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Plant species and biomass, soil respiration, soil environment data on Whapmagoostui-Kuujjuarapik, Quebec, Canada

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Abstract: Ongoing climate change affects various interconnected biotic and abiotic components in the Arctic ecosystem. However, capturing data on multiple components of the Arctic ecosystem simultaneously and sympatrically is difficult. We investigated vascular plant community composition, plant biomass, soil respiration and several soil environmental factors in the Canadian subarctic zone. We recorded 88 vascular plant species, seven soil environmental factors, above- and below-ground biomass, soil respiration within 1 × 1-m quadrats in tundra and forest sites. Shrub species were recorded at the highest frequency in all sites. Environmental factor data showed that the soil was relatively acidic and, in the tundra site, shallow, suggesting the strong contribution of country-rock in the Canadian shield. These data filling data gaps in the Arctic region have potential value to help our understanding of the ecosystem and can be used for future predictions or global-scale analyses.

1. Background & Summary

Ongoing climate change is substantially altering the composition, abundance, and distribution of organisms in Arctic regions[1]. Moreover, the effect on biodiversity could lead to local environmental conditions and even ecosystem functions via biological activities (e.g., primary production and soil respiration). For example, climate change can alter not only primary production via vegetation, but also soil respiration via microbial activities because the aboveground shifts modify the quantity or quality of soil organic matter through the litter input[2,3]. The southern boundary of the tundra biome particularly has experienced remarkable shrub increasement (i.e. infilling of existing patches, increase in growth and an advancing shrub line), and the drastic vegetation shift has been known to affect soil environments such as permafrost conditions[4]. Thus, to grasp the impact of climate change on the Arctic ecosystems, we should obtain data on multiple ecosystem components connected to each other, simultaneously and sympatrically. The preservation of such data will increase our understanding of the effect of climate change on ecosystems on the temporal scale or the global scale. To obtain this data, we investigated vascular plant composition, several soil environmental factors, above- and below-ground biomass, soil respiration in the subarctic tundra of Whapmagoostui-Kuujjuarapik, Quebec, Canada.

In summary, we recorded 88 vascular plant species, seven soil environmental factors, above- and below-ground biomass, soil respiration within 1 × 1-m quadrats in tundra and forest sites. From this data set, we showed the frequency (number of occurrences) of species and environmental factors, as Figures 2 and 3, respectively. Shrub species show higher frequency in any sites (Figure 2). Environmental factor data showed that the soil was relatively acidic and, in the tundra site, shallow, suggesting that this ecosystem is strongly affected by the country-rock of the Canadian shield (Figure 3). Using parts of these data, Masumoto *et al.*[5] have reported about the relation between shrub coverage and soil respiration, or Kitagawa *et al.*[6] have reported about vascular plants' community assembly process.

2. Location (or Observation)

We conducted this study in Whapmagoostui-Kuujjuarapik (KW; 55.3°N, 77.7°W), Quebec, Canada (Figure 1-a). KW is located in the subarctic zone along the eastern territory of Hudson Bay. The mean annual temperature was −2.6 ± 1.2 °C, and the mean annual precipitation was 656 mm, 40% of which fell as snow, in 2001–2010[7]. The study area, located south of the current tree line, is a mosaic landscape, including boreal forest and tundra vegetation. Tundra vegetation exists on outcrops with thin organic deposits, and shrub species dominate (Figure 1-b).

3. Methods

3.1. Field survey

Sampling was performed in two periods: from July 7th to August 31th, 2016, and from August 12th to 21th, 2017. Tundra vegetation sites were surveyed in the first period in 2016, and forest vegetation sites were surveyed in the second period. We established eight 144-m line transects in the tundra vegetation on outcrops (Figure 1-c). Along each transect, we established 1 × 1-m quadrats at 6-m intervals (in total, 200 quadrats: 25 quadrats × 8 transects). If no vegetation was present or if conditions made it difficult to set the quadrats at the assigned position, the quadrat was shifted to the closest vegetation patch (8' and 17' in Figure 1-d). At the tundra site, we established additional sites to evaluate the patchy structure of vegetation (closed quadrats in Figure 1-d). The "patch survey" quadrats (1 × 1-m) were established at the center of all vegetation patches overlapping 10 m × 150 m plots (area shown by broken lines in Figure 1-d). If multiple patches were overlapped by more than 50 cm, they were treated as a single patch. The total number of "patch survey" quadrats was 433. In the forest stand near each tundra transect, we established eight 100-m line transects and 1 × 1-m quadrats at 6-m intervals (in total, 128 quadrats: 16 quadrats × 8 transects). Where tall trees interrupted the 6-m intervals in the forest stand, the quadrat was randomly repositioned.

Different survey items were investigated at the three sites (tundra transect, tundra patch, and forest transect) (Table 1).

3.2. Vegetation survey

We identified species or morphospecies of vascular plants and measured the percentage cover (%) by visual estimation within each quadrat. Total coverage could exceed 100% when some species are presented in different layers. In the forest stand, we recorded only understory vegetation (<1.0 m in height).

3.3. Soil environmental factors

To represent the abiotic environment, we measured several soil properties within each quadrat. In the field, we measured soil water content (%) at three arbitrary positions within each quadrat using a soil moisture sensor (HH2, DeltaT Devices Ltd., Cambridge, UK) and averaged these values. We measured soil depth, including plant litter and mineral soil (up to 150 mm), at three locations adjacent to each quadrat's boundary and obtained a mean value. To measure other properties, we collected approximately 200 g of soil samples from the O-A horizon after removing slightly decomposed litter, including the Oi horizon. These soil samples were transported to the laboratory and used for the following measurements.

Using a soil sample from each quadrat, pH, electrical conductivity (Ec), inorganic nitrogen concentration, the ratio of soil carbon to nitrogen, soil melanic index were measured. We obtained

pH and Ec values of dry sample soil in water (soil/water weight ratio of 1:5) using pH and Ec meters (Twin pH and Twin *Ec*, Horiba Ltd., Kyoto, Japan). To measure inorganic nitrogen content, soil extraction was performed using 0.01 M $CaCl_2$ in water (weight ratio of 1:3). After filtration, NH_4^- (detectable range: 0.2–7.0 mg/L) and NO_3^- (detectable range: 3–90 mg/L) contents were measured using an RQflex reflectometer (Merck, Darmstadt, Germany). To determine the ratio of soil carbon to nitrogen (CN ratio), we measured C and N concentrations in sample soil using an NC analyzer (Sumigraph NCH-22F, Sumika Chemical Analysis Service, Tokyo, Japan). We also measured the melanic index (MI) of samples to characterize humus compounds, significant soil organic material components. Soil MI represents the chemical stability of soil organic matter[8]. We measured A_{450} and A_{520} using a UV-Vis spectrophotometer (HITACHI U-2800, Japan) and determined the MI (A_{450}/A_{520}) following the methods of Yamamoto *et al.*[9]

3.4. Above- and below-ground biomass, soil respiration

To estimate above- and below-ground biomass (AGB and BGB) of plants, we measured weight of vascular plants' samples from each quadrat. For AGB, we cut all plants from a 20 × 20 cm vegetated area within each quadrat and measured the dry weight of the samples after removing dead parts and non-vascular plants (i.e., mosses and lichens). For BGB, one100-cm^3 soil block was collected using a soil core sampler (Φ5 × 5 cm) from each quadrat, then samples were sieved through a 0.5-mm mesh size to obtain root tissues of >0.5 mm. We determined the dry weights of all root and rhizome biomasses and calculated dry root mass (mg) per dry soil weight (g) as the root biomass value.

The concentration of ATP in the soil sample, which is an index of the living microbial biomass[10], was determined using the method of Jenkinson and Oades[10] with some modification. Freeze-dried soil samples (200–300 mg) were extracted by addition of 10 ml of the TCA reagent (a mixture of 0.5 M TCA and 0.25 M Na 2 HPO 4) followed by immediate ultrasonic homogenization (Astrason 3000; Misonix Inc., NY, USA) at 150 W for 2 min. After centrifugation of soil suspensions at 5000 rpm for 15 min at 5°C, 100 µl of the clear supernatant was carefully removed using a sterilized pipette to another centrifuge tube. Then, 9.9 ml of 0.025 M HEPES at pH 7.0 solution was added to the tubes and 100 µl was used for ATP analysis. Sample ATP concentrations were quantified using the luciferin-luciferase enzyme method with light emission measured using an ATP tester (AF-50; TOA-DKK Corp., Tokyo).

Soil respiration rate (SR) was measured by a closed chamber with a CO_2 sensor and measurement indicator (GMP343 and MI70, Vaisala Inc., Helsinki, Finland). The camber was a cylindrical shape and the volume was $7.5*10^{-3}$ m^3. We removed the aboveground vegetation and slightly decomposed litter including the Oi horizon, and left plots at least 1 day before the SR measurement. We monitored the CO_2 concentration in the chamber for 5 min to determine the

respiration rate (μmolCO_2 m^{-1} s^{-1}). As SR is strongly affected by soil temperature, soil temperature (S_{temp}) 1 cm below the soil surface was also measured.

4. Data Records

All data on vascular plant species and soil environmental factors in each quadrat, in MS format (xls., MS Office, 2020), were deposited to Discover and accessed from the Arctic Data archive System (ADS, https://ads.nipr.ac.jp/) under the accession number A20191225-005. The deposited raw data can be downloaded directly from the data archives. Figures 2 and 3 were established by the data files of A20191225-005 (No1a-KW_vegetation.xlsx and No1b-KW_abiotic-biotic_properties.xlsx, respectively).

5. Technical Validation

We identified vascular plant species according to a plant catalog that describes the local species in the study area and their distribution[11]. Outliers were excluded from soil environmental factors, below-ground biomass, soil respiration datasets.

6. Figures

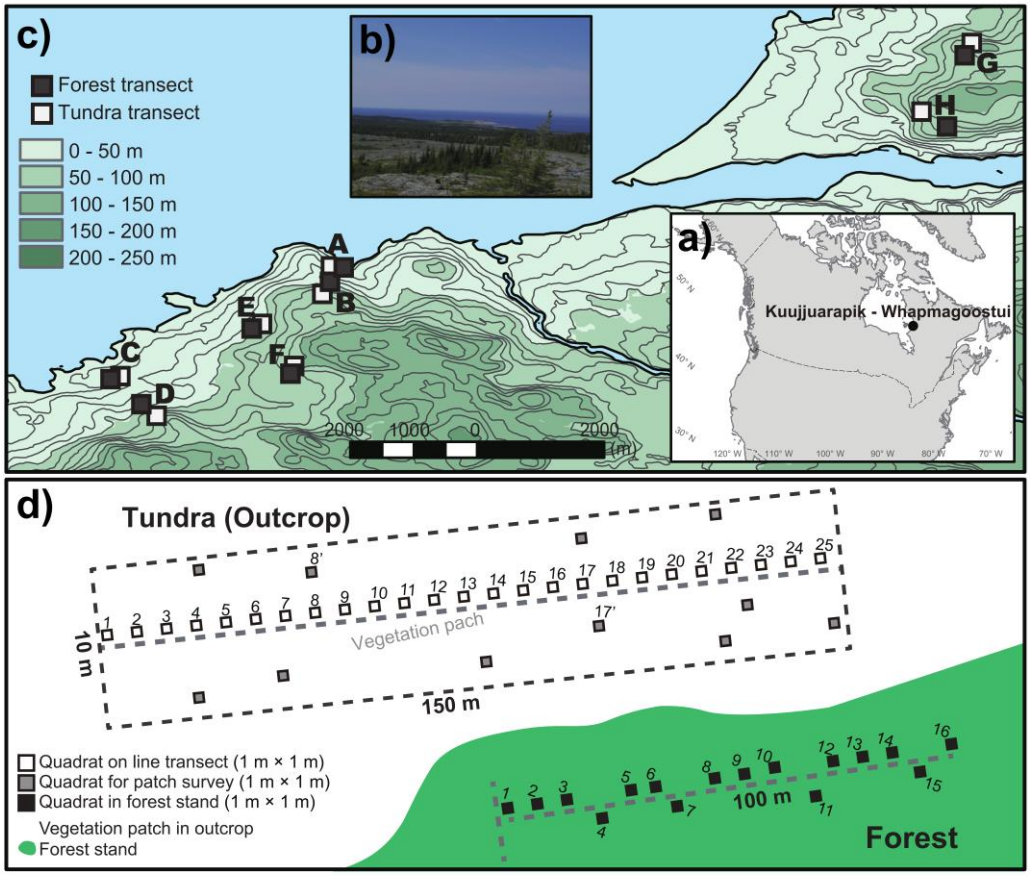

Fig. 1. Study site and experimental design in the subarctic tundra of Canada. (a) Geographical location, (b) Topography of the study site, (c) locations of eight transects, and (d) positions of each quadrat within a transect.

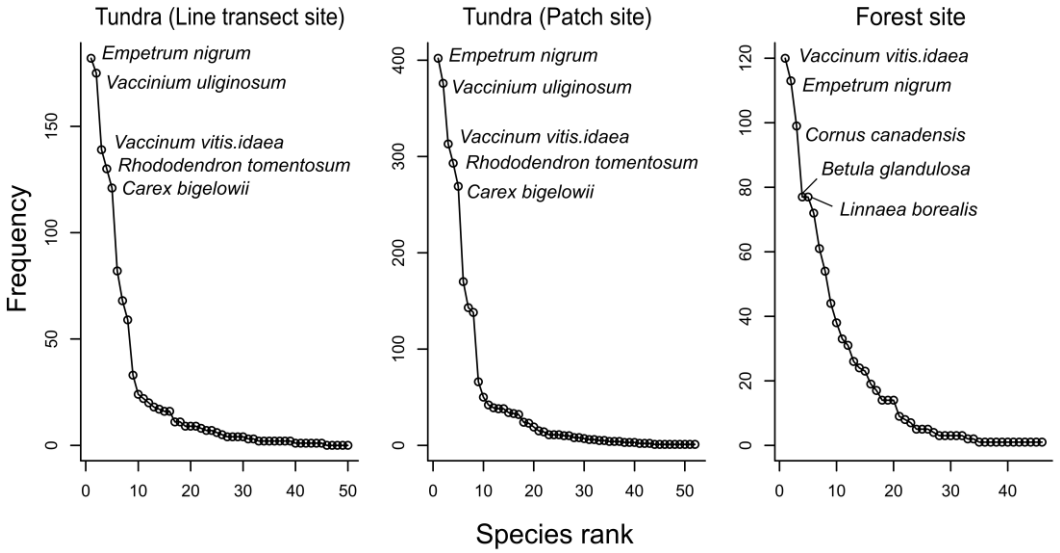

Fig. 2. Species rank-frequency relationship in the three sites.

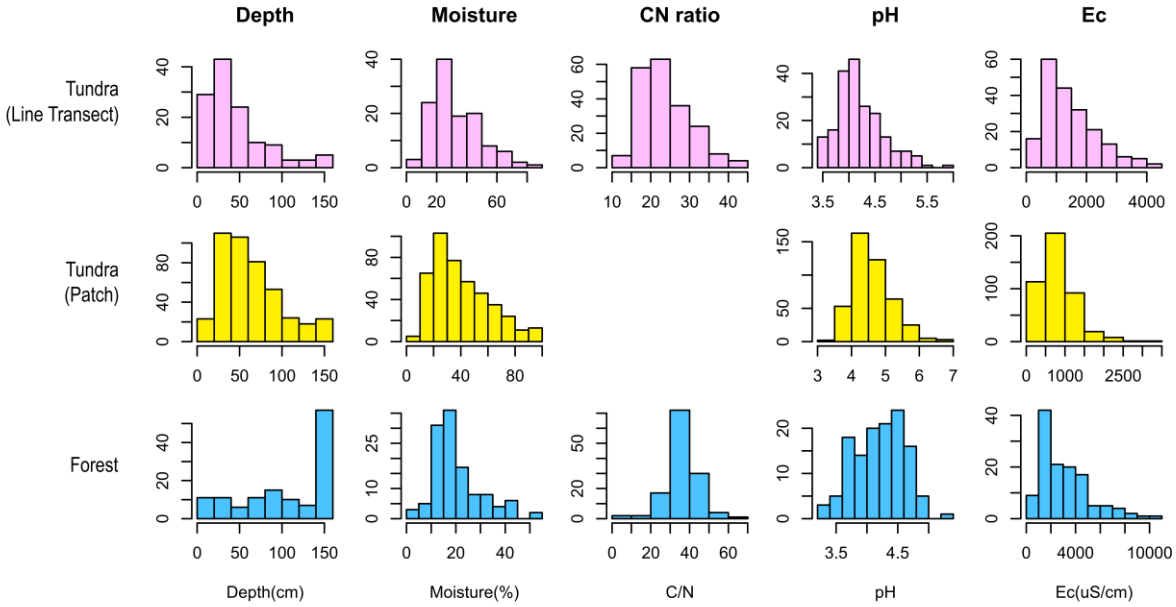

Fig. 3. Histograms of soil environment items in the three sites. y axes of all graphs are “number of Quadrats.”

7. Table

Table 1. Survey items in each study site.
The items investigated at all quadrats were shown as a circle, and that in some quadrats is shown as a triangle. AGB and BGB: above- and below-ground biomass, SR: soil respiration, IN: inorganic nitrogen, MI: soil melanic index.

Habitat	Site	Vegitation data	Ecosystem funtions			Soil environmental data						
			AGB	BGB	SR	Depth	Moisture	pH	Ec	CN ratio	IN	MI
Tundra	Line transect	○	○	○	○	○	○	○	○	○	○	○
Tundra	Patch	○				○	○	○	○	○	△	
Forest	Line transect	○				○	○	○	○			

Author contributions

Kitagawa, R. and Nishizawa, K. identified plant species. Masumoto, S., Kitagawa, R., Nishizawa, K., Osono T., Hasegawa M., and Mori, A. S. conducted the survey for soil environment items in the field. Uchida, M. and Mori, A. S. contributed to the acquisition of the funding and experimental design. Iimura Y. performed soil chemical analyses. All authors wrote the manuscript or provided editorial advice.

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