Soil Respiration in the Vicinity of Syowa Station, Antarctica 2. Estimation of Carbon Dioxide Amount Evolved from the Naked Part of West Ongul Island

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南極昭和基地周辺の土壌呼吸 2. 西オングル島の地表面から放出される CO_2 量の推算

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要旨：1979年1月と2月に東，西オングル島の9カ所で48点の表層土壌が採取された．それらの CO_2 放出速度を赤外線ガス分析計を使って測定した．また，土壌中の水，窒素，有機態炭素量の測定も行った．5000分の1の西オングル島の地形図を5mm目の格子に切り，各区画の CO_2 放出速度を湖沼水面または氷雪帯との位置関係から3段階に推定した．それらを月平均地表面温度と関連させて12月から2月までに西オングル島の地表面から放出される CO_2 量を計算した．その結果，炭素量にして2.1tが3カ月間に放出されることになった．この値を裸地全域に平均すると7.7kgC/haとなり，有機物の平均炭素含有率を45%とすると17.2kg 有機物/haとなる．この地域で CO_2 の固定量と放出量が平衡状態にあるとすれば，この値は WHITTAKER (Communities and Ecosystems, 2nd ed., New York, 385p, 1975) の示した表で「真の砂漠，岩石，砂地，氷雪地」生態系の一次総生産量に相当する．

***Abstract*:** In January and February 1979, 48 samples of surface sandy soil were taken at East and West Ongul Islands. The soil respiration rates, *i. e.* carbon dioxide evolution rates, of the samples were measured with the infrared gas analyzer. There were positive correlations between the soil respiration rate and the water content, the nitrogen content or the organic carbon content.

Meshes of 5 mm×5 mm squares were laid on the contour map of West Ongul Island on the scale of 1 : 5000. The soil respiration rate in each mesh was estimated from the geographical features. The carbon dioxide evolution amount in West Ongul Island was calculated at 2.1 t

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CO_2-C during a period from December to February. This amount corresponds to 7.7 kg C/ha of the ice-free area without the moss community.

1. Introduction

To estimate the biological productivity and the matter circulation, the measurements of the biomass, the organic matter on and in the soil, and the mineral elements in the organic matter and soil are usually done at given times. If the physiological activities such as photosynthesis and respiration are measured at those times, it is certain that they will provide more information on the matter flow in the ecosystem.

In Antarctica, most of biological activities in the ice-free area where flora is meagre are performed with soil. In such ecosystem, the measurement of soil respiration, *i. e.* carbon dioxide evolution from soil, is very valuable to the study of the matter flow in the ecosystem. The soil respiration rate has been usually measured to estimate the decomposition rate of soil organic matter (*cf.* SINGH and GUPTA, 1977). But in the ecosystem where the inflow and the outflow of organic matter are little, and where the fluctuation of the organic matter content is very low, it is considered that the biological fixation of carbon dioxide balances with the carbon dioxide release in the ecosystem. In other words, the evolved carbon dioxide amount is roughly equal to the primary gross production in that ecosystem.

INO *et al.* (1980) measured the respiration rate of the surface soil that was sampled in January and February 1978, in the vicinity of Syowa Station, Antarctica. They reported that the soil respiration rate was higher than expected and that the rate had a positive correlation to the water content or the nitrogen content. In the present study, a detailed experiment was done to understand the carbon budget in the ecosystem by using the samples from East Ongul Island and West Ongul Island in January and February 1979.

Based on the data obtained, the authors estimated the amount of the soil respiration in the naked area of West Ongul Island.

2. Materials and Methods

Surface sandy soil was sampled at four sites on East Ongul Island and at five sites on West Ongul Island (Fig. 1) by Y. OHYAMA, one of the authors.

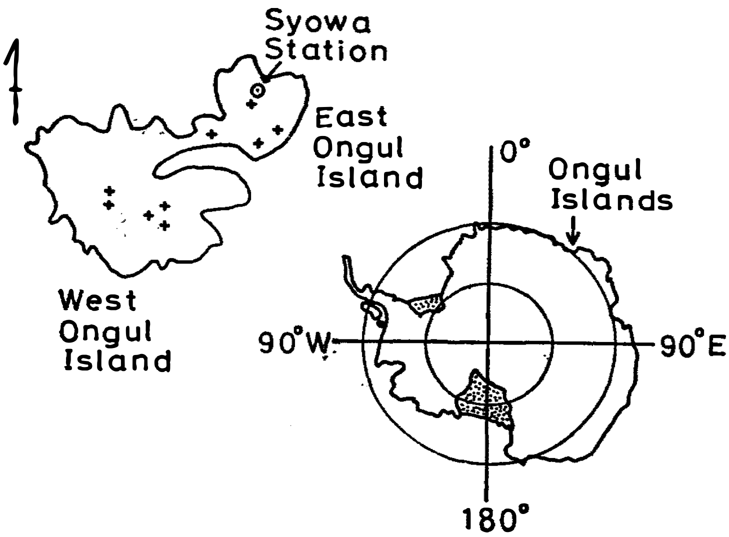

Fig. 1. Localities of soil sampling. +: sampling site.

The sampling was made at 48 points on the various slopes on the above nine sites, and samples were taken at every one meter along the line of the moisture gradient of soil from a pond, a stream or a snow patch. The mean angles of inclination between sampling points were recorded. Samples were sandy soil which was composed of the efflorescence of gneiss. These samples were kept in a frozen condition at −20°C throughout the transport and the storage.

The samples were put in a dark container at 10°C for one day before the measurements, and settled in airtight plastic vessels for the respiratory measurement. The soil respiration rate was determined by the difference of carbon dioxide concentration between the inflow air to the vessel and the outflow from the vessel. Carbon dioxide concentration was measured with the infrared gas analyzer of differential type (Beckman, 315A). The details of the method are the same as those in the previous report (INO *et al.*, 1980). In the present study, the soil respiration rate was measured at 5°, 10° and 20°C in a dark condition. Then the samples were dried at 80°C. The difference between the wet weight and the dry weight was regarded as the water content, which was represented by the percentage to the dry weight of the sample soil. Nitrogen was analyzed with the Technicon Auto Analyzer by the industrial method 30-69A using 1 to 5 g dry sample soil. Organic carbon was analyzed with the YANACO C-N corder using about 5 g dry sample soil.

3. Results and Discussion

Table 1 shows the ranges, the average values and the standard deviations of the soil respiration rate, the water content, the nitrogen content and the organic carbon content. The water content was low, because most of the samples were composed of sand and gravels. The nitrogen and the organic carbon contents were also very low and the C-N ratios were about ten. The average soil respiration rate at 10°C in the present study was lower than that of the previous study (INO *et al.*, 1980).

Table 1. Ranges, averages and standard deviations of the soil respiration rate, the water content, the nitrogen content and the organic carbon content.

	Range		Average	Standard deviation	
	Minimum	Maximum			
Soil respiration rate	0.00	3.57	0.85	0.90	(mg C/100 g dry soil·day) at 10°C
Water content	0.31	46.3	9.59	9.46	(percent of dry soil weight)
Nitrogen content	0.02	0.16	0.13	0.16	(mg N/g dry soil)
Organic carbon content	0.00	5.92	1.41	1.54	(mg C/g dry soil)

The relationships between the soil respiration rate and the water content, the nitrogen content or the organic carbon content are shown in Figs. 2, 3 and 4. These correlations were shown with a regression equation in the form of $Y=aX^b$, where Y is the soil respiration rate (mg CO_2-C/100 g dry soil·day), X is the water content (% of dry soil weight), the nitrogen content (mg N/g dry soil) or the organic carbon content (mg C/g dry soil), and a and b are the coefficients. In these Figures, the correlation coefficient (r) of each equation is shown. There were positive correlations between the soil respiration rate and each element.

The positive correlation between the biotic activity and the amount of environmental resources such as carbon, nitrogen and water, is one of the characteristics in the environment where biotic resources are meager.

Soil samples were taken on the slope. If the water content gradually changes with the sampling position on the slope, good correlations are expected between the height from the lowest position of the sampling line and

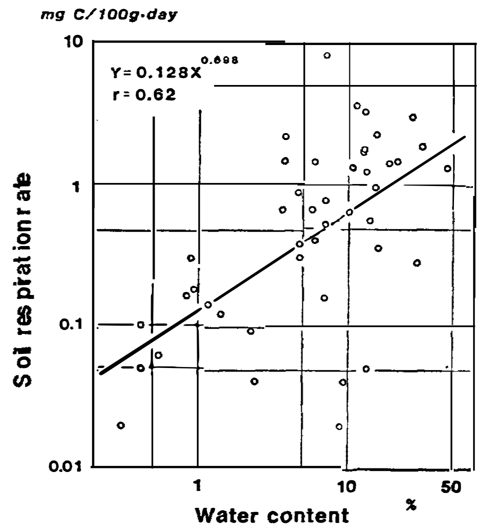

Fig. 2. Relationship between the soil respiration rate and the water content of soil.

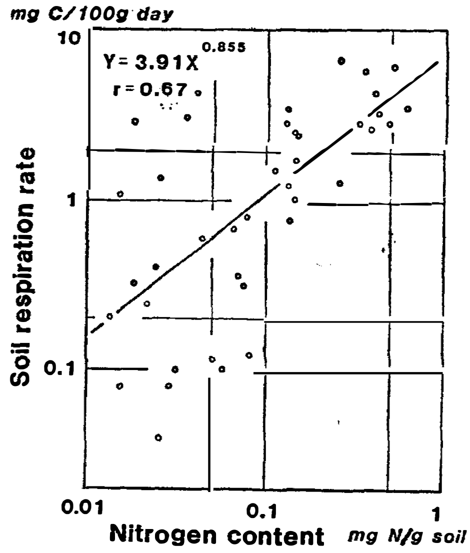

Fig. 3. Relationship between the soil respiration rate and the nitrogen content of soil.

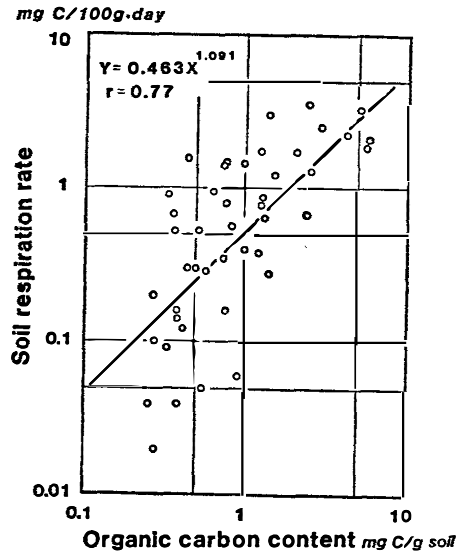

Fig. 4. Relationship between the soil respiration rate and the organic carbon content of soil.

the soil respiration rate, the nitrogen content or the organic carbon content. In this experiment it was clear that the lower positions had the higher contents and rates (Fig. 5). It means that the biotic resources are abundant at the position near water. Temperature-soil respiration rate curve was drawn from the averages of the soil respiration rates at 5°, 10° and 20°C of 48 samples (Fig. 6). The amount of carbon dioxide evolved from the sample soil at the freezing point is estimated by the curve extrapolated.

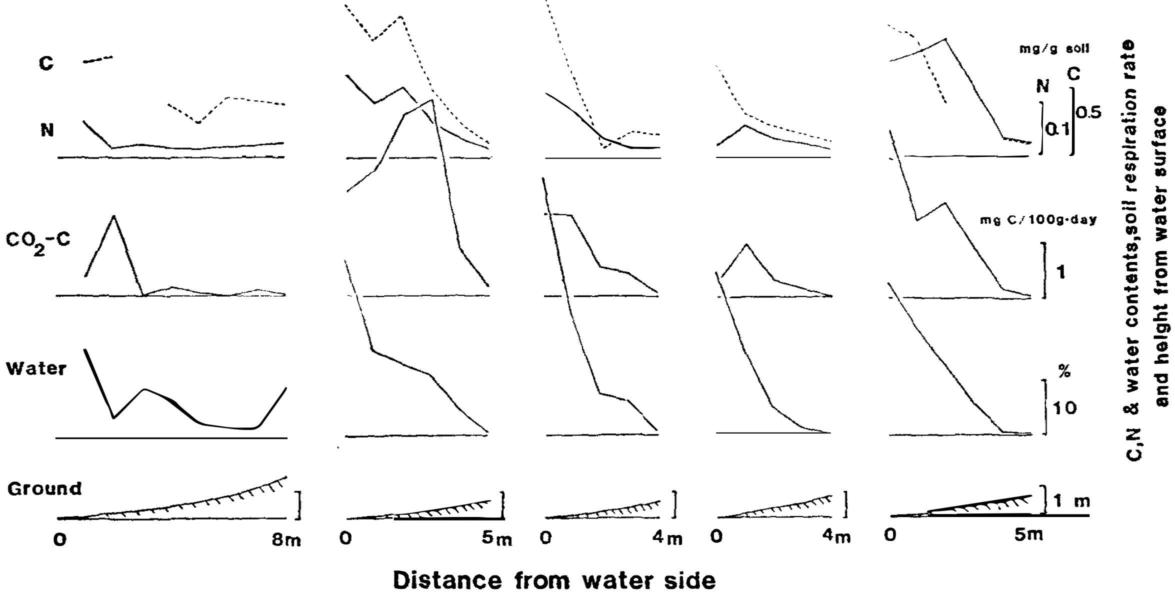

Fig. 5. Changes of the organic carbon content, the nitrogen content, the water content and the soil respiration rate with the height from the land water surface.

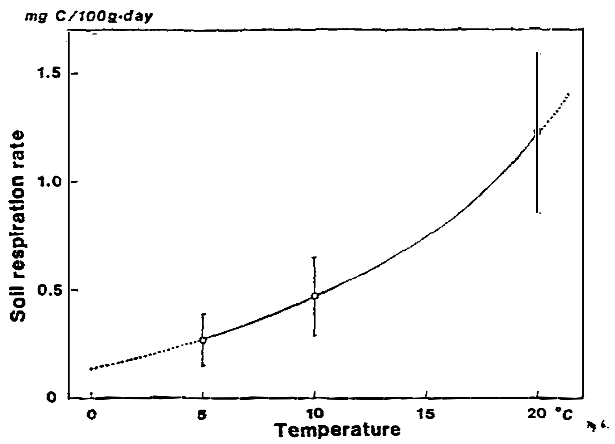

Fig. 6. Temperature-soil respiration rate curve drawn from the values of 48 samples. Ordinate lines show 95% confidence limits of the average values.

The amount of carbon dioxide evolution in West Ongul Island was calculated on some assumptions. East Ongul Island where Syowa Station exists was not dealt with as an object of the calculation because the disturbance of the soil by the expedition members was expected. The correlation between the soil respiration rate and sampling position expressed as the height above the nearest water surface is shown with the negative linear regression

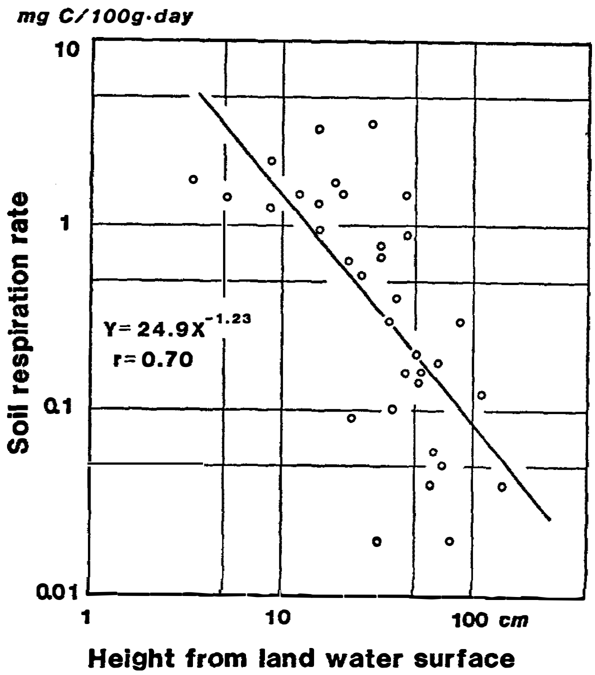

Fig. 7. Relationship between the soil respiration rate and the sampling position expressed as the height above the land water surface.

(Fig. 7).

The contour map of West Ongul Island on the scale of 1 : 5000 was made on the basis of the air photograph of January 15, 1962, controlled by triangulation points established by the Japanese Antarctic Research Expeditions in 1957 and 1961. The contour line on the map was drawn at 1.25 m each altitude. Meshes of 5 mm × 5 mm squares were laid on the map. One mesh corresponded to the area of 625 m^2. The meshes with more than 50 % occupied by ice-free areas were picked out. Further, among them, the meshes which cover from the water surface to the 1.25 m height or which abut on the lower part of the snow and ice patches were treated as the region of high soil respiration rate. The meshes abutting on the high rate region, or the meshes abutting on the snow and ice patches at the same altitude were regarded as the region of low soil respiration rate. The others were regarded as regions of no evolution.

As the soil respiration rate of the high evolution region, the rate at 63 cm, the mathematical mean of 0 and 125 cm above the nearest water surface, was used and for the low evolution region, the rate at 188 cm, the mean of

125 and 250 cm, was used. The soil respiration rates of 0.16 and 0.04 mg CO_2-C/100 g·day were given to the high soil respiration rate region and the low soil respiration rate region, respectively, from the relationship shown in Fig. 7. The area of the high rate region, the low rate region and the region of no evolution was 17.6, 31.6 and 224.4 ha, respectively. The area of the snow and ice region was 523.3 ha and the water surface 17.2 ha, and the respiration rates in these areas were assumed 0.00 mg CO_2-C/100 g·day.

Good correlations were noticed between the soil respiration rate and the soil temperature in various ecosystems (*cf.* INO and MONSI, 1969; SINGH and GUPTA, 1977). In the ice-free area without moss community, most of the biotic activities are caused by blue green algae and bacteria surrounding algae on and in the soil. Therefore, it was assumed that the soil respiration rate of antarctic soil is controlled by the mean monthly soil temperature. MATSUDA (1968) measured the temperature at different sites and depths with the thermister thermometer from February 1961 to January 1962 at East Ongul Island. During this period, the soil temperature at a 10 cm depth remained below the freezing point. Therefore, it is considered that the close relationship is held between the soil surface temperature and the soil respiration rate. Mean monthly temperature at the soil surface calculated from the mean monthly maximum temperature and the mean monthly minimum temperature at the soil surface measured by MATSUDA (1968) is shown in Fig. 8. Months whose mean monthly temperatures are above the freezing point were from

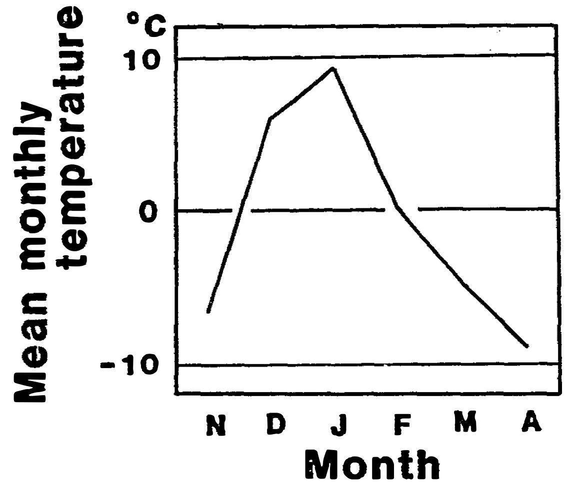

Fig. 8. Mean monthly temperature at the soil surface in East Ongul Island.

December to February, and the mean monthly temperature at the soil surface in December, January and February was 6.0°, 9.3° and 0.0°C, respectively.

Using the relationship in Fig. 6, high and low respiration rates of 0.16 and 0.04 mg CO_2-C/100 g·day at 10°C were correlated respectively to 0.102 and 0.026 mg CO_2-C/100 g·day at 6.0°C which is December's mean monthly temperature.

The soil respiration rate per weight must be changed to the rate per area. It is assumed that most of the biotic activities are performed in a 5 cm layer. Average soil weight per 1 m^2 of a 5 cm layer was calculated at 91.5 kg in a dry state on the basis of the bulk densities of all soil samples. The soil respiration rates at 10°C came to 146 and 36.6 mg CO_2-C/m^2·day in the high rate region and in the low rate region, respectively. These ratios were changed to the rates at the mean temperatures of each month using the relationship between the soil respiration rate and the temperature in Fig. 6.

During the summer season, the area of each region would change. But it is assumed that each area did not change, because the speed of the change was not clear. This is one of the causes to overestimate the actual amount of carbon dioxide evolution. It is considered that in the region of no evolution, a small amount of carbon dioxide was evolved from small puddles and streams which are not distinguishable on the map, but the amount was negligible. This is one of the causes to underestimate the actual amount of carbon dioxide evolution.

The carbon dioxide evolution from December to February amounted 2.1 t CO_2-C in West Ongul Island. This amount corresponds to 7.7 kg C/ha of the ice-free area. When the carbon content of the organic matter which is decomposed to carbon dioxide is 45%, the carbon amount of 7.7 kg comes to 17.2 kg of the organic matter. If this amount is equal to the primary gross production, the productivity in this area corresponds to that of the "extreme desert, rock, sand and ice" ecosystem (WHITTAKER, 1975).

In this paper, only the biotic activities in the soil were discussed. In the wet habitat, moss communities whose dominant species is *Bryum pseudotriquetrum* CARD. are developed in a cushion form. It was reported that the primary production of bryophytes was 1 to 50 kg/m^2·year near Barrow in Alaska (OECHEL and SVEINBJÖRNSSEN, 1978). Also, microfauna such as rotifer, tardigrade, protozoan, etc., live in the moss cushion. Therefore, the moss cushion is regarded as the place of high biotic activity. To understand the carbon flow in this region, the carbon dioxide budget not only in the ice-free area but also in the moss cushion must be measured.

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(Received April 16, 1981)