Quantification of biological nitrogen fixation in primary forest and secondary vegetation in NE Amazonia

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ABSTRACT

The fluxes of nitrogen in tropical moist forests are poorly quantified, due primarily to the lack of suitable techniques allowing accurate estimation of inputs through biological nitrogen fixation or losses through denitrification. We present evidence of the absence of symbiotic nitrogen fixation by selected leguminous trees in a primary forest that apparently turn into active N fixers following slashing and burning. $\delta^{15}N$ data from leaves and litter of secondary forests at various degrees of development showed an abrupt drop in $\delta^{15}N$ values after burning followed by a gradual increase until these values approached those of the underlying soil as the forest matured. These findings point to a gradual loss of rhizobial fixation activity as the N cycle in the growing forest is closed, possibly regulated by the N enrichment of the forest soil over time.

RESUMO

A ciclagem de nitrogênio em florestas tropicais está pouco quantificada devido a falta de técnicas adequadas de avaliação da quantidade de nitrogênio que entra no sistema pela fixação biológica de nitrogênio (FBN) ou que sai pela denitrificação. Os resultados experimentais aqui mostrados, evidenciaram a ausência de FBN em algumas árvores leguminosas analisadas na floresta primaria. Entretanto, a FBN parece reativada depois da derruba e queima da floresta. Valores de $\delta^{15}N$ em folhas novas e na liteira em vegetações de pousio de diferentes idades mostraram uma diminuição abrupta após a derruba e queima. Por outro lado, com o envelhecimento da vegetação secundária, os valores de $\delta^{15}N$ das folhas se aproximam dos valores de $\delta^{15}N$ do solo. Os resultados obtidos mostram a existência de uma gradual redução da FBN acompanhada de uma fecha successiva da ciclagem interna de nitrogênio no sistema. Tal situação, provavelmente é regulada pela quantidade de nitrogênio acumulada no solo ao longo do tempo.

ZUSAMMENFASSUNG

In tropischen Regenwäldern ist der Stofffluß von Stickstoff aufgrund noch unausgereifter Techniken, z.B. den Eintrag von N über die biologische N_2-Fixierung (BNF) oder seinen Austrag über Denitrifikation zu ermitteln, nur unzureichend erfaßt. In dieser Untersuchung werden Hinweise darauf präsentiert, daß die biologische N_2-Fixierung untersuchter Baumarten im Primärwald ausbleibt, diese aber anscheinend durch die Brandrodung wieder aktiviert wird. $\delta^{15}N$-Daten junger Blätter und der Streuauflage aus Sekundärvegetationen verschiedenen Stadiums zeigten einen abrupten Abfall nach der Brandrodung, gefolgt von

einem sukzessiven Anstieg bis hin zum Primärwald, bei dem sich die Blattwerte immer mehr an die Boden-$\delta^{15}N$-Werte anglichen. Diese Ergebnisse weisen auf eine graduelle Deaktivierung der symbiontischen N_2-Fixierung bei zunehmend geschlossenem N-Kreislauf hin, die eventuell über die Stickstoffanreicherung des Waldbodens geregelt wird.

INTRODUCTION

Information regarding biological nitrogen fixation (BNF) in tropical primary forests is scarce. Jordan (1989) estimated the N_2 fixation by non-symbiotic organisms in the upland primary forest to reach 35 kg N $ha^{-1}yr^{-1}$ as compared to 16 kg N under lowland conditions (Herrera and Jordan, 1981). This fixing capacity of the system partially was lost upon slashing and burning. Sylvester-Bradley et al. (1980), Moreira et al. (1992) and Magelhães et al. (1982) found only weak nodulation of leguminous tree species in primary forests of the Amazon, and if any, then in nutrient-poor sandy locations. Moreover, the effectiveness of the nodules was found to be weak. The methods used in those studies do not lend themselves for quantitative assessments of biological N inputs in such heterogeneous ecosystems, but better methods for this purpose are lacking. This deficiency is hampering progress in our understanding of the nitrogen dynamics in tropical rainforests.

So we conducted extensive studies to quantify these changes in the region east of Belém (Pará), one of the first regions of the Amazon to be colonized. Following a century of shifting cultivation, the area has lost most of its primary forest and may be representative of what large tracts of the Amazon will look like in the coming century. The slash and burn practice of land preparation leads to significant losses of nitrogen, particularly due to volatilization of nitrogen, estimated by Hölscher (1995) at 200 kg N ha^{-1}. Supposedly, these losses are recuperated by BNF. We undertook to assess the BNF capacity of native leguminous trees in the forest regrowth of the Northeastern Amazon to verify this supposition, using the natural abundance ^{15}N method, which was recently successfully applied in natural pastures (Sanford et al., 1995; Sprent et al., 1996).

MATERIAL AND METHODS

We took soil, litter and leaf samples of 4 distinct phases of the terra firme forest of the Bragantina region and analyzed them fort natural abundance of ^{15}N. As proposed by Shearer and Kohl (1986) we compared non nitrogen fixing an nitrogen fixing plants of the vegetation (Table 1) and calculated the % nitrogen derived from atmosphere (%NdfA) of the latter. Using biomass data estimated by Vieira (1996), Saldarriaga (1988), Nunez (1995) and the %NdfA we computed the N input via BNF for different aged vegetation.

Table 1: Species of different stages of secondary vegetation and primary forests sampled for ^{15}N analyzes

non fixing plants	**family**	**fixing legumes**	**subfamily**
Banara guianensis	Flacourtiaceae	*Piptadenia psilostachya*	Mimosoideae
Conceveiba guianensis	Euphorbiaceae	*Stryphnodendron pulch.*	Mimosoideae
Cordia exaltata	Boraginaceae	*Abarema cochleata*	Mimosoideae
Croton matourensis	Euphorbiaceae	*Abarema jupunba*	Mimosoideae
Didymopanax morototoni	Araliaceae	*Dipteryx odorata*	Papilionoideae
Jacaranda copaya	Bignoniaceae	*Inga alba*	Mimosoideae
Lacistema pubescens	Lacistemataceae	*Inga edulis*	Mimosoideae
Lecythis lurida	Lecythidaceae	*Inga heterophylla*	Mimosoideae
Nectandra cuspidata	Lauraceae	*Inga macrophylla*	Mimosoideae
Neea oppositifolia	Nyctaginaceae	*Inga rubiginosa*	Mimosoideae
Ocotea opiffera	Lauraceae	*Inga thibaudiana*	Mimosoideae
Poecilanthe effusa	Papilionoideae	*Inga stipularis*	Mimosoideae
Rinorea neglecta	Violaceae		
Rollinia exsucca	Annonaceae		
Tapirira guianensis	Anacardiaceae		
Vismia guianensis	Guttiferae		

RESULTS

^{15}N data from leaves and litter of secondary forests at various degrees of development showed an abrupt drop in ^{15}N values after burning followed by a gradual increase until these values approached those of the underlying soil as the forest matured (Figure 1).

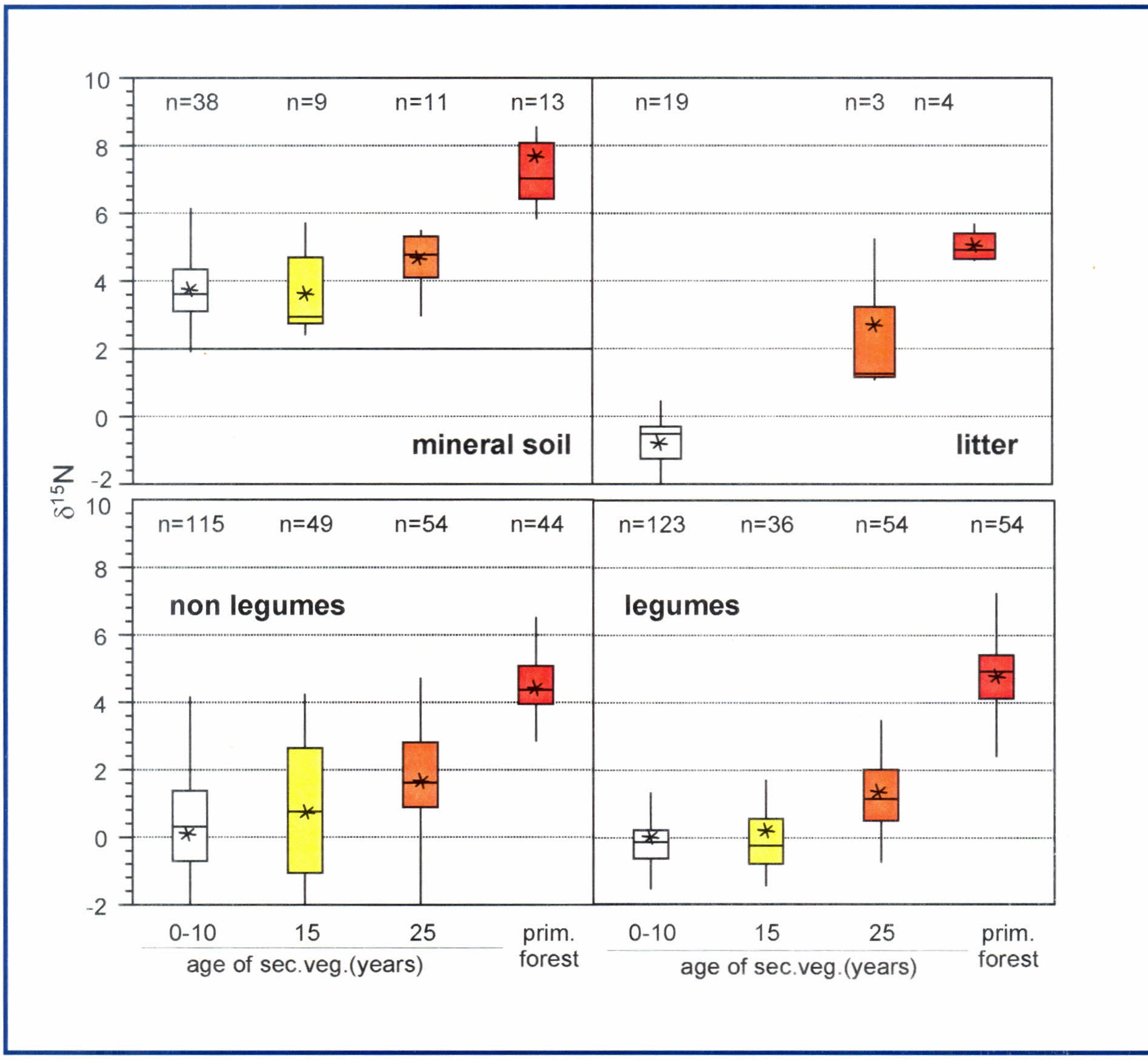

Figure 1: $\delta^{15}N$ of mineral soil, litter, young leaves of tree legumes and non-fixing tree species in different stages of secondary and primary forests (Box Whisker Plots are indicating minimum, maximum, lower and upper quartile, median and mean).

The $\delta^{15}N$ of non-leguminous plants varied widely, whereas those of legumes did not. They showed values consistently near 0, indicating nitrogen fixation, except in the older and primary vegetation. The variation of $\delta^{15}N$ was as high as for non legumes in the primary forest only, showing the dependence on soil N availability. Our calculation of the N-input also showed a gradual loss of activity of BNF. In the first years we found 5 and 25 kg N ha^{-1} $year^{-1}$. With time the symbiotically fixed nitrogen decreased (Figure 2).

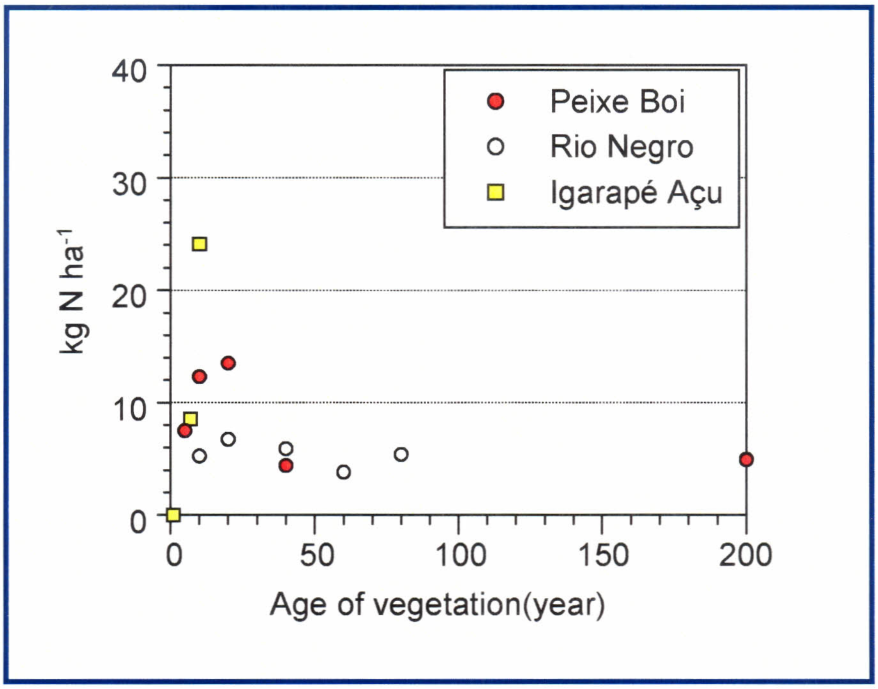

Figure 2: Nitrogen fixed biologically by leguminous trees (kg N/ha) in different stages of secondary vegetation and primary forest.

CONCLUSION

These findings point to a gradual loss of rhizobial fixation activity as the N cycle in the growing forest gradually is closed, possibly regulated by the N enrichment of the forest soil over time.

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