

**Dynamics of sediment organic matter along Bandama River in the department of Sinématiali (northern Côte d'Ivoire)**

**ABSTRACT**

This study examines the distribution of organic matter in areas affected by frequent floods along the east bank of the Bandama River in the department of Sinématiali. The sites sampled are defined by two zones, one near the stream and one far from the stream. Samples collected were analyzed, including for texture with aggregation analysis by the Robinson pipette, and standard sediment analysis methods for measuring organic carbon (CO), nitrogen (N), and organic matter (MO). Statistical analyzes were carried out to assess the differences between the physico-chemical parameters of the different sampling areas. Results show that sediment from the various study sites has a sando-limonous to limono-clay texture. Total organic matter levels are higher in surface sediments that contain the lowest proportions of clay. Rates range from 31.98gkg<sup>-1</sup> to 38.98gkg<sup>-1</sup>. The low rates recorded in depth are reported to be related to leaching caused by periodic flooding. These results show that successive floods have a direct effect on the dynamics of the physico-chemical properties of the sediments along the shore.

**Keywords:** sediment, shore, organic matter, particle size, flooding

**1. INTRODUCTION**

During the past decade, the number of studies on the effects of climate change on the environment has increased steadily. One of the potential impacts of climate change on the water cycle is an increase in the number and intensity of floods [1,2,3]. At present, it is important to quantify the impact of climate change on the river environment in order to better understand how these environments will evolve in the coming decades. Riparian ecosystems vary widely depending on river dynamics [4]. The constant supply of sediment transported by successive floods has an impact on the physico-chemical properties of soils. The latter can vary greatly in vertical distribution and spatial distribution, which are affected by various hydrological processes [5,6]. Sediment is a relatively heterogeneous matrix consisting of water, inorganic and organic materials and anthropogenic compounds. It can be described by its composition and structure [7] (Power and Chapman. Surface sediments are among the most important storage and dynamic reservoirs of organic matter [8]. Each year, nearly 0,4 Gt of terrestrial organic carbon is transported to coastal environments [9]. MO consists of a large number of chemical species that may be of size, chemical composition, and complex and varied physical forms [10]. These different parameters will depend primarily on the origin but also on the environment in which the MO will be located [11]. MO is a complex substance consisting primarily of carbon and hydrogen and in variable proportions of oxygen, nitrogen, sulfur and phosphorus [11] (Labanowski, 2004). Nitrogen and organic carbon play very important roles in MO biogeochemistry [12] particularly in microbiological activity [13] and metal complexation processes [14]. The study of sedimentary organic matter in current environments could be used as a basis for paleoclimatic, and paleoenvironmental interpretations [15]. Previous work indicates little information on the distribution of these physico-chemical parameters in sediments along Bandama River shore. As a result, this study will attempt to highlight the impact of recurring flooding on sediment organic matter in this area. The aim is to assess the levels of organic matter in sediments away from the stream and compare them with those in the surrounding environment in order to highlight the impact of the floods on the river environment. To carry out this work, a multidisciplinary approach has been taken. It is based in particular on sedimentological and pedological studies.

56 **2. MATERIAL AND METHODS**

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58 **2.1 Location and sampling**

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60 Four sampling points along the shore were predefined (figure 1) and were sampled from surface  
61 sediments at a depth of 10 to 150 cm. The various analyzes carried out in this study were carried out  
62 on the fine length part (< 2 mm), which we separated at the laboratory a few weeks later after  
63 sampling.

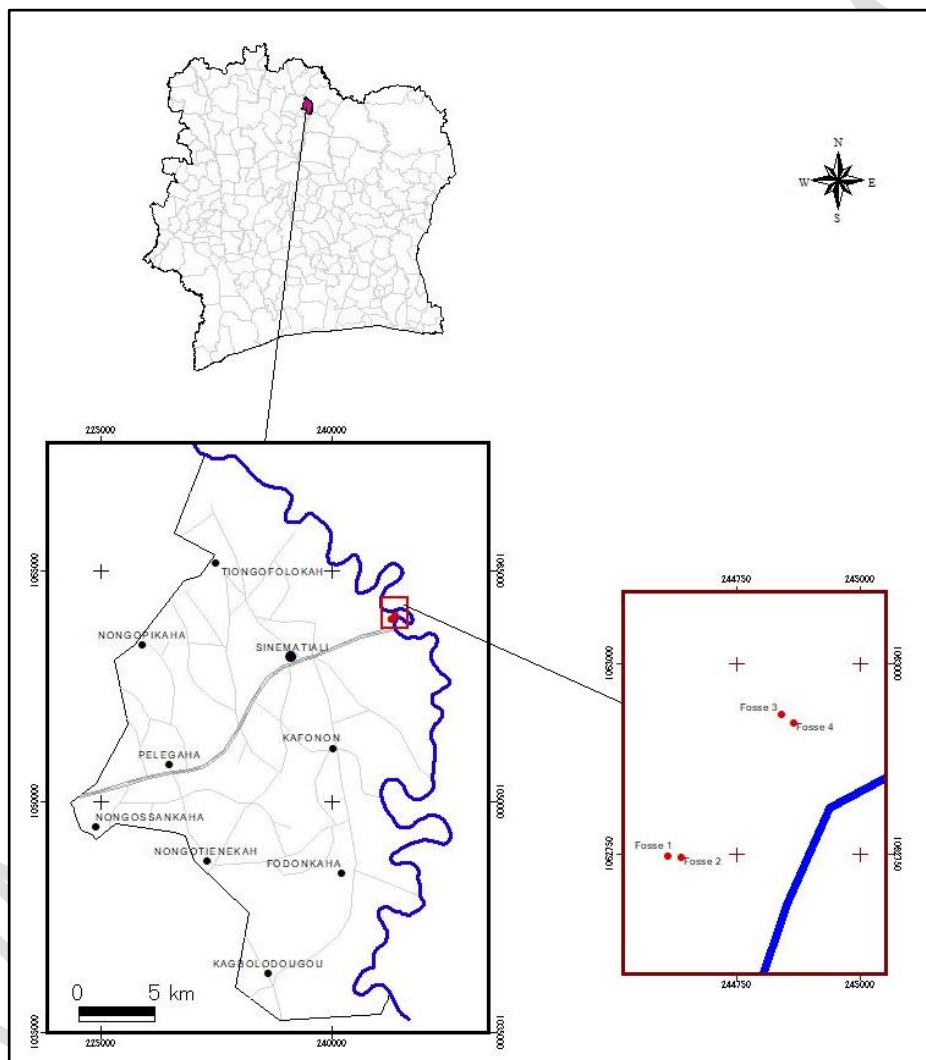
64 These samples were analyzed to determine:

65 - The particle size (sandy, clay and lemon fraction), pH, total organic carbon, total nitrogen and  
66 organic matter.

67 - The analysis of each of these parameters involved specific methods as described below.

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71

72 Figure 1: **Localization of the study area** ( Location map)

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75 **2.2 Physico-chemical characterization of sediment**

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77 **2.2.1 Physical Parameters of Sediments**

78 • **Granulometry**

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80 It was determined by Robinson's Pipette method [16].

81 The application of this analysis allowed:

- 82 - to know the substances (MO and nitrogen) associated with the particle size contained in the  
83 sediment. It is used to determine whether they are in the fine, medium or coarse fractions;  
84 - to reconstitute the conditions for transport and deposition of particles.

85  
86 • **Texture**

87 We used the triangular diagram of fine soils proposed by [17]. This type of diagram is particularly  
88 suitable for sediments because sediments can then be characterized according to the respective  
89 content of these three particle size fractions (clays, silt and sand) [18,19].

90  
91 **2.2.2 Chemical sediment parameters**

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93 On the same samples we also determined CO, MO, nitrogen and PH levels.

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95 **pH**

96 pH of water was determined by measuring H<sub>3</sub>O<sup>+</sup> ion activity using a pHmeter [20].

97  
98 **Organic carbon**

99 Organic carbon of sediments is determined by Anne's method [21]. The carbon of the organic matter is  
100 oxidized by potassium bichromate in sulfuric medium.

- 101  
102 • **Organic matter**

103  
104 The assessment of the organic matter content was made by quantifying its major constituent element,  
105 organic carbon, which represents almost 50% of this element [22]. The content of the MO was  
106 assessed based on the following conventional relationship:  $MO = C \times 1,72$  [23].

- 107  
108 • **Nitrogen**

109 Nitrogen in sediments was determined by the Kjeldahl method [20]. The principle of this method is to  
110 transform the nitrogen of organic compounds from a finely crushed sediment sample into ammoniacal  
111 nitrogen under the action of concentrated sulfuric acid, which, when boiled, behaves as an oxidant.  
112 Organic substances are decomposed: carbon comes out as carbon dioxide, hydrogen gives water,  
113 and nitrogen is transformed into ammonia nitrogen. The latter is fixed immediately by sulfuric acid in  
114 the form of ammonium sulfate.

- 115  
116 • **Carbon-to-Nitrogen Ratio (C/N)**

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118 The C/N ratio is an indicator of sediment biological activity that provides information on the degree of  
119 organic matter evolution, biological activity, mineralization. The smaller the biological activity, the more  
120 difficulties encountered in mineralization. This reflects conditions of anaerobic, excessive acidity. The  
121 study of the C/N report is an approach to the problem of the origin, nature and evolution of organic  
122 matter [24].

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126 **2.2.3 Statistical analysis**

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128 For data analysis, we used variance analysis of different variables using SAS 9.4 software. The  
129 significance test is Fischer's distribution or "F test" at the 5% probability threshold. Correlation tests  
130 (Pearson) were also performed between variables (MO, pH, C.O., N, texture). These tests allowed  
131 comparisons of different parameters according to the horizontal gradient (channel distance) and  
132 vertical (depth). Finally, a primary component (PCA) analysis was conducted to verify that there is a  
133 link between the different physico-chemical parameters, the layers and the positions close to or far  
134 from the stream. We converted the units of % to gkg<sup>-1</sup> (international unit) for carbon, nitrogen and  
135 organic matter (MO).

136 **3. RESULTS**

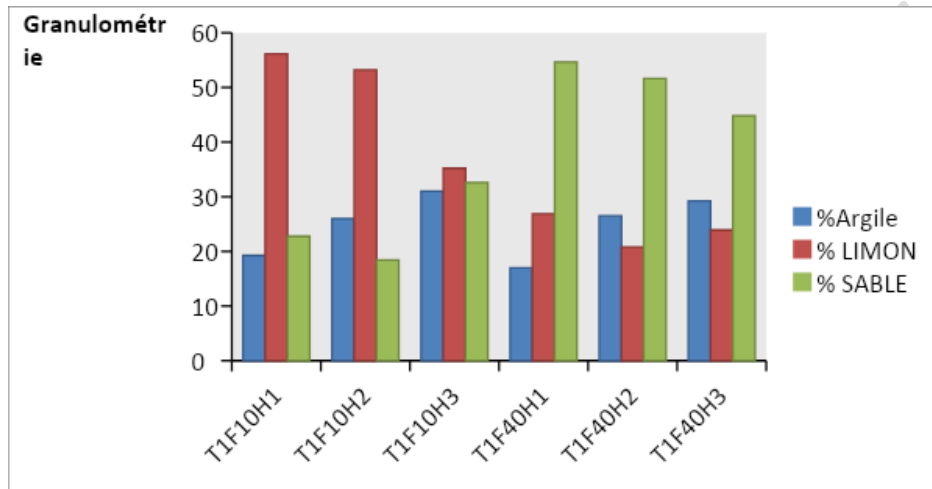
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138 **3.1 Sediment Granulometry and Texture**

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140 The clay fraction increases with depth in the profile near the stream bed (Figure 2). The remote profile  
 141 of the source has similar characteristics. Limon percentages decrease with depth near the channel  
 142 while sand percentages increase. The sandy fraction is greater when you move away from the  
 143 channel. Sediments are coarser by moving away from the stream (Figures 2 and 3). Sediments near  
 144 the river are characterized by higher percentages in silt. The results of our analyzes reveal a limono-  
 145 clay texture near the channel and a sandy-clay texture as one moves away from the channel (Table  
 146 1).

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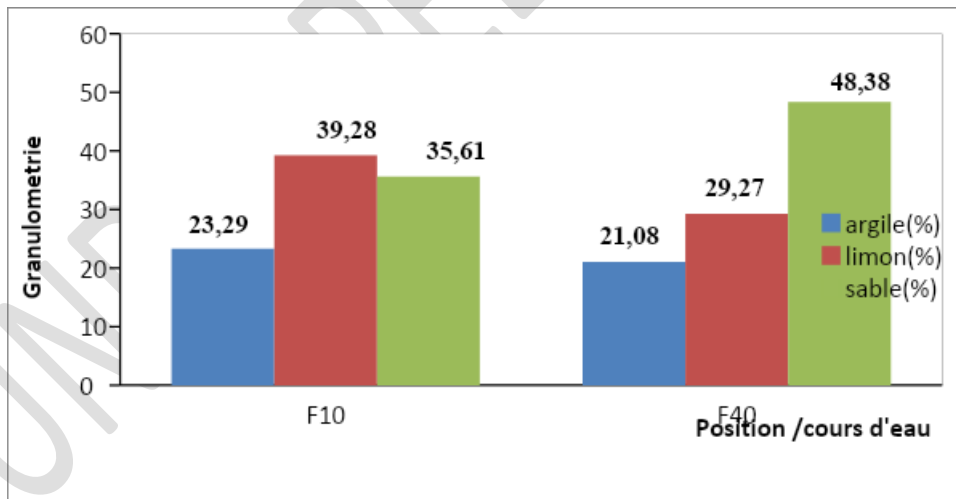
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150 **Figure 2** : particle size composition  
 151 F10 = pit near the river F40 = remote pit

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**Figure 3** : Granulometry relative to profile positioning

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159

160 Table 1: Granulometry and sediment texture of layers according to positions

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Layer	F10 <sub>1</sub>	F10 <sub>2</sub>	F10 <sub>3</sub>	F40 <sub>1</sub>	F40 <sub>2</sub>	F40 <sub>3</sub>
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Coarse sand (p.c.)	5,55	5,25	24,95	16,95	17,55	14,75
Fine sand (p.c.)	17,2	13,15	7,65	37,7	34,1	30,1
Coarse Limon (p.c.)	42,65	44,2	24,2	16,35	12,55	16,15
Fine Limon (p.c.)	13,5	9	11	10,5	8,25	7,75
Clay (p.c.)	19,25	26	31	17	26,5	29,25
Texture	LS	LA	LA	SL	SA	SA

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### 3.2 Chemical parameters

#### 3.2.1 pH

The pH of the sediments relative to their stream position. Sediments have low acidity pH ranging from 5.72 to 5.79 (Figure 4). This low acidity could be explained by the absence of abundant surface litter in this area. Decomposition of litter and humus releases acidifying products such as fluvial and humic acids that acidify surface sediments.

#### Change in pH in different layers

A change in the pH value from the surface to the depth is noted (Figure 5). Biomass is often almost non-existent in depth and therefore very little input from acidifying products. This could explain the high pH value in the depth layers.

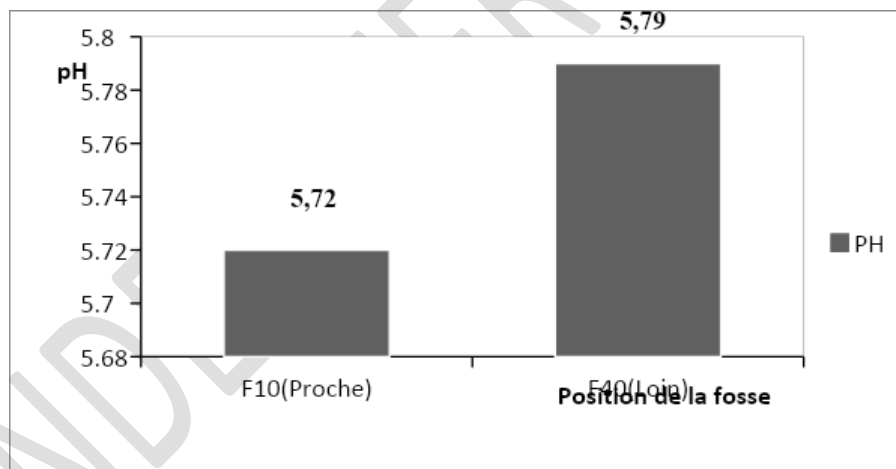
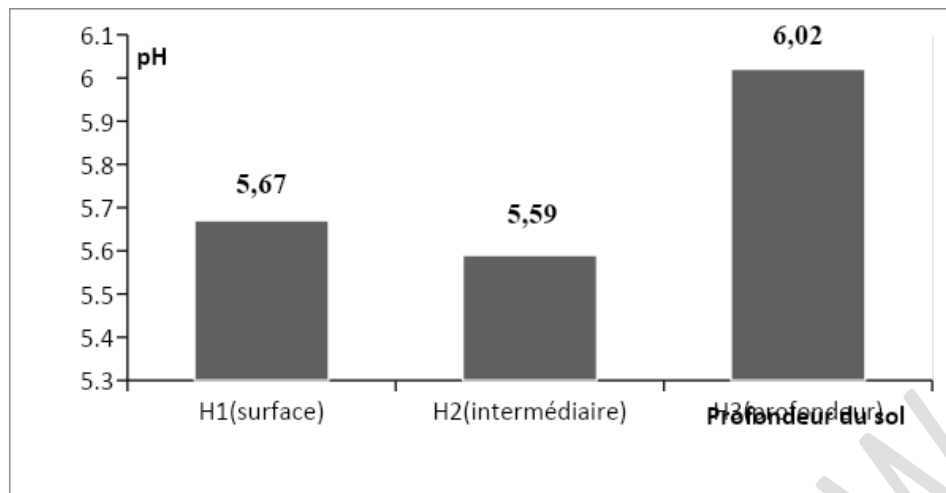


Figure 4 : Change in pH by position

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185 **Figure 5** : Variation in layers

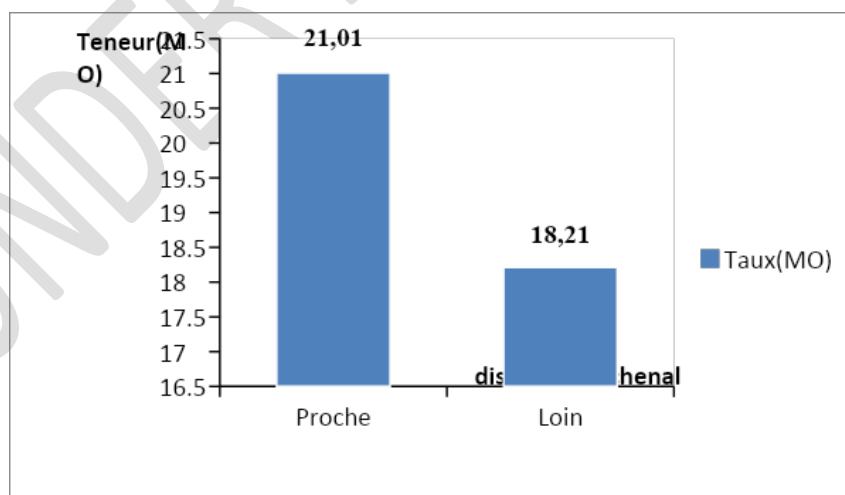
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188 **3.2.2 Organic Matter**

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191 **Change of MO in pits to position**

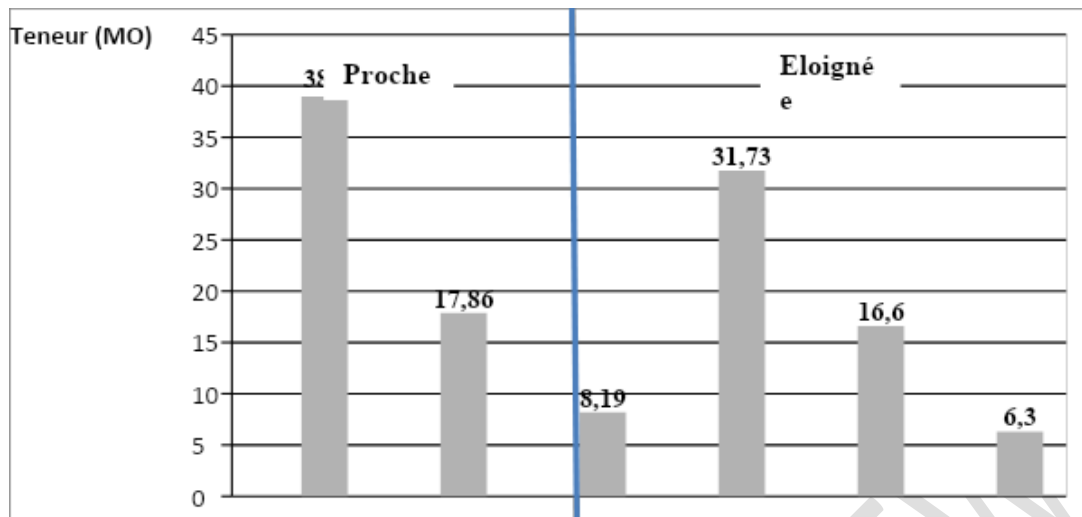
192  
193 Organic matter does not vary significantly from pit position (Figure 6). These values indicate relatively  
194 lower rates in areas far from the stream. Concentrations ranging from 21.01 to 18.21 (gkg-1) indicate  
195 medium-rich organic sediment [25].

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198 **Change in MO in layers**

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200 Analyzes show a sharp decrease in organic matter content when going deep (Figures 6 and 7). The  
201 MO rate increases from 38.98gkg-1 on the surface to 8.19 gkg-1 deep when close to the stream.  
202 Further away from the watercourse, surface rates are 31.73gkg-1 and depth rates are 6.3gkg-1.



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206 **Figure 6**: Change in organic matter content by position



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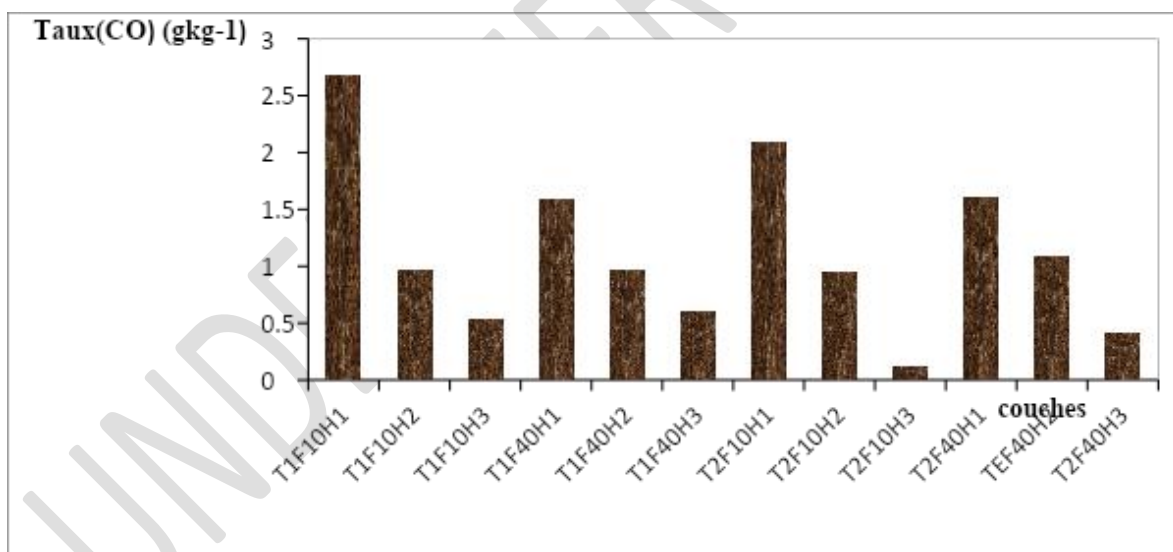
**Figure 7:** Change in MO content in layers by position

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### Organic Carbon

The results of our investigations show a decrease in organic carbon in all pit areas at the base of the profile (Figure 8). However, it is noted that this organic carbon is slightly elevated at the surface layer level. For remote pits it would be the lack of plants on the ground and therefore the absence of litter. Generally, reduced organic matter intake in soil directly influences low organic carbon levels in the different profile horizons [26].

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**Figure 8:** Change in CO in transects and layers relative to profile position

F10= Close Fosse F40= Fosse distant

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### 2.4. The Nitrogen

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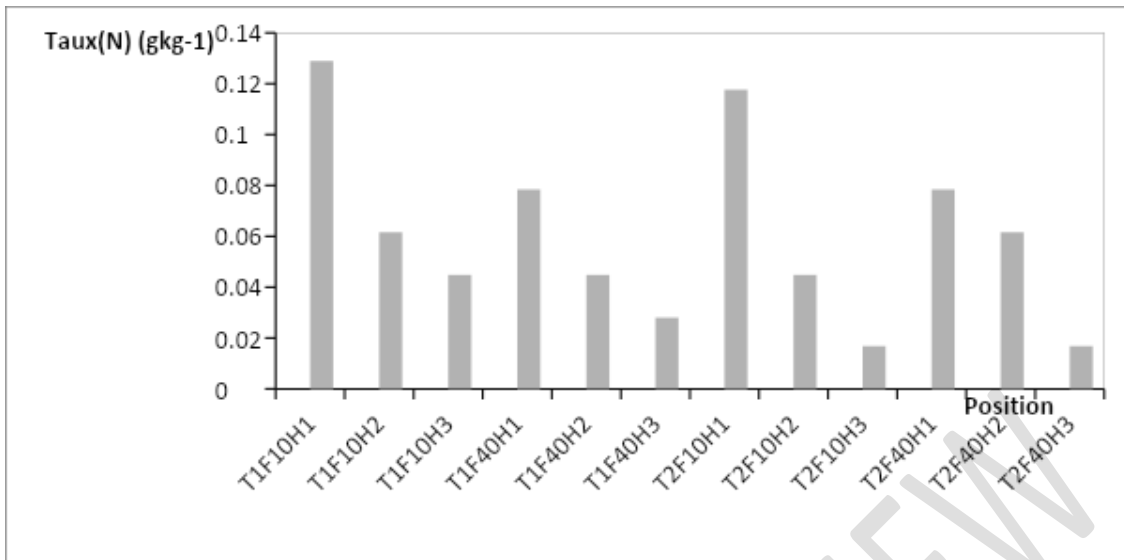
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Analyzes show that nitrogen has approximately the same evolution in the profiles as organic carbon and organic matter (Figure 9). This suggests a correlation between these three elements.



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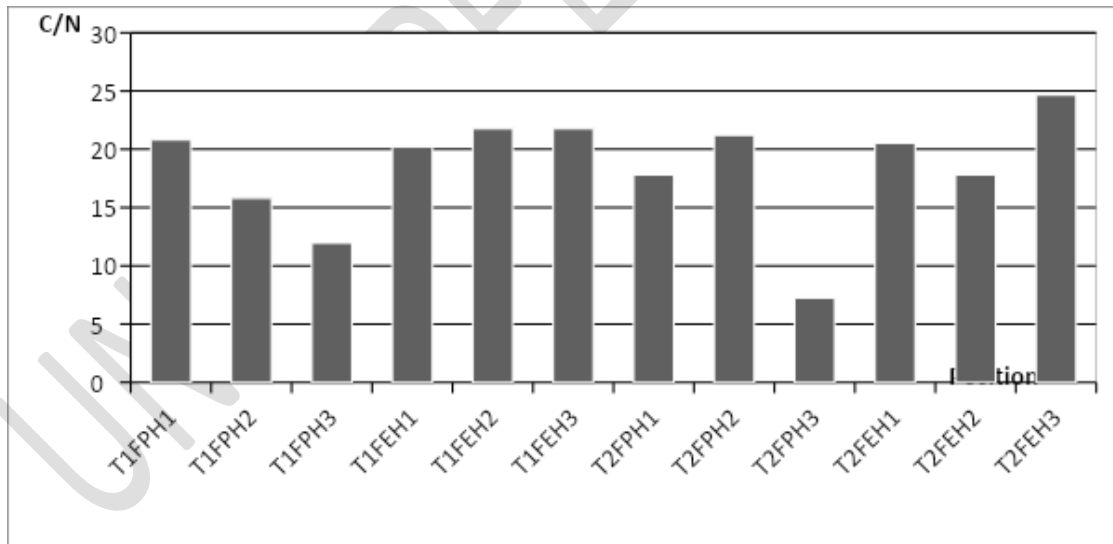
**Figure 9:** Changes in nitrogen levels in layers

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### 3.2.5. Report C/N

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Analytical results indicate a decrease in C/N ratio with depth near the stream (Figure 10). This ratio ranges from 20.81 to 7.25. Biological activity in sediments is therefore reduced and organic matter decomposition is slowed. In addition, this ratio increases slightly with depth for the remote layers of the stream. Values range from 20.20 to 24.66. The slight increase in C/N in the deep layers reflects faster degradation of nitrogen compounds.



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**Figure 10:** Change in C/N ratio to stream position

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249 **3.3. Statistical analyzes**

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251 **3.3.1 Analysis of variance and significance testing**

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253 The analyzes show that there is no significant difference between areas far from the stream and areas  
 254 close to the clay. There is also no significant variation in sand levels in the different layers in the two  
 255 sectors after ANOVA (Table 2). The results show that there is no significant change in the carbon,  
 256 nitrogen, organic matter and pH levels in sediment from the 5.p.c. threshold position according to the  
 257 Fischer test. Whether the pit is distant or near the stream, the levels of chemical elements in the  
 258 sediment are substantially the same. However, significant variations are recorded by the vertical  
 259 gradient (Table 3).

260

261 Table 2: Comparison of physical soil characteristics between positions and layers

262

	% clay	% limon	% sand	% physical elements
<b>Position</b>				
F10 (Near)	23,29 a	39,28 a	35,61 a	98,18 a
F40 (far away)	21,08 a	29,27 b	48,38 a	98,73 a
<b>Pr &gt; F</b>	0,8025	0,0180	0,9134	0,8834
<b>layer</b>				
C1	17,38 b	41,03 a	40,05 a	98,45 a
C2	22,75 a	33,40 a	42,33 a	98,48 a
C3	26,44 a	28,39 a	43,60 a	98,43 a
<b>Pr &gt; F</b>	0,0135	0,1702	0,9972	0,9985
<b>Moyenne</b>	0,22	0,34	0,42	0,98
<b>C.V. (p.c.)</b>	5,80	12,67	12,34	2,73

263 **Nb:** Means followed by the same letters in a column are not significantly  
 264 different from the 5 p.c. threshold

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266

267 Table 3: Comparison of chemical characteristics between positions and layers

268

	Carbon (gkg <sup>-1</sup> )	N (gkg <sup>-1</sup> )	C/N	OM (gkg <sup>-1</sup> )	pH
<b>Position</b>					
F10 (Near)	12.19 a	0.65 a	18.60 a	21.01 a	5.72 a
F40 (far away)	10.56 a	0.55 a	18.34 a	18.21 a	5.79 a
<b>Pr &gt; F</b>	0.6724	0.1407	0.1709	0.6697	0.7342
<b>Layer</b>					
C1	19.93 a	1.00 a	19.84 a	34.35 a	5.67 b
C2	9.99 b	0.53 b	19.15 a	17.23 b	5.59 b
C3	4.20 b	0.27 c	16.41 a	7.25 b	6.02 a
<b>Pr &gt; F</b>	0.0119	0.0079	0.6409	0.0119	0.0388
<b>Moyenne</b>	11.38	0.60	18.47	19.61	5.76
<b>C.V. (p.c.)</b>	19.10	14.66	27.83	19.15	2.77

269 **Nb:** Means followed by the same letters in a column are not significantly  
 270 different from the 5 p.c. threshold

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273 **3.3.2 Pearson Correlation**

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275 The Pearson correlation test showed a very good correlation between carbon and organic matter with  
 276 a correlation coefficient  $r = 1$  and a probability  $P < 0.0001$ . Also, the Pearson correlation test showed  
 277 good correlations between nitrogen and organic matter with a correlation coefficient  $r = 0.989$  and a

278 probability  $P = 0.0001$ , between carbon and nitrogen with a correlation coefficient  $r = 0.989$  and a  
 279 probability  $P = 0.0001$ . The silt was positively correlated with nitrogen with a correlation coefficient  $r =$   
 280  $0.816$  and a probability  $P = 0.048$ . Clay was negatively correlated with carbon ( $r = -0.897$ ;  $P = 0.015$ ),  
 281 nitrogen ( $r = -0.893$ ;  $P = 0.016$ ) and organic matter ( $r = -0.897$ ;  $P = 0.015$ ). The silt was negatively  
 282 correlated with sand ( $r = -0.844$ ;  $P = 0.035$ ) (Figure 11).  
 283

	limon	sand	total	carbon	N	C/N	OM	pH
Clay	-0,491	-0,053	-0,311	-0,897	-0,893	-0,521	-0,897	0,605
	0,323	0,921	0,549	0,015	0,016	0,290	0,015	0,204
limon	1.00000	-0,844	-0,451	0,759	0,816	0,270	0,759	-0,589
		0,035	0,369	0,080	0,048	0,605	0,080	0,219
sand		1.00000	0,728	-0,324	-0,387	-0,011	-0,324	0,305
			0,101	0,530	0,448	0,984	0,530	0,556
total			1.00000	-0,118	-0,084	-0,316	-0,118	0,100
				0,824	0,874	0,542	0,824	0,850
carbon				1.00000	0,989	0,587	1,000	-0,656
					0,000	0,220	< 0,0001	0,157
N					1.00000	0,507	0,989	-0,657
						0,305	0,000	0,156
C/N						1.00000	0,587	-0,649
							0,220	0,163
OM							1.00000	-0,656
								0,157

284 Values in blue are different from 0 to a level of  $\alpha=0.05$  meaning  
 285 Figure 11: Correlation matrix (Pearson) of sediment characteristics following positions and layers

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### 288 3.3.3 Principal Component Analysis (PCA)

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290 The CPA showed that 83.76 p.c. information is reported by the F1 and F2 axes. For variables, clay,  
 291 silt, carbon, nitrogen, organic matter, and pH were well correlated with F1 factor, respectively, with  
 292 squared cosinus of 0.685, 0.711, 0.944, 0.945, 0.944, and 0.600 and the sand and total of the physical  
 293 elements that formed the F2 factor respectively with squared cosines of 0.720 and 0.747. For  
 294 individuals, F10mC1, F10mC3, F40mC1 and F40mC3 constituted the bulk of the information reported  
 295 by the F1 axis. Finally, the PCA showed a link between silt, carbon, nitrogen, organic matter and  
 296 F40mC1, F10mC1 individuals; also a link between clay, pH and the individual F10mC3; finally, a link  
 297 between sand, total physical elements and the F40mC2 horizon (Figure 12).

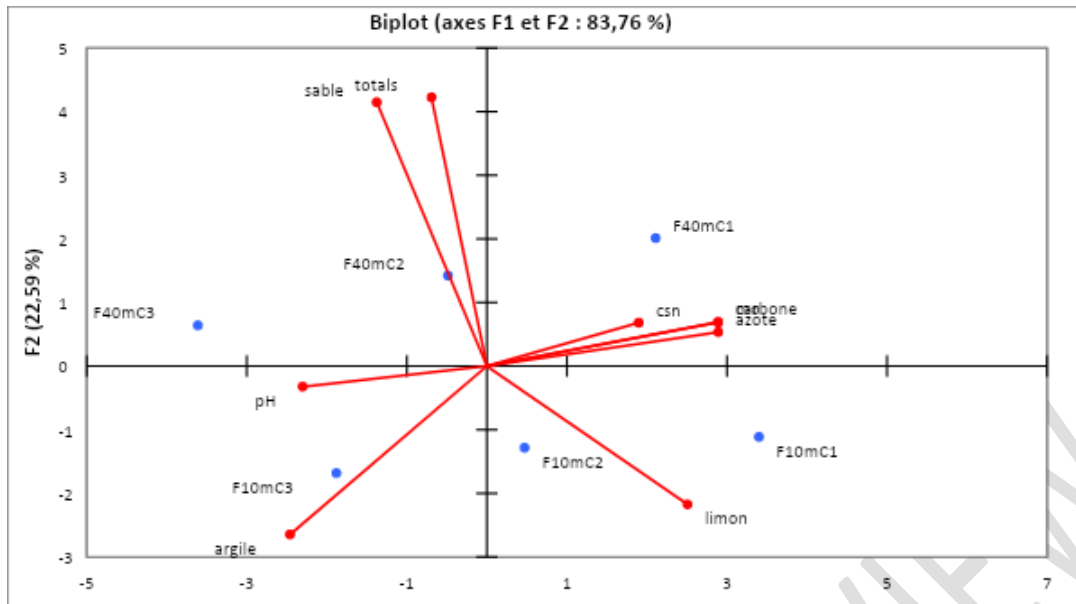
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Figure 12: Primary Component Analysis (PCA) on F1 and F2 axes for physico-chemical characteristics of sediments according to position and layer

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#### 4. DISCUSSION

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##### 4.1 Variation in the physico-chemical properties of the sediment by the horizontal gradient

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Results show relatively low levels of organic matter in the study area. These relatively low levels appear to be characteristic of this medium. They are the response of the disturbances related to successive floods. The accumulation of organic matter is difficult due to the flood and decay phenomena, which is an obstacle to the formation of dense vegetation cover. Successive or periodic river floods are causing changes in riparian ecosystems [27]. These results are identical to the work done by [28], who argue that alluvial soils are also characterized by low concentrations of organic matter in situ due to the absence or near-absence of surface litter. Lower M.O. values have been recorded in sediments away from the stream. These results are inconsistent with those of [29] which show that the highest concentrations of M.O. are found in areas further away (5, 10, 20, 30 m) from the watercourse that are less prone to flooding than areas directly affected by frequent flooding. The results of our investigations could be explained in two non-contradictory ways: first, the high

340 sedimentation rate prevents oxidative degradation of this material at the interface, where degradation  
341 processes are generally most active [30]. However, the sedimentary organic matter, partially altered  
342 by its river transit, is particularly resistant to bacterial attacks [31]. The organic matter content depends  
343 on alluvial sedimentation [32]. then the allochthonous organic matter transported by the stream (the  
344 river) and deposited near the stream near the banks could explain the higher levels of organic matter  
345 in areas near the stream. This reflects the diversity of sources of intake in this area. In fact, organic  
346 matter deposited in an aquatic environment may have an indigenous origin, and to a more variable  
347 degree, an allochthonous origin [33]. A significant fraction of this organic matter is chemically and  
348 biologically degraded in the water column. A more or less significant amount (10-60%) occurs at the  
349 sediment surface [34] where it will undergo further chemical and biological transformations. A final,  
350 most stable fraction will be buried [35]. Numerous studies have shown the different impacts of water  
351 front flooding [36,37,38]. Floods and decouples can have beneficial or adverse effects on riparian  
352 ecosystems [39,40,41]. The C/N ratio is generally between 10 and 20 or higher. Values between 10  
353 and 20 are typical in the organic matter corresponding to soil plants humified [42]. Values above 18  
354 characterize sediments where terrestrial plant debris has accumulated [43, 24]. A low C/N ratio clearly  
355 indicates a significant source of organic matter of detritic origin [44].  
356

#### 357 **4.2 Variation in the physico-chemical properties of sediment by vertical gradient**

358

359 At the vertical gradient, our analyzes show that the highest concentrations of MO, CO, and N are  
360 mainly in the surface layers. Our results are consistent with those of [26]. For Drouin and his  
361 collaborators, there is usually a strong correlation between organic carbon and surface layers, and in  
362 many cases the concentration of organic carbon decreases with depth. For [45], CO has very low  
363 concentrations in depth and its highest concentrations are within the first 20 centimeters of soil. The  
364 high rate in this area is due to the biochemical exchanges taking place there, but this may vary  
365 depending on the conditions of the environment. The slight increase in C/N in the deep layers reflects  
366 faster degradation of nitrogen compounds, which overlaps the results of [36, 46, 24]. The distribution  
367 of organic matter in sediment depends on many and various factors. The content of a sample depends  
368 on the inputs themselves, the degree of evolution of the inputs and their dilution by the minerals [28].  
369 In depth, we record the highest pH values. The increase in pH results in the dissolution of organic  
370 matter [47]. This may partly explain the low levels of deep organic matter. Nitrogen and organic carbon  
371 have a strong similarity in the distribution of levels within pedols. The values of these two variables  
372 decrease with depth. This trend towards a decrease in N and C.O. In fact, in the deeper layers,  
373 various studies have been carried out [48]. Organic Carbon (CO) and Organic Nitrogen (AO) are  
374 reported to have similar behavior in soils, sediments and aquatic environments [12].  
375

#### 376 **4.3 Variation of organic matter content by particle size fractions**

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378 Results show that CO is higher in surface areas than in depths containing the highest proportions of  
379 clay. The vast majority of authors agree that the levels of clay and C.O. are positively correlated. [49],  
380 organic carbon concentration in sediments is related to the abundance of different granulometric  
381 fractions. There is a significant correlation between organic carbon and particle size distribution. The  
382 work of [50, 51] indicate that high organic carbon is often associated with a high proportion of clays in  
383 sediments. Indeed, the proportion of clay is an important factor in the stabilization of the O.C. in the  
384 soil because of the formation of the argilo-humic complex and the physical protection it provides to the  
385 O.C. linking to the inside of the aggregates. Furthermore, the stability of aggregates caused by an  
386 increase in clay levels would reduce the risk of erosion, which may affect organic carbon reserves  
387 [50,51]. There are close relationships between sediment mineralogical composition, including clay  
388 fraction and organic matter preservation [52], organic carbon concentration is higher in fine matrix  
389 sediments than those with coarse matrix [53, 48, 56, 32]. However, several studies have shown that  
390 there may be significant variability in concentrations in O.C. in the entire profile, in particular for  
391 riparian soils [48, 45]. This diversity of opinion makes any categorical conclusion difficult.  
392

### 393 **5. CONCLUSION**

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395 Results show that sediment from the various study sites has a sando-limonous to limono-clay texture.  
396 The observed textural variability in the area is due to the diversity of moveable deposits. This area is  
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399 characterized by large and extremely rapid sedimentary rearrangements that influence sediment  
400 particle size distribution. Organic content of surface sediments on the east bank of the Bandama River  
401 in the locality of Sinématiali ranges from 31.98gkg<sup>-1</sup> to 38.98gkg<sup>-1</sup>. These relatively average rates  
402 would be related to the mineralization of organic matter, which occurs primarily within the first  
403 centimeters of the sediment, due to reducing conditions and stream-related inputs. We record a slight  
404 decrease in organic matter as we move away from the stream. But these are not significant. However,  
405 this indicates that the constant supply of alluvium transported by successive floods and reflecting  
406 current hydroclimatic conditions contributes to the organic enrichment of the near stream area. In  
407 depth, the rates obtained are very low and range from 6.3gkg<sup>-1</sup> to 8.19 3gkg<sup>-1</sup>. These low rates are  
408 due to leaching caused by periodic flooding. The MO content is generally higher in sediments of  
409 surfaces that contain the lowest proportions of clay. Organic carbon and nitrogen follow almost the  
410 same pattern as MO. These results show that successive floods have a direct effect on the dynamics  
411 of the physico-chemical properties of the sediments along the shore. An imbalance in organic matter in  
412 sediments can have a long-term impact on the vitality of the ecosystem in general.

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