Carbon Dioxide Efflux from Subterranean Ant Nests in Dry Evergreen Forest at Sakaerat Environmental Research Station, Thailand

By

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Ants are social insects, classified in the family Formicidae, order Hymenoptera, consisting of 12,500 described species in 290 genera, 21 subfamilies.

Ants show not only high species diversity, but also high variation in species component at local as well as regional scales.
Role of ants

Ants play the role of the so-called “ecosystem engineers”, and they significantly influence ecosystems by creating or modifying their habitats.

Beavers are the most typical example of “ecosystem engineers”, and they dominantly influence the ecosystem properties by creating huge nests called “beaver dams”
Diverse ant species utilize a variety of habitats, from underground up to canopies, for their nesting places.

Among them, subterranean nesting species are dominant component of ant fauna in tropical ecosystems, where the greatest diversity and density of ants occurs.
Subterranean-nesting ants largely modify their nesting sites, and have been thought to affect the processes in the soil, which are an important part of ecological processes in tropics.
In nesting sites of subterranean-nesting species, ants generally construct underground tunnels and chambers, causing an intensive alteration in the soil profiles. Additionally, there can be found accumulations of organic matters (for example, food and nesting material).
Although there have been studies that investigated effects of subterranean ant nests on soil chemical and physical properties, few studies have focused on the idea below—
Ant nests could enhance aeration in the soil, which not only provide oxygen to underground organisms (for example, ant individuals), but also facilitate emission of waste gases such as carbon dioxide.
Carbon dioxide in subterranean ant nests can be expected to be emitted from entrance holes at high concentrations, which may affect carbon balance in tropical ecosystems.
A recent study in Malaysian forest proposed that subterranean ant nests may cause “hot spots of soil respiration (extremely high emission of carbon dioxide from the soil), which will significantly affect the current estimate of carbon dioxide emission from tropical forests.
Objectives

1. Quantification of the CO$_2$ efflux from subterranean ant nests by comparing them to CO$_2$ efflux from the surrounding soil.

2. Relationship between environmental factors of ant nests and their CO$_2$ effluxes.

3. Variation of nest CO$_2$ efflux among ant species.

4. Potential impacts of nest structure on the CO$_2$ efflux in subterranean nests.
We conducted our experiment from October, 2010 to September, 2011.
We identified the entrance holes of potential Subterranean ant nests using the food baiting method.
Materials and methods: number of entrance holes

Single hole types  Multiple hole types
Ant nests were observed and selected, based on the number of entrance holes (Fig 1). We carefully selected and measured to the CO$_2$ emission rate without effects of ant nest (i.e., major holes), seedling, insect nest, and big or small root on forest floor, it were estimated by naked eye.

1. The colony sampling method

Measurements of CO$_2$ efflux
Nest and soil CO₂ efflux measured by using commercial respiration chamber and infrared gas analyzer.
Measurements of environmental factors

Soil temperature and moisture content at CO₂ measured point measured at each measurement point.

1. A thermometer (MODEL PC-9215, SATO, Japan)
2. A moisture sensor (ThetaProbe type ML2x, Delta-T Devices Ltd., UK)
3. A moisture sensor (ThetaProbe type ML2x, Delta-T Devices Ltd., UK)

A thermometer (MODEL PC-9215, SATO, Japan)
The difference in CO$_2$ effluxes among ant nests and the soils, season and ant species by General Linear Model analysis.

The effect from the different hole type on CO$_2$ efflux for ant nests were determined using a two-way ANOVA.

To compare the relationship between CO$_2$ efflux and environmental factors (i.e., soil temperature and moisture content) by linear regression analyses.

The relationship between the mean diameter of entrance holes per nest and nest CO$_2$ efflux by linear regression analysis.

All statistical analyses were performed with SPSS ver. 20.0.0 for Windows.
### Result: CO₂ efflux from ant nests in the wet and dry seasons

<table>
<thead>
<tr>
<th>Species</th>
<th>Species Code</th>
<th>Number of ant nest</th>
<th>Ant body size</th>
<th>Number of nest holes</th>
<th>Hole diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Anochetus graeffei</em> Mayr, 1870</td>
<td>A1</td>
<td>4 [1,3]</td>
<td>4.2 (0.03)</td>
<td>1</td>
<td>4.1 (0.3)</td>
</tr>
<tr>
<td><em>Anochetus</em> sp.2 of AMK</td>
<td>A2</td>
<td>4 [1,3]</td>
<td>4.9 (0.02)</td>
<td>1</td>
<td>4.5 (0.2)</td>
</tr>
<tr>
<td><em>Anoplolepis gracilipes</em> (Smith, 1857)</td>
<td>AG</td>
<td>5 [2,3]</td>
<td>4.8 (0.03)</td>
<td>1-3</td>
<td>37.3 (1.0)</td>
</tr>
<tr>
<td><em>Aphaenogaster</em> sp.1 of AMK</td>
<td>AP</td>
<td>6 [3,3]</td>
<td>5.4 (0.04)</td>
<td>1</td>
<td>9.9 (0.4)</td>
</tr>
<tr>
<td><em>Diacamma cf. vagans</em> (Smith, 1860)</td>
<td>DV</td>
<td>5 [2,3]</td>
<td>9.8 (0.11)</td>
<td>1</td>
<td>12.8 (0.8)</td>
</tr>
<tr>
<td><em>Harpegnathos venator</em> Donisthorpe, 1937</td>
<td>HV</td>
<td>3 [3,0]</td>
<td>12.8 (0.11)</td>
<td>1</td>
<td>18.3 (0.9)</td>
</tr>
<tr>
<td><em>Odontoponera denticulata</em> (F. Smith, 1858)</td>
<td>OD</td>
<td>6 [3,3]</td>
<td>9.5 (0.08)</td>
<td>1-3</td>
<td>3.6 (0.2)</td>
</tr>
<tr>
<td><em>Odontomachus rixosus</em> Smith, 1857</td>
<td>OR</td>
<td>6 [3,3]</td>
<td>10.8 (0.05)</td>
<td>1-2</td>
<td>43.5 (6.4)</td>
</tr>
<tr>
<td><em>Pachycondyla astuta</em> (Fr. Smith, 1858)</td>
<td>PA</td>
<td>4 [1,3]</td>
<td>16.3 (0.28)</td>
<td>1-2</td>
<td>4.9 (0.1)</td>
</tr>
<tr>
<td><em>Pheidole hongkongensis</em> Wheeler, 1928</td>
<td>PH</td>
<td>4 [1,3]</td>
<td>2.5 (0.00)</td>
<td>1-2</td>
<td>1.6 (0.1)</td>
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<tr>
<td><em>Pheidole plagiaria</em> Smith, 1860</td>
<td>PP</td>
<td>5 [2,3]</td>
<td>3.5 (0.01)</td>
<td>1</td>
<td>48.8 (1.6)</td>
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<tr>
<td><em>Pheidole parva</em> Mayr, 1865</td>
<td>PV</td>
<td>4 [1,3]</td>
<td>1.7 (0.03)</td>
<td>1</td>
<td>1.3 (0.2)</td>
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<tr>
<td><em>Tetramorium lanuginosum</em> Mayr, 1870</td>
<td>TL</td>
<td>5 [2,3]</td>
<td>2.5 (0.03)</td>
<td>1</td>
<td>1.9 (0.1)</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
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<td></td>
<td><strong>61</strong></td>
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</table>
Results: CO$_2$ efflux from ant nests in the wet and dry seasons

Dry season:
- A
- a
- 0.8-24.7 µmol CO$_2$ m$^{-2}$ s$^{-1}$

Wet season:
- A'
- a'
- 1.3-6.1 µmol CO$_2$ m$^{-2}$ s$^{-1}$

- B
- b
- 3.6-14.5 µmol CO$_2$ m$^{-2}$ s$^{-1}$

- B'
- b'
- 6.1-63.2 µmol CO$_2$ m$^{-2}$ s$^{-1}$
### Result: Inter-species variations of CO₂ efflux

<table>
<thead>
<tr>
<th>Ant species</th>
<th>A1</th>
<th>A2</th>
<th>AG</th>
<th>AP</th>
<th>DV</th>
<th>HV</th>
<th>OD</th>
<th>OR</th>
<th>PA</th>
<th>PH</th>
<th>PP</th>
<th>PV</th>
<th>TL</th>
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<tbody>
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<td>NS</td>
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<td>A2</td>
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</table>
Results: Inter-species variations of CO₂ efflux

*, ** and *** indicate significant differences between nest and soil CO₂ effluxes within the ant species at $P < 0.05$, $P < 0.01$ and $P < 0.001$.
Results: Relationship between CO$_2$ efflux, soil temperature and soil moisture content
In a tropical forest, the CO$_2$ efflux from ant nest was significantly higher than those from surrounding soil. Similar results were also reported in boreal forests, subalpine forest, wetland, pasture and coastal plains.

The CO$_2$ efflux from ant nests were highly variable among the ant species, relatively high CO$_2$ efflux rates were found in 3 ant species, *H. venator*, *O. rixosus* and *P. plagiaira*, and relatively low rates in 7 ant species.
Our results showed positive relationships between soil CO$_2$ efflux and temperature, similar to previous studies, but there was no significant relationship between soil temperature and nest CO$_2$ efflux.

Our results suggest that ant, soil microbes and roots activity may be controlled by soil moisture content.
During our experiments, we excavated more than two nests of each ant species when we found the ant trails (data not shown).

Nest structure may explain the difference.
Examples of the structure of subterranean ant nests. These illustrations were modified from Tschinkel (2003) based on observations from our study.
The relationship between entrance hole diameter and nest CO$_2$ efflux supported the idea that nest structure is an important factor causing nest CO$_2$ efflux variation.

There was no significant difference in CO$_2$ efflux rates between single- and multiple-hole type nests.

There may be other reasons that cause nest CO$_2$ efflux variation such as: the number of ants within a colony; ant body size and behavior; indirect effect of ants on other CO$_2$ sources and the phenology of each colony.
Acknowledgements

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Thanks you very much for your attention

Photo by Yoshiaki Hashimoto