

Submission to Journal of Ecological Engineering

New manuscript received by Editorial Office (JEENG-05028-2023-01)

1 message

Journal of Ecological Engineering <kontakt@editorialsystem.com>

Sun, Nov 26, 2023 at 10:22 AM

Reply-To: "gabriel@borowski.net.pl" <gabriel@borowski.net.pl>

To: Bambang Priatmadi <bj_priatmadi@ulm.ac.id>

Dear Dr. Priatmadi,

Thank you for your manuscript: Reduction in Carbon Dioxide Production of Tropical Peatlands Under Nitrogen Fertilizer with Coal Fly Ash Application.

The following number has been assigned to it: JEENG-05028-2023-01.

The manuscript will be checked by Editors and then sent to the Reviewers.

You will be informed by email about any further decisions on this article.

Thank you for submitting your work to our journal.

Kindest regards,
Prof. Gabriel Borowski
Editor-in-Chief
Journal of Ecological Engineering

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Revision

Decision on manuscript JEENG-05028-2023-01

1 message

Journal of Ecological Engineering <kontakt@editorialsystem.com>

Fri, Dec 1, 2023 at 6:31 PM

Reply-To: "gabriel@borowski.net.pl" <gabriel@borowski.net.pl>

To: Bambang Priatmadi <bj_priatmadi@ulm.ac.id>

December 01, 2023

JEENG-05028-2023-01

Reduction in Carbon Dioxide Production of Tropical Peatlands Under Nitrogen Fertilizer with Coal Fly Ash Application

Dear Dr. Priatmadi,

I am pleased to inform you that your manuscript, entitled: Reduction in Carbon Dioxide Production of Tropical Peatlands Under Nitrogen Fertilizer with Coal Fly Ash Application, might be accepted for publication in our journal, pending some minor changes suggested by reviewers (see below).

Please revise your paper strictly according to the attached Reviewers comments. Your manuscript won't be taken into consideration without the revisions made according to the recommendations.

Authors of our journal are requested to prepare a revised version of their manuscript as soon as possible. This may ensure fast publication if an article is finally accepted.

Thank you for submitting your work to us.

Kindest regards,
Justyna Kujawska
Managing Editor
Journal of Ecological Engineering

Please note that this email may not include all details of your article's evaluation. The full decision is available here:
<https://www.editorialsystem.com/jeeng/article/384771/view/#showDecisionLetter383548>

Review 1:

The article is presented by The Effect of CFA Application on Carbon Mineralization in Peatlands. The article presents interesting and new topics.

Based on the provided text, here are some critical questions:

The study states that pH changes due to treatments did not alter carbon mineralization, which contradicts previous studies. Can you explain this discrepancy in more detail?

What are the long-term implications of using CFA in peatlands, especially concerning soil health and sustainability?

How does your study's findings align or contrast with previous research on CFA application in similar contexts?

The article can be supplemented with a correction statistic

Were environmental and ecological impacts of applying CFA to peatlands considered in the study?

Remember to prepare the article in accordance with the Publisher's requirements, especially pay attention to the correct preparation of references both in the text and in the reference list.

Reduction in Carbon Dioxide Production of Tropical Peatlands Under Nitrogen Fertilizer with Coal Fly Ash Application

Keywords

global warming, retention, carbon mineralization, carbon cycles, exchangeable cation

Abstract

The utilization of nitrogen (N) fertilizer in peatlands, with the aim of increasing crop growth and production, is also reported to increase carbon dioxide (CO₂) emissions. The application of coal fly ash (CFA) to soil may change soil physico-chemical characteristics, thereby influence carbon mineralization, but its effect on CO₂ production is not yet clear. Consequently, the purpose of this study was to quantify the CO₂ production of tropical peatlands that received N fertilizer and CFA. In the laboratory experiment, CFA equivalent to the application of 150 Mg ha⁻¹ in the field was added to peatlands with and without N fertilizer. These mixtures were then incubated at 70% water-filled pore space (WFPS) for 30 days at room temperature. Carbon mineralization was measured on a 5-day basis, while several chemical characteristics of treated peatlands, including pH, hot water-soluble C, exchangeable-Ca, -Mg, -Fe, and -Al were measured at the conclusion of the incubation period. This study identified that N fertilizer application increased the CO₂ production of tropical peatlands from 29.25 g kg⁻¹ to 37.12 g kg⁻¹. Furthermore, the application of CFA on tropical peatlands reduced CO₂ production of tropical peatlands with and without N fertilizer. Decreasing the amount of hot water-soluble carbon from peatlands may account for the reduced CO₂ production of peatlands with CFA. The study also showed that exchangeable-Ca, -Mg, -Fe, and -Al increased in peatlands with CFA application, and these multivalent cations were also attributed to a reduction of CO₂ production. In conclusion, the negative effects of N fertilizer application on peatlands in increasing CO₂ emission may be reduced by the application of CFA.

Explanation letter

Dear Managing Editor of Journal of Ecological Engineering,

We have submitted revised version of this manuscript in which all of the points raised by the reviewer and editor have been addressed. We thank you very much for the comments and suggestions. The comments and suggestions are valuable and very helpful for revising and improving our manuscript. Our responses to each individual comment are detailed in attached file below.

Yours sincerely,
Bambang J. Priatmadi

[Revision Notes.docx](#)

Revision Notes

Dear Managing Editor of Journal of Ecological Engineering,

We have submitted revised version of this manuscript in which all of the points raised by the reviewer and editor have been addressed. We thank you very much for the comments and suggestions. The comments and suggestions are valuable and very helpful for revising and improving our manuscript. Our responses to each individual comment are detailed below.

Yours sincerely,

Bambang J. Priatmadi

The article is presented by The Effect of CFA Application on Carbon Mineralization in Peatlands. The article presents interesting and new topics.

Based on the provided text, here are some critical questions:

The study states that pH changes due to treatments did not alter carbon mineralization, which contradicts previous studies. Can you explain this discrepancy in more detail?

We have provide more explanations on the discrepancy between results obtained from our study and those reported in the previous studies (please see the last paragraph in page 7). The results of our research showed that the application of CFA results in an increase in peat pH but conversely reduces C mineralization of peatlands. In addition, in peatlands that received additional N which had a lower pH compared to peatlands without additional N, C mineralization on the contrary increased. The results of this study indicate that mineralization of C in peatlands is not related to changes in peat pH. Meanwhile, several previous studies have shown that an increase in soil pH due to a treatment will be followed by an increase in C mineralization, and vice versa. This is contrary to the research results obtained from our study.

What are the long-term implications of using CFA in peatlands, especially concerning soil health and sustainability?

We have added a paragraph to specify the positive and negative effects of CFA application on soil health and sustainability of peatlands. Positive effect CFA application on soil health and sustainability of peatlands including the provision of essential nutrients and improving peat pH, while the negative effect of CFA

application on peatlands is related to changes in the composition and activity of soil microorganisms (please see the first paragraph in page 12).

How does your study's findings align or contrast with previous research on CFA application in similar contexts?

We have added a paragraph to indicate that our findings in this study are in line with several previous studies, especially in the context of improving peat characteristics and reducing carbon dioxide production (please see last paragraph in page 11).

The article can be supplemented with a correction statistic.

We have added a supplement of statistical analysis.

Were environmental and ecological impacts of applying CFA to peatlands considered in the study?

We have a paragraph to indicate that the ecological and environmental impact of CFA application on the peatland ecosystem (please see the last paragraph in page 12).

Remember to prepare the article in accordance with the Publisher's requirements, especially pay attention to the correct preparation of references both in the text and in the reference list.

We have revised the references in the text and in the reference list according to the author guidelines of this journal (please see the reference list of this manuscript).

Reduction in Carbon Dioxide Production of Tropical Peatlands Under Nitrogen Fertilizer with Coal Fly Ash Application

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ABSTRACT

The utilization of nitrogen (N) fertilizer in peatlands, with the aim of increasing crop growth and production, is also reported to increase carbon dioxide (CO₂) emissions. The application of coal fly ash (CFA) to soil may change soil physico-chemical characteristics, thereby influence carbon mineralization, but its effect on CO₂ production is not yet clear. Consequently, the purpose of this study was to quantify the CO₂ production of tropical peatlands that received N fertilizer and CFA. In the laboratory experiment, CFA equivalent to the application of 150 Mg ha⁻¹ in the field was added to peatlands with and without N fertilizer. These mixtures were then incubated at 70% water-filled pore space (WFPS) for 30 days at room temperature. Carbon mineralization was measured on a 5-day basis, while several chemical characteristics of treated peatlands, including pH, hot water-soluble C, exchangeable-Ca, -Mg, -Fe, and -Al were measured at the conclusion of the incubation period. This study identified that N fertilizer application increased the CO₂ production of tropical peatlands from 29.25 g kg⁻¹ to 37.12 g kg⁻¹. Furthermore, the application of CFA on

tropical peatlands reduced CO₂ production of tropical peatlands with and without N fertilizer. Decreasing the amount of hot water-soluble carbon from peatlands may account for the reduced CO₂ production of peatlands with CFA. The study also showed that exchangeable-Ca, -Mg, -Fe, and -Al increased in peatlands with CFA application, and these multivalent cations were also attributed to a reduction of CO₂ production. In conclusion, the negative effects of N fertilizer application on peatlands in increasing CO₂ emission may be reduced by the application of CFA.

Keywords: carbon mineralization, carbon cycles, exchangeable cation, global warming, retention

INTRODUCTION

Tropical peatlands contribute significantly to carbon dioxide emissions as a result of the decomposition of organic carbon containing in the peats. These peatlands are formed over centuries through the accumulation of partially decayed plant material under waterlogged conditions (Osaki et al., 2021). In addition, this organic matter decomposes rapidly when peatlands were drained and converted into agricultural or industrial land, thereby emitting much carbon dioxide to the atmosphere (Mishra et al., 2021; Page et al., 2022). These areas are of particular concern as they contain some of the largest reserves of carbon in the world. Consequently, peatlands are a crucial focal point in the battle against climate change, as their destruction leads to the release of significant amounts of greenhouse gases into the atmosphere (Warren et al., 2017; Deshmukh et al., 2021).

The use of nitrogen fertilizer to enhance crop growth and production may have unintended consequences for tropical peatlands. Previous studies have indicated that adding nitrogen to the soil results in an increased rate of peat decomposition, leading to a greater release of carbon dioxide (Moore and Bubier, 2020). This is because nitrogen stimulates the growth of microorganisms that more actively break down the organic matter in the peatlands (Song et al., 2017; Song et al., 2022). Therefore, it is necessary to adopt sustainable and responsible farming practices that consider tropical peatlands in mitigating climate change.

49 As an industrial waste product generated by coal-fired power plants, coal fly ash (CFA) contains
50 significant amounts of plant essential nutrients, including calcium, magnesium, sodium, and potassium
51 (Kaur and Goyal, 2015; Bhatt et al., 2019; Mathapati et al., 2022). Consequently, CFA is frequently used to
52 enhance the fertility of soil and plant growth. Furthermore, CFA neutralizes pH, reduces soil compaction,
53 and improves soil structure (Tsadilas et al., 2018; Yadav and Pandita, 2019; Dwibedi et al., 2023).
54 Accordingly, CFA increases the nitrogen and phosphorus (Singh et al., 2011; He et al., 2017), which
55 promotes better plant growth and yield (He et al., 2017; Shakeel et al., 2021; Priatmadi et al., 2023). The
56 results of previous studies indicated that CFA has a high potential to be utilized as ameliorant to increase
57 soil quality and improve the production of crops.

58 CFA includes substantial cations, such as Ca, Mg, Al, and Fe, which influence biochemical reactions
59 when applied to soils. Previous studies have shown that the presence of multivalent cation in soils, including
60 Ca and Mg, suppresses carbon mineralization, thereby increasing the organic matter content (Das et al.,
61 2019; Galicia-Andrés et al., 2021). Multivalent cation form organic carbon–cation complexes through a
62 mechanism and function as a bridge between the negative charge and the functional groups of organic
63 materials (Rakhsh et al., 2017; Solly et al., 2020). Application of CFA containing multivalent cation to
64 peatlands may also decrease the rate of carbon mineralization, leading to reduction in CO₂ production. Even
65 though there have been many studies on its use as a soil ameliorant, there is still very limited information
66 on the role of CFA in suppressing carbon mineralization. Therefore, the aim of this study was to quantify
67 the effect of CFA application on carbon mineralization in peatlands.

68 **METHODS AND MATERIALS**

69 **Sampling of Peatlands and CFA**

70 Peatlands sample (Hemic Histosols) were collected from the Desa Landasan Ulin Utara, Liang Anggang
71 Sub-district, Banjarbaru Regency, South Kalimantan, Indonesia. The sampling was carried out from 0-30
72 cm depth in various sampling points, followed by meticulous cleansing cleaning of roots and plant litter,

74 and then homogenized. During peat sampling, bulk density (BD) was also determined using the ring soil
75 sampler technique (Blake and Hartge, 1986). The sampled peat was then stored at 4 °C used for the study,
76 and some was used to determine peat characteristics, as shown in Table 1.

77 CFA was sampled from dumping areas of a power plant situated at the Desa Asam Asam, Jorong Sub-
78 district, South Kalimantan, Indonesia. Determination of the BD of CFA using the method of ring soil
79 sampler (Blake and Hartge, 1986) was also carried out during sampling. After the sampling process was
80 complete, CFA was air-dried, sieved to a size of 2.00 mm, then stored at 4 °C, and some were used for CFA
81 characterization.

82 **Incubation Experiment**

83 The CFA effect on changes in mineralization of carbon in peatlands with nitrogen addition was
84 quantified through an incubation study in the laboratory employing a completely randomized design. The
85 treatment has 6 replications consisting of (1) peatlands without treatment/control (peat), (2) peatlands with
86 CFA application (peat + CFA), (3) peatlands with nitrogen application (peat + N), and (4) peatlands with
87 nitrogen and CFA application (peat + N + CFA). The amount of nitrogen and CFA added to peat is
88 equivalent to 150 kg urea ha⁻¹ and 100 Mg ha⁻¹ in field application, respectively.

89 An amount of peat sample was placed in the incubation vessel (1.95 cm diameter), and then nitrogen
90 and CFA based on the treatment were applied to the incubation vessel and combined equally with the peats.
91 The amount of peat in the incubation vessel was measured to acquire the exact BD as the measurement
92 results in the field following the compression to a depth of 2.0 cm. Aquadest was added carefully to the
93 mixture of peats-nitrogen-CFA to acquire 70% water-filled pore space (WFPS), and compressed to a depth
94 of 2.0 cm. The incubation vessel was placed in a 1000 mL Mason jar equipped with an airtight lid with
95 rubber septa for gas sampling. The jar was then incubated for a duration of 30 days, in darkness, at a constant
96 temperature. In the Mason jar, 15 mL distilled water is also placed in a 20 mL glass vial to retain humidity
97 during the incubation period.

Table 1. Characteristics of peatlands and CFA. Numbers after \pm represent the standard deviation of the mean (n=3).

Characteristics	Peatlands	CFA
Peat decomposition:		
- von Post' scale ^a	H5	-
- Pyrophosphate index ^a (%)	27.87 \pm 6.34	-
- Rubbed fiber content ^a (%)	32.45 \pm 2.56	-
BD (Mg m ⁻³)	0.29 \pm 0.07	1.83 \pm 0.07
pH (H ₂ O) ^b	4.65 \pm 0.12	7.87 \pm 0.23
Organic carbon ^c (g kg ⁻¹)	265.78 \pm 4.76	3.87 \pm 0.08
Total nitrogen ^d (g kg ⁻¹)	2.76 \pm 0.05	0.58 \pm 0.05
Total phosphorous ^e (g kg ⁻¹)	12.56 \pm 4.56	4.56 \pm 0.76
Calcium ^f (mg kg ⁻¹)	2.21 \pm 0.06	867.45 \pm 9.65
Magnesium ^f (mg kg ⁻¹)	1.87 \pm 0.08	376.65 \pm 8.84
Aluminium ^f (mg kg ⁻¹)	3.45 \pm 0.12	487.34 \pm 9.88
Iron ^f (mg kg ⁻¹)	4.87 \pm 0.15	354.55 \pm 8.67
Manganese ^f (mg kg ⁻¹)	1.23 \pm 0.09	143.23 \pm 5.87
Cation exchangeable capacity ^g (cmol kg ⁻¹)	46.78 \pm 4.87	-

^aMethods for determination of physical properties of organic soils (Parent and Caron, 1993); ^bMethod of electrode glass in moist sample and water (1:5, mass:volume) (McLean, 1982); ^cMethod of wet oxidation Walkley-Black (Nelson and Sommers, 1996); ^dMethod of Kjeldahl (Bremer and Mulvaney, 1982); ^ePeat and CFA digested using 60% HClO₄ and then measured at 660 nm (Olsen and Sommers, 1982); ^fPeat and CFA digested using the mixture of HNO₃, HClO₄, as well as the concentration of cation in the digested solution were quantified utilizing an atomic absorption spectrophotometer (Barnhisel and Bertsch, 1982; Knudsen and Peterson, 1982; Lanyon and Heald, 1982; Olson and Ellis, 1982); ^gMethod of ammonium acetate (pH 7.0) (Rhoades, 1982).

The measurement of carbon mineralization was carried out every 5 days by taking out 10 mL of headspace gas in every jar utilizing syringe at a 10 mL. The sampled gas was then injected into a gas chromatograph (Shimadzu GC-14A equipped with a thermal conductivity detector) for CO₂ measurement. Accurate water addition to the peat in each incubation vessel is also carried out every time the jar is periodically opened to maintain a consistent water content throughout the incubation period. Total carbon mineralization during a 30-day incubation period for each jar was determined as the total of each carbon mineralization quantified every 5 days and stated as the cumulative carbon mineralization.

133 After the completion of the incubation period, selected soil chemical characteristics were examined,
134 including soil pH, hot-water soluble carbon, exchangeable Ca, Mg, Fe, and Al. The soil pH of incubated
135 peat was specified using the method of glass electrode in water (1:5 = peat:water) (McLean, 1982), while
136 the concentration of hot-water soluble carbon of the peat was measured using the anthrone-sulfuric acid
137 technique (Grandy et al., 2000). Furthermore, the extraction of exchangeable Ca and Mg was carried out
138 using ammonium acetate 1.0 N pH 7.0. For Al and Fe, KCl 1.0 N and 0.05 M EDTA (pH 7.0), were used
139 for the extraction, respectively. The contents of Ca, Mg, Al, and Fe in the extracted solution were measured
140 utilizing an atomic adsorption spectrophotometer (Barnhisel and Bertsch, 1982; Lanyon and Heald, 1982).

141 **Data Analysis**

142 This study used ANOVA (analysis of variance) to determine the impact of CFA application on the
143 observed variables. The Bartlett and Shapiro-Wilk tests were completed on all observed variables before
144 ANOVA to ensure the homogeneity of variance and the normal distribution of all data. Furthermore, the
145 LSD (least significant difference) test was carried out at $P \leq 0.05$ when the treatments had a significant
146 impact on the variables. All examinations were carried out utilizing the statistical package of GenStat 12th
147 Ed. (Payne, 2008).

148 **RESULTS AND DISCUSSIONS**

149 **Characteristics of Peatlands and CFA**

150 The peat used in this study according to the von Post scale, pyrophosphate index, and rubbed fiber
151 contents, was classified as moderately decomposed or hemic (McKinzie, 1974; Parent and Caron, 1993).
152 This peat has a relatively low BD, namely 0.29 Mg m^{-3} with a very acidic soil reaction (pH = 4.65), as
153 shown in Table 1. Accordingly, the peatland respectively contains an organic C and total N contents
154 reaching 266 g kg^{-1} and 2.8 g kg^{-1} (Table 1). Exchangeable Ca and Mg contents in the peat used were
155 relatively low, with total Al and iron contents reaching 3 and 5 mg kg^{-1} , respectively (Table 1). Cation
156 exchange capacity (CEC) of peat was very high at 47 cmol kg^{-1} (Table 1).

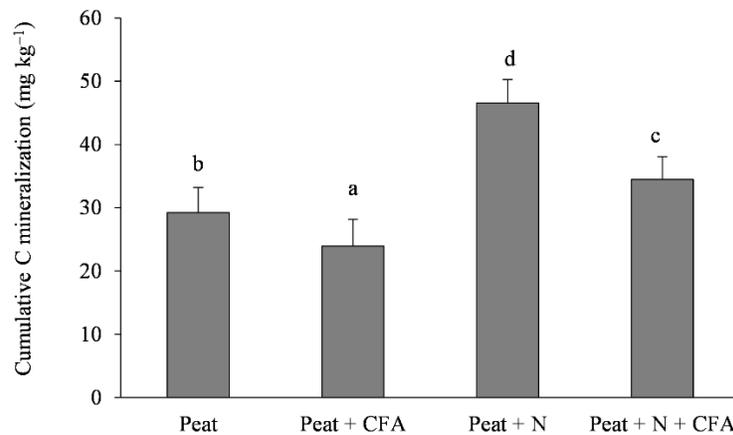
158 CFA had a high BD (1.8 Mg m^{-3}), with an alkaline reaction (pH 7.9). Furthermore, there was low organic
159 C and total N content in CFA, but Ca, Mg, Al, Mn, and Fe were very high (Table 1). Having an alkaline
160 pH with an increased level of Ca, Mg, Fe, and Al cation was characteristics commonly found in CFA (Bhatt
161 et al., 2019; Laxmidhar and Subhakanta, 2020).

162 **Effect of CFA on Carbon Mineralization of Peatlands with Nitrogen Addition**

163 The study results showed that applying N fertilizer to peat increased carbon mineralization from 29 mg
164 kg^{-1} to 47 mg kg^{-1} , as shown in Figure 1. Based on the theory of substrate use, microorganisms prioritize
165 the use of added N due to its relatively easier breakdown of the organic material, thereby leading to
166 increased carbon mineralization (Wang et al., 2018). The addition of N does not increase carbon
167 mineralization under conditions where the amount of C is limited for the microbial decomposition.
168 However, when the amount of organic C is not a limiting factor, the addition of N will increase C
169 mineralization (Song et al., 2014). Due to the high amount of organic C in the peat used in this study, it is
170 expected that increasing N will stimulate C mineralization, resulting in a high CO_2 production. Previous
171 studies have also shown increased C mineralization in soil with the N application (Gao et al., 2022; Luo et
172 al., 2022).

173 Application of CFA increased pH from 3.8 to pH 5.5 in peat without N addition, and increased from pH
174 3.3 to pH 4.7 in peat with N addition (Figure 2A). However, increases in peat pH due to the CFA application
175 were not followed by an increase in C mineralization. In a condition of peat pH increased with CFA
176 application in both with and without N addition, C mineralization, on the other hand, decreased (Figure 1).
177 Furthermore, peatlands with added N had a lower pH than those without N (Figure 2A), while C
178 mineralization of peatlands increased in peat with N addition treatment (Figure 1). This shows that C
179 mineralization in peatlands in this study is not controlled by the pH of the peatlands. These results contrast
180 to the results of previous studies showed that pH is the dominant factor controlling C mineralization in
181 peatlands (Preston and Basiliko, 2016; Zhang et al., 2020). An increase in soil pH due an application of soil
182 ameliorant generally results in increased C mineralization in soils (El-Naggar et al., 2018; Xiao et al., 2018).

184 No relationship was found between the rate of C mineralization and the changes in peat pH in this study
185 was due to small changes caused by CFA application, namely from pH of 3.3-3.8 to pH of 4.7-5.5 (Figure
186 2A).

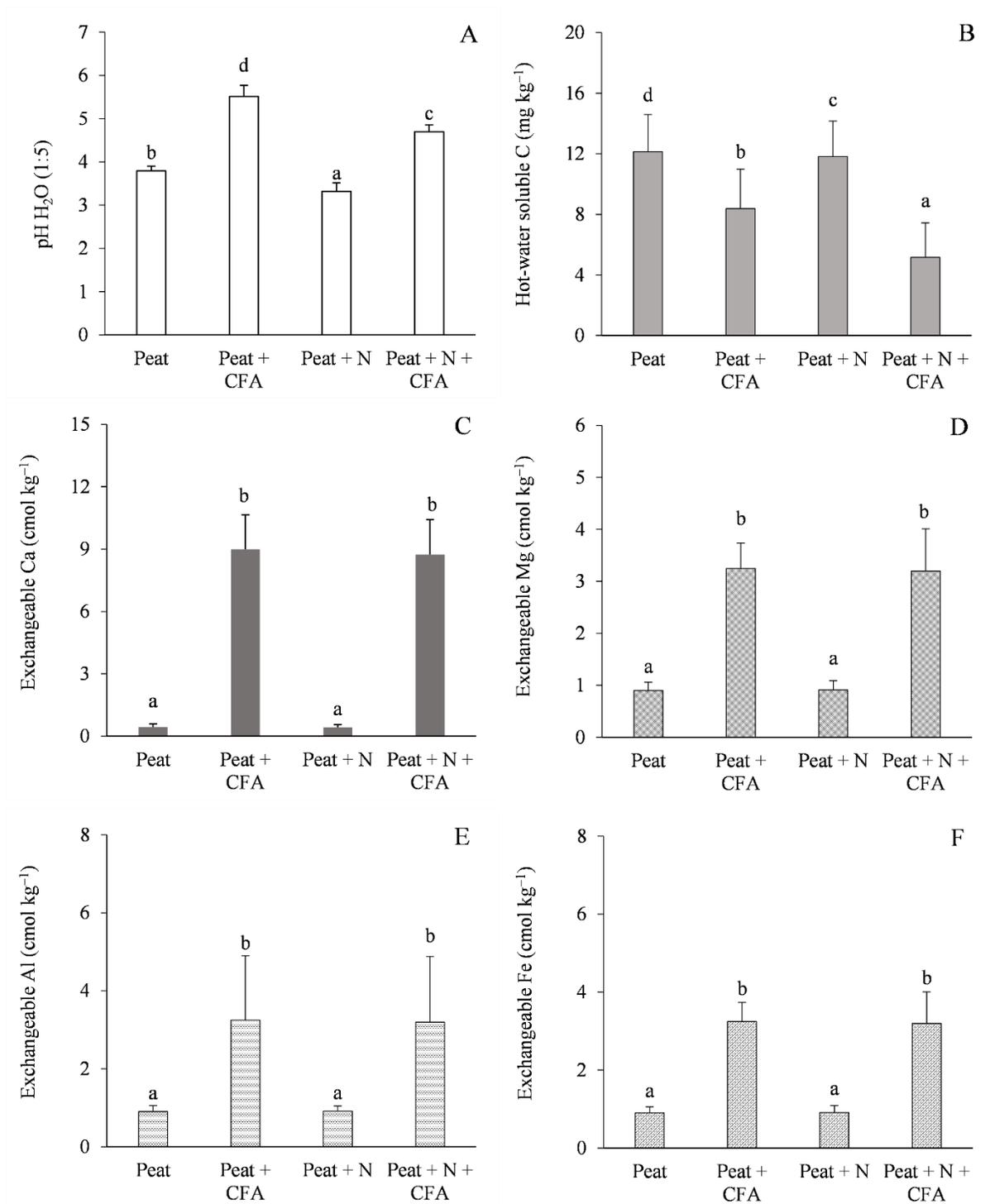


187 Figure 1. Carbon mineralization of peatlands under nitrogen addition with CFA application. The lines
188 above the bar mean the standard deviation of the mean (n=6). Similar letters above the line show
189 comparable effects of treatments according to the LSD test at $P < 0.05$

190 Carbon mineralization was reduced due to application of CFA to peatlands with and without the N
191 application. The decrease in C mineralization was due to a low substrate availability with the addition of
192 CFA. The decrease in the amount of substrate available for microbial decomposition occurs due to the
193 binding process by multivalent cation present in CFA. A large amount of multivalent cation was present in
194 CFA, including Ca, Mg, Al, and Fe (Table 1. The presence of these multivalent cation in peatlands result in
195 the stabilization of the organic C containing in the peats through an adsorption process between the organic
196 C and multivalent cation. This adsorbed organic C is resistant to microbial decomposition processes
197 (Sowers et al., 2018; Liu et al., 2019). Prior examinations also showed that application of CFA reduces the
198 substrate availability for microorganisms, therefore it produces low carbon mineralization in organic soils
199 (Saidy et al., 2022) and mineral soils (Lim and Choi, 2014; Lim et al., 2017; Saidy et al., 2020).

201 A low substrate availability in peatlands for C mineralization with CFA application is showed by a
202 decrease in hot-water soluble C, which is easily decomposable. Application of CFA to peatlands reduced
203 the amount of hot water-soluble C from 12 mg kg⁻¹ to 8 mg kg⁻¹ in of peat without N and from 12 mg kg⁻¹
204 to 5 mg kg⁻¹ in those with N (Figure 1B). Hot-water soluble C is a form of carbon that is very easy to
205 undergo microbial decomposition for CO₂ production (Soong et al., 2015; Miao et al., 2017). In a study
206 used 11 varied peatlands based on nutrient status, land use, and temperature in an aerobic incubation study,
207 Normand et al. (2021) showed that carbohydrate (hot-water soluble C) is the best predictor for aerobic CO₂
208 production. A low amount of hot-water soluble C with application of CFA reduced the amount of the C for
209 microbial decomposition to produce CO₂. Furthermore, the result of a previous study showed a low CO₂
210 and CH₄ production results from a reduction in the amount of hot-water soluble C in peatlands with CFA
211 addition (Saidy et al., 2022).

212 CFA addition also increased the exchangeable Ca, Mg, Al, and Fe concentrations. Ca and Mg increased
213 by 19 and 2 times greater in peatlands with CFA application compared to those without CFA (Figure 2C
214 and 2D). In addition, Al dan Fe on peatlands with and without the N application increased from 0.6 cmol
215 kg⁻¹ to 4.9 cmol kg⁻¹ and from 0.3 cmol kg⁻¹ to 3.0 cmol kg⁻¹ with CFA, respectively (Figures 2E and 2F).
216 Increasing the Ca, Mg, Al, and Fe concentrations of peatlands with CFA application decreased the hot-
217 water soluble C. This outcome affirmed the necessary function of these multivalent cation in the
218 stabilization of easily decomposable C. The presence of exchangeable cation of Ca, Mg, Al, and Fe from
219 added CFA also increased the sorption of easily decomposable C, resulting in reduction of organic C for
220 microorganisms (Rowley et al., 2018; Singh et al., 2018).



222 Figure 2. Changes in pH (A), carbohydrate content/hot-water soluble C (B), exchangeable Ca (C),
 223 exchangeable Mg (D), exchangeable Al (E), and exchangeable Fe (F) of peatlands with nitrogen and CFA
 224 application. The lines above the bar mean the standard deviation of the mean (n=6). Similar letters above
 225 the line show comparable effects of treatments according to the LSD test at $P < 0.05$

227 A low C mineralization in peatlands with the application of CFA also results from a decrease in the
228 activity of microorganisms. CFA used in this study includes moderately high Al, Mn, and Fe (Table 1),
229 which suppress microbial activity in the decomposition of organic C. This result is consistent with
230 Fiałkiewicz-Kozieł et al. (2015) who indicated a decrease in microbial population in peatlands with highly
231 concentrated Al, Cu, and the extreme amount of CFA particles. Rodríguez-Salgado et al. (2017) also showed
232 a reduction in C mineralization of bentonite waste due to the existence of high toxic compound
233 concentrations. Application of CFA at 100 Mg ha⁻¹ decreased microbial activity due to reduction in the
234 number of beneficial microorganisms (*Azotocater*) (Parab et al., 2015). Furthermore, high CFA application
235 reduced the activities of several enzymes, including L-asparaginase, b-glucosidase, arylsulfatase, and alkali
236 phosphatase, and soluble C in composting public green waste (Belyaeva and Haynes, 2009). This study
237 demonstrated the detrimental impact of compounds in CFA on decreases in microbial activity in peatlands,
238 resulting in low C mineralization of peatlands.

239 This study indicated that the reduction in CO₂ production of peatlands with the N application was higher
240 than those without N. CFA added to peatlands without N resulted in a 34% reduction in CO₂ production,
241 while the addition of N led to a reduction of 44% (Figure 1). The high reduction in CO₂ production in
242 peatlands with N addition is due to the reaction between added N and CFA, which does not enhance C
243 mineralization. This is consistent with the study of Hamidi et al. (2022) who showed the use of CFA as a
244 geopolymer for urea coating to produce controlled-release fertilizer. Previous studies also showed the use
245 of CFA as a material to slow down the reaction of urea in soils (Hermawan et al., 2019; Manzoor et al.,
246 2022).

247 Results obtained in our study suggest that the application of CFA brings several benefits, such as
248 increasing peat pH and reducing carbon dioxide production. These results are in line with several previous
249 studies that stated mixing CFA and compost increased soil pH and availability of P in peatland (Ichriani et
250 al., 2021). The amendment of CFA mixing with other industrial wastes such as paper factory sludge and
251 rice husk ash increases organic carbon, pH, available nutrients (Singh et al., 2022). Increasing peat pH was
252 observed when peatlands applied with CFA at a rate of 60 Mg ha⁻¹ (Priatmadi et al., 2023). In a study on
253

254 the application of CFA to peatlands at rates 25-150 Mg ha⁻¹, Saidy et al. (2022) reported that production
255 carbon dioxide and methane decreased significantly with increasing the amount of applied CFA. Results
256 of this study highlight the potency of CFA as an ameliorant for reducing the emission of green house gases
257 from peatlands.

258 The long-term implications of using coal fly ash (CFA) in peatlands may have both positive and negative
259 effects on soil health and sustainability. On the positive side, CFA improve soil fertility by providing
260 essential nutrients and enhancing soil structure. Another positive effect of CFA application is the increase
261 in pH levels of acidic peat soils. Peatlands are naturally acidic environments, and the addition of CFA
262 neutralize the acidity, making the soil more suitable for plant growth. This may lead to increase plant
263 diversity and biomass in peatland ecosystems. However, it's important to note that the long-term application
264 of CFA on peatlands may also have negative effects. Long-term CFA application on peatlands also
265 influence soil microbial communities and biodiversity. Several studies suggest that CFA application leads
266 to the changes in the composition and activity of soil microorganisms (Woch et al., 2018; Varshney et al.,
267 2020), which play crucial roles in nutrient cycling and ecosystem functioning. This could have implications
268 for the overall sustainability and resilience of peatland ecosystems.

269 The results of this research show that industrial waste such as coal fly ash has high potential as an
270 amendment material in peatlands. The application of CFA may result in ecological and environmental
271 impact on the peatland ecosystem. The presence of CFA suppresses carbon mineralization in peat, which
272 helps to slow down the process of peat loss due to microbial decomposition. This leads to positive
273 environmental impacts by extending the longevity of peatlands and reducing carbon emissions. However,
274 CFA may also contain the trace amount of heavy metals such as arsenic, lead, and mercury, which
275 potentially leach into the surrounding soil and water, leading to heavy metal pollution. Carefully monitor
276 and manage the application of CFA is crucial to minimize any potential negative impacts on the
277 environment. Therefore, further research and monitoring are necessary to fully understand the
278 environmental and ecological impacts of applying CFA to peatlands.

CONCLUSION

In conclusion, the addition of nitrogen (N) fertilizer to systems with abundant substrate availability, including peatlands, enhanced the process of carbon mineralization, resulting in increased carbon dioxide production. The application of CFA also decreased the availability of hot-water soluble carbon (carbohydrates) for microbial decomposition. This decrease resulted in low carbon mineralization when CFA was applied to peatlands. Additionally, the presence of Al and Fe in CFA suppressed microbial activity in peatlands, leading to a decrease in C mineralization of peatlands. This study showed the possibility of CFA as a soil ameliorant material for reducing carbon mineralization in peatlands.

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Dear Dr. Priatmadi,

Thank you for the revision of the manuscript: Reduction in Carbon Dioxide Production of Tropical Peatlands Under Nitrogen Fertilizer with Coal Fly Ash Application.

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Sat, Dec 23, 2023 at 6:25 AM

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Reduction in Carbon Dioxide Production of Tropical Peatlands Under Nitrogen Fertilizer with Coal Fly Ash Application

Dear Dr. Priatmadi,

I am pleased to inform you that your manuscript, entitled: Reduction in Carbon Dioxide Production of Tropical Peatlands Under Nitrogen Fertilizer with Coal Fly Ash Application, has been accepted for publication in our journal.

Thank you for submitting your work to us.

Kindest regards,
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