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The Role of Earthworms to CO_2 Concentration in Various Land-Uses

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Abstract
This research aims to study the influence of earthworms to the CO_2 concentration in various land-uses. As more forest areas are converted into plantation area, more closed ecosystems also shift to open ecosystems. The shifting has allegedly caused earthworms' population density to decrease and, consequently, influenced the CO_2 concentration. This research selects six areas as the location of the research including forest area, complex agroforestry area, simple agroforestry area, teak forests, teak-acacia forests and groundnut plantation area in Gondangrejo, Central Java, Indonesia. The earthworm's inventory is gathered with monolith method. On the 20^{th} day of measurement, CO_2 from fume hoods prepared for the research is collected. This research finds that the type of land-use influences significantly to earthworms' population density and to CO_2 concentration. The research finds that earthworms can reduce CO_2 concentration in forest area, complex agroforestry area, simple agroforestry area, teak forests and teak-acacia forests. Earthworms, on the other hand, increase CO_2 concentration in groundnut plantation area. This research, therefore, concludes that earthworms' density and soil's humidity contribute to the animals' role in impacting CO_2 concentration of a certain area.
Keywords: *earthworm population density, land-use, CO_2 concentration*

1. Introduction

The conversion of forest areas into agriculture areas has stripped trees off its function to provide land cover. Open ecosystems become ubiquitous compared to closed ecosystems. Such land-use management system, scholars have argued, has impacts to CO_2 concentration, a pivotal key to the success of a harvest in agricultural area (Flessa *et al*. 2002; Dalgaard *et al*. 2003). Various land-uses cultivated with diverse horticulture plants have been proven to influence CO_2 concentration both in the atmosphere and in soil. Some natural factors contribute to the CO_2 concentration in soil. They include temperature, rainfall rate, organic materials in the soil, nutrients, oxygen volume and the type of ecosystem. Recent studies show that our soil emits more CO_2. However, our earth currently lacks of forest areas that can absorb CO_2 as their numbers are continuously dwindling. Therefore, such condition has resulted to global warming and climate change unfolding in our era.

Besides the global warming, forests cover's existence is also influential to the lives of various macrofauna that rely on them, including earthworms. Forests cover sets a microclimate of a certain area that will subsequently influence soil's humidity, an essential factor needed by earthworms to live (Hairiah. K. *et. al.,*2004). Without proper number of forests cover, earthworms will find it difficult to find a suitable microclimate to live in. Without such, earthworm will also find troubles to find plant litters to feed on. Earthworm indeed needs an exclusive environment to live.

Hale *et al* (2006) states that the changing chemical structure and the number of nutrients in soil will influence the invasion of earthworm. Foth (1994) states that earthworms dislike saturated soil and avoid ultra violet radiation. In dry season, therefore, earthworms move to other more humid areas or to deeper soil layers (Sugiyarto, 2003). Earthworms also cannot feed on fresh litters as they can only eat on litters that have been decomposed in a certain period (Edward & Lofty, 1977).

According to various scholars, earthworms bring benefits to the soil they live in. Suin (1997) states that earthworms will increase the number of organic materials needed to repair the condition of soil structure, increase soil biological activity and add the number of nutrients. Earthworms feed on plant litters and decompose them as their casts (Rahmawaty, 2004). Yulipriyanto (2010) states that earthworms' cast contains Carbon, nutrients at a highest amount and a vast population of microorganism if compared to other soil minerals. Earthworm, in addition to the aforementioned benefits, will also make burrows functioning as pores through which CO_2 can be released to the atmosphere faster.

Given to the importance of earthworms, this research studies that animal's influence to the CO_2 concentration in various land-uses. This research argues that earthworms allegedly emit different CO_2 concentration depending on their habitat and the microclimate they live in. This research also argues that the density of earthworm population does not guarantee to the increasing CO_2 concentration produced from their respirations.

2.Research Methodology

This research took six types of land-use as its samples, consisting of forest area, complex agroforestry area, simple agroforestry area, teak forest area, teak-acacia forest area and groundnut plantation area. The earthworms were collected in dry season with monolith procedure. The earthworms' density was calculated by dividing the number of species with population (worms/m^2). The microclimate was measured every morning and afternoon, twice a week. To measure the microclimate, we observed soil's temperature, air's temperature, air's humidity, soil's humidity and light intensity. Microclimate is an important factor that influences the earthworm's density.

The research used a mesocosm facility that was divided into experimental group and control group. The first group contained earthworms and plant litters. While the second only contained plant litters. Acclimatization of earthworm in the mesocosm was conducted after the soil was incubated.

Meanwhile, CO_2 sample were gathered in the morning from various land-use on the 20^{th} day of observation. The CO_2 were collected inside a mesocosm facility, therefore, the gas collected really originated from earthworms being researched.

Analysis of variance (ANOVA) was then employed to study how a type of land-use may influence an environment where earthworms can live. The most significant result of the ANOVA test was then tested again with DUNCAN analysis.

T-test was also employed to study the differences between the experimental and control group. This research calculated the difference between CO_2 emission in each land-use of the experimental and control group (E-K) to study the influence of earthworm to the gas. The CO_2 volume increases if the difference is more than 0 and, in contrary, it decreases if the difference is less than 0.

3. Result and Discussion

3.1. The Influence of Land-Use to Earthworms' Density

Corrupted environments have less diverse vegetations that cause the number of plant litters to decrease. They also alter the biological, physical and chemical traits of the soil. Such environments also change the microclimate (Erniwati, 2008; Nuril *et al*., 1999). Therefore, corrupted environments usually home less diverse soil fauna.

According to Hairiah (2005) and Dewi (2007), the shifting function of forest to agriculture area has caused the soil to be more exposed. The absence of forests cause the number of plant litters to decline. It has a domino effect on the increasing soil's temperature and the decreasing soil's humidity. The soil, therefore, has fewer nutrients. Litters originating from plants living in environments poor of nutrient will decompose less easily and in result will delay the enrichment process of nutrient in that area. In contrast, litters from plants in a rich-nutrient environment will expedite the enrichment process of nutrient (Sulistiyanto, et al. 2005.,Van Breemen, 1995; Aerts & Caluwe, 1997).

Soil's humidity, as stated earlier, influences the density of earthworms. However, it is not the only key factor crucial to the density of the animal. The type of vegetations growing in the soil where the macrofauna live also influences its density (Rombke, J., Schmidt,P., Hofer,H. 2009). Therefore, that part of soil can be said as an ecosystem because the organisms living there have a dynamic relationship with its ever changing environment.

The research shows that there is a significant influence ($p<0,05$) between various types of land-use and the earthworms' density. In dry season, plant litters cover the soil's surface to maintain its humidity and other food resources for earthworms underground. In that season, earthworms will move the deeper soil layer to maintain its respiration system. The animal's ability to consume plant litters depends on the availability of litters as well as their carbon and nitrogen contents (Sulistiyanto,Y.et al. 2005).

Suprayogo *et. al.* (2003) explains that trees, annual plant and weeds in agroforestry area provide organic litters, encompassing fallen leaves, branches and tweaks, so that earthworms can feed on them. Therefore, the lost of diversity in an ecosystem will threaten the whole set of biological process at that environment. In consequence, the natural process will be replaced by some agro-chemical process (Dewi, 2007).

3.2. The influence of land-use to CO_2 concentration

Hairiah (2005) argues that the shifting function of forest area to agricultural area can increase CO_2 concentration because many plants, functioning to absorb the gas from atmosphere, no longer exist. The gas' increasing concentration, according to her, is also caused due to the decomposing process of dead vegetations.

Another scholar, Yulnafatmawita (2004), also asserts the same argument. She states that
the conversion of forests area to agriculture and plantation area may expedite the release of CO_2. The gas' emission is the product of soil's autotrophic and heterotrophic respiration happening underground. The gas will be released through soil's pores to the atmosphere.

This research tries to prove the aforementioned theories. The ANOVA test shows that various land-use plays a significant role ($p<0,05$) to the concentration of CO_2 emitted from earthworms in mesocosm on the 20th day of measurement. Soil in the annual plant area – the groundnut plantation area – lost a considerable amount of carbon due to land cultivation. Land cultivation activity, which includes fertilizing, increases the volume of carbon in the plants' biomass. Such activity will consequently change the structure of the soil itself. Therefore, in this term, humans play role to add CO_2 volume emitted to the atmosphere.

Meanwhile, in the complex agroforestry area, the soil harbors different types of trees that produce various kinds of litters. Therefore, earthworms will have a high biomass which can decrease the emitted CO_2 volume. According to Hairiah *et. al.* (2008), agroforestry areas contribute to the decreasing concentration of CO_2 in the atmosphere quite significantly because the areas store a considerable amount of carbon. The stored carbon at the agroforestry may not be compared to those at natural forests, but still, they are better than carbon stored at monoculture plantation. Yet, the most significant benefit of agroforestry lies on its capability to solve land-use conversion issues. Agroforestry can protect the income of farmers as long as they can make correct choices of trees to plant. In addition, correct land-use management system and supportive market policy are also needed to support agroforestry.

Different types of plantation cover grounds on different types of land-use. Consequently, Carbon emission in such areas will also differ one to another due to the diversity of vegetations' photosynthesis process. CO_2 emitted from soil is the product of root respiration, the decomposition of soil organic materials, biological oxidation of microorganism, soil organism and vegetation's part under the surface. Soil respiration releases CO_2 to the atmosphere.

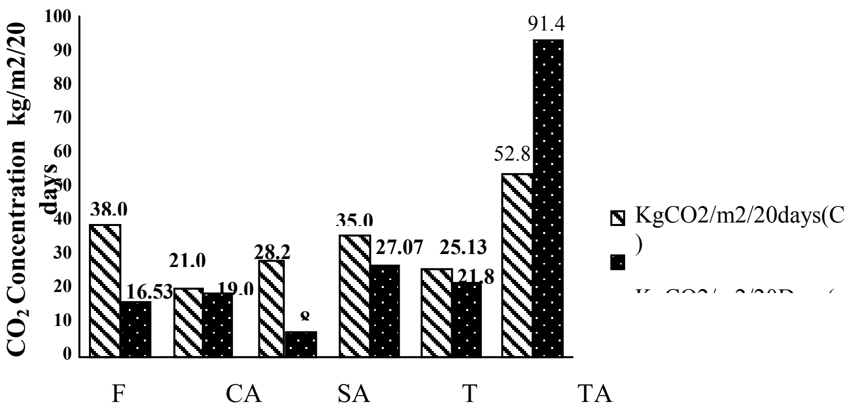
CO_2 concentration in various land-uses also depends on earthworms' density and soil density. This research finds that forests area which has the highest population of earthworms, in fact, has the declining emission of CO_2. This is because the gas' concentration in the area is also related to the soil's humidity.

This research also specially finds various variables pivotal to the role of earthworms' to influence CO_2 concentration in various land-uses. They include fertilizing activity, soil's humidity, type of seasons and earthworms' density.

3.3. The Role of Earthworm to CO_2

In each type of land-use, earthworms play different roles in determining the concentration of CO_2. They may both decrease or increase the concentration of the gas. They, therefore, have important roles in our lives.

The result of t-test conducted on the 20th day of measurement shows a significant difference ($p<0,05$) of CO_2 concentration in both experimental and control group. Within 20 days, this research records an average CO_2 concentration at 33.41 kg $CO_2/m^2/20$ days emitted from control group's mesocosm. The gas was emitted from plant litters' decomposition process. Meanwhile, within the same period, the research records some 30.67 kg $CO_2/m^2/20$ days of CO_2 emitted from earthworms' respiration and plan litters' decomposition at the experimental group's mesocosm. The research recorded the average difference of CO_2 concentration in 20 days at minus 2.74, meaning that the gas' concentration decreased by 2.74 kg $CO_2/m^2/20$ days.



Earthworms' density in different land-uses

Figure 1: The histogram of CO_2 concentration produced by earthworms on the 20th day of measurement

Notes: F= Forest area, CA = Complex Agroforestry area, SA = Simple Agroforestry area, T = Teak forest area, TA = Teak-acacia forest area, G= Groundnuts plantation area

C= Control group (without earthworms), E= Experimental group (with earthworms)

Figure 1 shows the level of CO_2 concentration at the experimental group on the 20th day of measurement from the highest to the lowest one consecutively as follows: annual groundnut plant (91.46 kg/$CO_2/m^2/20$ days), teak

(27.07 kg/CO_2/m^2/20 days), teak-acacia (21.87 kg/CO_2/m^2/20 days), forests (16.53 kg/CO_2/m^2/20 days), complex agroforestry (19.07 kg/CO_2/m^2/20 days) and simple agroforestry (8 kg/CO_2/m^2/20 days).

The study chooses *Ponthoscolex corethrurus* and *Metaphire javanica* as the type of earthworms from the inducted worms because they naturally live in the six areas being researched. The CO_2 concentration at groundnuts areas is very high because it belongs to an open space area which has higher temperature than the other five areas.

This research records a decreasing number of CO_2 concentration at all areas except the annual groundnut areas both in the experimental and control group. The decreasing, as well as the increasing, of the CO_2 concentration is influenced by both earthworms' density and the soil's humidity, according to the result of stepwise regression test conducted on the 20th day of measurement as depicted by figure 2.

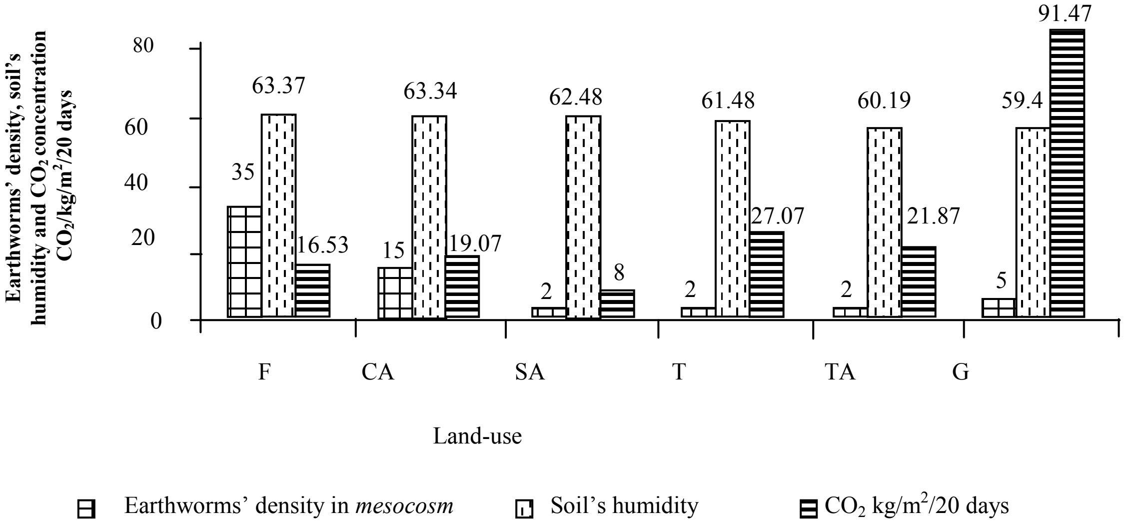


Figure 2. The histogram on earthworm density, soil huimdity and CO_2 concentration on the 20th day of measurement

Notes: F= Forest area, CA = Complex Agroforestry area, SA = Simple Agroforestry area, T = Teak forest area, TA = Teak-acacia forest area, G= Groundnuts plantation area

The research records a declining concentration of CO_2 in these mesocosm facilities from the highest amount of volume consecutively as follows: in forest area at 21.54 kg CO_2/m^2/20 days, complex agroforestry at 20.27 kg CO_2/m^2/20 days, teak area 8 kg CO_2/m^2/20 days, teak-acacia 3.26 kg CO_2/m^2/20 days and complex agroforestry 2 kg CO_2/m^2/20 days. The concentration of CO_2 however increases at annual groundnut plantation area at 38.6 kg CO_2/m^2/20 days, the research shows.

Figure 3 is provided below to elaborate more on the increasing and the decreasing volume of CO_2 emission on the 20th day of measurement.

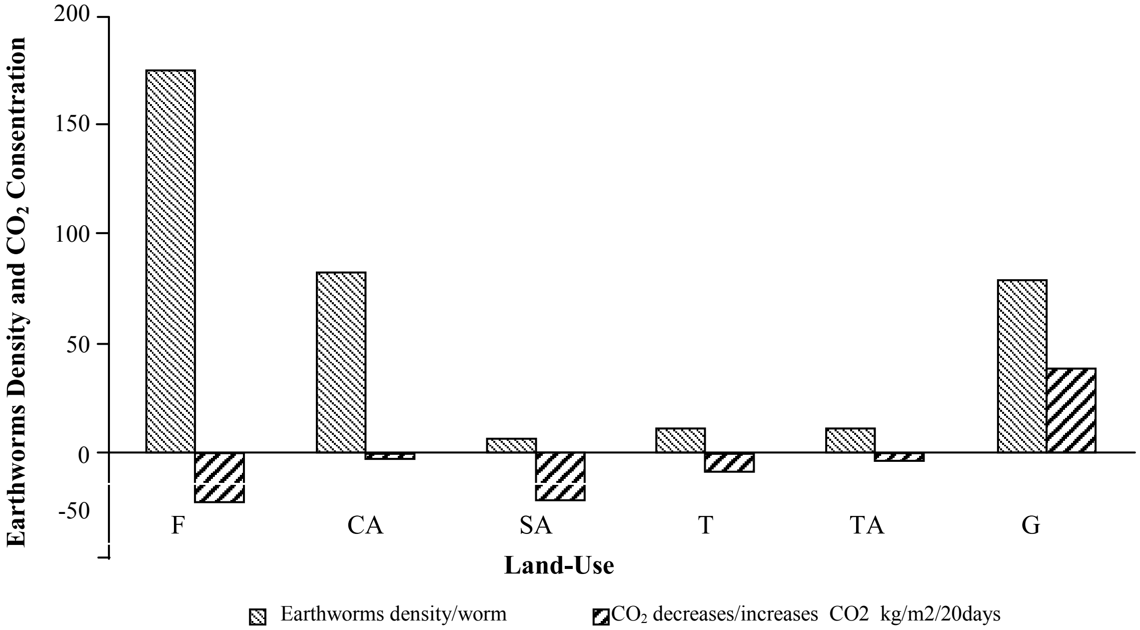


Figure 3. The histogram on earthworm density, CO_2 concentration on the 20th day of observation in various land-uses

Notes: F= Forest area, CA = Complex Agroforestry area, SA = Simple Agroforestry area, T = Teak forest area, TA = Teak-acacia forest area, G= Groundnuts plantation area

The result of the measurement of CO_2 on the 20th day shows that forest area is an area that has the least concentration of CO_2 and has the highest density of earthworms. This result, therefore, is consequent with the stepwise regression test conducted earlier, saying that soil's humidity and earthworms' density contribute to suppress the emission of CO_2. In both rainy and dry season, soil in forest area is always humid because the area homes so many trees to cover the land. Thanks to the humid soil, the number of earthworms can multiple. However, the vast numbers of earthworms only emit a relatively small volume of CO_2. The gas is often easily carried away by the water due its insignificant volume. The humidity in the area has kept the soil from releasing too much amount of CO_2. This is different when we compare it to hotter and more open area, like at groundnut plantation, where CO_2 is released at a considerable volume. The absence of forests cover has increased the soil's temperature and consequently increased the emission of CO_2 from the ground.

Our nature has a complex and yet stunning system regarding to the relation of soil, earthworms, plants and CO_2. The density of earthworms is physiologically related with CO_2 in terms of the animal's respiration system. Meanwhile, as we have noted, the macrofauna's live depends heavily on the microclimate and plant litters as their source of food. If a soil hosts more earthworms, the soil will become more fertile. However, at the same time, that more fertile soil releases a larger amount of CO_2. In addition to those complex natural linkages, the climate also influences the concentration of CO_2. In dry season, soil respiration activity will be higher than at rainy season. Therefore, in result, soil releases more CO_2 in dry season. Any disruption to the link, therefore, will influence of CO_2 concentration.

A study by Lessard *et. al.* (1994) cited by Ade Irawan (2009) shows that soils in forest areas produce larger CO_2 flux compared to agricultural area, bare ground area or plantation area because forest area host more diverse organic materials in its soil. In dry season, earthworms will move to the lower soil layers. Therefore, the production of CO_2 inside the soil is higher than at the surface. Despite living underground, earthworms continue to feed on organic resources the mother earth provides for them. They will resurface once the microclimate is at their favor. The CO_2 released by earthworms in mesocosm also depends on their density, the number of species and the speed of decomposition process. Besides, the environments where earthworms live also influence their emission of CO_2.

More earthworms mean more burrows or micro pores underground (Dewi, 2007) through which CO_2 can be released to the atmosphere. Without such pores, CO_2 difussion from soil to the atmosphere will be hampered, if not disturbed. Pores created by earthworms will also help water circulate freely and trees' roots move easier. The pores will also make the soil more fertile and friable.

4. Conclusion

This research notes that earthworms' population is very dense at forest area and followed consecutively by complex agroforestry area, groundnut plantation area, teak area, teak-acacia area and simple agroforestry area. They give diverse influence to the CO_2 concentration at those areas. Earthworms can increase CO_2 emission in groundnut area and decrease the emission, from the highest to lowest, at forest area, simple agroforestry area, teak-acacia forestry and complex acacia area.

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