Nitrous Oxide Emissions in Pineapple Cultivation on a Tropical Peat Soil

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Abstract: Farming systems on peat soils are novel, considering the complexities of these organic soil. Since peat soils effectively capture greenhouse gases in their natural state, cultivating peat soils with annual or perennial crops such as pineapples necessitates the monitoring of nitrous oxide (N2O) emissions, especially from cultivated peat lands, due to a lack of data on N2O emissions. An on-farm experiment was carried out to determine the movement of N2O in pineapple production on peat soil. Additionally, the experiment was carried out to determine if the peat soil temperature and the N2O emissions were related. The chamber method was used to capture the N2O fluxes daily (for dry and wet seasons) after which gas chromatography was used to determine N2O followed by expressing the emission of this gas in t ha−1 yr−1. The movement of N2O horizontally (832 t N2O ha−1 yr−1) during the dry period was higher than in the wet period (599 t N2O ha−1 yr−1) because of C and N substrate in the peat soil, in addition to the fertilizer used in fertilizing the pineapple plants. The vertical movement of N2O (44 t N2O ha−1 yr−1) was higher in the dry season relative to N2O emission (38 t N2O ha−1 yr−1) during the wet season because of nitrification and denitrification of N fertilizer. The soil temperature did not affect the direction (horizontal and vertical) of the N2O emission, suggesting that these factors are not related. Therefore, it can be concluded that N2O movement in peat soils under pineapple cultivation on peat lands occurs horizontally and vertically, regardless of season, and there is a need to ensure minimum tilling of the cultivated peat soils to prevent them from being an N2O source instead of an N2O sink.

Keywords: fertilization; greenhouse gases; horizontal emissions; tropical peat lands; vertical emissions

1. Introduction

The estimated peatlands occurrence in Southeast Asia is 27.1 million ha [1], and in Malaysia, the occurrence is approximately 2.6 million hectares [2,3]. In the tropics, peatlands occur in woody wetlands with intermittent wet and dry conditions [3,4]. Peatlands are classified as organic soils whose organic matter ranges between 50% and 65% and where within one meter of the soil from the surface, 40 to 50 cm of this the soil is organic matter [5–7]. The peat soil is categorized as a marginal soil (Class 4) with severe limitations.

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for crop cultivation because it requires careful agronomic management [8,9]. Furthermore, peat soils have less than 35% mineral ash [5–7]. In Malaysia, peatlands are used for agriculture. For example, 1.08 million ha of the peat land are cultivated with oil palm, pineapple, sago, rubber, coconut, and mixed agriculture practices [10–12]. However, only high-value crops such oil palm and pineapple are grown on a significant commercial scale on peat soils [11]. Under the mixed planting system, the cultivated peatlands contribute 16% of the fruit farming in Malaysia [13]. Low pH, nutritional deficiencies, irreversible drying, poor cropping capacity, and flooding are the challenges in cultivating peat soils [13,14].

It is believed that draining peat soils for agricultural purposes speeds up the decomposition of peat organic matter. The likelihood of N\textsubscript{2}O being released once peatlands are drained for agriculture is high. Because of its ozone-depleting properties, nitrous oxide has been related to global warming [15,16]. In comparison to other greenhouse gases, the lifetime of N\textsubscript{2}O is around 120 years. Nitrous oxide has 310 times the global warming potential of a molecule of CO\textsubscript{2} [17]. Both nitrification and denitrification produce nitrous oxide [18,19] where microbial activities control these processes. The microbial activities are also affected by soil nitrogen and nitrogen fertilization [20–22]. In drained and fertilized peat soils, for example, nitrification occurs under aerobic conditions [23]. This is due to organic nitrogen decomposition, which accelerates soil mineralization [19]. Nitrification leads to an increase in inorganic nitrogen and the release of N\textsubscript{2}O into the atmosphere. The presence of anaerobic conditions in peats encourages the development of N\textsubscript{2}O by nitrifying bacteria. In peats, anaerobic conditions encourage N\textsubscript{2}O emission by nitrifying bacteria that use nitrate in their metabolic processes. Since nitrous oxide emission is high at intermediate soil moisture content, it is thought to be controlled by soil moisture [24]. Nitrous oxide emission is also affected by the water table, fertilization, and the availability of organic matter [18,19,25].

Nitrous oxide is a by-product of the biological process of nitrification and an intermediate product of denitrification. Factors affecting the production of N\textsubscript{2}O in peat soils are temperature, humidity, water-filled pore spaces, and nitrogen-containing substrates [25–27]. According to the study of [26,28] the largest N\textsubscript{2}O emissions in peat soils usually occur regardless of the degree of waterlogging and in nonwaterlogged conditions. Peat soil’s hydrological changes affect nitrous oxide emissions [26,28]. Upon poor draining of peat water, mineralization of peat soils, especially nitrification, increases N\textsubscript{2}O emission [26–29]. Similarly, the application of N fertilizers usually increases the N\textsubscript{2}O emission rate [29,30] but this is temporary if the N utilization rate is not maintained [26,28]. The N\textsubscript{2}O that are emitted from uncultivated peatlands could be low [31,32] but unbalanced N fertilization in cultivated peat soils could increase N\textsubscript{2}O emission [33,34]. Nitrous oxide emission is an important part of the peat greenhouse gas balance because in a 100-year timeframe, the global warming potential of N\textsubscript{2}O is 298 times that of CO\textsubscript{2} [35]. However, once the peat soils are cultivated, the top part oxidizes to release N\textsubscript{2}O [36,37].

Oil palm (Elaeis guineensis), pineapple (Ananas comosus (L.) Merr.), rubber (Hevea brasiliensis), and sago (Metroxylon sagu) are grown on around 600,000 hectares of peatland in Malaysia [38]. Attempts to quantify N\textsubscript{2}O emission from cultivated tropical peats have been made, but these studies have been restricted to paddy (Oryza sativa) and rice-soybean fields [39,40]. There is currently a lack of data on N\textsubscript{2}O emissions from pineapple production on drained peat soils. This knowledge is critical because peat soils in Malaysia account for 90% of pineapple production [40]. To this end, determining N\textsubscript{2}O emissions in pineapple cultivation on peat soils is critical. Furthermore, pineapple is distinct in that it is known as a C3 and C4 plant, or a Crassulacean Acid Metabolism (CAM) plant [41–43], which may explain why it emits at a different rate than crops like oil palm, which is commonly planted on tropical peat soils. With increasing concern about the impact of greenhouse gas on environmental quality and the need for sustainable agriculture, direct N\textsubscript{2}O measurement from cultivated peat soils is needed to provide a foundation for potential emission factors under various land uses.
The literature is replete with mentions of greenhouse gas (GHG) emissions from oil palm plantations on peat soils [33,44,45]. The development of peatlands for agriculture has raised concerns in the international community partly because of the ongoing debate on the effects GHG on the quality of the environment [46]. The greenhouse effect is explained as increased warming of the Earth’s surface because of the increasing emissions of carbon dioxide and trace gases including \( N_2O \) into the atmosphere by human activities, over and above any warming due to natural processes [47].

However, there is less attention paid to drained peatlands that are cultivated with pineapples. It was hypothesized in this study that peat soils cultivated with pineapple will produce more \( N_2O \) emissions. This hypothesis is focused on the assumption that nitrification and denitrification regulate \( N_2O \) emission from cultivated peat, processes that are influenced by fertilization with plenty of substrate for heterotrophic microbial metabolism. Quantifying \( N_2O \) emissions from drained tropical peats cultivated with pineapples may be used to enhance long-term pineapple farm management practices aimed at reducing greenhouse gas emissions.

Currently, there is no specific method or guidelines on the best way to measure GHG fluxes. The best method actually depends on the size of the working area, the sampling duration, and also the desired GHG, while the second method is the Eddy covariance method, as the method is accurate but complex. Nonetheless, some organization prefers the first method, which is the closed chamber method, as it is cheap and easy to use, and is the most widely used method compared to Eddy covariance. Moreover, there are no specific guidelines on the size of the chamber and interval sampling time at the chamber head space to enable accurate measurements of GHG fluxes from drained peat. The appropriate size of the chamber should be taken into consideration, which relates to the type of peat and land use management at the experimental site.

In this present study, it was assumed that horizontal and vertical movement of gases in peatlands control the \( N_2O \) release from pineapples’ cultivation in peat soils of gas transportation system in soils. We expect that these findings will pave the way for appropriate methods in the measurement of \( N_2O \) emissions, thereby improving the accuracy of \( N_2O \) measurement. This will ultimately minimize the ongoing controversy in the \( N_2O \) results. In addition, it will provide instructions for farm management procedures dealing with \( N_2O \) emissions. An on-farm experiment was carried out to estimate the horizontal and vertical movements of \( N_2O \) out of tropical peat soils cultivated with pineapple. Based on the above rationale, the objective of this study was to quantify \( N_2O \) emissions from a drained tropical peat grown with pineapple. In addition, the experiment was carried out to determine if the horizontal or vertical movement of \( N_2O \) out of tropical peatlands cultivated with pineapples and temperature are related.

2. Materials and Methods

2.1. Information about the Experimental Area

This field trial was performed at the Peat Research Station of the Malaysian Agricultural Research and Development Institute (MARDI) in Saratok, Sarawak, Malaysia (Figures 1–3). The 387-hectare research station is situated on a logged-over forest with a flat topography of 5 to 6 m above mean sea level. The peat soil is graded as well-decomposed, dark brown to almost dark-colored sapric peat with a heavy odor on the Von Post Scale of H7 to H9 (Table 1) (Histosols). The peat soil thickness varies from 0.5 to 3.0 m. The peat area’s average temperature ranges from 22.1 to 31.7 °C. The area’s relative humidity ranges from 61 to 98%. The area’s annual average rainfall is 3749 mm. The monthly rainfall in the wet season (November to January) exceeds 400 mm, while the mean rainfall in the dry season (particularly in July) is 189 mm.
The location and close-up of the experimental site are as follows (Figure 3):

![Map of Sessang, Saratok, Sarawak.](image1)

**Figure 1.** Map of Sessang, Saratok, Sarawak.

![Aerial view of MARDI Sessang.](image2)

**Figure 2.** Aerial view of MARDI Sessang.

| Symbol | Description                               |
|--------|-------------------------------------------|
| H1     | Completely undecomposed peat.             |
| H2     | Almost entirely undecomposed peat.        |
| H3     | Very slightly decomposed peat.            |
| H4     | Slightly decomposed peat.                 |
| H5     | Moderately decomposed peat.               |
| H6     | Moderately highly decomposed peat.        |
| H7     | Highly decomposed peat.                   |
| H8     | Very highly decomposed peat.              |
| H9     | Practically fully decomposed peat.        |
| H10    | Completely decomposed peat.               |

**Table 1.** Classification of peat soils based on von post description.

Source: [48].
2.2. Greenhouse Gases Emission Measurements

Chamber methods were used to measure the horizontal and vertical movements of N$_2$O out of the soil (Figures 4a,b and 5a,b). The I-shaped closed chamber method was used to measure the horizontal movement of the N$_2$O out the soil whereas the L-shaped closed chamber method was used to measure the vertical emission of N$_2$O [49]. The measurement of N$_2$O emissions was performed at two soil depths (0–5 cm and 5–10 cm). The measurement of N$_2$O emissions was conducted on 100 m$^2$ (10 m × 10 m) plots with pineapples. Previously, there were no agriculture activities were done on this plot. Pineapple suckers were planted at a distance of 30 cm. The pineapples were managed based on standard agronomic practices for pineapple cultivation on peats [43].

Figure 4. (a): Soil N$_2$O vertical emission measurements using I-shaped chamber. (b): I-shaped chamber was installed to soil surface by pressing the chamber onto the soil.
Figure 4. (a): Soil N$_2$O vertical emission measurements using I-shaped chamber. (b): I-shaped chamber was installed to the soil surface by pressing the chamber onto the soil.

Figure 5. (a): Soil N$_2$O vertical emission measurements using L-shaped chamber, (b): L-shaped chamber was installed to the soil wall by pressing the chamber onto the soil.

The gas flux was measured in the early morning I (06:00 a.m.–07:00 a.m.), afternoon (12:00 p.m.–13:00 p.m.), evening (18:00 p.m.–19:00 p.m.), midnight (00:00 a.m.–01:00 a.m.), and early morning II (06:00 a.m.–07:00 a.m.) to obtain a 24 h N$_2$O emission (Table 2). The flux measurements were carried out in July 2015 and August 2015 to represent the concentrations of N$_2$O in the dry season whereas September 2015 and December 2015 flux measurements represent the concentrations of N$_2$O in the wet season. Soil temperature was measured using digital thermometer at the same time of GHG measurement. Rainfall, temperature, and air humidity data were also recorded using a portable weather station (WatchDog 2900) installed at the experimental site.

| Season | Month                  | Sampling Time                      |
|--------|------------------------|------------------------------------|
| Dry    | July 2015, August 2015 | Early Morning I 06:00 a.m. to 06:35 a.m. |
|        |                        | Afternoon 12:00 p.m. to 12:35 p.m.  |
|        |                        | Evening 18:00 p.m. to 18:35 p.m.    |
|        |                        | Midnight 00:00 a.m. to 12:35 a.m.   |
|        |                        | Early Morning II 06:00 a.m. to 06:35 a.m. |
| Wet    | September 2015, December 2015 | Early Morning I 06:00 a.m. to 06:35 a.m. |
|        |                        | Afternoon 12:00 p.m. to 12:35 p.m.  |
|        |                        | Evening 18:00 p.m. to 18:35 p.m.    |
|        |                        | Midnight 00:00 a.m. to 12:35 a.m.   |
|        |                        | Early Morning II 06:00 a.m. to 06:35 a.m. |

2.2.1. Soil Nitrous Oxide Horizontal Emission Measurements

The closed chamber method was used to measure the horizontal N$_2$O emission [50,51] by pressing the I-shaped chamber from the top of the soil to a 3 cm to 5 cm depth after
which it was left equilibrated for 30 min (Figure 4a,b). A 50 mL syringe was used to extract 20 mL gas samples from the chamber from one minute to six minutes. Thereafter, a syringe needle was used to transfer the extracted gas into a 20 mL vacuum vial. A gas chromatograph (GC-Agilent 7890A) equipped with a thermal conductivity detector (TCD) was used to measure the concentration of nitrous oxide.

2.2.2. Soil Nitrous Oxide Vertical Emission Measurements

Vertical emission of the N$_2$O was measured beginning from the surface of the soil to a 10 cm depth. The L-shaped chamber was horizontally installed to the wall of the soil pit (20 cm). This installation was equilibrated for 30 min (Figure 5a,b). A volume of 20 mL of N$_2$O was extracted from the chamber from one minute to six minutes using a 50 mL syringe. Thereafter, the N$_2$O was transferred into a 20 mL vacuum vial after which the gas content was determined using a Gas Chromatography (GC—Agilent 7890A) with a thermal conductivity detector (TCD).

2.2.3. Nitrous Oxide Flux Calculation

The gas flux results were based on the measured N$_2$O from the three replications using different methods (I-chamber and L-chamber) in the dry and wet seasons. Extracted gas samples from the chamber were analyzed for N$_2$O using gas chromatography (Agilent 7890A) equipped with thermal conductivity detector (TCD). The values were averaged and converted into units of t ha$^{-1}$ yr$^{-1}$. The gas flux was calculated from the increase in the chamber concentration over time using the chamber volume and soil area covered. The N$_2$O fluxes were then calculated using the following equation [20,52,53]:

$$Flux = \left[ \frac{d(Gas)}{dt} \right] \times \frac{PV}{ART}$$

where (i) $d(Gas)/dt$ is the evolution rate of N$_2$O within the chamber head space at a given time soon after the chamber were placed into the soil, (ii) $P$ is the atmospheric pressure, (iii) $V$ is the volume head space gas within the chamber, (iv) $A$ is the area of soil enclosed by the chamber, (v) $R$ is the gas constant, and (vi) $T$ is the air temperature.

Carbon dioxide (CO$_2$) and methane (CH$_4$) emissions from peat soils cultivated with pineapple were also quantified. However, results for CO$_2$ and CH$_4$ emissions were not reported in this paper.

2.2.4. Statistical Analysis

The effects of different sampling time were determined using one-way analysis of variance (ANOVA) whereas the means were separated using Tukey’s Studentized Range (HSD) Test at $p \leq 0.05$. Nitrous oxide emission and soil temperature were correlated using Pearson correlation analysis. These statistical analyses were performed using the Statistical Analysis System (SAS) version 9.4 [54].

3. Results and Discussions

3.1. Horizontal Movement of Nitrous Oxide

There was no consistent trend across sampling intervals for the four monitoring periods (Figure 6). In addition, the N$_2$O emissions were not significantly different regardless of sampling interval (Figure 6). This trend might be due to the attributed to the biological activity of microorganisms for N$_2$O production. Moreover, the production of N$_2$O through nitrification and denitrification in drained and fertilized peat soils through nitrogen fertilizer suggest the inconsistent N$_2$O emissions because the decomposition of organic nitrogen accelerates the soil mineralization, and this results in the formation of inorganic nitrogen. This is because the decomposition of organic nitrogen accelerates soil mineralization, which results in the formation of inorganic nitrogen and is commonly accompanied by the release of N$_2$O into the atmosphere [55]. Similar observations with no significant differences were reported for all soil temperature across sampling intervals.
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3. Results and Discussions

3.1. Horizontal Movement of Nitrous Oxide

There was no consistent trend across sampling intervals for the four monitoring periods (Figure 6). In addition, the \( \text{N}_2\text{O} \) emissions were not significantly different regardless of sampling interval (Figure 6). This trend might be due to the biological activity of microorganisms for \( \text{N}_2\text{O} \) production. Moreover, the production of \( \text{N}_2\text{O} \) through nitrification and denitrification in drained and fertilized peat soils through nitrogen fertilizer suggest the inconsistent \( \text{N}_2\text{O} \) emissions because the decomposition of organic nitrogen accelerates the soil mineralization, and this results in the formation of inorganic nitrogen. This is because the decomposition of organic nitrogen accelerates soil mineralization, which results in the formation of inorganic nitrogen and is commonly accompanied by the release of \( \text{N}_2\text{O} \) into the atmosphere [55]. Similar observations with no significant differences were reported for all soil temperature across sampling intervals.

![Figure 6. Horizontal nitrous oxide emission and soil temperature (error bars represent standard errors) at different monitoring intervals and different monitoring periods (the error bars represent standard errors, and the mean values of different letters have significant differences when \( p \leq 0.05 \)).](image)

3.2. Vertical Movement of Nitrous Oxide

There was consistent and moderate increase in \( \text{N}_2\text{O} \) emissions across sampling intervals for all the four monitoring periods (Figure 7). However, \( \text{N}_2\text{O} \) emissions were not significant across all sampling intervals. The increase in \( \text{N}_2\text{O} \) emissions was due to the availability of ammonium from the compound fertilizer used in cultivating the pineapple in this present study. Furthermore, the native nitrogen and carbon of the peat soil played an essential role in denitrifying and nitrifying processes, which also affects \( \text{N}_2\text{O} \) emissions [21].
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3.3. Summary on the Movements of the Nitrous Oxide Out of the Peat Soil

The horizontal N$_2$O fluxes from August 2015 to December 2015 were different (Figure 8) with the highest N$_2$O flux occurring in August 2015 due to the application of foliar fertilizer to the four-and-half-month-old pineapple plants. The application of this foliar fertilizer might have increased nitrate content in the peat soils (through mineralization) to cause an increase in the N$_2$O emission through mineralization [6,15,24]. The higher temperature in August 2015 could also be one of the reasons for this high N$_2$O emission. Soil N$_2$O flux and soil temperature did not correlate, suggesting they are not related. Moreover, the fact that the N$_2$O flux and soil temperature are not related (Table 3) suggests that the N$_2$O out of the soil is not related to the soil temperature fluctuations, but rather depends on N fertilization [6,15,24].

Figure 7. Vertical nitrous oxide emission and soil temperature (error bars represent standard errors) at different monitoring intervals and different monitoring periods (the error bars represent standard errors, and the mean values of different letters have significant differences when $p \leq 0.05$).

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Figure 8. Total horizontal emissions of nitrous oxide from tropical peat soils grown with pineapples (error bars represent standard error and soil mean fluxes with different letters are significantly different at \( p \leq 0.05 \)).

Table 3. Correlation between horizontal soil N\(_2\)O emission and soil temperature of a drained tropical peat soils.

| Soil Temperature | July 2015 | August 2015 | September 2015 | December 2015 |
|------------------|-----------|-------------|----------------|---------------|
| Soil N\(_2\)O emission | \( r = -0.04 \) | \( r = -0.09 \) | \( r = 0.15 \) | \( r = -0.07 \) |
| \( p = 0.89 \) | \( p = 0.76 \) | \( p = 0.60 \) | \( p = 0.82 \) |

The vertical N\(_2\)O fluxes were different (Figure 9) with the highest N\(_2\)O flux occurring in December 2015 because of the C and N substrates of the soil and that from the fertilizer used (application of compound fertilizer to nine-month-old pineapple plants) as the sources that enhanced nitrification and denitrification [15]. The soil N\(_2\)O emission and soil temperature did not relate in July 2015, August 2015, September 2015, and December 2015 suggesting that N\(_2\)O emission and soil temperature are not related (Table 4).
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Table 3. Correlation between horizontal soil N$_2$O emission and soil temperature of a drained tropical peat soils.

| Month Variable          | July 2015 | August 2015 | September 2015 | December 2015 |
|-------------------------|-----------|-------------|----------------|---------------|
| Soil N$_2$O emission    | $r = 0.14$| $r = -0.03$ | $r = 0.27$     | $r = 0.11$    |
|                         | $p = 0.55$| $p = 0.89$  | $p = 0.25$     | $p = 0.65$    |

3.4. Limitation of Greenhouse Gases Emissions Using Closed Chamber Methods

Although the chamber method is a well-established, cheap, and widely used for soil GHG flux measurement in tropical peat soils, it is good to consider the coverage of the chamber, the sampling time of the gas from the chamber head space, and also the limited number of sampling cycles that can be done at a time [55]. This is due to the controversial findings where most measurements are made on a small scale (few cm$^2$), in addition to the limited time of measurement expressed in t ha$^{-1}$ yr$^{-1}$ [26,56,57]. In some cases, results are inconsistent and controversial. However, limited number of time interval during sampling will not reflect the gases emission from the soil because it may be influenced by gas diffusion through pores into the air. However, if the sampling time interval is extended excessively, gas fluxes might not be accurately measured as they are affected by chamber humidity and temperature head space [5].

Greenhouse gases flux measurement using the closed chamber method is affected by the coverage of the area and also the duration of sampling. In this study, for the horizontal emission, only an area of 10 m $\times$ 10 m was measured and at an interval of 6 h over 24 h. This may have led to the inconsistencies of data due to a small area and shorter time. As for the vertical emission, only two depths (0–5 cm and 5–10 cm) were measured for GHG emission. Therefore, it is suggested that in the future, a larger area should be considered as well as a longer sampling time to increase consistencies. It is also recommended that studies in the future should measure GHG emission from the soil surface up to the water table surface so as to understand how the depth of peat soils influences GHG emissions. In addition, it is important to measure GHG emission regardless of dry and wet periods; or in other words, measuring GHG emission for one whole year for a perfect GHG emission trend instead of only one or two months for both dry and wet periods.
4. Conclusions

Soil N\textsubscript{2}O emission from the cultivated peat soils was affected by fertilization. Applications of nitrogen fertilizer generally increased the rate of N\textsubscript{2}O emission as it increased the availability of nitrogen substrate in the peat soils in the dry and wet periods. Horizontal N\textsubscript{2}O flux from the peat soil cultivated with pineapple was higher during the dry period (832.77 t N\textsubscript{2}O ha\textsuperscript{-1} yr\textsuperscript{-1}) than in the wet period (599.81 t N\textsubscript{2}O ha\textsuperscript{-1} yr\textsuperscript{-1}) because of C and N substrate in the peat soil, in addition to the fertilizer used in fertilizing the pineapple plants. Vertical N\textsubscript{2}O emission was higher in the dry seasons (44.64 t N\textsubscript{2}O ha\textsuperscript{-1} yr\textsuperscript{-1}) than in the wet season (38.95 t N\textsubscript{2}O ha\textsuperscript{-1} yr\textsuperscript{-1}) because of nitrification and denitrification of N fertilizer. There was no correlation between the horizontal or vertical movements of N\textsubscript{2}O and soil temperature, suggesting that these factors are not related. Therefore, it can be concluded that N\textsubscript{2}O movement in peat soil under pineapple cultivation on peatlands occurs horizontally and vertically, regardless of season, and there is a need to ensure minimum tilling of the cultivated peat soils to prevent them from being an N\textsubscript{2}O source instead of an N\textsubscript{2}O sink.

Therefore, it is hoped that the findings from this study are capable of providing indication on appropriate approach and methodology in their measurement so as to improve the accuracy and subsequently minimize controversies. It is also a hoped that the proposed study will provide an indication on farm management procedures in dealing with the emission of the potent gases.

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