Catena 127 (2015) 250–257

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Nitrogen Dynamics in Hydrological Flow Paths of a Small Tropical Pasture Catchment

Luiz Felippe Salemi [a,*], Juliano Daniel Groppo [a], Rodrigo Trevisan [a], Silvio Frosini de Barros Ferraz [c], Jorge Marcos de Moraes [a,b], Luiz Antonio Martinelli [a]

[a] Laboratório de Ecologia Isotópica, Centro de Energia Nuclear na Agricultura, Universidade de São Paulo, Piracicaba, São Paulo State, Brazil
[b] Escola de Engenharia de Piracicaba, Piracicaba, São Paulo State, Brazil
[c] Laboratório de Hidrologia Florestal, Escola Superior de Agricultura 'Luiz de Queiroz', Universidade de São Paulo, Piracicaba, São Paulo State, Brazil

ARTICLE INFO

Article history:
Received 13 December 2013
Received in revised form 11 December 2014
Accepted 9 January 2015
Available online 14 January 2015

Keywords:
Ammonium
Nutrients
Surface runoff
Nitrate
Hydrological pathways

ABSTRACT

In this paper we report nitrogen (N) dynamics within hydrological flow paths of a small tropical pasture catchment within the Atlantic Rainforest region in Natividade da Serra, São Paulo State, Brazil. By collecting soil solution through 27 tension lysimeters, surface runoff through 9 plots, groundwater through one well and one stream over the course of a year, N species concentration and fluxes could be clarified. All hydrological flow paths were dominated by organic N (~60–85%). This finding is explained as a consequence of a drop of soil N cycling rates and N gaseous fluxes previously reported in the literature. Nitrogen input via bulk precipitation (~3.5 kg N ha^{-1} $year^{-1}$) exceeded N hydrological output through stream water (~2 kg N ha^{-1} $year^{-1}$). Similar findings have been described for pastures of the Brazilian Amazon Basin. If pastures like these are maintained without fertilization, catchments whose land use is old pastures may not be an important direct source of inorganic N for downstream regions.

1. Introduction

Pasture for livestock is the most important land cover in Brazil, as 200 million ha of mostly forestlands have been replaced by African grasses since Brazil was settled in the 1500s (Carmo et al., 2012). Tropical pastures are typically the final land use following the conversion of tropical forests to crop system. After a few years of relatively high yields under a given crop, crop yields substantially drop and pasture is typically the final land use. These pastures generally present low productivity since soils have already been depleted of nutrients as a consequence of slash-and-burn practice used for forest conversion to agricultural uses (Dias-Filho et al., 2001).

A chronosequence study done in Costa Rica showed that nitrous oxide (N_2O) and nitric oxide (NO) emissions decline with pasture age (Keller et al., 1993). For N_2O, it ranged from ~55 ng-N cm^{-2} h^{-1} when pastures are young (<5 years) to ~3 ng-N cm^{-2} h^{-1} when pastures are old (>25 years). In the case of NO, it ranged from ~5 ng-N cm^{-2} h^{-1} when pastures are young (>5 years) to ~1 ng-N cm^{-2} h^{-1} when pastures are old (<25 years). Four years later, this trend could still be detected in the same sites (Veldkamp et al., 1999). These results strongly suggest that nitrogen (N) is one of the nutrients whose limitation increases as pastures age.

Also using the chronosequence approach, other authors have reported a decline of net N mineralizations rates of pastures located in Rondônia, Brazil (Piccolo et al., 1994; Neill et al., 1995); a similar trend was also reported in Costa Rican pastures (Veldkamp et al., 1999).

It seems that most findings reported in the literature point toward a pattern of N limitation and/or N content decline within pasture soils (Keller and Reiners, 1994; Veldkamp et al., 1998; Erickson et al., 2001; Garcia-Montiel et al., 2001; Neill et al., 1997, 2005; Wick et al., 2005; Cerri et al., 2006).

This N depletion view described above has also been confirmed by beef cattle producers as the initial productivity following pasture establishment is high but pasture quality and growth rates decline in a short period thereafter, leading to lower liveweight gains in cattle and, as a consequence, a substantial drop in economic return (Robbins et al., 1986; Boddey et al., 2004).

The studies just outlined focused more on N cycling rates and N oxide gas fluxes within Amazonian and Costa Rican pastures. Despite these findings on N dynamics, there is a lack of studies focusing on N in water flow paths in small tropical catchments (Chaves et al., 2009). There have been few simultaneous measurements of N concentrations in pasture flow paths including surface runoff, groundwater and soil solution reported in the literature (Biggs et al., 2006; Drewry et al., 2006; Neill et al., 2011) with most being restricted to a limited number of locations in the Amazon Basin and with few flow paths sampled year-round (Neill et al., 2011).

* Corresponding author.
E-mail address: piposalemi@gmail.com (L.F. Salemi).

http://dx.doi.org/10.1016/j.catena.2015.01.009

Here we present the N dynamics within hydrological flow paths of a small pasture catchment located in the once enormous Atlantic Rainforest biome, the second largest rainforest of Brazil (Morellato and Haddad, 2000) and one of the most important biodiversity hotspot in the world (Murray-Smith et al., 2009). Knowledge on the ecosystem functioning of this highly degraded tropical biome and related land uses has only recently begun to emerge (e.g. Alves et al., 2010; Andrade et al., 2011; Dittmar et al., 2012; Carmo et al., 2012; Salemi et al., 2013). Despite five hundred years of European settlement (Morellato and Haddad, 2000), no studies have focused on N fluxes on pasture catchments in this region. Aiming to bridge this gap, we describe the N fluxes and temporal dynamics of organic and inorganic N species in various hydrological flow paths (i.e. bulk precipitation, surface runoff, soil solution, groundwater and stream water) of a small pasture catchment over the course of a year.

Findings from a small pasture catchment of the Southwestern Amazon Basin showed that pasture catchments behaved like net sinks for inorganic N, when comparing hydrological N inputs and outputs (Germer et al., 2009). This catchment retained around 5 kg N ha^{-1} $year^{-1}$ (Germer et al., 2009). In addition, vertical flowpaths from soil surface to the water table in this catchment transported around 0–0.1 N ha^{-1} $year^{-1}$ (Chaves et al., 2009) reflecting a very closed nitrogen cycle. Based on these results, we expected that our small pasture catchment in the Atlantic Rainforest would present a similar pattern to its counterpart in the Amazon Basin of Brazil.

2. Methods

2.1. Study Site

The study was carried out from December 2007 to November 2008 in a small catchment covered by pasture located in Natividade da Serra Municipality, São Paulo State, Brazil. The catchment area is 4.7 ha and the average slope is 37 ± 25% (Fig. 1). The average slope followed by standard deviation indicates a wide variety of slopes, which is typical of this region. This average was obtained from a 5-meter resolution digital elevation model. Slopes are generally characterized as convex–concave, in the direction of the topographical divide to the stream channel. The stream in this catchment is perennial and presents high levels of sediment deposition. Consequently, there is a poorly defined fluvial channel surrounded by wetland plants (e.g. *Typha* sp. and *Hedychium coronarium* J. König) rooted in a saturated area that extended about 5 m around both sides of the watercourse.

The catchment is situated in an adjacent area on the Atlantic Plateau (23°24′54 S and 45°15′04 W), close to the State Park of Serra do Mar in the Santa Virginia unit on the crest of a mountain chain. A complete description on forest type in this region and shared similarities with forests throughout the world can be found elsewhere (see, respectively, Alves et al., 2010; Bruijnzeel et al., 2011).

Geologically, this region is characterized by dissected landscapes with crystalline rocks composed mainly of granites, gneisses and migmatites. According to the U.S. Soil Taxonomy system, the soils in the catchment are young and classified mainly as Entisols and Inceptisols (Udepts), with the latter predominating, with all of them being derived from gneisses. These soils are classified as Cambissolos Háplicos and Neossolos Litólicos, respectively, in the Brazilian soil classification system. More details on pasture soil characteristics can be found elsewhere (see Table 1 in Salemi et al., 2013). The soil type underneath the macrophytes mentioned earlier (e.g. *Typha* sp. and *H. coronarium* J. König) is an Aquept (U.S. Soil Taxonomy) or Gleissolo in the Brazilian soil classification system.

With regard to climate, mean annual precipitation in the region is 2180 mm and mean annual temperature is 21 °C (Salemi et al., 2013). The rainy season occurs from October to March with the maximum rainfall in November–February and minimum in June–August, although, precipitation is rarely absent in all months (Tabarelli and Mantovani, 1999). In addition to the influence of equatorial and tropical air masses, this frequently humid environment is strongly influenced by orographic

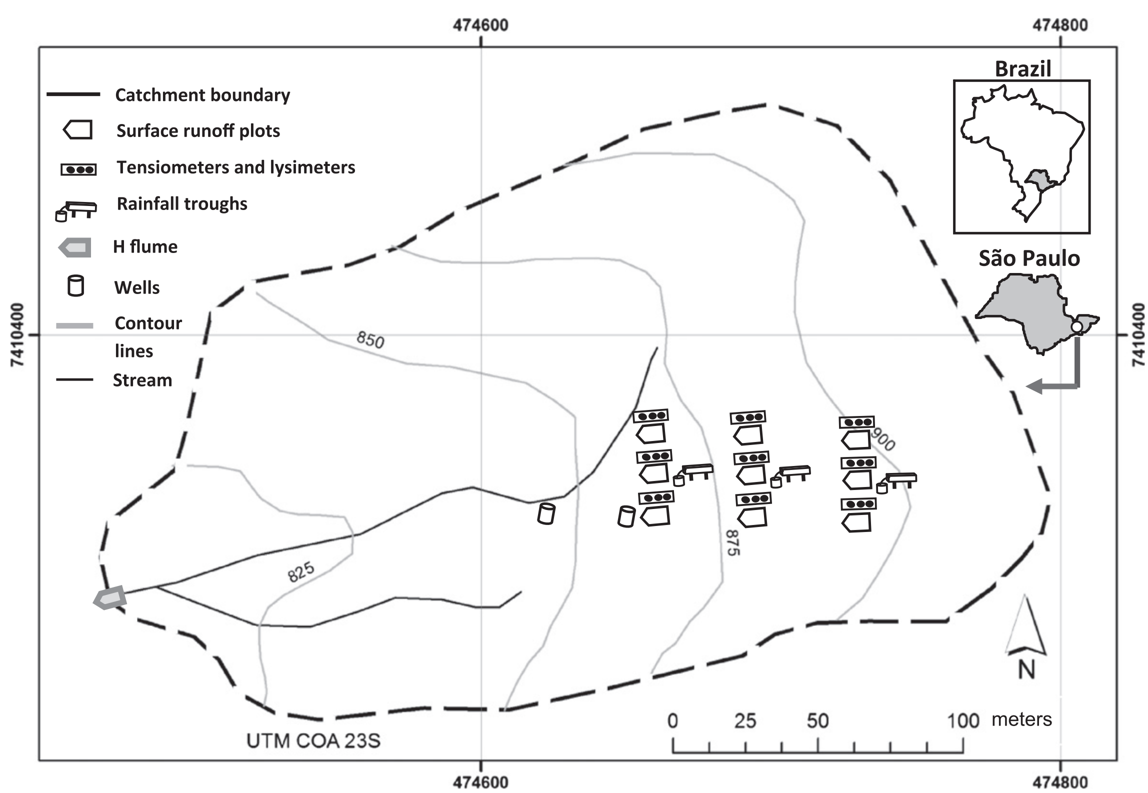

Fig. 1. Pasture catchment and experimental design.