Nitrogen fixation in cryptogams at a high elevation cloud forest in Costa Rica

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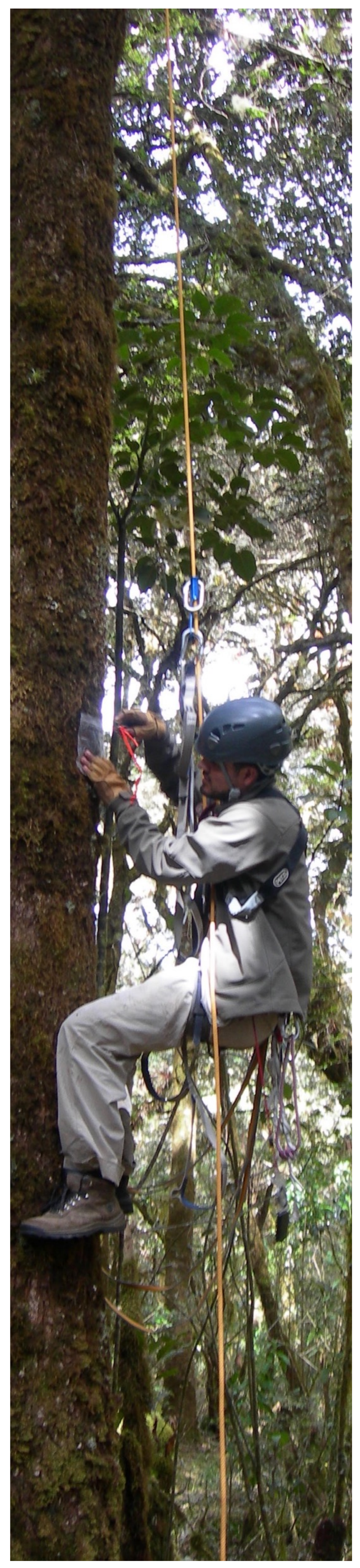
Introduction

High latitude and high elevation terrestrial ecosystems are nitrogen limited. However, montane tropical ecosystems can have more nitrogen leaving them than enters, by about 5 kg N ha^{-1} yr^{-1}. These system also lack nitrogen fixing plants to make up for the lost nitrogen. To date, the source of the N exported from montane ecosystems is unaccounted for. Cloud forests in tropical montane regions have almost year-round high humidity, allowing them to support a large biomass of tree epiphytes, including cryptogams. Since cryptogams can harbor nitrogen-fixing cyanobacteria, they may help to make up for the nitrogen lost from these ecosystems. The purpose of this study was to quantify the contributions of epiphytic cryptogams to the nitrogen fixed in a montane cloud forest. This was done by estimating the surface area of tree parts, the abundance of cryptograms on different tree surfaces, and their rates of N fixation.



Methods

The study took place in the Talamanca Mountain range, ca. 2 km NE of Cerro de la Muerte. The sampled forest stands are near the treeline (3300 m asl) and almost exclusively composed of *Quercus costaricensis,* with an understory of *Chusquea talamancensis*. Mean daily temperature is 9 ± 1 ˚C. Most of the water entering the forest is in the form of clouds intercepted by the trees. Mean daily relative humidity is 93 ± 6% with only 7 days in the year where maximum relative humidity does not exceed 95%.

Tree surface area was estimated by dividing the boles and branches of trees into diameter classes. The sub canopy (lower) branches were always >10 cm and the canopy (upper) branches < 10 cm. On 30 trees we estimated the length of the boles and all branches using a hypsometer and correcting for branch angles. These visual estimates were compared to the lengths and diameters of fallen branches. The area of tree surfaces and tree density, estimated from three 20 x 20 plots, were then used to estimate tree surface area per unit land area.

Cryptogam mass was estimated in 212 samples on the ground, boles and branches collected from 16 x 16 cm quadrates. The area of the the different surfaces was then used to estimate cryptogam abundance per unit land area.

Nitrogen fixation was measured on samples using the uptake of $^{15}N_2$ generated from ammonium sulfate in the field. Samples were incubated with 17% ^{15}N for 24 hours in acrylic chambers suspended from trees. Assays were conducted over a 1 month period in February. To account for error propagation in the estimation of N fixed per unit land area, a bootstrapping approach was used to estimate the N fixation rate per per area of each cryptogram taxa and to estimate the cover of each taxa on each surface. The product of these estimates was then used to calculate N-fixation per land area.

Results

Tree surface area (m^2 ha^{-1})

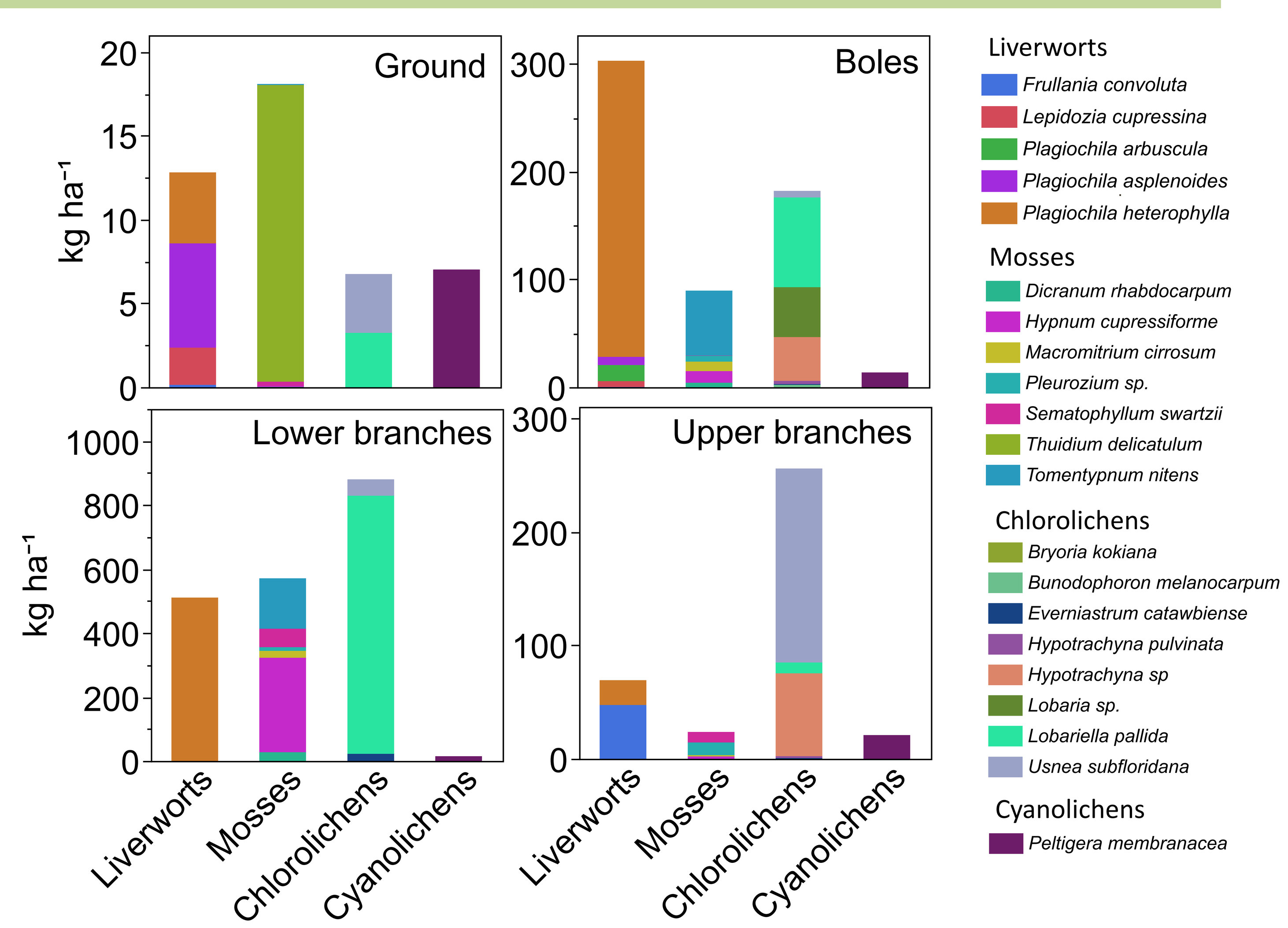
Boles:	9 620
Lower branches:	10 410
Upper branches:	5 980

Trees surfaces are 2.6 times the area of land they occupy

Cryptogam biomass (%). Total mass: 289 kg ha^{-1}

	Ground	Boles	Lower branches	Upper branches	Total
Liverworts	0.4	10.5	8.8	3.2	22.9
Mosses	0.6	3.1	19.0	1.3	24.0
Chlorolichens	0.2	6.3	30.1	14.2	50.8
Cyanolichens	0.2	0.5	0.5	1.1	2.3
Total	1.5	20.3	58.3	19.9	100.0

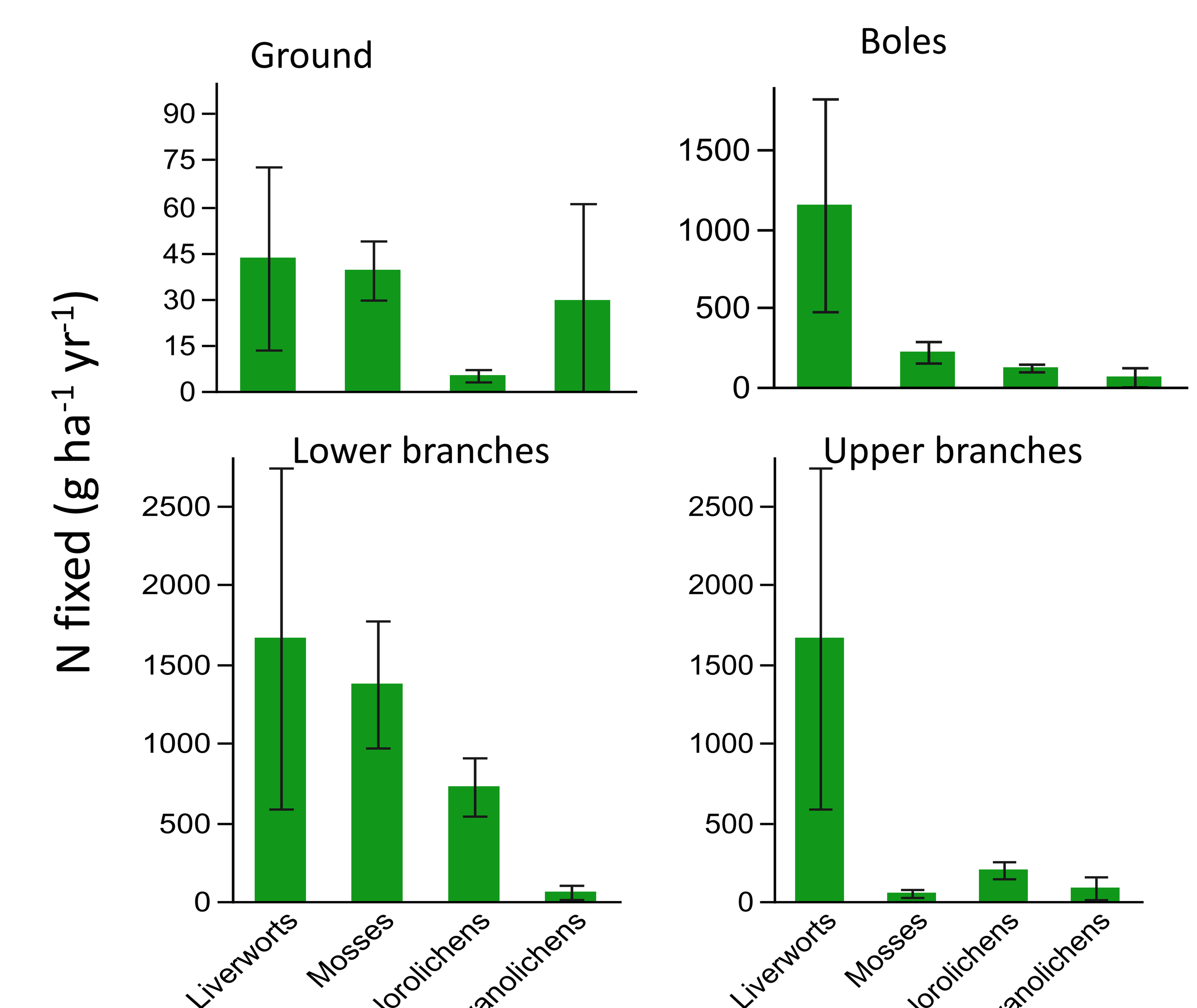
Cryptogam biomass by species



N fixation per cryptogam mass

Taxa (n)	N fixation µg g^{-1} d^{-1}	Samples fixing N (%)
Liverworts (20)	**9.1 ± 17.1**	**60**
Plagiochilla heterophylla (14)	9.1 ± 18.2	57
Frullania convolute (6)	9.1 ± 6.2	68
Mosses (27)	**4.7 ± 5.2**	**70**
Dicranum rhabdocarpum (6)	4.3 ± 6.1	50
Hypnum cupressiforme (9)	2.6 ± 3.2	68
Pleurozium sp. (6)	2.9 ± 1.1	83
Tomentypnum nitens (6)	10.1 ± 7.0	83
Chlorolichens (57)	**2.3 ± 2.0**	**51**
Everniastrum catawbiense (8)	1.6 ± 1.7	50
Hypotrachyna pulvinate (15)	0.9 ± 0.4	47
Hypotrachyna sp.(6)	2.7 ± 2.3	68
Lobariella pallida (16)	3.9 ± 1.8	50
Yoshimuriella sp.(6)	0.8 ± 0.6	33
Usnea subfloridana (8)	1.7 ± 0.8	63
Cyanolichens (17)	**12.0 ± 21.1**	**41**
Peltigera membranacea (17)	12.0 ± 21.1	41

N fixation per hectare



Conclusions

Cryptogams fixed 6.0 ± 1.9 kg N ha^{-1} yr^{-1}, enough to make of for the N typically lost from tropical montane systems.
Liverworts accounted for 60% of the N fixed.
98% of the N fixed by cryptogams occurred on tree surfaces.
Almost 2/3 of the N fixed occurred on the lower branches.

References: Markham, J. and Fernández Otárola, M. 2021. Bryophyte and lichen biomass and nitrogen fixation in a high elevation cloud forest in Cerro de La Muerte, Costa Rica. Oecologia **195**(489-497).

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