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Contribution to the Physicochemical Characterization of Peat in the Inongo Peatlands: The Case of the Wildlife Works Carbon/the Era-Congo Concession/DR Congo

Patience Ngelinkoto Mpia[1,2], Junior Matondo Falanga[2,3*], Happy Kimvwela Salabiaku[4], Constantin Lubini Ayingweu[4], Jean-Robert Bwangoy Bakanja[4], Félicien Lukoki Luyeye[4], Dieudonné Musibono Eyul'anki[4], Raymond Lumbuenamo Sinsi[4], Honoré Belesi Katula[4]

[1]Faculty of Science and Technology, National Pedagogical University, Kinshasa, DRC
[2]Water and Environment Research Center, Ministry of Scientific Research and Technological Innovation, Kinshasa, DRC
[3]Department of Biology-Chemistry, Teaching Higher Institute of Mbandaka, Mbandaka, DRC
[4]Faculty of Science and Technology, University of Kinshasa, Kinshasa, DRC
Email: *juniormatfal@gmail.com

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Abstract

This study characterized the physical and chemical properties of the Inongo peatlands in the Wildlife Works Carbon/Era concession in the Mai-Ndombe province of the Democratic Republic of Congo. This concession covers an area of 301,100 hectares, located between 17˚ and 18˚20' east longitude and between 1˚ and 2˚ latitude. The Inongo peatlands in the Wildlife Works Carbon/Era concession - Congo belong to the ombrotrophic peatland category. The samples analyzed show that the Inongo peatlands in the ERA concession in Mai ndombe, DRC, have an average total organic carbon content of 56.4%, which classifies them as mature peatlands. The average pH is 3.3, which means that these peatlands are acidic; the average electrical conductivity is 278.6 µs/cm and the redox potential is 278.6 mV.

Subject Areas

Geochemistry

Keywords

Era-Congo, Peatland Area, Physicochemical

1. Introduction

The issue of global warming is a major challenge that requires special attention from society in general and scientists in particular in their studies and protection of specific and sensitive environments. These environments can make an effective contribution to mitigating global warming.

A true nature-based solution, peatlands are a unique ecosystem in terms of their contribution to global climate mitigation. They capture and store carbon, purify water, and are home to unique biodiversity [1] [2]. Although they cover only about 3% of the Earth's surface, the ecological services they provide and their positive impact on the planet fully justify their careful management [3] [4].

The peatlands of the central Congo Basin play a vital role at the local, regional, and global levels. Covering an area of 145,000 km^2 [3], they contain approximately the equivalent of the volume of carbon present in the above-ground biomass of trees in all the forests of the Congo Basin [5] [6].

As the Democratic Republic of Congo has most of the peatlands in the Congo Basin, it is desirable, if not imperative, that studies be conducted on these particular ecosystems in order to determine their actual natural capital [7]. Hence, the research on the peat wetlands of Inongo in the province of Mai-Ndombe was conducted to obtain data on their physical and chemical properties.

2. Materials and Methods

This section presents the materials used during the conduct of this study, as well as the methods employed, starting with an overview of the study environment.

2.1. Study Environment

This study was conducted in the Wildlife Works Carbon/ERA-Congo concession located in the Inongo territory, Maï-Ndombe province. The province of Maï-Ndombe is located in the central basin of the Congo, dominated by plateaus, plains, and hills.

The Wildlife Works Carbon/ERA-Congo concession covers an area of 301,100 hectares, between 17˚ and 18˚20' east longitude and between 1˚ and 2˚ latitude, and is bounded, as shown in **Figure 1**:

- To the north by the Bolongo-Lule River;
- To the south by the territory of Kutu;
- To the east by Lake Maï-Ndombe;
- To the west by the territory of Mushie.

We divided this area into five plots because this allows us to take samples systematically and reduce the risk of bias. It also gives us an overview while taking local variations into account. The spatial constraints are the difficulty of access due to the vastness of the forest and the climatic conditions.

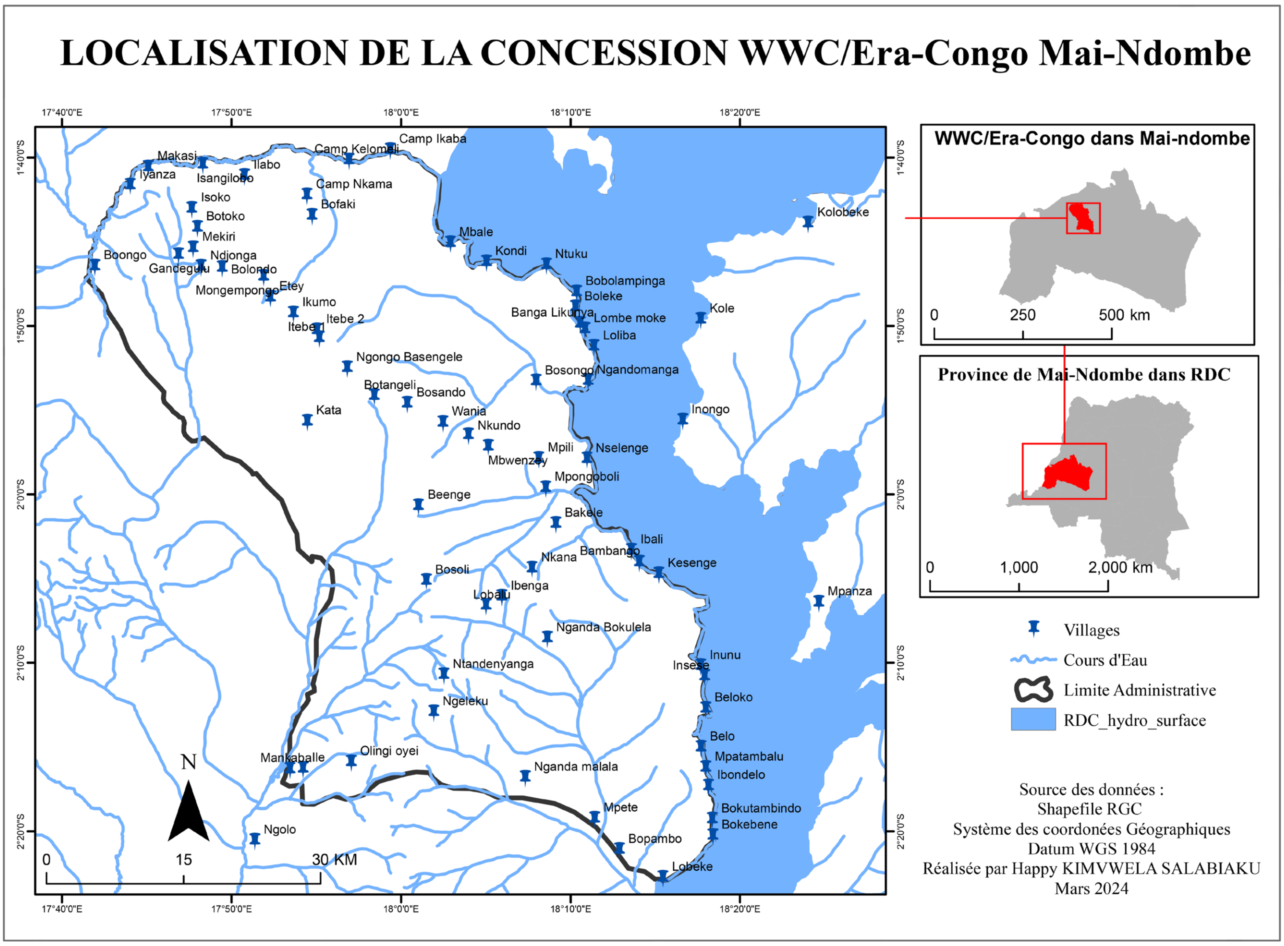

Figure 1. Location of the WWC/ERA concession - Congo in the DRC.

2.2. Materials

The materials used to carry out this work are divided into two categories: non-biological materials and laboratory materials.

2.2.1. Biological Equipment

Biological equipment consists of peat samples.

2.2.2. Laboratory Equipment

1) **Devices**

- APERA SX731 MultiLine multiparameter probe;
- Core sampler;
- Canon camera;
- Garmin Dakota 20 GPS;

2) **Other equipment**

- Two 35-liter coolers;
- Pruning shears;
- Boots;
- Bags for transporting equipment in the field.

2.3. Methods

This section covers all the techniques and methods used to collect data, namely: documentary research and field observation, sampling and analysis techniques.

We took samples at a depth of 1.40 meters. We took nine subsamples per plot.

2.3.1. Laboratory Protocols

1) Total organic carbon

Total organic carbon was determined according to Robert. The protocol is as follows:

- Weigh 1.0 g of soil or sediment sample that has been dried in the open air and place it in a 300 mL conical flask.
- Add 10 mL of 1 N potassium dichromate. Place a magnetic bar in the conical flask.
- Add 20 mL of concentrated sulfuric acid (98% by mass) and place a watch glass over the conical flask.
- Shake vigorously for 1 minute and cool the resulting digestate for 30 minutes.
- Rinse the watch glass.
- Then add 200 mL of distilled water, 10 mL of concentrated phosphoric acid, and 10 to 15 drops of ferroin indicator solution.
- Finally, titrate the excess potassium dichromate with the 0.5 N ferrous sulfate solution when the turquoise color appears, titrating slowly until the final brown color appears.
- Note the volume used.
- Also measure the control sample in the same way as the sample after first placing a magnetic rod, 10 mL of 1 N potassium dichromate, and 20 mL of 98% sulfuric acid in an Erlenmeyer flask.

2) *In situ* parameters (temperature, pH, electrical conductivity, TDS, dissolved oxygen, and redox potential)

These parameters were measured using HANNA HI 991300 and HANNA HI 9146 multi-parameter probes. Here is the procedure:

- Press the ON/OFF button to turn on the device.
- Rinse the electrode with distilled water and wipe it with a disposable tissue.
- Immerse the electrode in the medium to be measured to a minimum depth of 4 cm;
- Wait for the value to stabilize before reading.
- Press "Red" to change the parameters to be read.
- Rinse the electrode again with distilled water and wipe it with a clean disposable tissue to take the next measurement.

2.3.2. Sampling and Preparation of Equipment

Five permanent plots of 0.25 hectares, or 50 m × 50 m (for a total area of one hectare), were set up in a peatland stand. These plots are represented on the map by points P1, P2, P3, P4, and P5 (**Figure 2** and **Figure 3**).

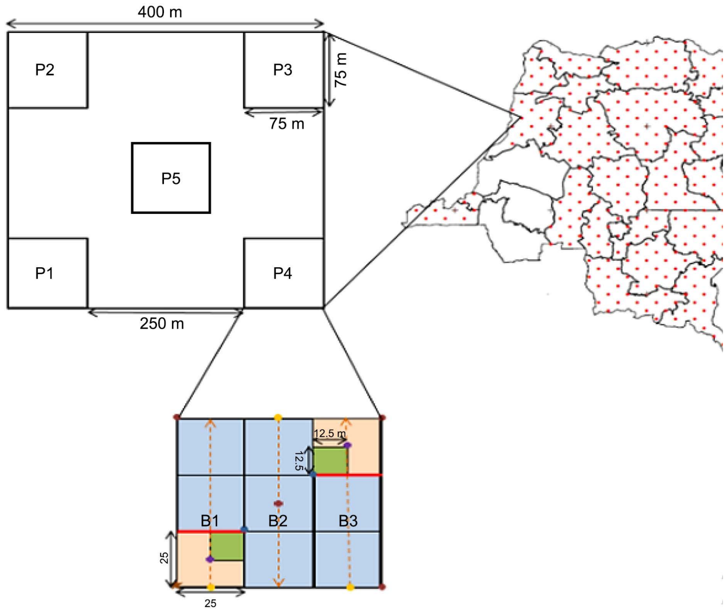

Figure 2. Plot layout according to the Japanese International Cooperation Agency (JICA) FAO, 2019. Plot coding: P1: first plot; P2: second plot; P3: third plot; P4: fourth plot; P5: fifth plot.

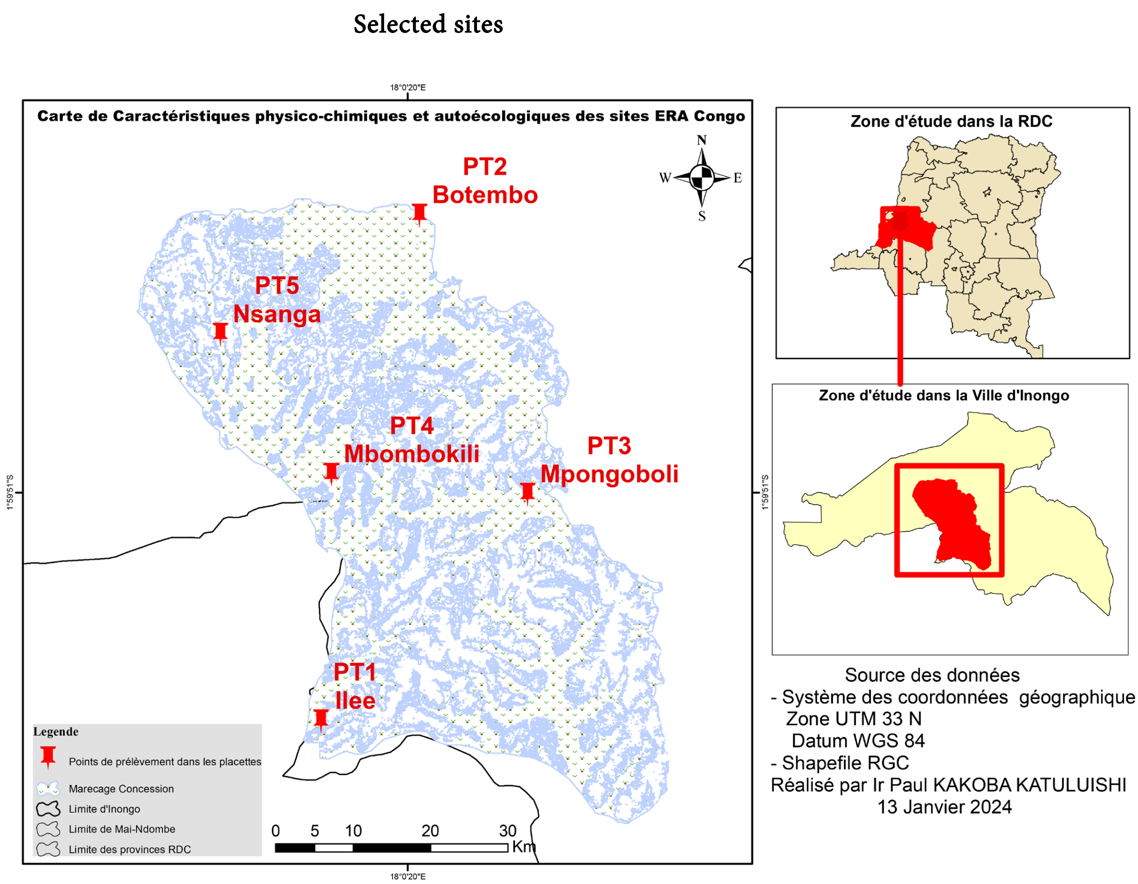

Figure 3. Different sampling points for peat samples in the villages of the Era-Congo Concession. Legend: PT1: peat sampling site 1 (Ilee village); PT2: peat sample collection site 2 (Botembo village); PT3: peat sample collection site 3 (Mpongoboli village); PT4: peat sample collection site 4 (Bombokili village); PT5: peat sample collection site 5 (Nsanga village).

3. Results

3.1. Physical Characteristics

Table 1 presents the physicochemical parameters measured in peat samples taken from five different sites (PT1 to PT5) in the Inongo region.

This table shows that: The temperature varies from 25˚C to 26˚C, typical of a tropical environment, with no significant variation, allowing the other parameters to be compared without thermal bias. The pH varies from 3.1 to 3.7, with all samples being highly acidic (pH < 4), which is one of the characteristics of peatlands, where the accumulation of organic matter and anaerobic decomposition generate organic acids. Such marked acidity can influence the bioavailability of metals and microbial activity. Electrical conductivity ranges from 296 to 325 µS/cm^2 (low to moderate values), indicating low mineralization, and TDS ranges from 3.5 to 6.6 mg/L, confirming a low dissolved ion load. Dissolved oxygen varies from 2.37 to 4.1 mg/L, which are relatively low levels typical of water-saturated environments rich in organic matter where oxygen consumption through decomposition is high. The lowest value (PT1) could indicate a more stagnant area or one richer in easily degradable organic matter. The redox potential varies from 218 to 317 mV. Some sites (PT4, PT1) appear to be more oxidizing, while others (PT5, PT2) appear to be more reducing; these fluctuations reflect heterogeneous conditions within the Inongo bog, influenced by water saturation, organic matter, and biological activity. Total organic carbon varies from 55.6% to 57.2%, which are very high and homogeneous levels, confirming the highly organic nature of the samples.

Table 1. Physico-chemical parameters of Inongo peat.

PARAMETRES	T(˚C)	pH	CE (µs/Cm^2)	TDS (mg/L)	O_2 (mg/L)	PR (mV)	COT (%)
PT1.Vl: ILEE	25 ± 0.1	3.27 ± 0.2	296 ± 4.3	5.5 ± 1.2	2.37 ± 0.4	296 ± 79	56.5 ± 0.24
PT2.Vl: Botembo	26 ± 1.1	3.1 ± 0.8	325 ± 35.0	6.6 ± 1.1	3.37 ± 0.5	236 ± 16.4	55.6 ± 0.31
PT3.Vl: Mpongoboli	26 ± 1.8	3.2 ± 0.2	298 ± 38.4	3.5 ± 0.6	4.1 ± 0.7	280 ± 77.6	57.1 ± 0.18
PT4.Vl: bombokili	25 ± 2.2	3.1 ± 0.1	296 ± 69.5	5 ± 0.2	3.7 ± 0.5	317 ± 69.7	55.7 ± 0.30
PT5.Vl: Nsanga	25.9 ± 0.1	3.7 ± 0.1	301 ± 28.8	5.9 ± 0.9	4 ± 0.4	218 ± 54.4	57.2 ± 0.19

1) Temperature

From Figure 4, the temperature values recorded during this study ranged from 25˚C to 25.9˚C, with an average of 25.78˚C and a standard deviation of ±0.8. The minimum value (25˚C) was recorded at site P1 in the Ilée-Mankaba swamp forest and P4 Mbombokili, while the maximum (25.9˚C) was observed at site P5 in Nsanga.

2) pH

Figure 5 shows that all pH values are between 3.1 and 3.7, with an average of 3.294 and a standard deviation of ±0.2. The lowest value is observed in the Mbombokili swamp forest at site P4, and the highest value is found at site P5 in Nsanga.

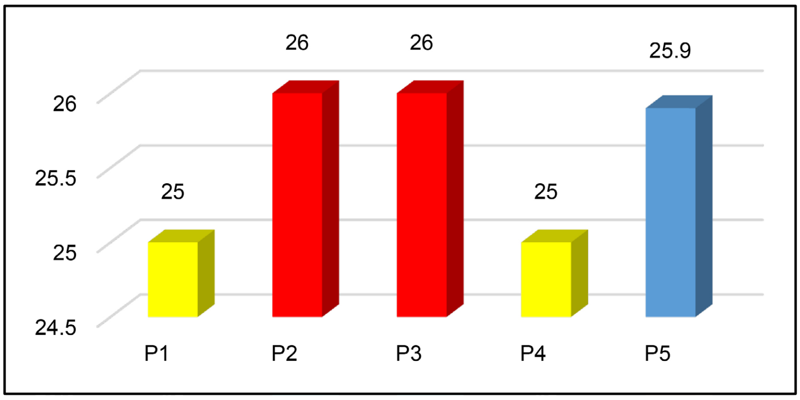

Figure 4. Temperature variation at different sites.

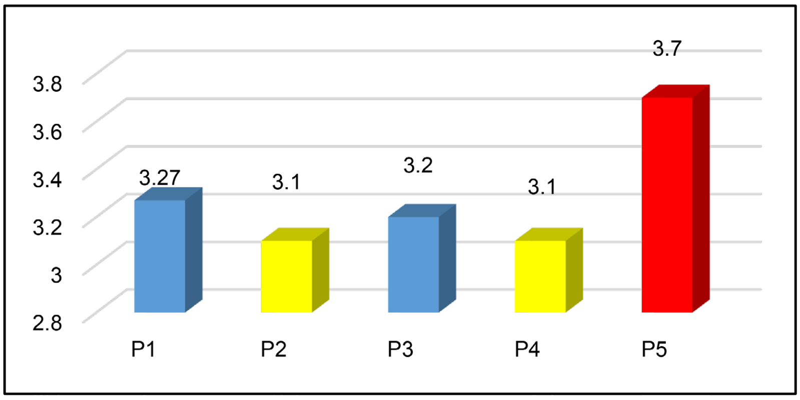

Figure 5. The variation in pH at the different sampling sites in the Era-Congo concession.

3) Electrical conductivity

From Figure 6, it can be seen that the measured electrical conductivity results show values ranging from 296 µs/cm to 325 µs/cm, with an observed average of 303.2 µs/cm and a standard deviation of ±12.3. Sites P1 in Ilée-Mankaba and P4 in Mbombokili have the lowest values, while the highest value was obtained in the Botembo forest at site P2.

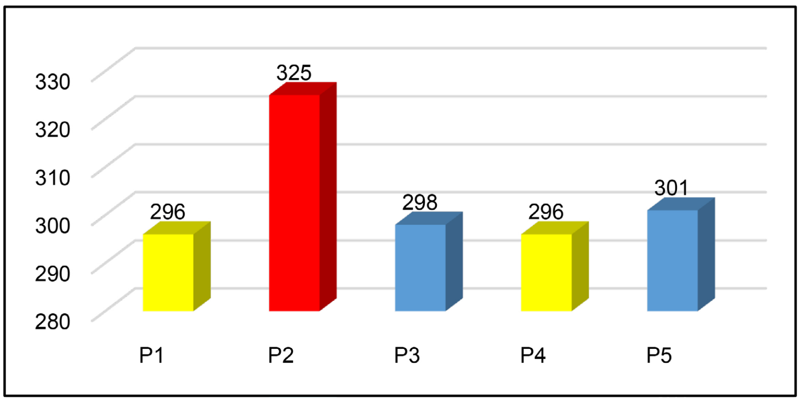

Figure 6. The types of variation in electrical conductivity at the various sampling sites in the Era-Congo concession.

4) TDS

From Figure 7, TDS varies between 3.5 and 6.5 mg/L, with the highest value recorded at site P2 in Botembo and the lowest at site P3 in Mpongoboli, with an average of 5.28 mg/L and a standard deviation of ±1.1.

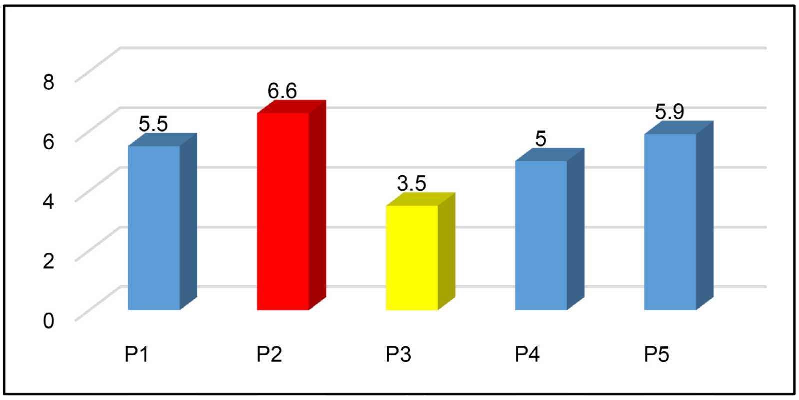

Figure 7. TDS values at the various sampling sites in the Era-Congo concession.

5) Dissolved oxygen

From Figure 8, Dissolved oxygen varies between 2.37 and 4.1 mg/L, with an average of 3.5 mg/L and a standard deviation of ±0.6. The minimum value is recorded at Ilée-Mankaba at site P1, and the maximum at Mpongoboli, site P3.

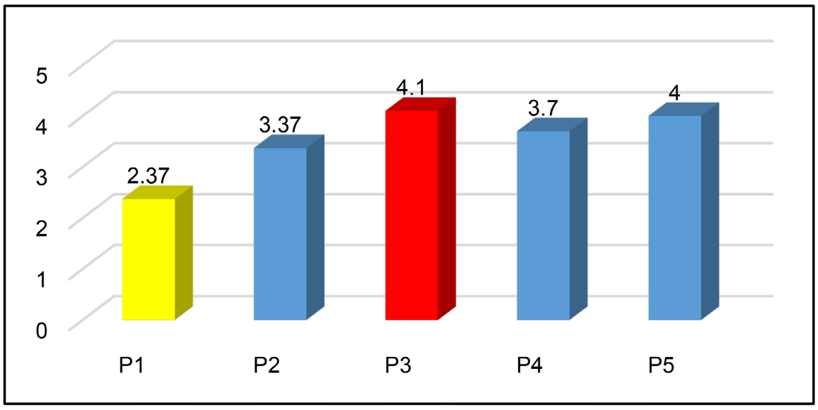

Figure 8. Amount of dissolved oxygen in peatlands at different sampling sites within the Era-Congo concession.

6) Redox potential

From Figure 9, the redox potential varies between 217 and 317 mV with an average of 278.6 mV and a standard deviation of ±37.3; the minimum value is recorded at site P2 in Botembo, the maximum at site P4 in Mbombokili.

7) Organic-carbon

Figure 10 shows that total organic carbon varies between 55.6 and 57.1%, with an average of 56.42% and a standard deviation of ±0.75; its lowest value is recorded at point P2, and its highest value at point P3.

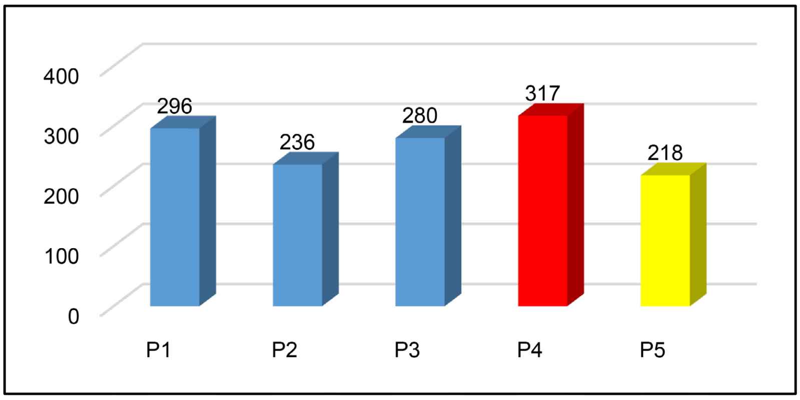

Figure 9. Variation in redox potential at the different sampling sites.

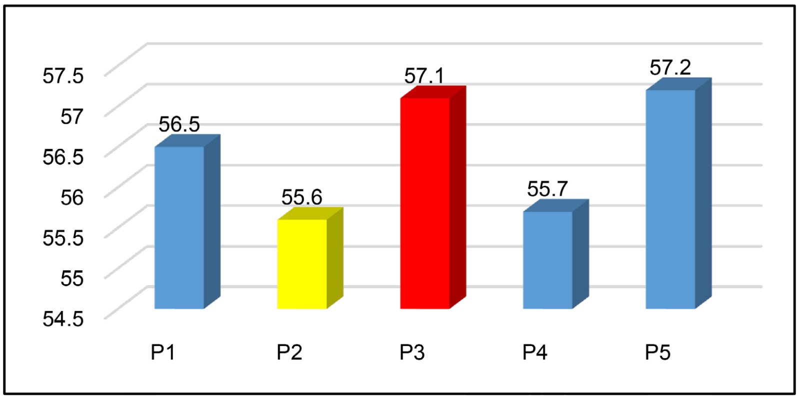

Figure 10. Variation of organic-carbon at the different sampling sites.

3.2. Statistical Analysis

Table 2 presents the results of a one-way ANOVA for several variables (pH, CE, TDS, O_2, PR, COT).

1) pH

F (11.726): The F value is high, but the significance (p-value = 0.079) is slightly above the typical threshold of 0.05.

Interpretation: The differences between the groups are not statistically significant at the 5% threshold, but they could be with a wider threshold (e.g., 10%). This suggests a trend toward difference, but not solid evidence. These results are close to [8].

2) Electrical Conductivity (EC µS/cm^2)

F (0.676): Low F value.

Significance (p-value = 0.597): Much greater than 0.05.

Interpretation: No significant difference between groups. Intra-group variability is much greater than inter-group variability. These results are close to [9].

3) TDS (mg/L)

F (0.099): Very low F value.

Significance (p-value = 0.910): Very high.

Interpretation: No significant difference between groups. The averages are very similar. These results are close to [10].

4) Dissolved oxygen (O_2 mg/L)

F (0.689): Low F value.

Significance (p-value = 0.592): Greater than 0.05.

Interpretation: No significant difference between groups. The observed variability is probably due to chance. These results are close to [11].

5) Redox potential (PR mV)

F (4.758): Moderate F value.

Significance (p-value = 0.174): Greater than 0.05.

Interpretation: Although the F value is relatively high, the p-value indicates that the differences are not statistically significant at the 5% threshold. This could suggest a marginal difference, but it is not conclusive.

6) Total Organic Carbon (COT)

F (0.570): Low F value.

Significance (p-value = 0.637): Greater than 0.05.

Interpretation: No significant difference between groups. The variations observed are likely random. These results are close to [12].

Table 2. One-way ANOVA.

		Sum of squares	ddl	Mean square	F	Signification
pH	Within groups	0.228	2	0.114	11.726	0.079
	Within groups	0.019	2	0.010		
	Total	0.248	4			
CE	Within groups	246.300	2	123.150	0.676	0.597
	Within groups	364.500	2	182.250		
	Total	610.800	4			
TDS	Within groups	0.490	2	0.245	0.099	0.910
	Within groups	4.930	2	2.465		
	Total	5.420	4			
O_2	Within groups	0.793	2	0.396	0.689	0.592
	Within groups	1.151	2	0.575		
	Total	1.943	4			
PR	Within groups	5654.700	2	2827.350	4.758	0.174
	Within groups	1188.500	2	594.250		
	Total	6843.200	4			
COT	Within groups	0.823	2	0.412	0.570	0.637
	Within groups	1.445	2	0.723		
	Total	2.268	4			

From this one-factor ANOVA test, we note: None of the variables show statistically significant differences between groups at the 5% threshold; pH is the variable closest to significance (p = 0.079), but would require more data or a less stringent threshold to be conclusive; The other variables (EC, TDS, O_2, PR, COT) have high p-values, indicating that the differences between groups are negligible or due to chance.

These results suggest that either the groups are very similar for these variables, or the sample is too small to detect an effect (low statistical power). An increase in sample size could be considered to refine the analysis. The degrees of freedom (df) are very low (intra-group df = 2 for each variable), which reduces the power of the test. This partly explains the high p-values despite apparent inter-group differences (e.g., for PR).

4. Discussion

Regarding the physical and chemical parameters (**Table 1**) measured *in situ*, the pH of the peat varies between 3.1 and 3.7. The temperature ranges from 25˚C to 26.9˚C. Electrical conductivity ranges from 296 to 325 µs/cm. TDS varies between 3.5 and 6.5 mg/L. These results are similar to those found by [13] [14].

Dissolved oxygen varies between 2.37 and 4.1 mg/L. It has a significant relationship with methane fluxes, and we believe that methane production is high due to the low dissolved oxygen values at this site, which leads us to suggest that future studies should quantify methane gas. [15] [16].

Low pH and moderate electrical conductivity are often associated with an advanced stage of peat decomposition, which can influence the carbon sequestration capacity of the Inongo peatlands. According to [17] [18], physicochemical characteristics can affect nutrient dynamics and microbial biodiversity, thereby impacting the effectiveness of carbon sequestration in Central African peatlands. [19] [20].

5. Conclusions

This research focuses on the physico-chemical characterization of the Inongo peatlands in the Wildlife Works Carbon/Era concession in the Mai-Ndombe province of the Democratic Republic of Congo. The physico-chemical parameters measured (pH, temperature, conductivity, dissolved oxygen, etc.) provide an understanding of their dynamics, evolution, and natural state for better management of this unique ecosystem, with a view to providing useful information for the conservation and use of resources. However, only a sound scientific understanding of these ecosystems can guarantee a rigorous and appropriate management policy.

This research has limitations due to spatial difficulties, including the small sample size and data collection over a single season. For more robust results, seasonal sampling or sampling at different depth profiles would be beneficial, allowing for a better understanding of spatio-temporal variations and their impact on carbon sequestration.

Conflicts of Interest

The authors declare no conflicts of interest.

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