

European beech is a net annual source of methane (CH₄)

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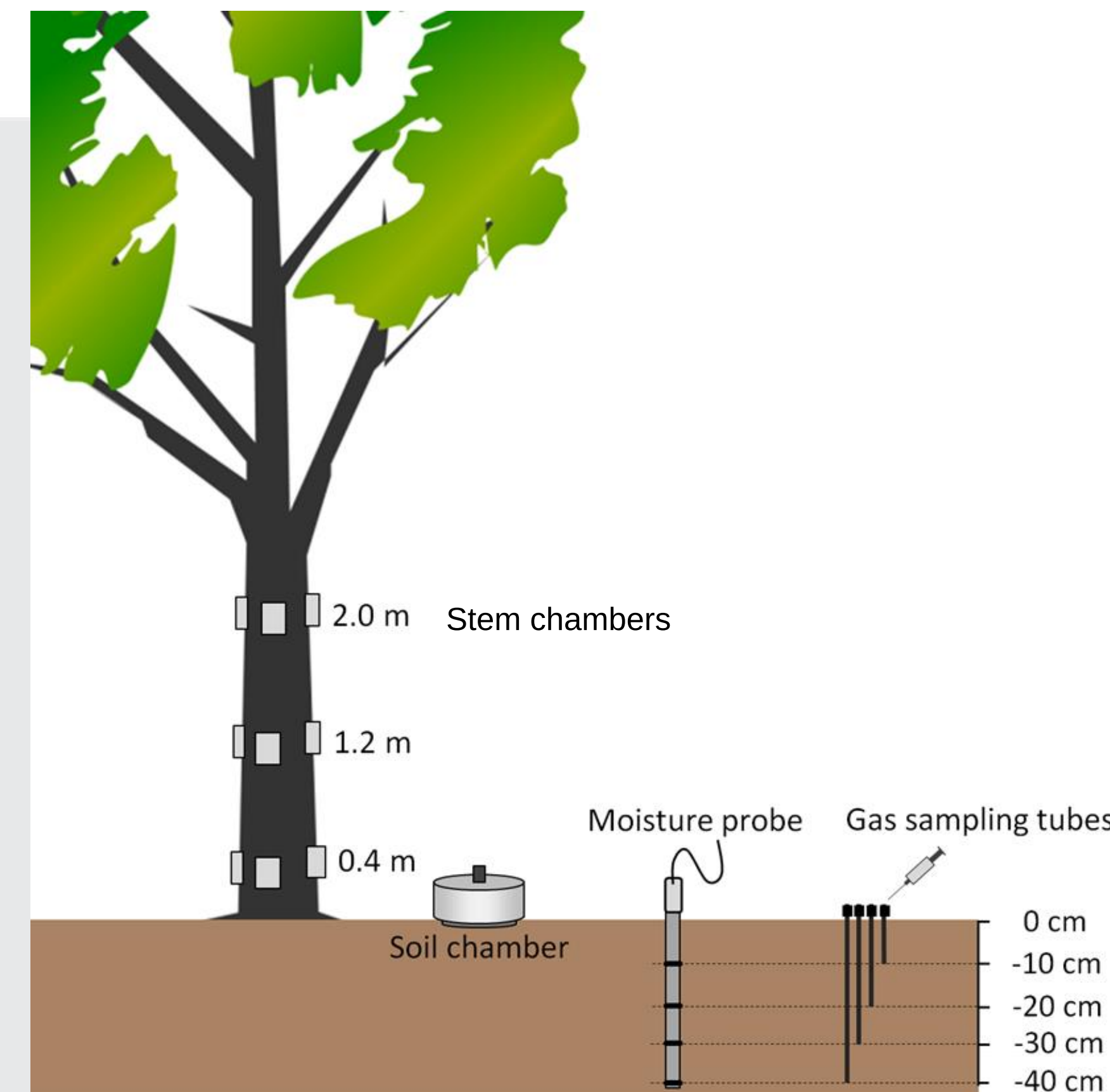
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Introduction

Temperate forests are considered to be the strongest methane (CH₄) sinks among natural forest ecosystems across climatic zones due to prevailing CH₄ uptake and oxidation in the upland soils. **Trees are known to emit CH₄ under certain conditions**; however, the role of trees, especially upland tree species, in the CH₄ exchange of forest ecosystems is still not well understood. Little is known about the seasonal dynamics of the tree stem CH₄ fluxes, particularly for the dormant season, and about the impact of environmental parameters on this gas exchange. This makes the estimation of net annual ecosystem CH₄ fluxes difficult.

Research aims

We determined CH₄ flux dynamics of forest floor and tree stems of mature European beech (*Fagus sylvatica*) representing common tree species in Central Europe. We investigated i) whether the beech CH₄ fluxes show seasonal dynamics, ii) whether the trees exchange CH₄ during winter dormancy, iii) whether the tree CH₄ fluxes are related to environmental and physiological parameters, and iv) how the tree fluxes contribute to the annual forest ecosystem CH₄ exchange.



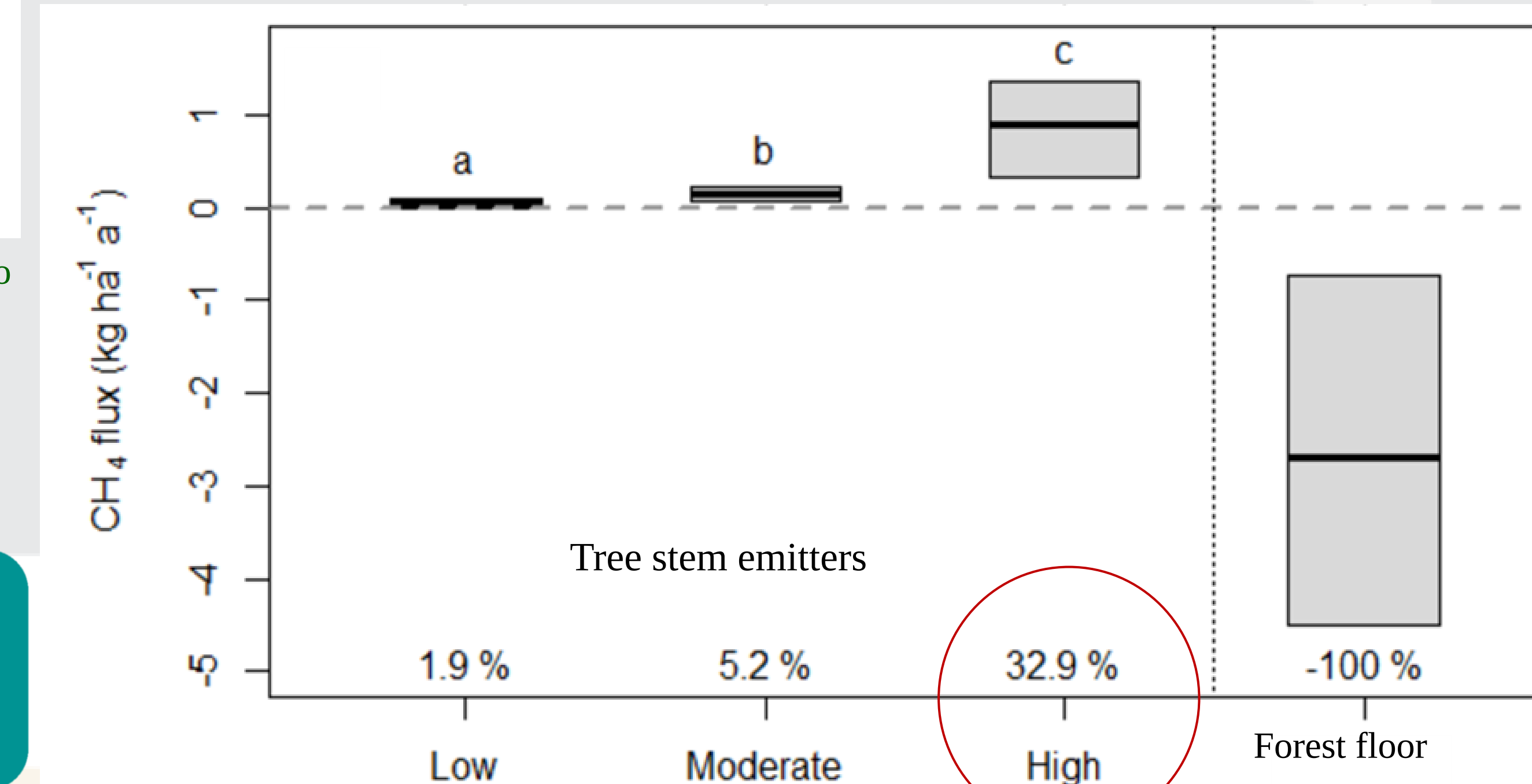
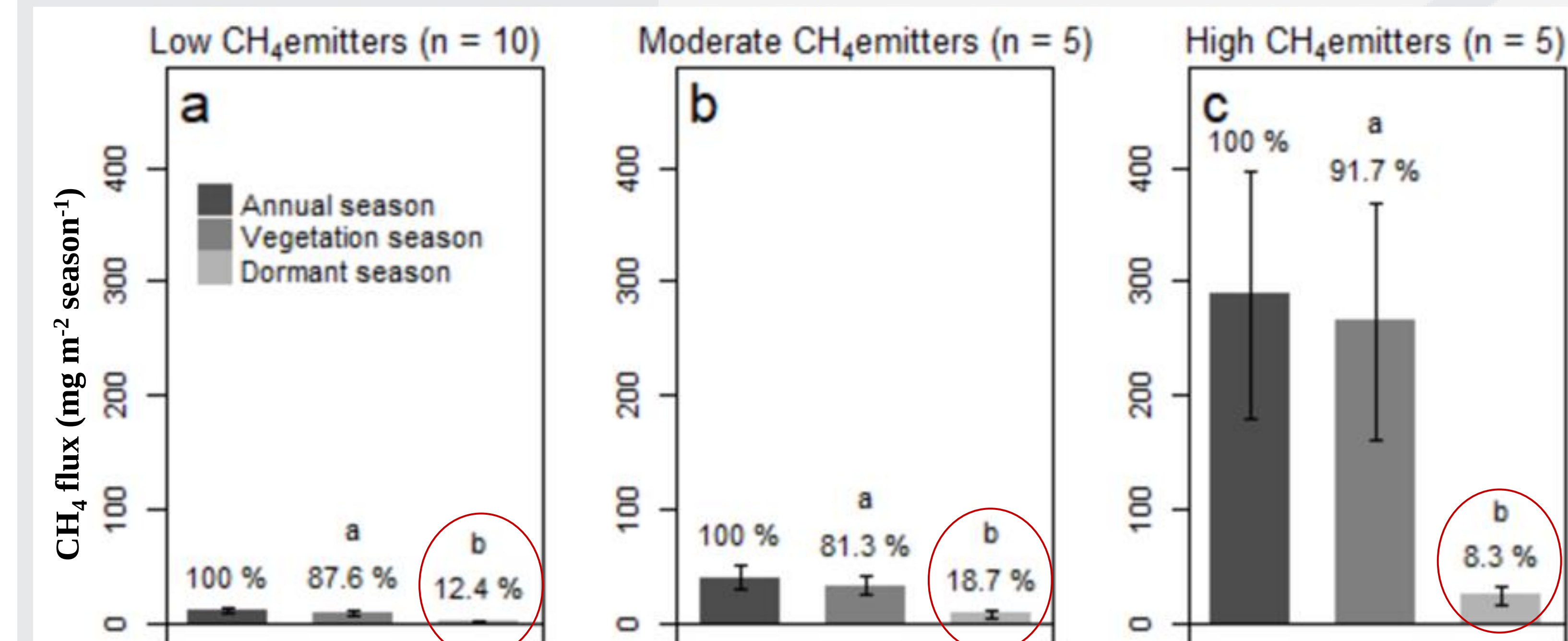
Experimental design

The study was performed in a temperate montane forest of White Carpathians, Czech Republic, from November 2017 to December 2018. Fluxes of CH₄ in mature tree stems ($n = 20$) and adjacent forest floor ($n = 20$) were measured using static chamber systems (Fig. 1,2) followed by gas chromatographic analyses of CH₄ concentration changes. The flux measurements were accompanied by parallel determination of forest floor and stem CO₂ exchange (CO₂ as indicator of tree physiological activity), and of environmental parameters describing soil and atmospheric conditions (soil CH₄ and CO₂ concentrations, water content and temperature; air temperature; photosynthetically active radiation).

← Fig. 1. **Schematic overview of the experimental design** for gas flux measurements at stem and forest floor level (chamber method) and for measurement of water content and gas concentrations in vertical soil profile. The scheme shows the stem chamber setup for beech trees number 1-7. For beeches number 8-20, the stem chambers were solely installed in 0.4 m height above the ground.



↓ Fig. 4. **Beech stem CH₄ fluxes at annual scale, for vegetation season (April–October) and for dormant season (November–March).** The fluxes (means ± standard error) are expressed per m² of stem area. Statistically significant differences between fluxes over vegetation and dormant season at $p < 0.05$ are indicated by different letters. The percentage contribution of fluxes over vegetation and dormant season to the annual fluxes (defined as 100%) is indicated.



↑ Fig. 2. **Chamber systems:** a) **Stem chambers** installed at three stem heights. Box stem chambers at one height were interconnected into one system; b) **Soil chamber.** Pumps/ventilators ensure air circulation in the systems.

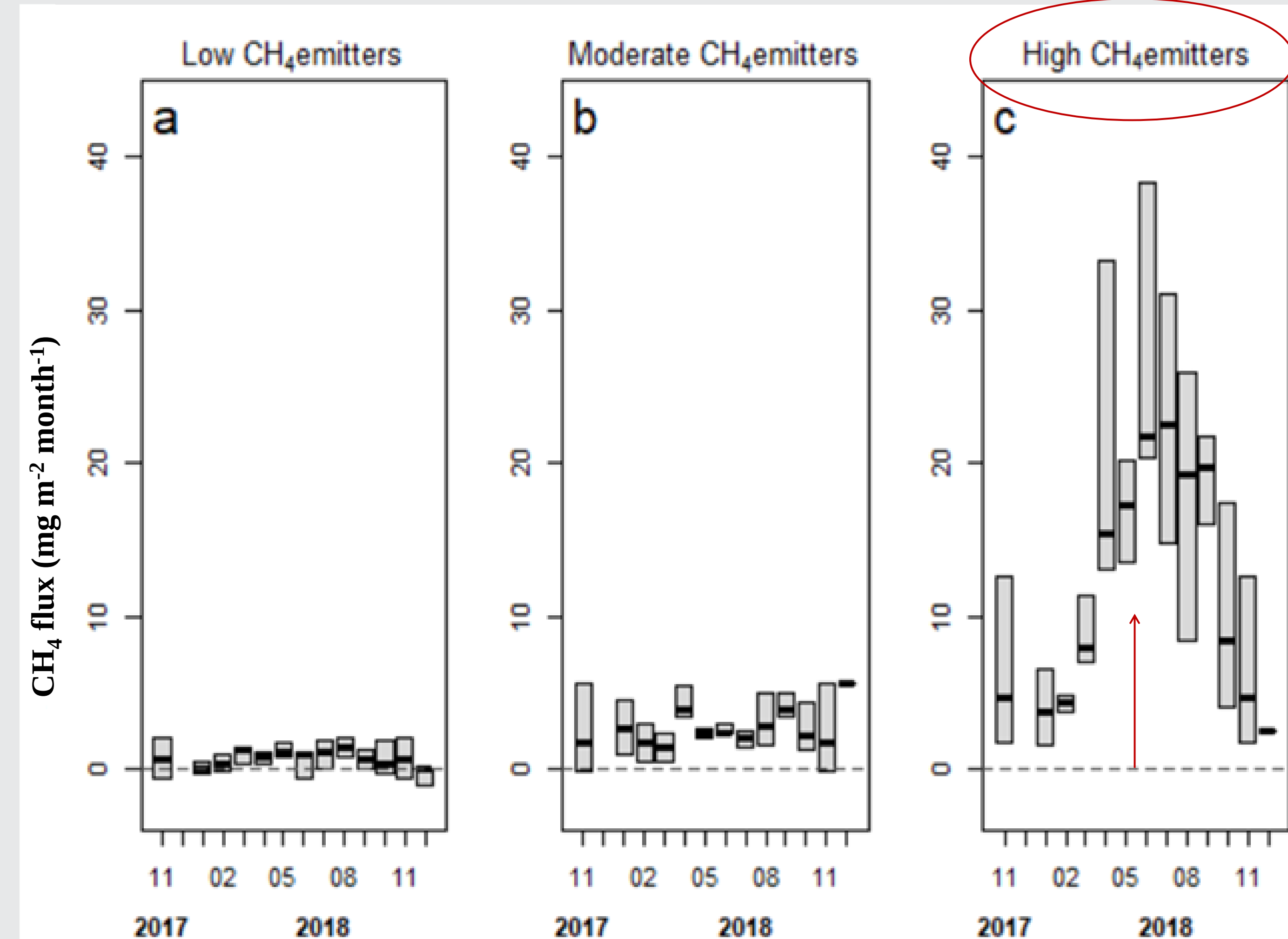
Result 3. All studied trees emit CH₄ not only during the vegetation season, but also during the dormant season. The “winter” emissions contribute by up to 19% to the annual fluxes (Fig. 4).

Result 4. Beech trees are net annual CH₄ SOURCES, whereas the forest floor is a net annual CH₄ SINK. “High tree CH₄ emitters” contribute by up to 33% to the forest floor CH₄ exchange (Fig. 5).

Result 1. All studied trees are predominant CH₄ emitters. The stem CH₄ emissions are characterized by high inter-individual variability (Fig. 3-5), which can be explained neither by forest floor CH₄ exchange, nor by soil CH₄ concentrations, water content and temperature in vertical soil profile (data not shown).

According to CH₄ emissions of the individual trees, the studied trees and forest plots were classified into three groups: „low CH₄ emitters“ ($n = 10$), „moderate CH₄ emitters“ ($n = 5$), and „high CH₄ emitters“ ($n = 5$).

Result 2. “High CH₄ emitters” within the beech trees show substantial seasonality in their stem CH₄ emissions (Fig. 3c) following the stem CO₂ efflux ($R^2 = 0.79$, $p < 0.001$).



↑ Fig. 3. **Annual course of monthly CH₄ fluxes of beech stems.** The 20 studied trees were divided into three groups according to their CH₄ emissions. The fluxes are expressed as medians per m² of stem area.

→ Fig. 5. **Annual CH₄ fluxes in beech stems and forest floor** expressed as medians up-scaled to unit ground area. Statistically significant differences in stem fluxes among the three groups at $p < 0.05$ are indicated by different letters. The contributions of stem fluxes to forest floor CH₄ fluxes (equal to 100%) are expressed as percentages of the forest floor flux.

Conclusion: In Central Europe native and widely spread beech trees markedly contribute to the seasonal dynamics of the ecosystem CH₄ exchange, and their contribution should be included into forest greenhouse gas emission inventories.