Thermal Distribution Analysis Of Heating System For Optimization Of Co2 Gas Sensor Detection

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Abstract. Soil takes a big role as a source of excess CO2 gas emissions mainly peat soils that contain a lot of organic matter. One of the factors that influence is soil temperature. The research aims to analyze the temperature distribution at the surface of the soil to optimize the detection of CO2 gas sensors. The method using peat soil placed in the chamber, the heater was placed on it, and a number of thermometer-digitals are placed at several points on its surface in the x-y axis by distance from the heater is 5cm, 10cm, and 15cm. The temperature distribution at 5cm, the temperature alteration toward time is 0.0020oC/s, at 10cm is 0.0004oC/s, and at 15cm is 0.0001oC/s. Based on it, the optimal distance used in the design of 5cm and 10cm distance. This result can be used as supporting data for a portable CO2 concentration gauge for soil.

Keywords: Temperature distribution, Temperature alteration, Peat soil, CO2

1 Introduction

Excess CO_2 gas emissions in the atmosphere are the cause of global warming. According to the Intergovernmental Panel on Climate Change, the earth's temperature has raised 0.74 ± 0.18 °C for one hundred years, from 1906 to 2005. The concentration of CO_2 in the period before the industrial revolution was 278 ppm (parts per million), and increased thereafter in 2005 to 379 ppm [1] CO_2 emissions also come from soil respiration, biomass burning, and decay of organic waste [2]. Indonesia emits quite large CO_2 gas from anthropogenic sources compared to other countries in Asia [3]. According to Klemedtsson, agricultural activity accounts for 25% of total CO_2 emissions from anthropogenic sources [4]. Meanwhile, according to Norberg, CO_2 emissions are also caused by agricultural activities that develop farming by making drainage, thus accelerating the process of decomposition of organic matter and emitting CO_2 into the air [5]. Therefore, soils play a large role as a source of CO_2 gas emissions, especially peat soils [6] that contain a lot of organic matter [7].

The CO_2 emissions influence by temperature, soil moisture, and electrical conductivity [8] [9]. While these factors depend on climate, hydrology, and soil type, so they also directly influence the amount of CO_2 emissions [10]. The temperature which is most of the factors causing CO_2 gas emissions from the soil can be studied through this research. The purpose of

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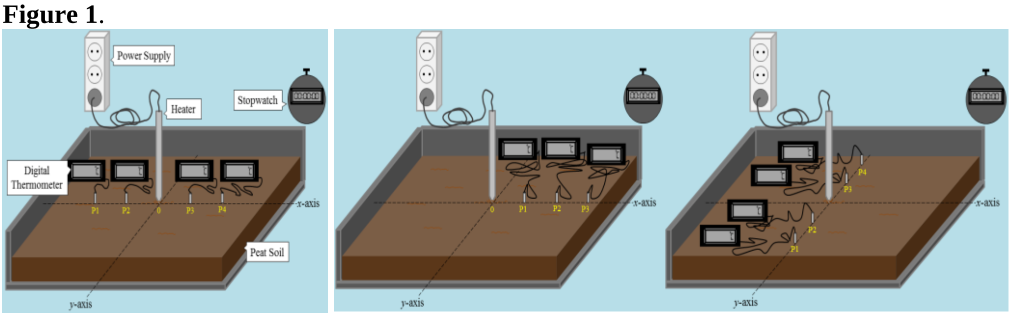
this study is to analyze the temperature distribution at the ground surface. The results of this study can be used as a benchmark in an effort to optimize the detection of CO_2 gas sensors on the ground by designing an appropriate heating system.

2 Method

This study uses an experimental method through a series of tests. Tests carried out using the equipment, namely the chamber earth, heater, digital thermometer, and stopwatch. The study used peat soils as soil samples. The soil had placed in a chamber with dimensions of $40 \times 26 \times 12$ cm^3, the heater has placed on it, and a number of thermometers are placed at several points of the ground surface in the *x*-axis and *y*-axis direction with variations in distance plotted from the heater which are 5 cm, 10 cm, and 15 cm. This test is carried out on the *x*-axis and *y*-axis as **Figure 1**.



(a) (b) (c)

Fig. 1. Schematic Test of Temperature Distribution at (a) x-axis and (b) y-axis,(c) Maximum Distance Testing Scheme Effect of Temperature Alteration.

Based on the characteristics of peat soils is hydrophobia irreversible. There are very dry, flammable, and cannot absorb water again, so it cannot be planted [11], so the heating proses had noticed. The processes were heating temperature and the length of time. In addition, a portable CO_2 concentration meter designed with a heating system from the results of this test was intended to not damage the measuring object. Therefore, the length of time for the soil heating process as well as data collection in each test was limited, only for about 15 to 20 minutes. Determination of the test point of the sensor distance to the heater was determined from the results of the temperature distribution test.

The sensor used to detect CO_2 gas was the MG811 gas sensor. The CO_2 gas detection part of the MG811 sensor was attached to a PVC pipe with a diameter of 20 mm, a thickness of 1.5 mm, and a length of 70 mm with half the end of the PVC pipe 10 mm open. The part of the open PVC pipe was faced with the heater with the aim that the CO_2 gas flowing or distributed due to heat from the heater was captured and entered the pipe until it can be detected by the MG811 sensor. Data retrieval takes 30 minutes. During the time of data collection, changes in ground surface temperature were observed and recorded. While the results of measurements of CO_2 concentrations at ground level are observed and recorded on a computer. Retrieval of CO_2 concentration data was regulated through a microcontroller program with data collection time set every 10 seconds.

3 Result and Discussion

Data obtained from temperature distribution testing was shown in the graphs of temperature alteration with respect to time at each predetermined test point, namely in the x-axis and y-axis directions. Meanwhile, effective distance testing was only done on one side of the axis. Furthermore, the CO2 gas sensor response testing carried out at the effective distance test point.

3.1 Testing Temperature Distribution on Peat Soil Surface

Peat soil have been weighed, it's 1998 g. Then placed in the chamber and leveled. All measurements of soil temperature observed to change simultaneously with the time of change by x-axis direction Observations were made using the help of video recording media via mobile phones so that changes in temperature at any time were easily observed. After getting an observational video track record, then the temperature change data at any time can be plotted and processed to obtain the graph shown by **Figure 2**. After testing the temperature distribution on the x-axis, peat soil had weighed again. The weight of the peat soil became 1880.7 g, which has been reduced as much as 117.3 g, because in this test the retrieval of the data collection took place, so the process of heating the land occurred quite long, that is for more than one hour. This shows that the heated peat soil experienced a reduction in mass, because the water content in the peat soil had evaporated during the soil heating process. Evaporation of water can also be an indication that CO_2 from the soil has been emitted into the air together with water vapor.

The peat soil used weighs 1880 g. This test carried out in the same manner as testing in the x-axis direction. From the observation video, it can be obtained temperature change data each time. Then the data was processed, so the graph shown by **Figure 3** by Y-axis direction. After this stage of testing completed, peat soil was re-weighed. The weight of the peat soil became 1858.8 g, the weight of the soil was reduced by 21.2 g.

The graph in **Figure 2** and **Figure 3** show the rise in temperature each time at each soil test point. At a soil test point distance of 10 cm from the heater it has a smaller gradient compared to a test point distance of 5 cm. While the gradient value on the graph was the value of temperature change with time, or also called the rate of temperature change. This showed that the soil which closer to the heater has a rate of temperature change greater than the more distant land.

The results of data processing from recorded video recordings obtained show **Figure 4**. It shows three temperature change graphs each time from temperature data measured by three thermometers on the right side of the heater. Graph $\Delta T1$ had the result of plot data from the thermometer which placed 5 cm from the heater, and has a temperature change rate of 0.0019°C/s. Graph $\Delta T2$ shown a plot of data from a thermometer that placed 10 cm from the heater, and has a temperature change rate of 0.0006°C/s. Whereas the $\Delta T3$ graph had a plot of data from a thermometer placed 15 cm from the heater, and has a temperature change rate of 0.0001°C/s. The data obtained in the test (with limited time) for a variation of the distance of 15 cm are only two data and the value of the temperature change rate too small to be used in testing the distribution of CO_2 on the ground surface.

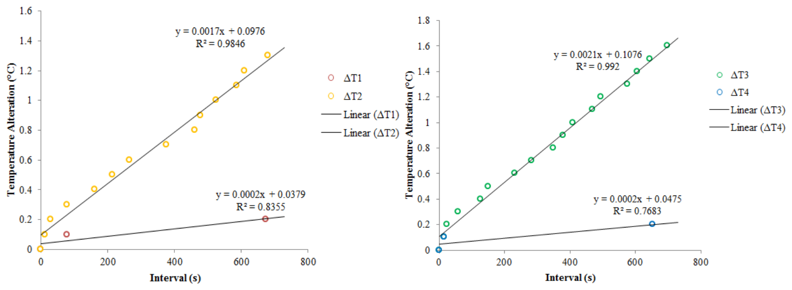
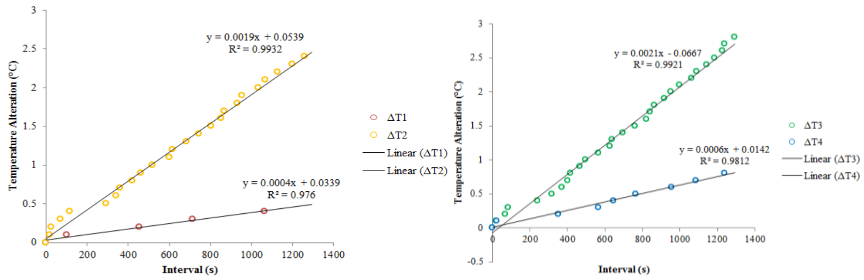


Fig. 2. Temperature Alteration toward Time Graph for x-axis (a) Left Side Heater and (b) Right Side Heater.

(a)



(a) (b)

Fig. 3. Temperature Alteration toward Time Graph for y-axis (a) in Front of Heater and (b) Behind Heater.

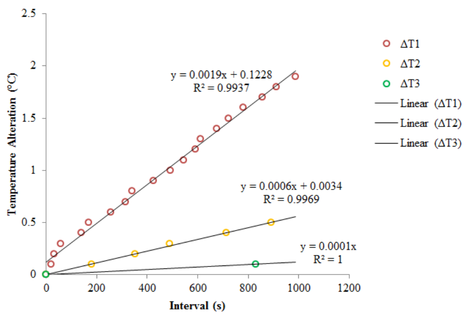


Figure 4. Graph of Temperature Change with Time for Three Test Points Based on the entire series of temperature distribution tests on the surface of the ground that have been carried out, the results obtained are as follows.

At a distance of 5 cm, the average temperature change rate is 0.0020°C / s, at a distance of 10 cm, 0.0004°C / s, and at a distance of 15 cm at 0.0001°C / s. Temperature distribution at the ground surface occurs evenly in the radial. This can be reviewed based on the values of the temperature change rate of each test in all radial directions shown by **Figure 5**. In fact, the temperature distribution on the ground occurs radially in all directions, three dimensions. However, this research limited to the surface of the soil was the *x*-axis and the *y*-axis direction.

The results in **Figure 5** also show that the rate of temperature change at the surface of the land which had closer to the heater had greater than the value of the rate of change in the surface temperature of the soil that had farther away. Based on these results, the optimal distance used in the design of the heating system were 5 cm and 10 cm. Because the rate of temperature change at a distance of 15 cm is very small, so it requires a longer data collection time compared to variations in the distance of 5 cm and 10 cm.

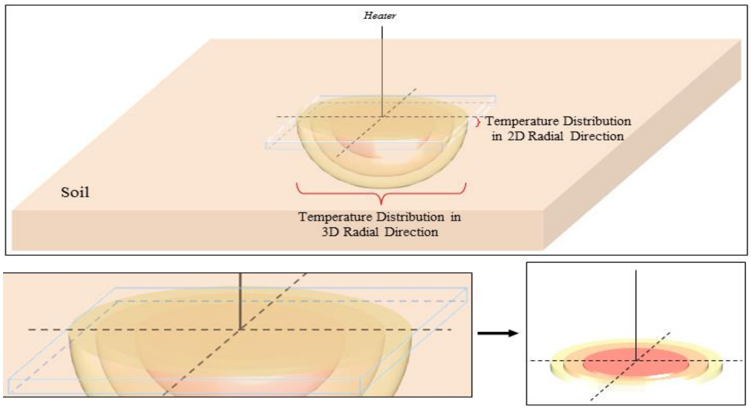


Fig. 5. Temperature Distribution Diagram at Surface of Land.

3.2 Testing of the CO_2 Gas Response Sensor to the Effective Distance of the Heater

Testing MG811 sensor response to CO_2 gas emitted at the surface of peat soil due to temperature rise by the heater using the range of distance that has been determined at the stage of temperature distribution testing, namely at points P1 and P2. Point P1 as point test was 5 cm from the heater and point P2 as point test was 10 cm from the heater.

P1 point test results obtained in the form of graphs of changes in CO_2 concentration each time are shown by **Figure 6**. Based on these results, the MG811 sensor only responds in the time span from the 100th s to the 1000th s, and outside the time range only reads the value "<400 ppm", because the sensor's ability can only detect CO_2 concentrations above 400 ppm [12][13]. So the optimal time range of the MG811 sensor to detect CO_2 concentrations from the soil is around 1000 s (17 mnt) in this test. Meanwhile, the concentration of CO_2 detected by the sensor is only in the range of 400 – 404 ppm. When 130th s, the sensor detects a CO_2 concentration of 401 ppm, with a soil temperature of 26.2°C, at the 150th s, of 404 ppm with the same temperature, 26.2°C, at the 920th s, at 402 ppm, with a temperature 27.6°C, and at the 1000th s, equal to 401 ppm, with a temperature of 27.8°C.

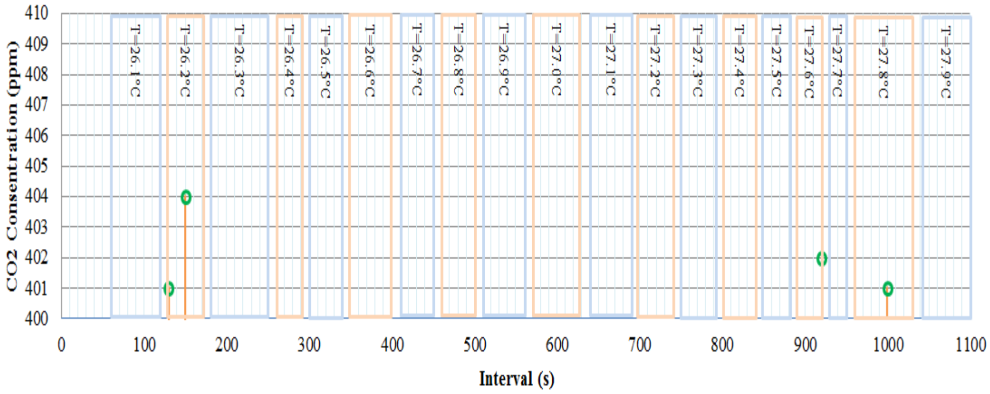


Fig. 6. Temperature Alteration Diagram of Changes in CO2 Concentrations Each Time Unit at Test Point P1.

The P2 test results are shown by **Figure 7**. Based on the graph, the MG811 sensor only responds in the time span from the 100th s to the 850th s, and outside the time range only reads the value "<400 ppm". So the optimal time range for the MG811 sensor to detect CO_2 concentrations from the soil is about 850 s (15 mnt) in this test. Meanwhile, the concentration of CO_2 detected by the sensor is only in the range of 400 – 434 ppm. Based on these results, the plot value is very volatile, but the CO_2 concentration value can be determined by calculating the average value. Calculation of the average CO_2 concentration values that are read by the MG811 sensor at point P2 during the optimal time in testing can be seen in Table. 1. In calculating the average, only high CO_2 concentration values are taken and there are quite a lot of data in a degree of temperature.

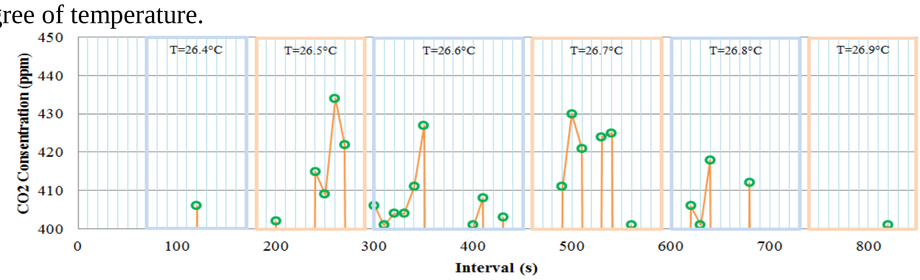


Fig. 7. Temperature Alteration Diagram of Changes in CO2 Concentrations Each Time Unit at Test Point P2.

Table 1. The Average Measurement Result of CO2 Concentration by the MG811 Sensor.

Temperature (°C)	Concentration of CO_2 (ppm)	Average (ppm)
26.5	402	416.40
	415	
	409	
	434	
	422	
26.6	406	407.22
	401	
	404	
	404	

Temperature (°C)	Concentration of CO_2 (ppm)	Average (ppm)
	411	
	427	
	401	
	408	
	403	
26.7	411	418.67
	430	
	421	
	424	
	425	
	401	

Based on the results of data processing, MG811 sensor response to P1 point testing is less stable. Because, it can be seen in **Figure 6**, the sensor detection results are not constant. Even in certain ranges it only reads "<400 ppm". According to the kinetic theory of gas, the higher the temperature of a system, the greater the average kinetic energy possessed by the gas particles in the system. Therefore, CO_2 particles that are bound to the surface of the soil when heated will get more kinetic energy to escape. With greater energy, it is possible for CO_2 particles to have greater speeds, making it difficult for sensors to detect. Meanwhile, point P2 testing is quite stable. It can be seen in Table. 1. Average 1 which shows the average value of CO_2 concentration for one temperature degree state, the value of CO_2 concentration is constantly fluctuating with each increase in temperature. At the time of data retrieval above the 850th s, the sensor does not detect CO_2, which reads only the value "<400 ppm". This is due to the surface of the ground has lost a lot of CO_2 particles.

4 Conclusions

Based on the results of research that has been done, it can be concluded that temperature distribution at the ground surface occurs evenly in all directions or radial directions. The further the distance of the soil from the heater, the smaller the influence of the heater on the change in temperature of the soil. The optimal distance that is good to use in the design of heating systems for the design of CO_2 level measuring devices on the soil is 5 cm and 10 cm. Testing the response of the MG811 sensor at an optimal distance of the 10 cm test point is more stable than testing at the 5 cm test point.

References

[1] IPCC WG1 Report: Climate Change 2007 The Physical Science Basis – Frequently Asked Questions and Selected Technical Summary Boxes. Retrieved Februari 27, 2019, from https://wg1.ipcc.ch/publications/wg1-ar4/faq/docs/AR4WG1_FAQ-Brochure_LoRes.pdf (2007)

[2] Samiaji, T.: Gas CO2 di Wilayah Indonesia. Berita Dirgantara, XII(2), 68-75 (2011)

[3] Streets, D. G., Bond, T. C., Carmichael, G. R., Fernandes, S. D., Fu, Q., He, D., et al.: An Inventory of Gaseous and Primary Aerosol Emissions In Asia In The Year 2000. Journal of Geophysical Research, CVIII(D21), GTE 30 - (1-23) (2003)

[4] Klemedtsson, A. K., Klemedtsson, L., Berglund, K., Martikainen, P., Silvola, J., & Oenema, O.: Greenhouse Gas Emissions from Farmed Organic Soil: a review. Soil Use and Management, XIII, 245-250 (1997)

[5] Norberg, L.: Greenhouse Gas Emissions from Cultivated Organic Soil – Effect of Cropping System, Soil Type, and Drainage. Uppsala: Swedish University of Agricultural Sciences (2017)

[6] Handayani, E. P., Idris, K., Sabiham, S., Djuniwari, S., & Noordwijk, v. M.: Emisi CO2 pada Kebun Kelapa Sawit di Lahan Gambut: Evaluasi Fluks CO2 di Daerah Rizosfer dan Non-Rizosfer. Jurnal Tanah dan Lingkungan, XI(1), 8-13 (2009)

[7] Iryanti, M., Nugraha, H,D., Setiawan, T., Bijaksana, S., Mapping Peat Morphology in Sag Pond with Ground Penetrating Radar, AIP Conf. Proc. 1554, 265-268 (2013)

[8] Setia, R., Marschner, P., Baldock, J., Chittleborough, D., & Verms, V.: Relationship Between Carbon Dioxide Emission and Soil Properties in Salt-Affected Landscapes. Soil Biology and Biochemistry, XLIII(3), 667-674 (2011)

[9] Aminudin, A., Hasanah, T. R., & Iryati, M.: The Characteristics of Electrical and Physical Properties of Peat Soil in Rasau Village, West Kalimantan. In Journal of Physics: Conference Series (Vol. 1013, No. 1, p. 012178). IOP Publishing (2018, May)

[10] Hirano, T., Segah, H., Kusin, K., Limin, S., Takahashi, H., & Osaki, M.: Effects on Disturbances on The Carbon Balance of Tropical Peat Swamp Forest. Global Change Biology, XVIII(11), 3410-3422 (2012)

[11] Najiyati, S., Muslihat, L., & Suryadiputra, I. N.: Panduan Pengelolaan Lahan Gambut untuk Pertanian Berkelanjutan. Bogor, Indonesia: Wetlands International – Indonesia Programme dan Wildlife Habitat Canada (2005)

[12] CCS MIAMI: Datasheet MG811. Retrieved from https://eph.ccs.miami.edu/precise/GasSensorSpecs/CO2.pdf.

[13] Nebath, E., Pang, D., & Wuwung, J. O.: Rancang Bangun Alat Pengukur Gas Berbahaya CO dan CO2 di Lingkungan Industri. E-Journal Teknik Elektro dan Komputer, 65-72 (2014)