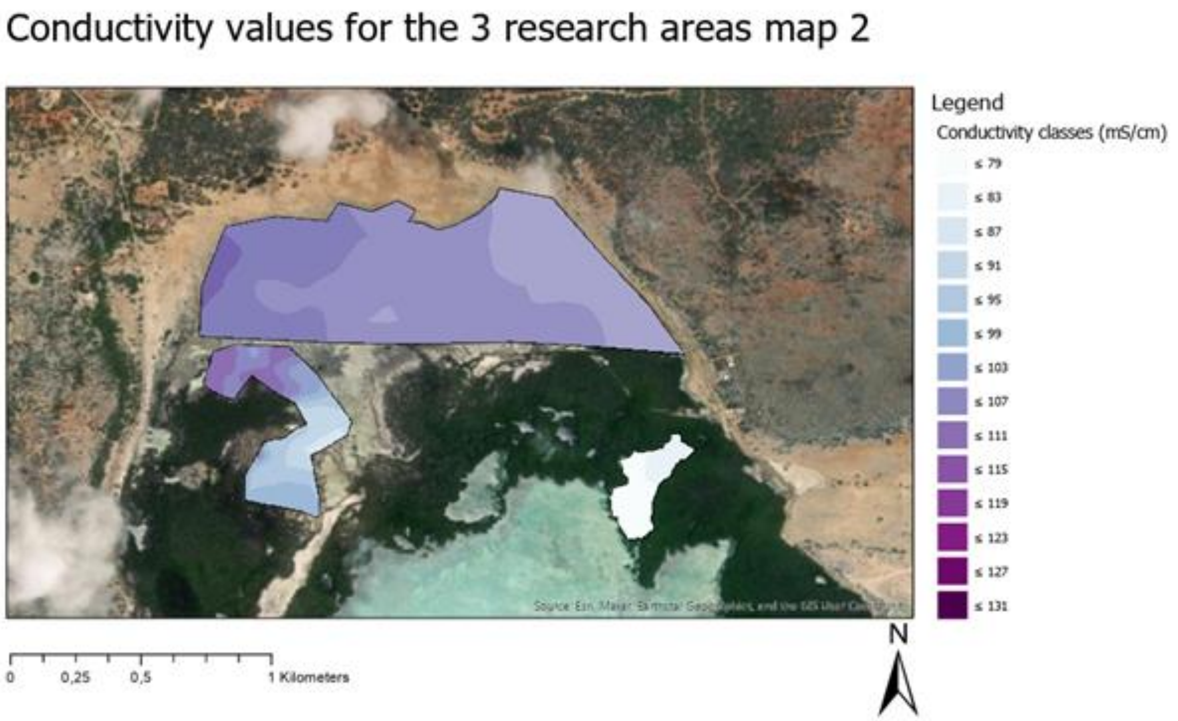

Figure 6: *Interpolated EC values of the second interval (Esri, 2022).*

Table 6: *Tides during the collecting of the EC samples of Area 1, second interval (Tide-forecast.com, 2022).*

Tides	Time and date	Tidal height (m)	Time interval of measuring
Low	2:36 AM(Tue 21 June)	0.42	
High	6:33 AM(Tue 21 June)	0.46	
Low	2:08 PM(Tue 21 June)	0.29	02:16 PM - 03:57 PM
High	9:11 PM(Tue 21 June)	0.5	
Low	4:13 AM(Wed 22 June)	0.37	
High	7:41 AM(Wed 22 June)	0.4	
Low	2:12 PM(Wed 22 June)	0.31	02:58 PM - 05:08 PM
High	9:30 PM(Wed 22 June)	0.54	
Low	5:27 AM(Thu 23 June)	0.33	
High	8:56 AM(Thu 23 June)	0.36	
Low	1:44 PM(Thu 23 June)	0.32	03:20 PM - 05:13 PM
High	9:56 PM(Thu 23 June)	0.57	

Table 7: *Tides during the collecting of the EC samples of Area 2, second interval (Tide-forecast.com, 2022).*

Tides	Time and date	Tidal height (m)	Time interval of measuring
High	3:33 AM(Sat 18 June)	0.61	
Low	12:56 PM(Sat 18 June)	0.21	12:50 PM - 02:53 PM
High	4:31 AM(Sun 19 June)	0.57	
Low	1:27 PM(Sun 19 June)	0.23	01:36 PM - 03:22PM
High	5:30 AM(Mon 20 June)	0.51	
Low	1:51 PM(Mon 20 June)	0.26	02:32 PM - 03:48 PM
High	9:21 PM(Mon 20 June)	0.46	

Table 8: *Tides during the collecting of the EC samples of Area 3 (Tide-forecast.com, 2022).*

Tides	Time and date	Tidal height (m)	Time interval of measuring
High	Not retrievable	Not retrievable	8:35 AM – 8:59 AM
Low	8:59 AM (Mon 13 June)	0.22	8:59 AM - 10:45 AM
High	12:05 AM(Tuesday 14 June)	0.67	

Results of Sediment Depths

All the measured sample points used for measuring the SD are visualized in *figure 7*, together with Area 1 and Area 2. The samples were taken from 11-03-2022 up till and including 20-05-2022 and measured once. The coordinates and the codes of the sample points are shown for Area 1 in *annex XIII* and for Area 2 in *annex XIV*. *Figure 8* shows the interpolated data. The ranges of the interpolated SD and the SD classes are shown in *table 9*. The individual SD values of the sample points are presented for Area 1 in *annex XIII* and for Area 2 in *annex XIV*.

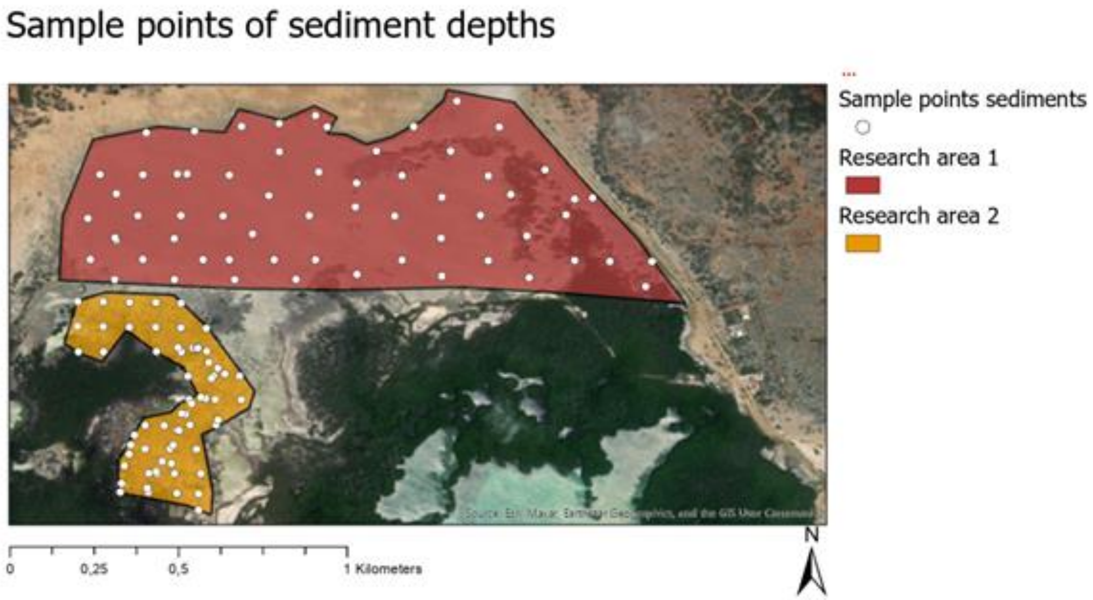

Figure 7: *The SD measuring locations of Area 1 and Area 2 (Esri, 2022).*

Table 9: *The ranges of the measured SD and the SD classes of Area 1 and Area 2.*

Area	Measured range of sediment depth (cm)	Range of sediment depth classes (cm)
1	1 – 284	≤30 - ≤ 300
2	104 – 390	≤ 120 - ≤ 390

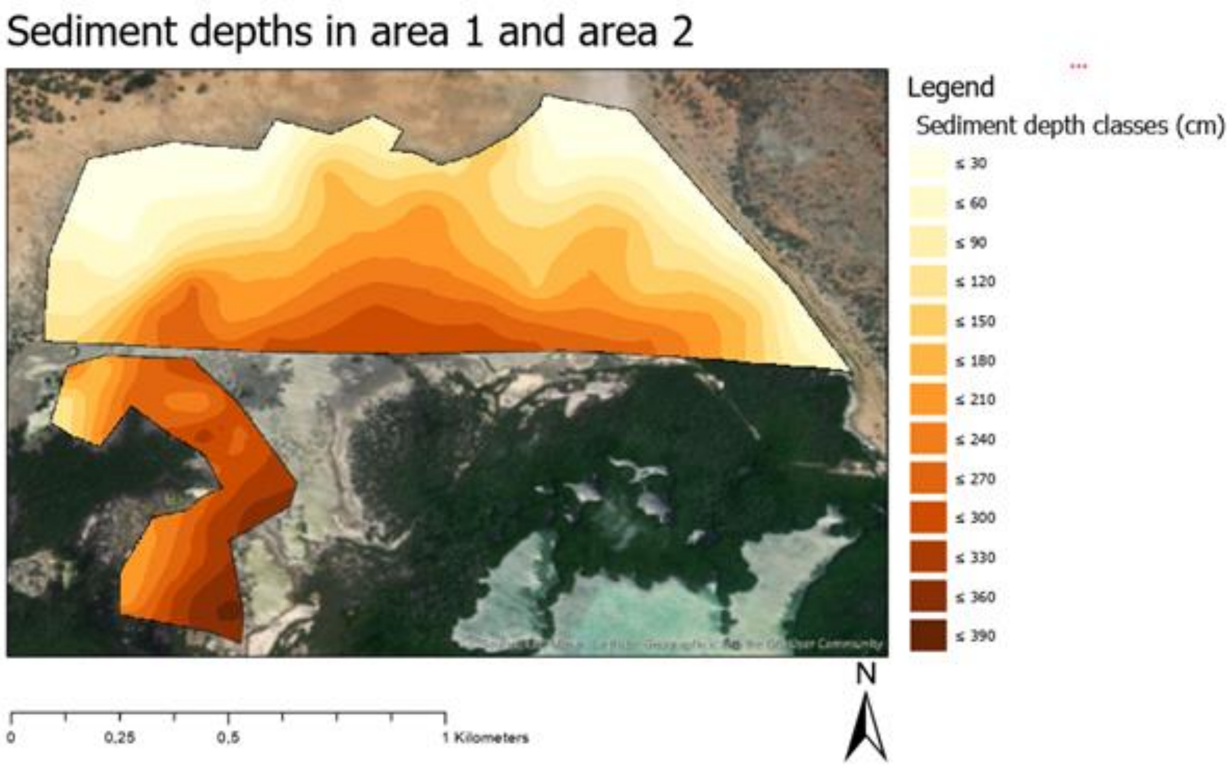

Figure 8: *Interpolated SD values of Area 1 and Area 2 (Esri, 2022).*

Discussion

The EC values in semi-arid and arid mangrove forests are a central topic in academic literature. The findings in this literature are also applied in this case study to explain and validate the findings of the measured EC values of Area 1, Area 2 and Area 3. The measured SD values are interpreted by the patterns which are found in this research, together with satellite imagery and historical maps of Lac Bay.

Interpretation of Research

The first time interval survey of Area 1 and Area 2 has higher EC classes than the second time interval survey, therefore showing that the EC varies over time. The difference in EC for the two intervals could be explained by the rainfall, which was present during the measuring of Area 1 and three days in a row before measuring Area 2 of the second time interval survey (*annex XV*). The research executed in the Gulf of Kachchh (Saravanakumar et al., 2007) shows that periods of rainfall decrease the salinity, which also indicates that EC values are affected when rainfall occurs. In addition to the rainfall as a factor, stronger tidal influences and wind (Regensburg, 2013) between the measuring of the first interval (*figure 5)* and the second interval (*figure 6)* could cause a bulkier water circulation through the feeder channels. Both time intervals of Area 1 and the first interval of Area 2 have the lowest EC values near the feeder channels. The EC values increase gradually further away from these channels, which supports the claim that tidal influences decrease the EC by allowing water with a lower EC to enter the areas via the feeder channels. The exception from this pattern is the second time interval of Area 2, where the lowest EC values are measured in the center part. This can be the result of an extra water influx due to stronger tides (Regensburg, 2013) during the measuring of the second time interval of Area 2. The first interval of Area 2 reaches lower maximum and higher minimum values for the tides than the second interval of Area 2 (*table 3 and table 7).* This could cause the water circulation increase, because it takes place through broader areas of mangroves during the second time interval, as it can temporarily flow over the accumulated sediments (*annex XVI)*. This temporary water movement towards the area on the eastside of Area 2 is visually observed on every day of the second interval and indicated with an arrow in *annex XVII.* A possibility is that water with a lower EC enters the center of Area 2 from the east side via the indicated arrow. The results in *Figure 6* indicate that this has a stronger influence on the EC values than the water circulation from the feeder channel in the south during the measuring of the second interval. However, it is difficult to know the direct influences of the tides in Lac Bay on the EC values and how they influence the water movement in the backwaters, as the water movement is also dependent on other factors, such as precipitation, runoff, evapotranspiration and groundwater flows (Regensburg, 2013). Moreover, no water samples were taken of the area at the east side of Area 2 to compare the EC values and no tidal measurements were taken as well to confirm the differences in tidal heights.

For Area 1, the lowest SD classes are located in the north-eastern and in the north-western parts. From all directions the SD increases towards the southern part of the area, which is located the furthest from the mainland. This can be explained by the elevation differences of the underlaying bedrock. Because of the lower elevation, sediment will be stored and level the elevation differences. However, this is not the case in the northern part, where the SD classes are a few classes greater. This is due to sediment inflow from the mainland in this part of the area, which is visible on satellite images (Google maps, 2023). Furthermore, the area used to be covered with mangroves (annex I), which caused the sediments to accumulate between the roots (Luom et al., 2021) and produce organic matter that is stored in the mangrove soils (Borboza et al., 2014). The lowest SD classes are measured in the north-west part and the highest SD classes in the eastern part of the area. The mainland is located on the west side of Area 2, which supports the findings in Area 1. However, some spots are visible in the northern part of Area 2 with higher or lower SD than their surroundings. This is the result of an irregularity in the underlaying limestone layer.

Limitations of Research

The measured EC values are a snapshot of the actual process. The EC course between the two time intervals is not monitored, so little can be said about how the shifts developed in between the intervals. The same can be said for the EC values before the first and after the second time interval. In addition, the measured EC values are interpolated using ArcGIS Pro (*annex IV)*. Therefore, the values of the EC in between the sample points can differ from the actual EC at that time. That is why the precise EC cannot be retrieved from the data, unless it is from a sample point. In addition, the results give indications of where the water with lesser EC values enter and spread in the backwaters. However, no samples were taken from the feeder channels or the surrounding areas to confirm that the water has lower EC values. The internal validity of the method used to collect the EC values is discussed in *annex III.*

Only the SD of Area 1 and Area 2 are measured, but sediment depths at the backlands outside of these areas cannot be retrieved from the data. The measured SD depths are also interpolated using ArcGIS Pro (*annex IV)* and, therefore the values of the SD in between the sample points can differ from the expected interpolated values. That is why the SD between measurement points can be used as an indication but it can be inaccurate when precise values are needed. Furthermore, this research is limited by the fact that other characteristics such as density or the composition of the sediments are not measured. The method used in this research was not found in other literature, thus no comparisons could be made. The internal validity of the method used to collect the SD values is discussed in *annex VI.*

Implications of Research

This research shows that the EC values near healthy mangroves are lesser than areas with dead and or degraded mangroves in Lac Bay. The mangroves that died in the period of 2014-2020 (*annex XVIII)* are mostly located in the areas with the greatest measured EC values of Area 2. These results support the assumption that the salinity can exceed the tolerable values for *rhizophora mangle* and *Avicennia germinans* growth (Chen & Twilley, 1998). When EC values cannot be lowered, the area cannot recover and new mangroves cannot reclaim the area and restore the habitat to the original state.

The findings give a first overall overview of the SD in both areas. This is important as sediments cause an indirect increase of the EC in the area, which in turn, causes mangrove die-off. It is important to know where the sediments enter and where they are stored to counter the mangrove die-off. Thus, the visualization of SD in this research can help to understand and prevent the current die-off.

Follow Up Research

As the two time intervals show that the EC fluctuates, a follow up longitudinal study with continuous EC measurements in both the areas and in the feeder channels could give a better understanding on how the EC develops over time. In addition, the factors that cause the decrease in EC values, such as the influence of the tides and the presence of feeder channels, need to be better understood to expand in the areas with the greatest EC values. Another interesting topic for follow-up research is to examine these factors to decrease the mangrove die-off and make it possible for mangroves to regrow in the backlands.

The measured SD can be used to make an overall estimation about the current volume in Area 1 and Area 2. Hereby, a baseline of the SD is created and can be used as a reference to see if the sediment volume increases over time. Furthermore, the data indicate where sediments enter the areas and where interventions that block the sediment influx can be improved or added to the current intervention measures (Debrot et al., 2012).

Conclusion

The performed research found data to answer the general research question: *"What are the values of the two factors, electrical conductivity (EC) and sediment depth (SD), in the backlands of Lac Bay, Bonaire?"* This is done to get a better overview where the greatest EC values occur, which gives an indication where the greatest risk areas for mangrove die-off are located. Furthermore, the measuring of the SD is done to know where the SD flux enters and is stored in the backlands. Both the EC and the SD are factors that play a role in mangrove die-off. The answer for what the EC values are in the backlands of Lac Bay can be found in *table 1, table 5, figure 5 and figure 6* (and *annex VIII up till and including annex XII*). The answer for what the SD values are in the backlands of Lac Bay can be found in *figure 8* and *table 9* (*annex XIII* and *annex XIV*).

The section above concludes the general research question. However, general conclusions can be drawn from the collected data for both the SD and the EC values. With the exception of some sample points in Area 2, the sediment depths gradually increase the further away from the mainland. The areas with the greatest SD are shown as well as the sediment influx in the northern part of Area 1 (*figure 8*).

It can be concluded that the EC values change over time for both Area 1 and Area 2. Furthermore, the EC values have greater values than the values in Area 3, which has healthy red mangroves. In addition, the largest EC classes in both time intervals can be found in the areas furthest away from the feeder channels that are connected to Lac Bay. The feeder channels, together with the tidal influences, are two important factors for the backlands to decrease the EC values and will play a key role to manage restoring Area 1 and Area 2 to healthy mangrove forests areas.

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Annexes

Annex I

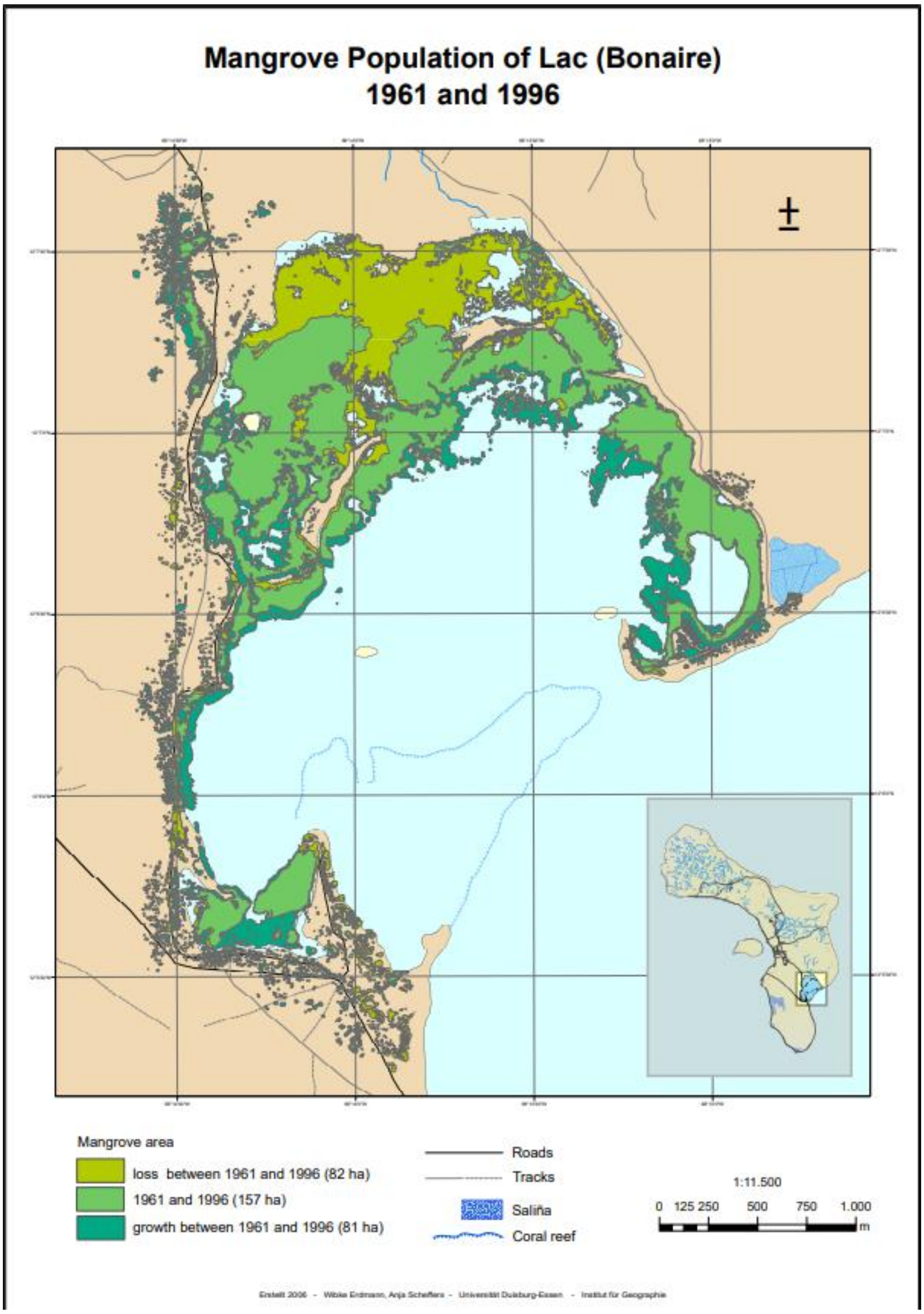

Figure 9: *Mangrove coverage and changes of Lac Bay in the time period 1961-1996 (Erdmann & Scheffers, 2006).*

Annex II

Table 10: *The measured water depths of Area 2.*

ID_SITE	Date 1	Time	WD 1 (cm)	Date 2	Time 2	WD 2 (cm)	Date 3	Time 3	WD 3 (cm)	Date 4	Time 4	WD 4 (cm)	coordinates
D_042	06/04/2022	13:30	40	10/05/2022	16:42	7	20/06/2022	14:57	44	19/06/2022	15:22	40	12.11484, -68.23731
D_038	06/04/2022	12:51	22	10/05/2022	17:08	20	20/06/2022	14:38	13	NA	NA	NA	12.11355, -68.23766
D_040	06/04/2022	13:16	28	10/05/2022	16:57	9	20/06/2022	14:48	15	NA	NA	NA	12.11433, -68.23746
D_039	06/04/2022	13:11	25	10/05/2022	17:02	12	20/06/2022	14:43	25	NA	NA	NA	12.11402, -68.23759
D_041	06/04/2022	13:24	20	10/05/2022	16:50	38	20/06/2022	14:53	28	NA	NA	NA	12.11458, -68.23742
D_037	06/04/2022	12:43	18	10/05/2022	15:21	15	20/06/2022	14:32	34	NA	NA	NA	12.11332, -68.2377
D_010	11/04/2022	15:28	5	12/05/2022	16:35	7	18/06/2022	14:22	14	NA	NA	NA	12.11772, -68.23746
D_006	11/04/2022	15:04	22	12/05/2022	17:14	16	18/06/2022	13:19	17	NA	NA	NA	12.11838, -68.23675
D_013	11/04/2022	16:02	3	11/05/2022	16:57	12	18/06/2022	13:39	17	NA	NA	NA	12.11769, -68.23541
D_007	11/04/2022	14:53	9	12/05/2022	17:05	13	18/06/2022	13:25	18	NA	NA	NA	12.11836, -68.23608
D_012	11/04/2022	15:50	9	11/05/2022	17:05	14	18/06/2022	13:32	20	NA	NA	NA	12.1177, -68.23608
D_005	11/04/2022	15:15	16	12/05/2022	17:22	17	18/06/2022	13:11	23	NA	NA	NA	12.11838, -68.23745
D_011	11/04/2022	15:40	13	12/05/2022	16:57	16	18/06/2022	14:14	25	NA	NA	NA	12.11772, -68.23675
D_003	18/04/2022	12:14	15	12/05/2022	17:42	10	18/06/2022	12:58	14	NA	NA	NA	12.1184, -68.23883
D_014	18/04/2022	11:19	18	12/05/2022	16:09	15	18/06/2022	14:53	15	NA	NA	NA	12.11706, -68.23881
D_004	18/04/2022	12:02	19	12/05/2022	17:32	7	18/06/2022	13:05	15	NA	NA	NA	12.1184, -68.23815
D_009	18/04/2022	11:49	19	12/05/2022	16:26	14	18/06/2022	14:33	18	NA	NA	NA	12.11774, -68.23815
D_015	18/04/2022	11:36	17	12/05/2022	16:18	12	18/06/2022	14:41	23	NA	NA	NA	12.11706, -68.23814
D_008	18/04/2022	12:26	58	12/05/2022	15:59	53	18/06/2022	12:50	65	NA	NA	NA	12.11774, -68.23883
D_033	19/04/2022	13:05	12	10/05/2022	16:11	8	19/05/2022	14:18	8	20/06/2022	15:13	7	12.11381, -68.23625
D_028	19/04/2022	11:44	15	11/05/2022	16:22	6	19/05/2022	15:09	9	19/06/2022	14:06	9	12.11511, -68.23514
D_035	19/04/2022	10:51	8	10/05/2022	15:30	5	19/05/2022	13:17	7	20/06/2022	15:48	10	12.11331, -68.23695
D_034	19/04/2022	11:18	16	10/05/2022	16:01	10	19/05/2022	14:05	13	20/06/2022	15:20	10	12.11381, -68.23555
D_031	19/04/2022	11:30	25	11/05/2022	16:14	5	19/05/2022	14:38	18	19/06/2022	13:50	11	12.11446, -68.23566
D_027	19/04/2022	11:55	20	11/05/2022	17:48	10	19/05/2022	14:52	20	19/06/2022	13:59	13	12.11511, -68.23584
D_036	19/04/2022	11:04	22	10/05/2022	15:39	15	19/05/2022	13:29	4	20/06/2022	15:39	21	12.11329, -68.23619
D_030	19/04/2022	12:51	21	11/05/2022	16:04	5	19/06/2022	13:43	9	NA	NA	NA	12.11447, -68.23704
D_029	19/04/2022	12:38	26	10/05/2022	16:27	11	19/06/2022	13:36	10	NA	NA	NA	12.11447, -68.23704
D_032	19/04/2022	13:22	16	10/05/2022	16:19	11	20/06/2022	15:06	13	NA	NA	NA	12.11382, -68.23694
D_025	19/04/2022	12:20	29	10/05/2022	16:35	8	19/06/2022	15:13	22	NA	NA	NA	12.1151, -68.23703
D_026	19/04/2022	12:08	37	11/05/2022	17:57	23	19/06/2022	15:05	28	NA	NA	NA	12.11509, -68.23653
D_001	20/04/2022	11:46	28	10/05/2022	15:47	11	19/05/2022	13:41	20	20/06/2022	15:32	10	12.11284, -68.23561
D_002	20/04/2022	11:56	14	10/05/2022	15:53	18	19/05/2022	13:52	14	20/06/2022	15:26	11	12.11327, -68.23561
D_017	20/04/2022	13:26	32	11/05/2022	17:13	12	20/05/2022	14:01	22	18/06/2022	13:56	13	12.11708, -68.23606
D_021	20/04/2022	12:34	23	11/05/2022	16:37	12	20/05/2022	13:26	19	19/06/2022	14:24	14	12.11642, -68.23452
D_024	20/04/2022	12:24	27	11/05/2022	16:31	10	20/05/2022	13:18	22	19/06/2022	14:17	20	12.11578, -68.23448
D_023	20/04/2022	14:33	32	11/05/2022	17:34	17	20/05/2022	13:11	29	19/06/2022	14:47	23	12.11579, -68.23517
D_016	20/04/2022	13:42	14	12/05/2022	16:48	6	18/06/2022	14:06	16	NA	NA	NA	12.11707, -68.23673
D_020	20/04/2022	12:48	25	11/05/2022	17:27	16	19/06/2022	14:30	22	NA	NA	NA	12.11642, -68.23521
D_019	20/04/2022	14:04	5	11/05/2022	17:20	15	19/06/2022	14:38	22	NA	NA	NA	12.11641, -68.23589
D_022	20/04/2022	14:16	47	11/05/2022	17:41	23	19/06/2022	14:54	25	NA	NA	NA	12.11578, -68.23586
D_018	20/04/2022	13:12	23	11/05/2022	16:49	15	18/06/2022	13:48	25	NA	NA	NA	12.11708, -68.23539
D_069	20/05/2022	13:04	4	NA	NA	NA	NA	NA	NA	NA	NA	NA	12.11525, -68.23509
D_067	20/05/2022	13:49	15	NA	NA	NA	NA	NA	NA	NA	NA	NA	12.11713, -68.23565
D_070	20/05/2022	13:42	15	NA	NA	NA	NA	NA	NA	NA	NA	NA	12.11716, -68.23566
D_071	20/05/2022	13:41	15	NA	NA	NA	NA	NA	NA	NA	NA	NA	12.11714, -68.23567
D_074	20/05/2022	14:13	22	NA	NA	NA	NA	NA	NA	NA	NA	NA	12.11718, -68.23616
D_072	20/05/2022	13:44	24	NA	NA	NA	NA	NA	NA	NA	NA	NA	12.11716, -68.23563
D_073	20/05/2022	14:05	24	NA	NA	NA	NA	NA	NA	NA	NA	NA	12.11705, -68.23607

Note. Table 10 shows the measured water depths of Area 2, together with the code name of the belonging sample point, the date and the time.

Note.
ID_SITE = The code name of a certain sample point in a research area.

NA = A certain sample point has not been measured for a 2nd, 3rd and / or 4th time.

WD = Water depth of a certain sample point in cm.

Annex III

Method of measuring EC

Step 1: the collecting of the water samples
The tubes used for water sampling have a volume measuring scale up to 50 ml. In addition, all individual tubes were marked with a unique number for later processing. To collect water samples a fixed procedure was followed, shown in *figure 10***.**

Figure 10A: *Flushing* **Figure 10B**: *Placing on sediments* **Figure 10C**: *Opening of tubes* **Figure 10D:** *Closing of tubes*

A: Two tubes are flushed with water near the measurement location (*figure 10A*). This is done to remove dried up salts from previous measurements.

B: Two tubes are placed on top of the sediment layer with the cap still on. Furthermore, the tubes are held next to each other (*figure 10B*).

C: The caps are removed, and the tubes fill themselves with water. The caps are held next to the tubes (*figure 10C*).

D: The caps are put back on the tubes (*figure 10D*). When this is done, the tubes can be removed from the top of the sediment layer.

Step 2: Diluting the water samples

After the collecting of the samples in step 1, the samples are diluted to measure the EC value. This was necessary as the used EC-meter (*annex I*) can only measure EC values up to 20.00 mS/cm. However, higher EC values were measured. The procedure of diluting the samples is shown in *figure 11*. Before the dilutions take place, the EC of the tapwater is also measured to know how much this affects the dilution.

Figure 11A: *Sample of 50 ml* Figure 11**B**: *Dilution of sample* **Figure 11C**: *Measuring of EC*

A: The tube is drained until the value reaches 50 ml (*figure 11A*).

B: The measuring cup is flushed with tap water and filled with tap water up to 950ml. 50ml of the sample tube is added (*figure 11B*), thus a dilution of factor 20X takes place.

C: The EC value of the water is measured and noted down, together with the time the sample tube was taken in the field and the corresponding coordinates of the sample point (*figure 11C*).

Step 3: Calculate actual EC by using the dilution

The two diluted values of the EC need to be calculated back to the actual EC. For obtaining this value, the average value of EC of the two tubes is taken and multiplied by a factor 20X. In this research, the EC value of the tap water is relatively low compared to the values of the water samples (*Annex VIII – Annex XII*) and is therefore neglected.

Step 4: Processing of the EC values in ArcGIS Pro
After collecting all the data of the sample points, the data is processed in the program called ArcGIS Pro. The steps executed are shown in *annex IV.*

Validity of method

The cleaning of the used tubes is done before taking a sample. However, it is possible that not all salt residues are removed from the tubes and can cause higher values for EC than the actual EC values. To limit the influence of salts residues, sample tubes are cleaned after diluting and flushed again before taking the sample. In addition, sediment spores can be present and fill up a part of the 50mL water volume. Therefore, less water is present within the sample and can cause lower EC values than the actual EC values. Although this is a possible factor for lower EC values: while observing the water samples the presence of sediments was not taking up a significant amount of the volume.
Factors that are expected to cause greater possible deviations from the actual EC are concerning the diluting process. For every point two water samples are taken and diluted following the method in *"Collection Method and Instruments for the Electrical Conductivity*". After the diluting of the samples and the calculation of the original EC values of the sample, a deviation between the two samples is present. The deviations between the two samples per sample point can be found in *annex VII – annex XII.*

For all of the water samples, the same EC-meter is used with the same temperature compensation of 1.9%/°C. Furthermore, one water samples was taken and measured with a different EC-meter as well as the EC-meter used in this research, to see if different values occurred. This was not the case, thus the EC-meter is not an expected cause for the differences between the two EC samples. The same can be said over the water used for the dilution, as the same water with the same EC is present. However, the dilution water has a lesser EC value and is accountable for an overall greater value of the EC than the actual EC value, but is considered as insignificant for this research as the influence is relatively low.

The observed deviating values of the two water samples, that are taken at the same sample points, the same time and with the same method are expected to be the cause of differences in volume of water samples and of the diluting water. It is possible that water samples have not an exact volume of 50 ml and that the diluting water has not an exact volume of 950 ml. This could influence the outcome of the measured EC value and therefore, the calculated EC.
At last, the data is processed in ArcGIS pro and a map is made using interpolation method kriging. The possible deviation of the used GPS points is ± 3,0m. The end results of the kriging method are visible in *figure 5* and *figure 6.* The points are taken within three days and approximately within the time intervals of the tides going from high tide to low tide. Therefore, precipitation, tidal influences and mixing of water can influence EC over the time span of three days. That means that EC values that are presented in the same figure are not taken at the same time and could have changed in between those three days. That is why the interpolation can give an distorted image, although the individual points are giving a representative value of the EC at the measured time.

Annex IV

The EC values are being imported using ArcGIS Pro. The data is imported using the “kml to layer” tool. The data sets are interpolated using the tool called ‘kriging’. Afterwards, classes and color schemes are adapted of the created layer with “symbology”. An example of these steps is visible in *figure 12.* The same steps are used for all of the created EC and SD maps.

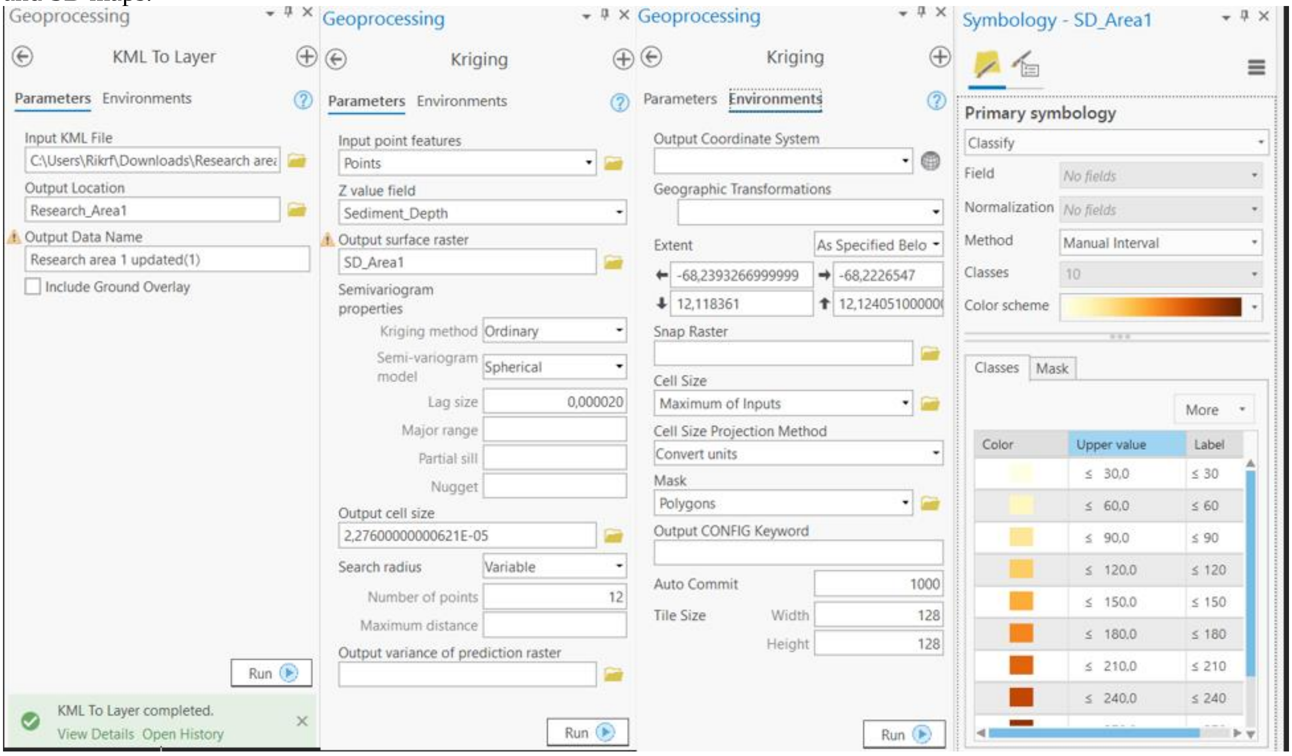

Figure 12A: *Importing data* **Figure 12B:** *Parameters Kriging* **Figure 12C:** *Environments Kriging* **Figure 12D:** *Altering symbology*

Annex V

List of used instruments

- EC-meter (Waterproof EC/TDS/Temperature Tester HI98311)
- Tubes for water sampling (50 ml volume)
- Measuring cup (1000 ml volume)
- GPS
- Program ArcGIS Pro 2.4.0

Annex VI

Method of measuring SD

Step 1: Measuring the sediment depths

The set up for measuring is partly illustrated in *figure 13*. *Figure 13* shows the rebar with the grip attached, together with the measuring tape hanging on top of the rebar. The measuring of the sediment depth is done in a specific order.

Figure 13: *Rebar with attached grip and measuring tape.*

A: The rebar is pushed vertically into the sediments. Because of the penetrability of the sediment layers, the rebar can be pushed through the sediments. However, it does not penetrate the bedrock. This way, it is possible to determine where the sediment layers stop and where the bedrock begins.

B: As the length of the rebar is known, the sediment depth can be calculated when the rebar is pushed into the sediment layers:

Sediment depth = total length of rebar – remaining length of rebar

The total length of the rebar is measured in advance and does not change. Therefore, only the remaining length of the rebar is measured using the measuring tape. However, at a certain point a second rebar with a different length is used during this research, as the length of the rebar was exceeded by the SD. Thus, the total length of rebar is different for certain sample points. This change in rebar length is taken into account while calculating the SD.

Step 2: Processing of the sediment depths in ArcGIS Pro

After collecting all the data of the sample points, the data is processed in the program called ArcGIS Pro. The EC values are being interpolated using the interpolation method called 'kriging'. Afterwards, classes and color schemes are adapted. A more detailed scheme on how the data is processed in ArcGIS Pro can be found in *annex IV.*

Validity of the method

It is assumed that the rebar is placed vertical into the sediments. This is done by eye vision of the person taking the measurements. However, small deviations are not always visible and the rebar can be inserted with a slight angle into the ground. Therefore, the measured SD could have greater values than the actual SD. Furthermore, the remaining part of the rebar is measured with measuring tape. This is done to fill in the formula: "*Sediment depth = total length of rebar – remaining length of rebar*". Because of the known value of '*total length of rebar'*, only the remaining length of rebar needs to be measured for every measurement. This is done by measuring from the top of the sediment layer up till the top of the remaining rebar. However, the turbidity of the water makes it for some measurements difficult to see when you reached the top of the sediment layer. That is why this is done by feeling where the sediment layers start and this can result in some deviations as well. The factors 'vertical placement' and 'start of sediment layer' are depend on the precision of the person measuring the SD. Thus, when different people measure, different values could occur. All SD in this research are measured by the same person.

Other factors could play a role in the validity of the research as well as the previous mentioned 'vertical placement' and 'start of sediment layer'. The measured SD can give a biased image when the sample point is not representable for the surrounding area. If the SD is measured in a crack of the limestone layer, the measured SD will have higher values than the surrounding area. The same goes the other way around for objects in the sediment layers, which cannot be penetrated as well as the limestone layer. This could be the case for leftover mangrove stems or lose stones.

At last, the data is processed in ArcGIS pro and a map is made using interpolation method kriging. The possible deviation of the used GPS points is ± 3,0m. The end result of the kriging method is visible in *figure 8*.

Annex VII

List of used instruments

- Rebar of 3,01m
- Rebar of 5,04m
- Wooden grip
- Rope to attach the grip to the rebar
- Measuring tape of 5,00m
- Additional measuring tape of 2,00m
- GPS
- Program ArcGIS Pro 2.4.0

Annex VIII

Table 11: *Measured EC values of the first time interval Area 1.*

ID_SITE	DATE	TIME	EC (mS/cm) TUBE 1	EC (mS/cm) TUBE 2	EC (ms/cm) multiplied 20X	T (°C) TUBE 1	T (°C) TUBE 2	Coordinates
_002	22/05/2022	15:08	4,98	5,01	99,9	28.6	28.6	12.12306, -68.23219
_004	22/05/2022	14:05	4,94	4,86	98	28.4	28.6	12.12307, -68.22988
_005	21/05/2022	13:55	4,64	4,6	92,4	28.8	28.8	12.12306, -68.2276
_006	22/05/2022	15:24	5,22	5,2	104,2	28.7	28.8	12.12069, -68.23266
_007	23/05/2022	16:40	5,21	5,21	104,2	28.8	28.7	12.12069, -68.23722
_008A	23/05/2022	17:09	5,31	5,32	106,3	28.9	28.7	12.12062, -68.23856
_009	22/05/2022	14:21	5,2	5,21	104,1	28.5	28.6	12.12068, -68.23039
_010	21/05/2022	15:00	5,01	5,01	100,2	28.9	29.2	12.1207, -68.22811
_012	23/05/2022	17:16	5,37	5,39	107,6	29.0	28.8	12.12179, -68.23824
_022	23/05/2022	16:53	5,54	5,5	110,4	28.7	28.6	12.11899, -68.23784
_023	23/05/2022	15:39	5,07	5,09	101,6	28.8	28.7	12.11899, -68.23625
_024	23/05/2022	15:50	5,21	5,21	104,2	28.7	28.6	12.12008, -68.23626
_027	21/05/2022	15:48	4,97	5	99,7	29.0	28.9	12.12015, -68.22687
_028	21/05/2022	15:25	4,98	4,92	99	29.0	29.0	12.11904, -68.22681
_029	21/05/2022	14:35	5,01	5,06	100,7	28.9	29.0	12.12009, -68.22915
_030	21/05/2022	14:44	5,12	5,14	102,6	29.0	29.0	12.11908, -68.22913
_031	22/05/2022	14:45	5,09	5,1	101,9	28.6	28.6	12.12009, -68.23142
_032	22/05/2022	14:39	5,08	5,09	101,7	28.6	28.7	12.11913, -68.23139
_033	22/05/2022	14:51	5,19	5,15	103,4	28.7	28.7	12.12092, -68.23144
_034	21/05/2022	14:26	5,08	5,07	101,5	28.9	28.9	12.12119, -68.22913
_036	22/05/2022	16:02	5,26	5,2	104,6	28.8	28.7	12.12122, -68.23374
_037	22/05/2022	15:53	5,2	5,19	103,9	28.8	28.8	12.1202, -68.23418
_039	21/05/2022	13:46	4,73	4,76	94,9	28.6	28.9	12.12192, -68.22639
_040	21/05/2022	14:11	4,64	4,59	92,3	28.8	28.9	12.12241, -68.2289
_042	22/05/2022	16:12	5,33	5,3	106,3	28.5	28.6	12.1224, -68.23346
_043	23/05/2022	16:08	5,27	5,24	105,1	28.9	28.7	12.12295, -68.23572
_044	21/05/2022	14:04	4,68	4,58	92,6	28.9	28.8	12.12375, -68.22873
_045	21/05/2022	15:13	4,84	4,84	96,8	29.1	29.1	12.12126, -68.2273
_046	21/05/2022	13:30	4,4	4,33	87,3	27.6	28.0	12.1188, -68.2237
_047	22/05/2022	16:20	5,03	5,04	100,7	28.6	28.6	12.12315, -68.23346
LB_30	22/05/2022	15:30	5,1	5,1	102	28.6	28.7	12.11952, -68.2325
LB_31	22/05/2022	14:28	5	5,05	100,5	28.5	28.6	12.11951, -68.2302
LB_32	21/05/2022	14:52	5,06	4,98	100,4	29.0	28.8	12.1195, -68.2279
LB_33	21/05/2022	15:40	NA	4,88	97,6	NA	29.0	12.1195, -68.2256
LB_36	23/05/2022	16:33	5,19	5,17	103,6	28.7	28.8	12.12179, -68.2371
LB_37	23/05/2022	15:14	5,23	5,23	104,6	28.4	28.5	12.12178, -68.2348
LB_38	22/05/2022	15:16	5,3	5,21	105,1	28.7	28.6	12.12186, -68.23241
LB_39	22/05/2022	14:14	5,24	5,24	104,8	28.4	28.5	12.12177, -68.2302
LB_40	21/05/2022	14:19	4,84	4,78	96,2	28.9	29.0	12.12176, -68.2279
LB_47	22/05/2022	15:41	5,01	5,05	100,6	28.6	28.7	12.11952, -68.2336
LB_48	23/05/2022	15:29	5,17	5,2	103,7	28.7	28.6	12.11952, -68.2355
LB_50	21/05/2022	13:40	4,74	4,8	95,4	28.5	28.7	12.12114, -68.2256
LB_51	23/05/2022	17:04	5,32	5,34	106,6	28.7	28.6	12.11953, -68.2385
LB_53	22/05/2022	14:58	5,2	5,27	104,7	28.6	28.6	12.12157, -68.23141
LB_54	23/05/2022	15:21	5,24	5,14	103,8	28.7	28.7	12.12069, -68.23496
LB_55	23/05/2022	16:00	5,19	5,15	103,4	28.8	28.8	12.12181, -68.23591
LB_56	23/05/2022	16:24	5,33	5,3	106,3	28.8	28.8	12.12291, -68.23701
LB_57	23/05/2022	15:08	5,21	5,24	104,5	27.8	28.1	12.12308, -68.23447

Note. The EC of the water samples used for the first time interval of area 1 can be found in the table above.

Note.

- ID_SITE = The code name of a certain point in a research area
- T= temperature in °C. Measured for a dilution consisting of a sample of 50 mL and 950mL tap water.
- TUBE 1 (or 2) = a dilution of a sample of 50 mL and 950mL tap water
- The 50 mL samples belonging to Tube 1 and Tube 2 are taken at the same time, at the same place and are both diluted with 950mL.
- To know the original EC of a certain ID_SITE, the average of Tube 1 and Tube 2 are taken and multiplied by a factor 20X.
- EC depends on temperature as well. Thus, a temperature compensation with coefficient β=1.9%/°C is already used in the data.
- The water used for the dilution is tap water with a relatively low EC value, therefore this EC value is not taken into account.

Note.
The measured EC of the tapwater at a certain date can be found in the following list:

21-5-2022, tapwater 0.14mS/cm, temperature 27.6°C
22-5-2022, tapwater 0.12mS/cm, temperature 28.0°C
23-5-2022, tapwater 0.15mS/cm, temperature 27.8°C

Annex IX

Table 12: *Measured EC values of the first time interval Area 2.*

ID_SITE	DATE	TIME	EC (mS/cm) TUBE 1	EC (mS/cm) TUBE 2	EC (ms/cm) multiplied 20X	TEMPERATURE TUBE 1 (°C)	TEMPERATURE TUBE 2 (°C)	Coordinates
D_001	10/05/2022	15:47	5,15	5,08	102,3	27.9	27.8	12.11284, -68.23561
D_002	10/05/2022	15:53	6,04	6,08	121,2	28.1	28.2	12.11327, -68.23561
D_003	12/05/2022	17:42	6,02	6,14	121,6	29.0	28.9	12.1184, -68.23883
D_004	12/05/2022	17:32	5,97	6,04	120,1	29.0	29.1	12.1184, -68.23815
D_005	12/05/2022	17:22	6,11	6,09	122	29.1	29.1	12.11838, -68.23745
D_006	12/05/2022	17:14	5,82	5,88	117	28.8	28.9	12.11838, -68.23675
D_007	12/05/2022	17:05	5,72	5,8	115,2	28.8	28.6	12.11836, -68.23608
D_008	12/05/2022	15:59	6	6,1	121	28.7	28.5	12.11774, -68.23883
D_009	12/05/2022	16:26	6,09	6,13	122,2	28.6	28.8	12.11774, -68.23815
D_010	12/05/2022	16:35	6,06	6,1	121,6	28.7	28.9	12.11772, -68.23746
D_011	12/05/2022	16:57	5,89	5,9	117,9	28.8	28.9	12.11772, -68.23675
D_012	11/05/2022	17:05	5,61	5,57	111,8	28.1	28.4	12.1177, -68.23608
D_013	11/05/2022	16:57	5,59	5,63	112,2	28.4	28.4	12.11769, -68.23541
D_014	12/05/2022	16:09	6,25	6,32	125,7	28.7	28.9	12.11706, -68.23881
D_015	12/05/2022	16:18	6,11	6,17	122,8	28.8	28.7	12.11706, -68.23814
D_016	12/05/2022	16:48	6,36	6,39	127,5	28.8	28.8	12.11707, -68.23673
D_017	11/05/2022	17:13	5,84	5,74	115,8	28.4	28.6	12.11708, -68.23606
D_018	11/05/2022	16:49	5,67	5,61	112,8	28.5	28.5	12.11708, -68.23539
D_019	11/05/2022	17:20	5,72	5,74	114,6	28.7	28.6	12.11641, -68.23589
D_020	11/05/2022	17:27	5,54	5,68	112,2	28.6	28.6	12.11642, -68.23521
D_021	11/05/2022	16:37	5,64	5,62	112,6	28.4	28.4	12.11642, -68.23452
D_022	11/05/2022	17:41	5,94	5,84	117,8	28.7	28.7	12.11578, -68.23586
D_023	11/05/2022	17:34	5,75	5,79	115,4	28.7	28.7	12.11579, -68.23517
D_024	11/05/2022	16:31	5,66	5,64	113	28.5	28.4	12.11578, -68.23448
D_025	10/05/2022	16:35	5,78	5,81	115,9	28.5	28.5	12.1151, -68.23703
D_026	11/05/2022	17:57	5,94	5,95	118,9	28.8	28.7	12.11509, -68.23653
D_027	11/05/2022	17:48	5,73	5,7	114,3	28.7	28.7	12.11511, -68.23584
D_028	11/05/2022	16:22	6,02	6	120,2	28.5	28.4	12.11511, -68.23514
D_029	10/05/2022	16:27	5,97	6,05	120,2	28.1	28.4	12.11447, -68.23704
D_030	11/05/2022	16:04	5,9	5,97	118,7	28.1	28.0	12.11447, -68.23637
D_031	11/05/2022	16:14	5,85	5,75	116	28.1	28.3	12.11446, -68.23566
D_032	10/05/2022	16:19	5,16	5,12	102,8	28.3	28.2	12.11382, -68.23694
D_033	10/05/2022	16:11	6,13	6,12	122,5	28.3	28.3	12.11381, -68.23625
D_034	10/05/2022	16:01	5,93	5,84	117,7	28.3	28.3	12.11381, -68.23555
D_035	10/05/2022	15:30	5,22	5,29	105,1	27.9	28.0	12.11331, -68.23695
D_036	10/05/2022	15:39	5,59	5,68	112,7	28.2	28.1	12.11329, -68.23619
D_037	10/05/2022	15:21	4,69	4,65	93,4	27.3	27.5	12.11332, -68.2377
D_038	10/05/2022	17:08	4,98	4,92	99	28.4	28.4	12.11355, -68.23766
D_039	10/05/2022	17:02	5,21	5,11	103,2	28.4	28.3	12.11402, -68.23759
D_040	10/05/2022	16:57	5,31	5,4	107,1	28.7	28.4	12.11433, -68.23746
D_041	10/05/2022	16:50	5,37	5,52	108,9	28.4	28.3	12.11458, -68.23742
D_042	10/05/2022	16:42	5,78	5,77	115,5	28.4	28.3	12.11484, -68.23731

Note.
The measured and calculated EC of the water samples used for the first time interval of area 2 can be found in the table above.

Note.

- ID_SITE = The code name of a certain point in a research area
- T= temperature in °C. Measured for a dilution consisting of a sample of 50 mL and 950mL tap water.
- TUBE 1 (or 2) = a dilution of a sample of 50 mL and 950mL tap water
- The 50 mL samples belonging to Tube 1 and Tube 2 are taken at the same time, at the same place and are both diluted with 950mL.
- To know the original EC of a certain ID_SITE, the average of Tube 1 and Tube 2 are taken and multiplied by a factor 20X.
- The EC depends on temperature as well. Thus, a temperature compensation with coefficient β=1.9%/°C is already used in the data.
- The water used for the dilution is tap water with a relatively low EC value, therefore this EC is not taken into account.

Note.

The EC of the tapwater at a certain date can be found in the following list:

10-5-2022, tapwater 0.13mS/cm, temperature 27.6°C

11-5-2022, tapwater 0.13mS/cm, temperature 28.5°C

12-5-2022, tapwater 0.14mS/cm, temperature 28.7°C

Annex X

Table 13: *Measured EC values of Area 3.*

ID_SITE	DATE 1	TIME	EC (mS/cm) TUBE 1	EC (mS/cm) TUBE 2	EC (ms/cm) multiplied 20X	T (°C) TUBE 1	T (°C) TUBE 2	Coordinates
E_008	13/06/2022	09:34	3,75	3,75	75	29,4	29,1	12.11346, -68.2251
E_011	13/06/2022	10:18	3,81	3,79	76	28,7	28,7	12.11277, -68.22509
E_002	13/06/2022	08:44	3,88	3,87	77,5	28,9	28,9	12.11478, -68.22427
E_016	13/06/2022	10:32	3,88	3,88	77,6	29,2	29,3	12.11225, -68.22386
E_013	13/06/2022	10:00	3,94	3,88	78,2	29,6	29,3	12.11271, -68.22444
E_010	13/06/2022	09:48	3,91	3,92	78,3	28,9	29,1	12.11345, -68.22369
E_012	13/06/2022	10:09	3,91	3,92	78,3	29,1	29,2	12.11271, -68.22444
E_005	13/06/2022	09:25	3,94	3,93	78,7	29,2	29,1	12.11413, -68.2246
E_006	13/06/2022	09:19	3,94	3,93	78,7	29,2	28,9	12.11414, -68.22398
E_014	13/06/2022	10:26	3,91	3,98	78,9	28,3	29,4	12.11228, -68.22471
E_009	13/06/2022	09:41	3,96	3,95	79,1	29,3	29,2	12.11346, -68.22438
E_015	13/06/2022	10:45	3,93	4	79,3	28,7	28,9	12.11225, -68.22386
E_007	13/06/2022	09:07	3,97	4	79,7	29,3	28,9	12.1141, -68.22321
E_003	13/06/2022	08:51	4,02	3,97	79,9	29	29,1	12.11477, -68.2236
E_004	13/06/2022	09:00	4,05	4,06	81,1	29,2	29,2	12.11476, -68.22291
E_001	13/06/2022	08:35	4,1	4,07	81,7	28,7	28,7	12.11545, -68.22296

Note.
The measured and calculated EC of the water samples used for Area 3 can be found in the table above.

- ID_SITE = The code name of a certain point in a research area
- T= temperature in °C. Measured for a dilution consisting of a sample of 50 mL and 950mL tap water.
- TUBE 1 (or 2) = a dilution of a sample of 50 mL and 950mL tap water
- The 50 mL samples belonging to Tube 1 and Tube 2 are taken at the same time, at the same place and are both diluted with 950mL.
- To know the original EC of a certain ID_SITE, the average of Tube 1 and Tube 2 are taken and multiplied by a factor 20X.
- The EC depends on temperature as well. Thus, a temperature compensation with coefficient β=1.9%/°C is already used in the data.
- The water used for the dilution is tap water with a relatively low EC value, therefore this EC is not taken into account.

The EC of the tapwater at a certain date can be found in the following list:
13-6-2022, tapwater 0.13mS/cm. Temperature 28.4°C

Annex XI

Table 14: *Measured and calculated EC values of the second time interval Area 1.*

ID_SITE	DATE 2	TIME	EC (mS/cm) TUBE 1	EC (mS/cm) TUBE 2	EC (ms/cm) multiplied 20X	TEMPERATURE TUBE 1 (°C)	TEMPERATURE TUBE 2 (°C)	Coordinates
_002	22/06/2022	16:07	5,19	5,2	103,9	29,2	29,3	12.12306, -68.23219
_004	22/06/2022	15:36	5,31	5,3	106,1	28,9	29,9	12.12307, -68.22988
_005	21/06/2022	14:39	5	4,93	99,3	28,8	28,4	12.12306, -68.2276
_006	22/06/2022	16:53	5,15	5,16	103,1	30,1	30,1	12.12069, -68.23266
_007	23/06/2022	16:13	5,34	5,3	106,4	29,1	29	12.12069, -68.23722
_008A	23/06/2022	16:20	5,51	5,59	111	28,9	29	12.12062, -68.23856
_009	22/06/2022	15:19	5,3	5,33	106,3	28,9	28,8	12.12068, -68.23039
_010	21/06/2022	15:23	5,13	5,15	102,8	29,8	29	12.1207, -68.22811
_012	23/06/2022	16:27	5,59	5,62	112,1	29,1	29,1	12.12179, -68.23824
_022	23/06/2022	15:48	5,52	5,52	110,4	28,9	29	12.11899, -68.23784
_023	23/06/2022	15:40	5,49	5,44	109,3	28,9	28,8	12.11899, -68.23625
_024	23/06/2022	16:06	5,33	5,29	106,2	29	29	12.12008, -68.23626
_027	22/06/2022	14:58	5,13	5,2	103,3	28,8	28,8	12.12015, -68.22687
_028	22/06/2022	15:05	5,28	5,24	105,2	30	28,8	12.11904, -68.22681
_029	21/06/2022	15:02	5,2	NA	104	29,3	NA	12.12009, -68.22915
_030	21/06/2022	15:08	5,17	5,14	103,1	29,6	28,8	12.11908, -68.22913
_031	22/06/2022	17:01	5,24	5,23	104,7	29,1	30,1	12.12009, -68.23142
_032	22/06/2022	17:08	5,29	5,33	106,2	30,1	29,1	12.11913, -68.23139
_033	22/06/2022	15:52	5,18	5,19	103,7	29	29,1	12.12092, -68.23144
_034	21/06/2022	14:57	5,16	5,17	103,3	29,3	28,4	12.12119, -68.22913
_036	22/06/2022	16:29	5,16	5,23	103,9	28,3	29,1	12.12122, -68.23374
_037	23/06/2022	15:20	5,31	5,29	106	28,7	28,8	12.1202, -68.23418
_039	21/06/2022	14:33	5,04	5,03	100,7	28,4	28,6	12.12192, -68.22639
_040	21/06/2022	14:51	5,08	5,05	101,3	28,3	28,4	12.12241, -68.2289
_042	22/06/2022	16:22	5,32	5,36	106,8	29,1	29,9	12.1224, -68.23346
_043	23/06/2022	17:06	5,41	5,37	107,8	29,2	29,2	12.12295, -68.23572
_044	21/06/2022	14:44	5,07	5,04	101,1	29	28,2	12.12375, -68.22873
_045	21/06/2022	15:39	5,02	5,1	101,2	28,6	29,2	12.12126, -68.2273
_046	21/06/2022	14:16	5,06	5,05	101,1	29,1	28,4	12.1188, -68.2237
_047	22/06/2022	16:15	5,27	5,28	105,5	30,1	29,9	12.12315, -68.23346
LB_30	22/06/2022	16:45	5,15	5,16	103,1	29,2	29,9	12.11952, -68.2325
LB_31	22/06/2022	15:13	5,21	5,25	104,6	28,9	29,8	12.11951, -68.2302
LB_32	21/06/2022	15:15	5,13	5,2	103,3	29,3	28,7	12.1195, -68.2279
LB_33	21/06/2022	15:57	5,15	5,1	102,5	28,5	28,5	12.1195, -68.2256
LB_36	23/06/2022	16:32	5,5	5,54	110,4	29	29	12.12179, -68.2371
LB_37	23/06/2022	16:50	5,46	5,39	108,5	29,2	29,1	12.12178, -68.2348
LB_38	22/06/2022	16:00	5,21	5,18	103,9	30,1	29,3	12.12186, -68.23241
LB_39	22/06/2022	15:26	5,26	5,24	105	30,1	28,8	12.12177, -68.2302
LB_40	21/06/2022	15:30	5,04	5,06	101	28,4	29	12.12176, -68.2279
LB_47	22/06/2022	16:38	5,22	5,12	103,4	29,1	29,1	12.11952, -68.2336
LB_48	23/06/2022	15:33	5,4	5,44	108,4	28,8	28,9	12.11952, -68.2355
LB_50	21/06/2022	14:27	5,1	5,1	102	28,9	28,4	12.12114, -68.2256
LB_51	23/06/2022	15:55	5,48	5,49	109,7	29	29,1	12.11953, -68.2385
LB_53	22/06/2022	15:45	5,25	5,24	104,9	28,8	28,9	12.12157, -68.23141
LB_54	23/06/2022	15:26	5,31	5,33	106,4	28,8	29,3	12.12069, -68.23496
LB_55	23/06/2022	16:41	5,48	5,48	109,6	29,1	29,2	12.12181, -68.23591
LB_56	23/06/2022	16:58	5,35	5,33	106,8	29,1	29,1	12.12291, -68.23701
LB_57	23/06/2022	17:13	5,43	5,35	107,8	29,1	29,2	12.12308, -68.23447

Note.

The measured and calculated EC of the water samples used for the second interval of Area 1 can be found in the table above.

Note.

- ID_SITE = The code name of a certain point in a research area
- T= temperature in °C. Measured for a dilution consisting of a sample of 50 mL and 950mL tap water.
- TUBE 1 (or 2) = a dilution of a sample of 50 mL and 950mL tap water
- The 50 mL samples belonging to Tube 1 and Tube 2 are taken at the same time, at the same place and are both diluted with 950mL.
- To know the original EC of a certain ID_SITE, the average of Tube 1 and Tube 2 are taken and multiplied by a factor 20X.
- The EC depends on temperature as well. Thus, a temperature compensation with coefficient β=1.9%/°C is already used in the data.
- The water used for the dilution is tap water with a relatively low EC value, therefore this EC is not taken into account.

Note.

The EC of the tapwater at a certain date can be found in the following list:
21-6-2022, tapwater 0.14mS/cm, temperature 28.6°C
22-6-2022, tapwater 0.14mS/cm, temperature 28.5°C
23-6-2022, tapwater 0.14mS/cm, temperature 28.8°C

Annex XII

Table 15: *Measured and calculated EC values of the second time interval Area 2.*

ID_SITE	DATE	TIME	EC (mS/cm) TUBE 1	EC (mS/cm) TUBE 2	EC (ms/cm) multiplied 20X	TEMPERATURE TUBE 1 (°C)	TEMPERATURE TUBE 2 (°C)	Coordinates
D_001	20/06/2022	15:32	4,83	4,78	96,1	29,0	29,2	12.11284, -68.23561
D_002	20/06/2022	15:26	4,84	4,8	96,4	28,6	28,9	12.11327, -68.23561
D_003	18/06/2022	12:58	5,43	5,43	108,6	30,3	30,2	12.1184, -68.23883
D_004	18/06/2022	13:05	5,44	5,4	108,4	30,2	30,2	12.1184, -68.23815
D_005	18/06/2022	13:11	5,42	5,39	108,1	30,2	30,2	12.11838, -68.23745
D_006	18/06/2022	13:19	5,43	5,42	108,5	30,2	29,9	12.11838, -68.23675
D_007	18/06/2022	13:25	5,38	5,4	107,8	30	30	12.11836, -68.23608
D_008	18/06/2022	12:50	5,37	5,31	106,8	30,1	30	12.11774, -68.23883
D_009	18/06/2022	14:33	5,35	5,32	106,7	30,1	29,9	12.11774, -68.23815
D_010	18/06/2022	14:22	5,36	5,39	107,5	30,2	30,3	12.11772, -68.23746
D_011	18/06/2022	14:14	5,36	5,36	107,2	30,2	30,1	12.11772, -68.23675
D_012	18/06/2022	13:32	4,96	5,05	100,1	30	30	12.1177, -68.23608
D_013	18/06/2022	13:39	4,93	4,99	99,2	30	30,3	12.11769, -68.23541
D_014	18/06/2022	14:53	5,45	5,38	108,3	30,3	30,2	12.11706, -68.23881
D_015	18/06/2022	14:41	5,32	5,32	106,4	30,1	30,1	12.11706, -68.23814
D_016	18/06/2022	14:06	5,52	5,46	109,8	30,2	30,2	12.11707, -68.23673
D_017	18/06/2022	13:56	5,28	5,27	105,5	30,3	30,2	12.11708, -68.23606
D_018	18/06/2022	13:48	5,08	5,06	101,4	30,2	30,3	12.11708, -68.23539
D_019	19/06/2022	14:38	4,47	4,45	89,2	28,3	28,2	12.11641, -68.23589
D_020	19/06/2022	14:30	4,43	4,45	88,8	28,2	28,2	12.11642, -68.23521
D_021	19/06/2022	14:24	4,5	4,56	90,6	28,2	28,2	12.11642, -68.23452
D_022	19/06/2022	14:54	4,7	4,69	93,9	28	28	12.11578, -68.23586
D_023	19/06/2022	14:47	4,45	4,43	88,8	28,2	28	12.11579, -68.23517
D_024	19/06/2022	14:17	4,32	4,35	86,7	28,4	28,2	12.11578, -68.23448
D_025	19/06/2022	15:13	4,72	4,75	94,7	28,3	28,3	12.1151, -68.23703
D_026	19/06/2022	15:05	4,68	4,64	93,2	28,2	28,4	12.11509, -68.23653
D_027	19/06/2022	13:59	4,36	4,36	87,2	28,2	28,2	12.11511, -68.23584
D_028	19/06/2022	14:06	4,24	4,29	85,3	28,2	28,2	12.11511, -68.23514
D_029	19/06/2022	13:36	4,64	4,61	92,5	28,5	28	12.11447, -68.23704
D_030	19/06/2022	13:43	4,54	4,54	90,8	28	28,2	12.11447, -68.23637
D_031	19/06/2022	13:50	4,46	4,49	89,5	28,1	28,2	12.11446, -68.23566
D_032	20/06/2022	15:06	4,79	4,66	94,5	2,88	28,8	12.11382, -68.23694
D_033	20/06/2022	15:13	4,86	4,77	96,3	28,9	28,8	12.11381, -68.23625
D_034	20/06/2022	15:20	4,78	4,73	95,1	28,8	28,8	12.11381, -68.23555
D_035	20/06/2022	15:48	4,91	4,84	97,5	29,1	29,0	12.11331, -68.23695
D_036	20/06/2022	15:39	4,88	4,9	97,8	28,9	28,8	12.11329, -68.23619
D_037	20/06/2022	14:32	4,76	4,76	95,2	28,6	28,6	12.11332, -68.2377
D_038	20/06/2022	14:38	4,77	4,76	95,3	28,8	28,6	12.11355, -68.23766
D_039	20/06/2022	14:43	4,72	4,73	94,5	28,7	28,7	12.11402, -68.23759
D_040	20/06/2022	14:48	4,76	4,78	95,4	28,6	28,7	12.11433, -68.23746
D_041	20/06/2022	14:53	4,85	4,77	96,2	28,6	28,6	12.11458, -68.23742
D_042	20/06/2022	14:57	5,35	5,24	105,9	28,8	28,6	12.11484, -68.23731
D_042	19/06/2022	15:22	5,21	5,63	108,4	28,6	28,5	12.11484, -68.23731

Note.
The EC of the water samples used for the second interval of Area 2 can be found in the table above.

Note.

- ID_SITE = The code name of a certain point in a research area
- T= temperature in °C. Measured for a dilution consisting of a sample of 50 mL and 950mL tap water.
- TUBE 1 (or 2) = a dilution of a sample of 50 mL and 950mL tap water
- The 50 mL samples belonging to Tube 1 and Tube 2 are taken at the same time, at the same place and are both diluted with 950mL.
- To know the original EC of a certain ID_SITE, the average of Tube 1 and Tube 2 are taken and multiplied by a factor 20X.
- The EC depends on temperature as well. Thus, a temperature compensation with coefficient β=1.9%/°C is already used in the data.
- The water used for the dilution is tap water with a relatively low EC value, therefore this EC is not taken into account.

Note.
The EC of the tapwater at a certain date can be found in the following list:

18-6-2022, tapwater 0.13mS/cm. Temperature 30,2°C

19-6-2022, tapwater 0.14mS/cm. Temperature 28,6°C

20-6-2022, tapwater 0.14mS/cm, temperature 28.9°C

Annex XIII

Table 16: *Measured SD of Area 1.*

ID_SITE	DATE	TIME	SD (cm)	COORDINATES
_001	11/03/2022	11:31	38	12.12181, -68.23618
_002	01/04/2022	09:09	60	12.12306, -68.23219
_004	01/04/2022	09:27	135	12.12307, -68.22988
_005	01/04/2022	09:39	16	12.12306, -68.2276
_006	06/05/2022	LOST	209	12.12069, -68.23266
_007	06/05/2022	LOST	50	12.12069, -68.23722
_008A	06/05/2022	LOST	61	12.12062, -68.23856
_009	06/05/2022	LOST	170	12.12062, -68.23856
_010	06/05/2022	LOST	176	12.1207, -68.22811
_011	06/05/2022	LOST	101	12.1207, -68.22811
_012	06/05/2022	LOST	12	12.12179, -68.23824
_020	29/04/2022	14:44	139	12.1207, -68.23608
_021A	02/05/2022	14:51	73	12.12011, -68.23785
_021B	02/05/2022	14:53	79	12.12005, -68.23781
_021C	02/05/2022	14:55	51	12.1201, -68.23784
_022	02/05/2022	15:09	182	12.11899, -68.23784
_023	02/05/2022	15:24	254	12.11899, -68.23625
_024	02/05/2022	15:36	246	12.12008, -68.23626
_025	29/04/2022	13:52	275	12.11898, -68.23465
_026	28/04/2022	14:15	141	12.11947, -68.22466
_027	28/04/2022	14:40	124	12.12015, -68.22687
_028	28/04/2022	14:52	239	12.11904, -68.22681
_029	28/04/2022	15:18	145	12.12009, -68.22915
_030	28/04/2022	15:04	265	12.11908, -68.22913
_031	29/04/2022	13:12	NA	12.12009, -68.23142
_032	29/04/2022	13:27	277	12.11913, -68.23139
_033	29/04/2022	13:03	189	12.12092, -68.23144
_034	28/04/2022	15:28	128	12.12119, -68.22913
_035	29/04/2022	13:39	284	12.11899, -68.23302
_036	29/04/2022	14:18	155	12.12122, -68.23374
_037	29/04/2022	14:09	186	12.1202, -68.23418
_038	02/05/2022	14:35	23	12.12128, -68.2378
_039	28/04/2022	14:29	39	12.12192, -68.22639
_040	28/04/2022	16:00	35	12.12241, -68.2289
_041	29/04/2022	12:53	118	12.12241, -68.23087
_042	02/05/2022	14:04	160	12.1224, -68.23346
_043	02/05/2022	14:19	15	12.12295, -68.23572
_044	28/04/2022	16:11	1	12.12375, -68.22873
_045	28/04/2022	15:43	152	12.12126, -68.2273
_046	28/04/2022	14:02	59	12.1188, -68.2237
_047	02/05/2022	13:52	79	12.12315, -68.23346
LB_21	23/03/2022	LOST	280	12.11726, -68.2348
LB_28	06/05/2022	LOST	230	12.11953, -68.2371
LB_29	23/03/2022	LOST	207	12.11952, -68.2348
LB_30	23/03/2022	LOST	282	12.11952, -68.2325
LB_31	23/03/2022	LOST	263	12.11951, -68.2302
LB_32	23/03/2022	LOST	219	12.1195, -68.2279
LB_33	06/05/2022	LOST	183	12.1195, -68.2256
LB_34A	01/04/2022	10:21	20	12.1194772, -68.2235430
LB_36	11/03/2022	11:41	32	12.12179, -68.2371
LB_37	11/03/2022	10:59	45	12.12178, -68.2348
LB_38	23/03/2022	LOST	141	12.12178, -68.2325
LB_39	23/03/2022	LOST	129	12.12177, -68.2302
LB_40	06/05/2022	LOST	126	12.12176, -68.2279
LB_41A	01/04/2022	10:06	8	12.1211726, -68.2251241
LB_43	11/03/2022	12:33	60	12.12337, -68.2325
LB_47	06/05/2022	LOST	252	12.11952, -68.2336
LB_48	06/05/2022	LOST	194	12.11952, -68.2355
LB_50	06/05/2022	LOST	51	12.12114, -68.2256
LB_51	06/05/2022	LOST	89	12.11953, -68.2385
LB_53	23/03/2022	LOST	207	12.12157, -68.23141
LB_54	06/05/2022	LOST	165	12.12069, -68.23496
LB_55	11/03/2022	11:16	39	12.12181, -68.23591
LB_56	11/03/2022	11:59	12	12.12291, -68.23701
LB_57	11/03/2022	12:18	13	12.12308, -68.23447

Note.
The measured SD of Area 1 is visible in the table above, together with the code name, the date, the time and coordinates.
Note.

ID_SITE = The code name of a certain point in a research area.

SD = sediment depth in cm.

LOST = was measured but data cannot be retrieved.

Annex XIV

Table 17: *Measured SD of Area 2.*

ID_SITE	DATE	TIME	SD (cm)	COORDINATES
D_001	19/05/2022	13:41	339	12.11284, -68.23561
D_002	19/05/2022	13:52	369	12.11327, -68.23561
D_003	18/04/2022	12:14	238	12.1184, -68.23883
D_004	18/04/2022	12:02	146	12.1184, -68.23815
D_005	11/04/2022	15:15	237	12.11838, -68.23745
D_006	11/04/2022	15:04	275	12.11838, -68.23675
D_007	11/04/2022	14:53	310	12.11836, -68.23608
D_008	18/04/2022	12:26	104	12.11774, -68.23883
D_009	18/04/2022	11:49	187	12.11774, -68.23815
D_010	11/04/2022	15:28	273	12.11772, -68.23746
D_011	11/04/2022	15:40	231	12.11772, -68.23675
D_012	11/04/2022	15:50	208	12.1177, -68.23608
D_013	11/04/2022	16:02	283	12.11769, -68.23541
D_014	18/04/2022	11:19	113	12.11706, -68.23881
D_015	18/04/2022	11:36	216	12.11706, -68.23814
D_016	20/04/2022	13:42	275	12.11707, -68.23673
D_017	20/05/2022	13:26	318	12.11708, -68.23606
D_018	20/04/2022	13:12	266	12.11708, -68.23539
D_019	20/04/2022	14:04	267	12.11641, -68.23589
D_020	20/04/2022	12:48	277	12.11642, -68.23521
D_021	20/05/2022	12:34	316	12.11642, -68.23452
D_022	20/04/2022	14:16	258	12.11578, -68.23586
D_023	20/05/2022	14:33	321	12.11579, -68.23517
D_024	20/05/2022	12:24	331	12.11578, -68.23448
D_025	19/04/2022	12:20	214	12.1151, -68.23703
D_026	19/04/2022	12:08	240	12.11509, -68.23653
D_027	19/05/2022	14:52	315	12.11511, -68.23584
D_028	19/05/2022	15:09	334	12.11511, -68.23514
D_029	19/04/2022	12:38	219	12.11447, -68.23704
D_030	19/04/2022	12:51	270	12.11447, -68.23637
D_031	19/05/2022	14:38	319	12.11446, -68.23566
D_032	19/04/2022	13:22	253	12.11382, -68.23694
D_033	19/05/2022	14:18	324	12.11381, -68.23625
D_034	19/05/2022	14:05	354	12.11381, -68.23555
D_035	19/05/2022	13:17	276	12.11331, -68.23695
D_036	19/05/2022	13:29	345	12.11329, -68.23619
D_037	06/04/2022	12:43	255	12.11332, -68.2377
D_038	06/04/2022	12:51	182	12.11355, -68.23766
D_039	06/04/2022	13:11	187	12.11402, -68.23759
D_040	06/04/2022	13:16	182	12.11433, -68.23746
D_041	06/04/2022	13:24	203	12.11458, -68.23742
D_042	06/04/2022	13:30	175	12.11484, -68.23731
D_050	05/05/2022	LOST	275	12.11342, -68.23698
D_051	05/05/2022	LOST	296	12.11381, -68.23672
D_052	05/05/2022	LOST	272	12.11387, -68.23674
D_053	05/05/2022	LOST	298	12.11409, -68.23634
D_054	05/05/2022	LOST	259	12.11414, -68.23658
D_055	05/05/2022	LOST	270	12.11457, -68.23629
D_056	05/05/2022	LOST	277	12.11497, -68.23619
D_057	05/05/2022	LOST	290	12.11497, -68.23613
D_058	05/05/2022	LOST	292	12.1154, -68.23596
D_059	05/05/2022	LOST	254	12.11542, -68.23606
D_060	05/05/2022	LOST	283	12.11568, -68.2358
D_061	05/05/2022	LOST	293	12.11582, -68.23542
D_062	05/05/2022	LOST	284	12.11585, -68.23556
D_063	05/05/2022	LOST	281	12.11636, -68.23527
D_064	05/05/2022	LOST	288	12.11647, -68.23491
D_065	05/05/2022	LOST	277	12.11662, -68.2351
D_066	05/05/2022	LOST	262	12.11678, -68.23534
D_067	20/05/2022	LOST	308	12.11713, -68.23565
D_068	05/05/2022	LOST	277	12.11716, -68.23576
D_069	20/05/2022	13:04	341	12.11525, -68.23509
D_070	20/05/2022	13:42	379	12.11716, -68.23566
D_071	20/05/2022	13:41	284	12.11714, -68.23567
D_072	20/05/2022	13:44	256	12.11716, -68.23563
D_073	20/05/2022	14:05	323	12.11705, -68.23607
D_074	20/05/2022	14:13	276	12.11718, -68.23616

Note.

The measured SD of Area 2 is visible in the table above, together with the code names, the dates, the time and coordinates.

Notes.

ID_SITE = The code name of a certain point in a research area.

SD = sediment depth in cm.

LOST = was measured but data cannot be retrieved.

Annex XV

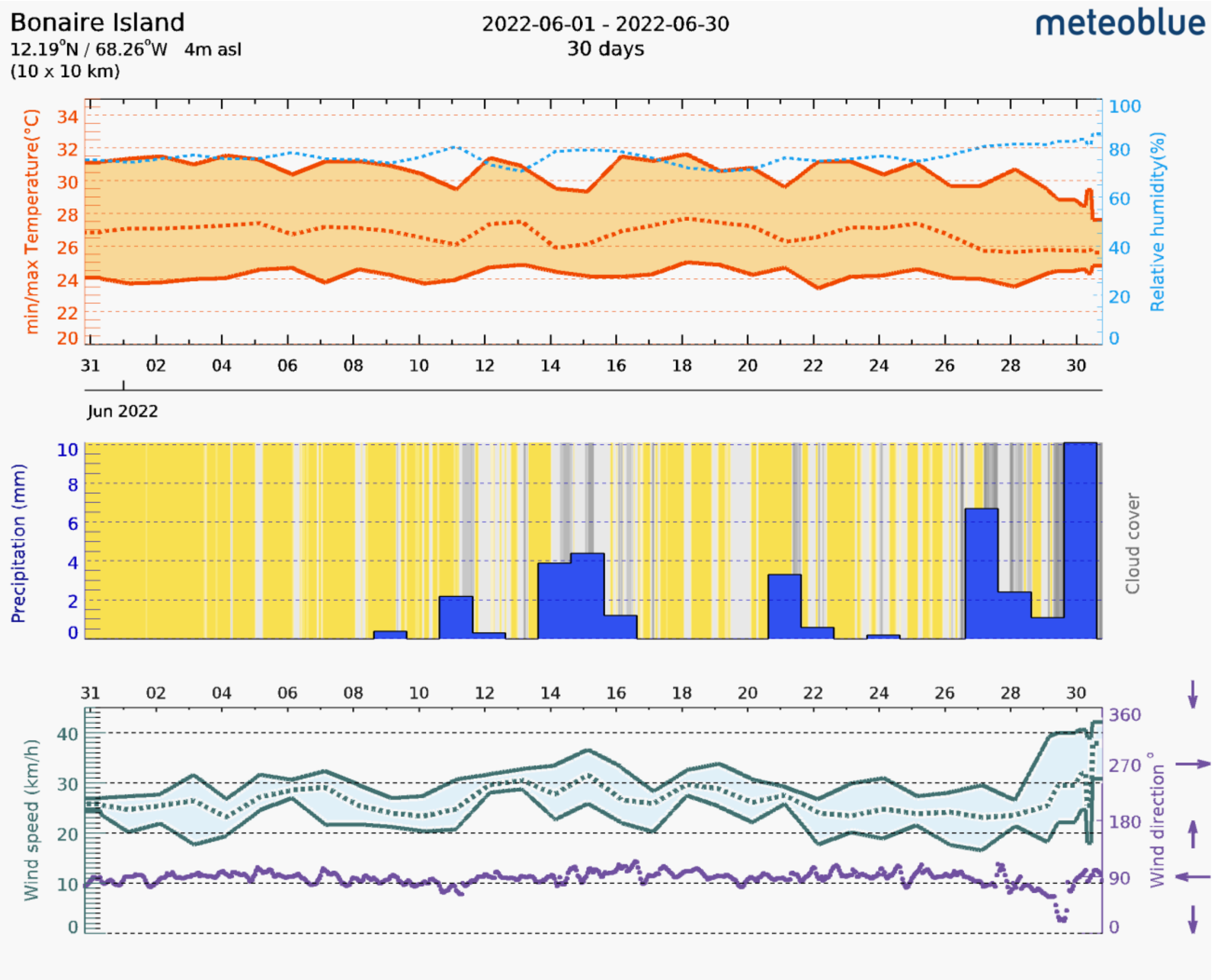

Figure 14: *Climate data of Bonaire of the month June in 2022 (*Meteoblue, 2022*).*

Note.

The precipitation in mm of the period 01/06/2022 – 30/06/2022 for Bonaire. Windspeed and min/max temperature are visible as well.

Annex XVI

Figure 15: *High tide at the channel located at the southern border of Area 2.*


Figure 16: *Low tide at the channel located at the southern border of Area 2.*

Annex XVII

Figure 17: *Possible water inflow from Lac Bay into the eastern part of Area 2. (google mymaps, 2023)*

Annex XVIII

Detail Lac Bay, Changes 2014 - 2020

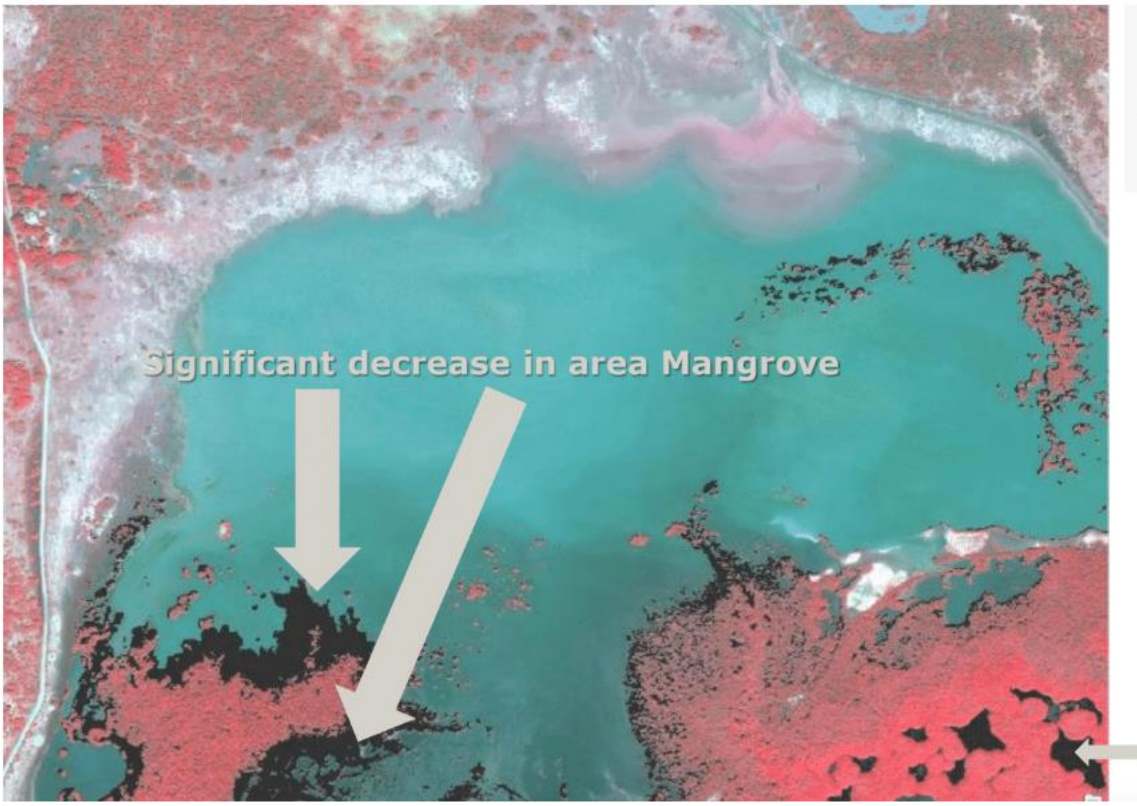

Figure 18: *Main mangrove loss in the period 2014-2020 (Mucher, personal communication, 2023).*

Note.
The black areas are mangrove areas that experienced die-off in the period of 2014-2020. It is visualized using satellite imagery.