Molecular characterization of soil organic matter along a soil chronosequence of Midtre Lovénbreen foreland in Svalbard

Sungjin Nam, Su-Jeong Jung, Se-Eun Kim, Yoo Kyung Lee, and Ji Young Jung*
Korea Polar Research Institute, KIOST, Incheon, Korea / *jyjung@kopri.re.kr

Abstract

Glacier forelands give an opportunity to study the successional processes in the terrestrial ecosystem along the chronosequence at a time. The newly exposed ground gives chances for plants and microorganisms to be established, and these organisms have contributed in building up soil organic matter (SOM) in this area. To investigate a shift in molecular compositions of newly added SOM along the soil chronosequence, surface soil from nine sites in Midtre Lovénbreen foreland in Svalbard were sampled, representing soil ages of 4, 9, 37, 58, 65, 71, and 78 years (site 1–7, respectively). Two sites outside the moraine (site 8, 9) were selected as a reference site. To obtain a clear picture of newly added SOM's composition, free light fraction (FLF) was separated by density fractionation with sodium polytungstate (1.55 g cm^{-3}). The molecular compositions of FLF were analyzed through pyrolysis-Gas Chromatography/Mass Spectrometry (py-GC/MS) and TMAH (tetramethylammonium hydroxide)-py-GC/MS at two pyrolysis temperatures (350 and 600 °C). In both analyses, SOM characteristics between inside and outside moraine were distinctly separated. However, we could not find clear trend of newly input SOM structure along the chronosequence inside glacier moraine in this study. Our results would help for better understanding of SOM formation and successional processes in a newly exposed soil and investigation of the relationships between SOM composition and vegetation.

Introduction

- It is predicted that the Arctic region will experience the most severe and rapid effects of global warming. Analysis of temperature series (1912-2010) on Svalbard has shown positive linear trends for annual values as well as spring, summer, and autumn series.
- Global warming has resulted in rapid melting of ice and glacier retreats, and the Svalbard glaciers are following the same pattern. The newly exposed glacier forefield gives chances for plants and microorganisms to be established and these organisms would contribute to build up new SOM pool in this region.
- Since SOM acts as the major sink and source of soil carbon, it is important to investigate its structure and function to understand the carbon cycle in the terrestrial ecosystem.
- Glacier forefields present us a good chance to study processes of SOM formation. The purpose of this study is to investigate molecular compositions in newly input SOM along a soil chronosequence.

Study area

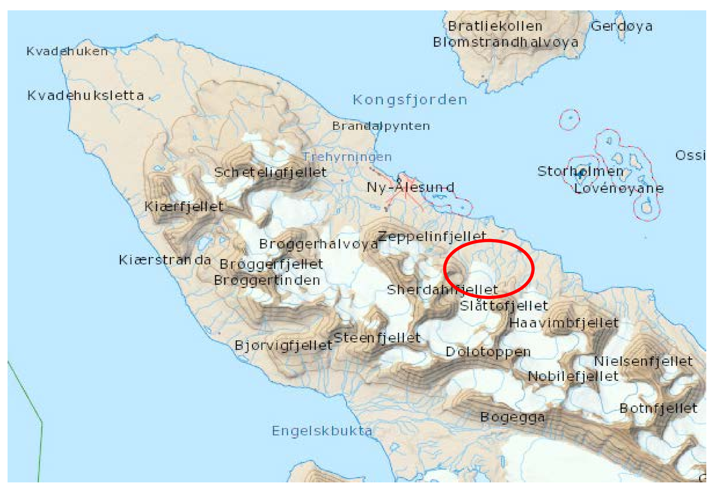

Fig. 1. Glacier foreland of Midtre Lovénbreen, Brøgger Peninsula, Svalbard (79°N, 12°W).

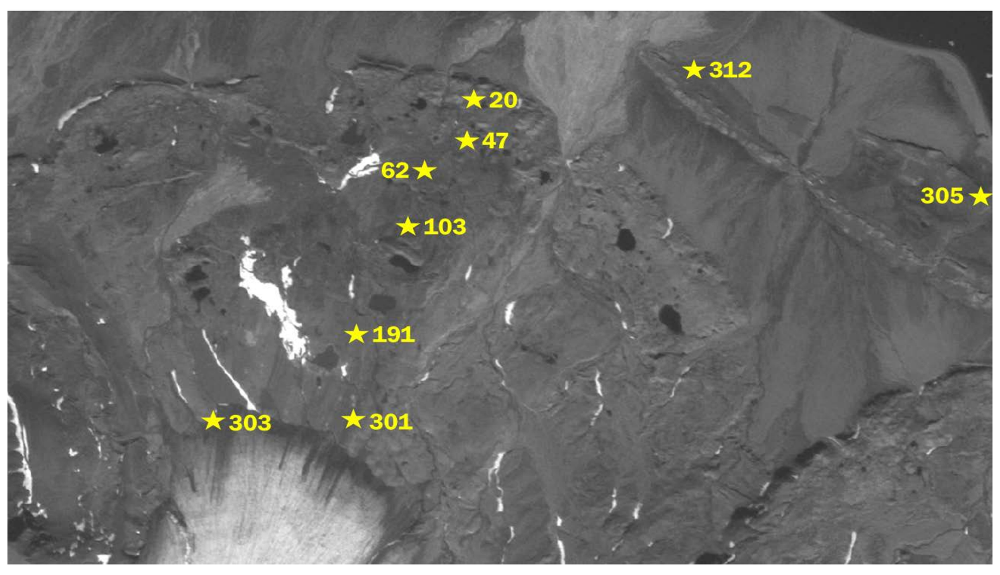

Fig. 2. Sampling location along the transect in Midtre Lovénbreen (7 sites inside moraine, and 2 sites outside moraine). Surface soil samples (0-5 cm depth) were taken from each site.

Methods

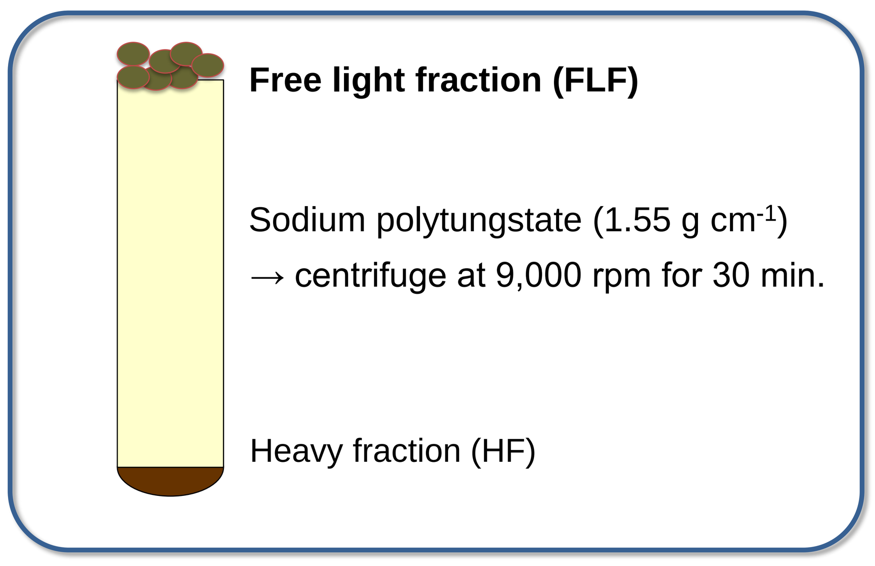

Fig. 3. SOM fractionation. Free light fraction (FLF) is used for analyzing multi-shot py-GC/MS. Some FLF samples is methylated using TMAH, and then analyzed.

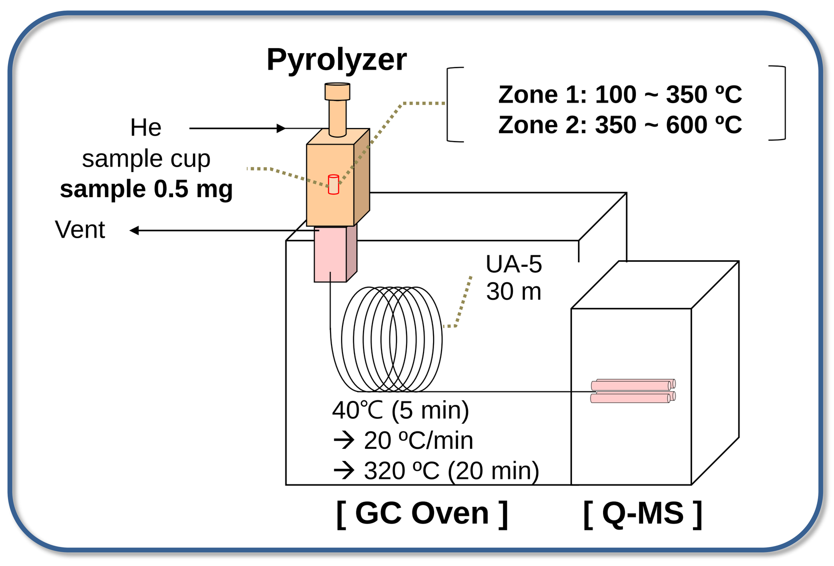

Fig. 4. Multi-shot pyrolysis GC/MS. First shot temperature is 350 ºC, and second is 600 ºC.

Derivatization

For improving detection of lignin, cutin, and suberin derived compounds, FLF samples were methylated using TMAH. Injected 10 uL TMAH (25% aqueous solution) to around 5 mg samples of 8 sites, and were incubated for 24 hours. We could not analyze sample of Site 1 (ML303) due to low yields of FLF.

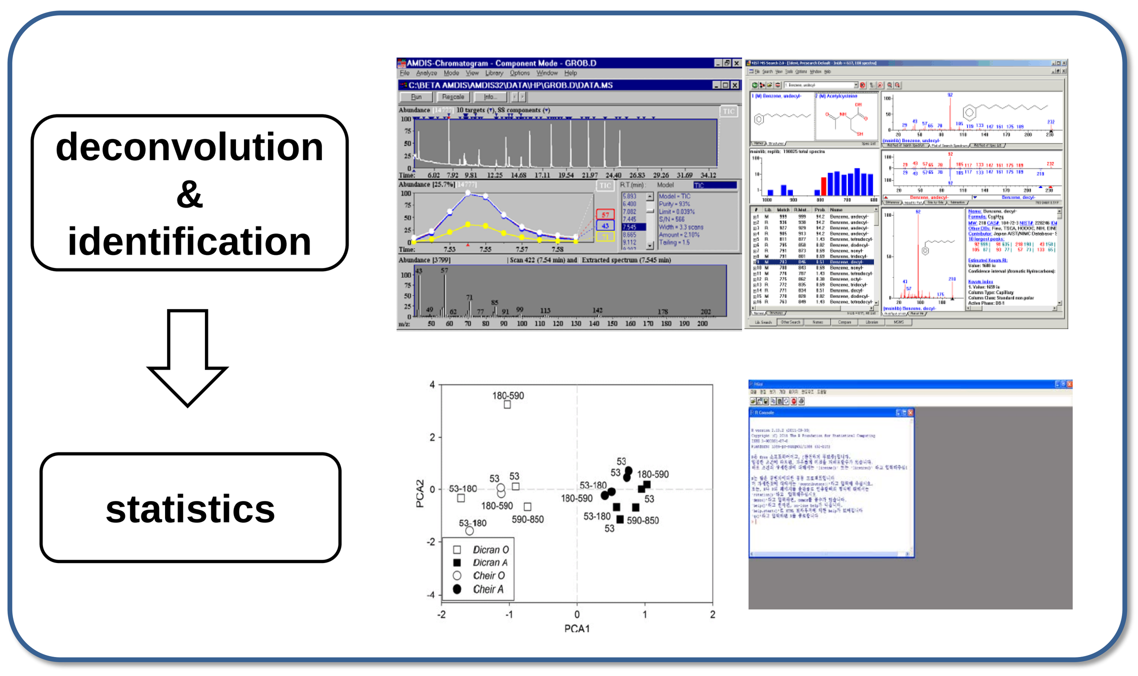

Fig. 5. Scheme of data analysis. 1) deconvolution and identification of peaks using AMDIS and NIST library, and 2) multivariative analysis principal component analysis (PCA) using R statistics.

Results and discussion

Table 1. Site description of 9 sampling sites, standard deviation in parentheses

	site number	sampling site	retreat year	age	SOC	TN	CNratio	vegetation	description
inside moraine	Site 1	ML303	2011	4	0.11 (0.01)	0.004 (0.02)	24.85 (0.48)		mostly rock
	Site 2	ML301	2006	9	0.24 (0.08)	0.015 (0.01)	16.05 (1.50)		mostly rock
	Site 3	ML191	1978	37	0.41 (0.19)	0.029 (0.01)	13.93 (0.39)	*Saxifraga opp.,* and black crust	a lots of rock
	Site 4	ML103	1957	58	0.45 (0.53)	0.026 (0.03)	19.24 (3.23)	Black crust, moss, and *Saxifraga opp.*	moist soil, a few gravel
	Site 5	ML62	1949	66	0.52 (0.49)	0.034 (0.03)	15.71 (1.55)	*Saxifraga opp.*	mostly gravel beside to a creek
	Site 6	ML47	1944	71	0.67 (0.43)	0.044 (0.03)	15.64 (1.16)	a few vegetation: black crust and *Silene aca.*	mixed rock, gravel and sand
	Site 7	ML20	1937	78	0.49 (0.32)	0.031 (0.02)	15.91 (1.02)	a few vegetation	mixed rock, gravel and sand
outside moraine	Site 8	ML305			2.33 (0.79)	0.165 (0.04)	13.88 (1.40)	*Saxifraga opp.*, moss, and black crust	moist soil
	Site 9	ML312			5.81 (1.49)	0.473 (0.11)	12.21 (0.55)	*Saxifraga opp.* and moss	moist soil

- In Site 1, which is closest to the glacier terminus, no compound was detected from py-GC/MS analysis. The yield of FLF and the soil organic carbon content were also very low. This could suggest that SOM in Site 1 had very labile SOM which could have converted into CO_2 under 350 ºC.
- From the py-GC/MS analysis on 8 samples, 57 compounds were detected in zone 1 (100 - 350 ºC), and 53 compounds in zone 2 (350 - 600 ºC).
- From TMAH py-GC/MS analysis, 75 substances were detected in zone 1, and 67 in zone 2. After methylation, more substances were detected from both zone 1 and 2. Many methylated substances were detected in zone 1, but in zone2, there was a small difference from those that were detected in py-GC/MS.

py-GC/MS analysis

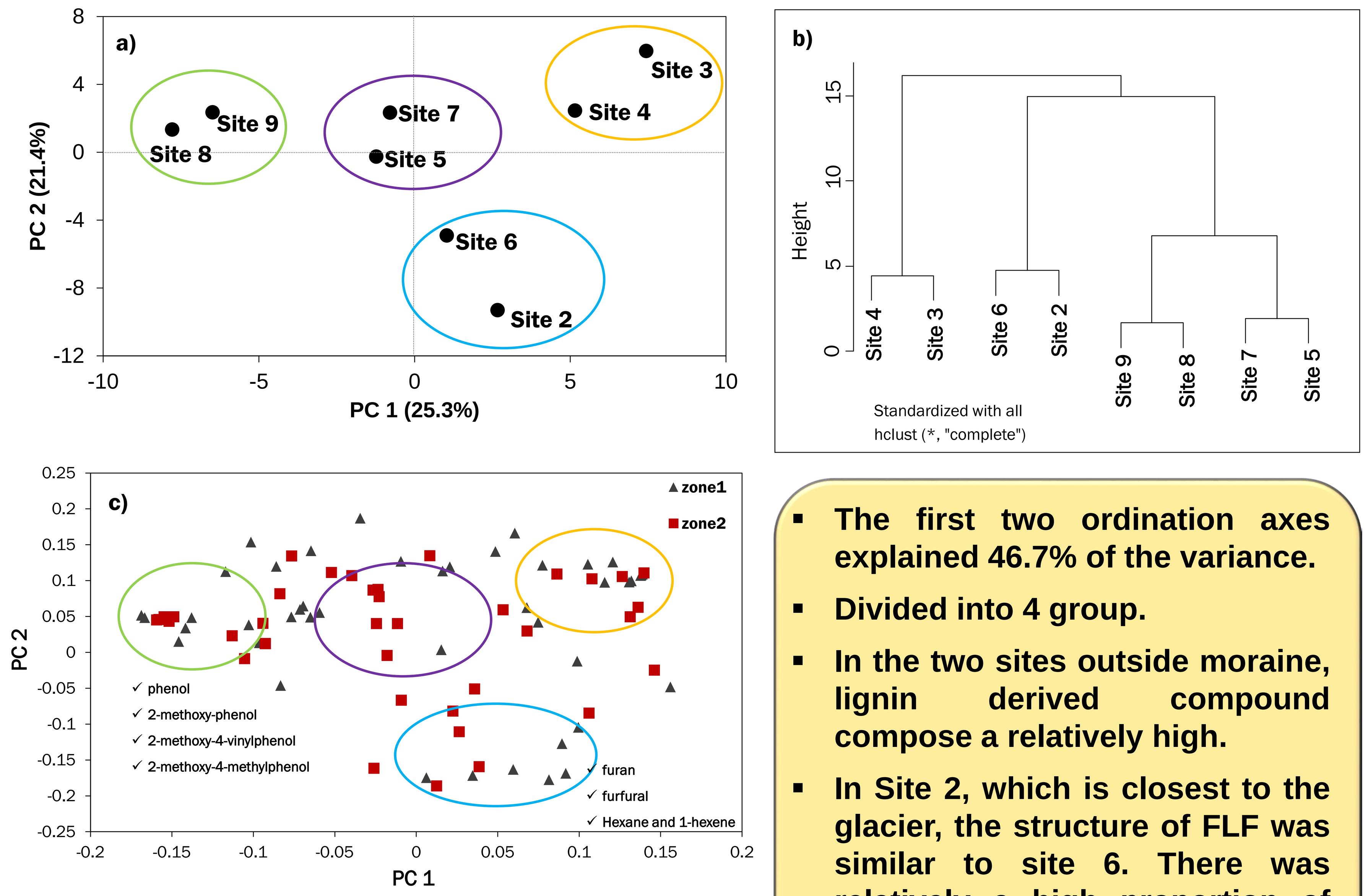

Fig. 6. Results of PCA using FLF structure from py-GC/MS analysis. a) score plot, b) dendrogram, and c) loading plot

- **The first two ordination axes explained 46.7% of the variance.**
- **Divided into 4 group.**
- **In the two sites outside moraine, lignin derived compound compose a relatively high.**
- **In Site 2, which is closest to the glacier, the structure of FLF was similar to site 6. There was relatively a high proportion of small sized matter such as furan, furfural, and hexane.**

TMAH py-GC/MS analysis

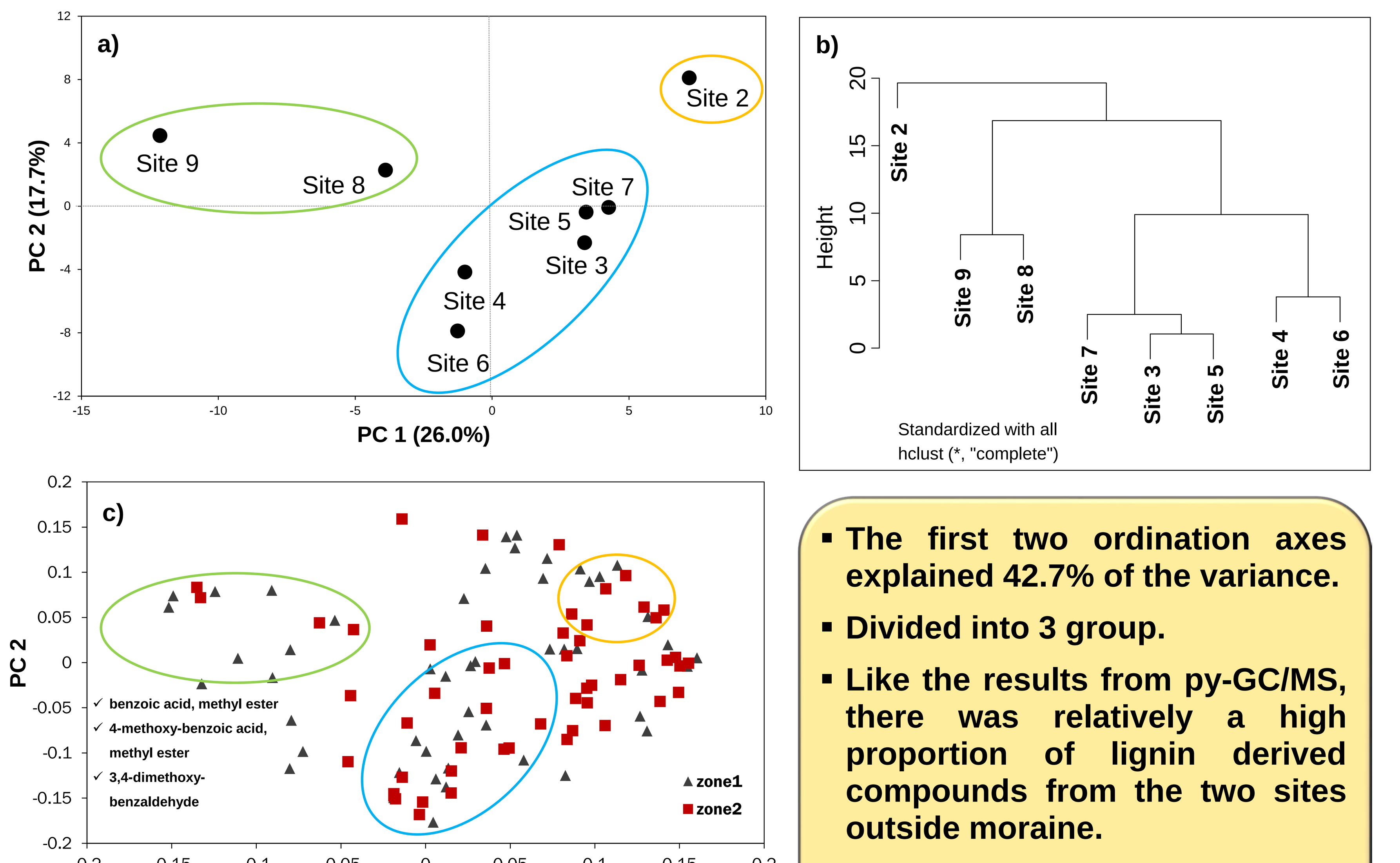

Fig. 7. Results of PCA using FLF structure from TMAH py-GC/MS analysis. a) score plot, b) dendrogram, and c) loading plot.

- **The first two ordination axes explained 42.7% of the variance.**
- **Divided into 3 group.**
- **Like the results from py-GC/MS, there was relatively a high proportion of lignin derived compounds from the two sites outside moraine.**
- **Only site 2 showed different SOM structure compared to other sites inside moraine.**

- **In both analyses, SOM characteristics between inside and outside moraine were distinctly separated. Two sites outside moraine showed similar SOM structure. Lignin derived compounds are relatively higher than inside moraine.**
- **However, there is not definite trend of newly input SOM structure along the chronosequence in our study area. For better understanding of difference among sites, relationship with soil environmental factors and vegetation composition should be studied.**

Acknowledgements

This study was supported by an "Analytical method development for soil organic matter in the Arctic (PE15160)" and "Environmental change studies based on the Arctic Dasan Station in terms of Geology, Atmospheric Science, and Ecology (PE15030)" funded by the Korea Polar Research Institute.