Dwarf birch growth in the low Arctic increases the surface carbon budget

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Context

Because of permafrost thaw, soil microbial respiration is releasing carbon that had been perennially frozen to the atmosphere in the form of CO_2 or CH_4. These greenhouse gas emissions could however be partly – or completely – counterbalanced by the emergence of shrubs in northern latitudes, as they absorb atmospheric carbon and reincorporate it in the soil through litter formation.

Objectives

- Determine the impact of the emergence of dwarf birch in the low Arctic on the tundra's carbon budget.
- Estimate the rate of carbon storage due to shrub growth.

Methods

- The study site is located near Umiujaq (Fig. 1 & 2), where the soils contain very little ancient carbon (< 1 kg m^{-2}).
- 23 soil pits were dug in the lichen tundra, where dwarf birch shrubs are emerging.
- At each study site, the lichen and birch biomass was measured.
- Shrub age was determined using dendrochronology.
- SOC stocks were measured to a depth of 30 cm.
- Carbon storage was determined from SOC and aerial and root biomass.

Figure 1: Location of Umiujaq, Nunavik, in the low Arctic. Image modified from Natural resources Canada.

Figure 2: A view of the Tasiapik Valley, near Umiujaq, where the study was performed. As shown, dwarf birch shrubs are growing throughout the valley's lichen tundra.

Results: Soil carbon budget

As dwarf birch emerges in Tasiapik Valley, the lichen cover is sometimes replaced by moss (Fig. 3).

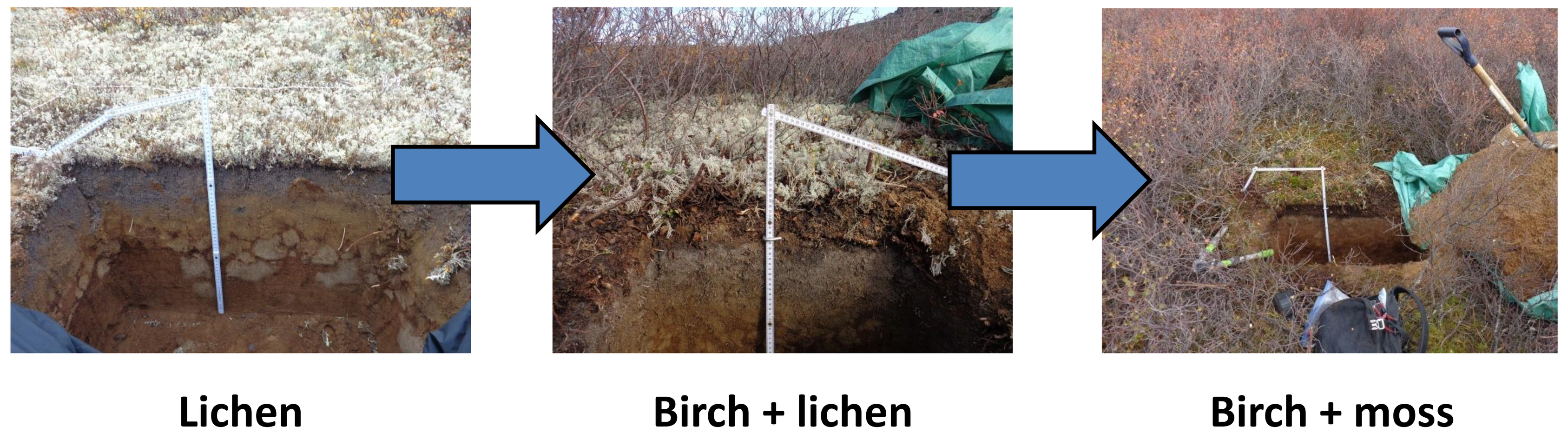

Figure 3: Evolution of the Tasiapik valley's vegetation cover.

Birch + moss sites have the highest SOC stocks, with an average of 6.2 ± 0.7 kg m^{-2}. These soils contain 4 ± 1 times more carbon than lichen beds in surrounding areas (Fig. 4).

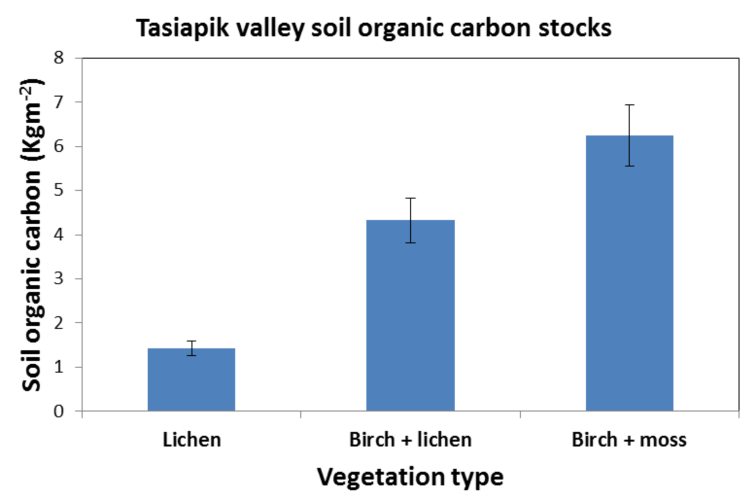

Figure 4: Tasiapik valley's soil carbon stocks in relation to vegetation cover.

Dendrochronological studies (Fig. 5 & 6), indicate that the minimum age of the sites, based on the oldest shrub sampled, ranged from 26 to 79 years.

- The age of the sites was not found to be a determining factor in estimating SOC stocks.
- Birch + moss sites are not necessarily older than birch + lichen sites.

Figure 5: Thin section of a dwarf birch, found to be 32 years old.

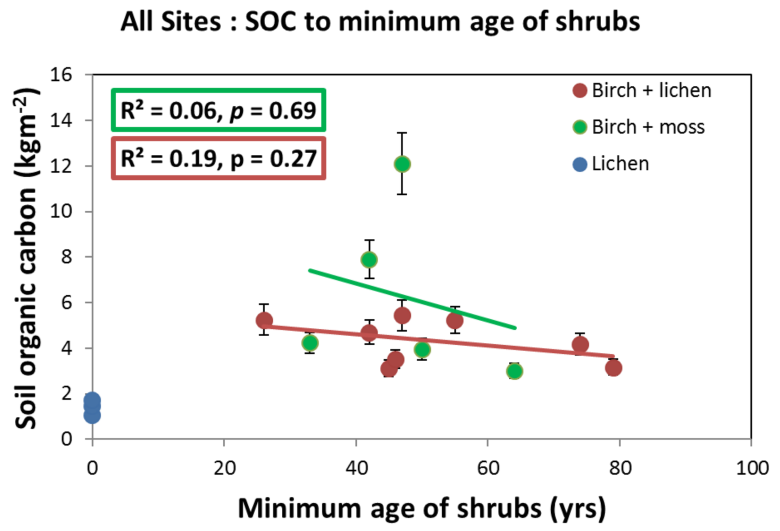

Figure 6 : The correlation of SOC stocks to the age of the oldest shrub sampled at each study site. Pure lichen sites are omitted from both regressions.

Results: Surface carbon budget, including biomass

Shown in Figure 7 is the Tasiapik Valley's overall carbon budget, which includes soil, lichen and birch carbon stocks. On average, birch sites hold 7 ± 3 kg m^{-2} of carbon. Results are underestimated, as the carbon from the moss covers found at birch sites was not accounted for.

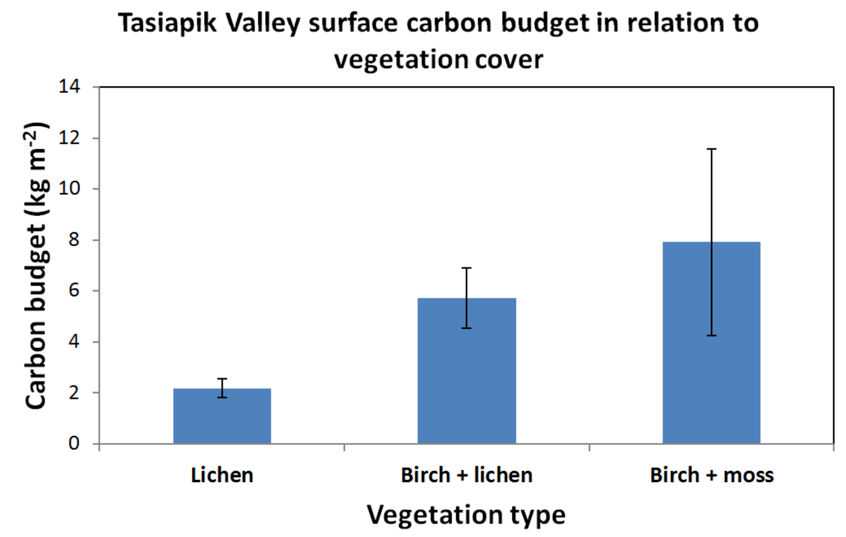

Figure 7: Tasiapik Valley's carbon budget in relation to vegetation cover. Estimates include soils, lichen and birch carbon stocks.

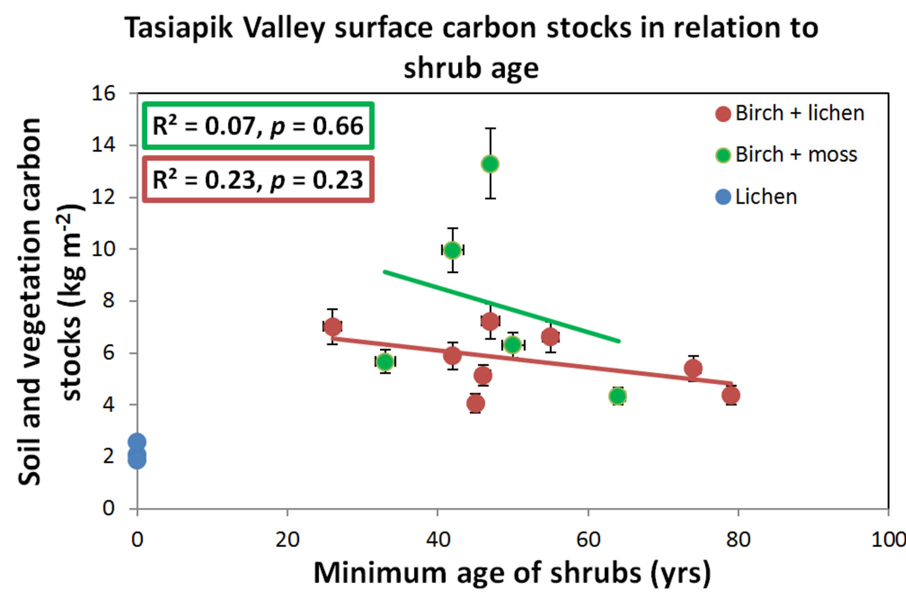

Figure 8: The correlation of the surface carbon stocks at every site (soil, lichen, birch) in relation to the age of the oldest shrub sampled. Pure lichen sites are omitted from both regressions.

The overall carbon stocks at every site (soil, lichen, birch) are not dependent on the age of the shrubs (Fig. 8). Results are in close accordance to those of Fig. 5, as soil is by far the largest carbon compartment in the valley.

Conclusions

- The transition from a lichen to a shrub tundra has increased the surface carbon budget from 2.2 ± 0.4 to 7 ± 3 kg m^{-2}.
- The carbon stocks in the valley have rapidly reached a steady state within less than 30 years of shrub growth.
- Shrub growth around Umiujaq will not cause a long term carbon sink.

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