Limnologica 40 (2010) 322–329

Contents lists available at ScienceDirect

Limnologica

journal homepage: www.elsevier.de/limno

Land use and topography as predictors of nutrient levels in a tropical catchment

María M. Castillo *

Departamento de Estudios Ambientales, Universidad Simón Bolívar, Apartado 89000 Baruta, Caracas 1080, Venezuela

ARTICLE INFO

Article history:
Received 19 November 2008
Received in revised form
11 August 2009
Accepted 30 September 2009

Keywords:
Tropical stream
Nitrate
Phosphorus
Land use
Nutrient
Topography
Runoff

ABSTRACT

The influence of landscape on nutrient concentration and yield was analyzed in a tropical catchment, the Guare River in northern Venezuela. Spatial and temporal variation in nitrate, SRP and total P were determined in 15 sites located along the river mainstem and tributaries. Higher nitrate concentrations and yields were reported from upper sites and both decreased in the downstream direction along the river mainstem. These trends appear to be related to more pronounced slopes and larger proportions of agricultural and forest lands in subcatchments located in the upper part of the basin, and dense algal mats in the lower reaches. Nitrate values were higher during periods of high discharge, suggesting that nitrate is primarily transported by shallow subsurface flow. SRP represented between 60 and 80% of total P. Phosphorus concentrations were homogeneous along the river mainstem and showed little seasonal variation, while yields were higher in the upper basin. Multiple regression identified slope, runoff and agriculture as primary predictors of nitrate and phosphorus across the watershed, which suggests that both natural and anthropogenic landscape characteristics have a strong influence on nutrient levels in the Guare catchment.

Introduction

Nutrients transported by rivers have a profound effect on water quality, habitat condition and trophic state of aquatic ecosystems. In streams, increased nutrient inputs can enhance algal growth which can lead to hypoxia, alter the structure of food webs and affect environmental services such as water supply and recreation (Dodds 2006; Mallin et al. 2006). In temperate streams, changes in land use and nutrient loading are strongly correlated (Jordan et al. 1997; Boyer et al. 2002; Filoso et al. 2003; Brodie and Mitchell 2005). Agriculture, atmospheric deposition and point source inputs from human population in the catchment have been identified as strong predictors for N exports (Howarth et al. 1996; Jones et al. 2001; Kemp and Dodds 2001), while discharges from urban centers and wastewater treatment plants and runoff from agricultural fields, can represent important sources of P (David and Gentry 2000, Little et al. 2003; Hart et al. 2004). Other variables such as riparian cover, catchment geology and topography can also influence nutrient loading (Castillo et al. 2000; Ekholm et al. 2000; Jones et al. 2001). Several studies have investigated nutrient transport in undisturbed tropical streams and rivers (Lewis 1986; McDowell and Asbury 1994; Castillo 2000; Saunders et al. 2006), but information on impacted tropical systems is limited. Streams located in the humid tropics can show a wide range of physical and biological features (Boulton et al. 2008); however, they are mostly located in developing countries, where socioeconomic factors and conservation and management practices can result in different impacts of land use changes on streams compared to those observed in developed nations (Ramírez et al. 2008).

In developed countries, most efforts have focused on controlling the input from point sources through wastewater treatment implementation and phosphate detergent bans (Carpenter et al. 1998; Litke 1999), and as a result diffuse sources remain as the main source of pollution (Hart et al. 2004; Royer et al. 2004). To reduce the export of nutrients from diffuse sources, particularly from cropland, measures such as conservation tillage, fertilizer management and conservation of highly erodible land have been proposed (Baker and Richards 2002; Moog and Whiting 2002). These practices have contributed to a reduction in N and P loading in some catchments of North America and Europe (Baker and Richards 2002; Kronvang et al. 2005).

In many developing countries, where wastewater management has not been implemented, both diffuse and point source pollution constitute major nutrient sources. In Latin America, about 73% of the population lives in cities and less than 14% of the municipal wastewater receives treatment (Howarth and Ramakrishna 2005; CEPAL 2006). In addition, deforestation is increasing in many developing regions, with land being converted primarily to agricultural use (F.A.O. 2007). Although N fertilizer use in Latin

* Tel.: +58 212 9063070.
E-mail address: muzcanga@usb.ve

0075-9511/$ - see front matter © 2009 Elsevier GmbH. All rights reserved.
doi:10.1016/j.limno.2009.09.003

America represents only 6.3% of the world consumption compared to 13.5% of North America, it is expected to increase at an annual rate of 2.4% in the next four years (F.A.O. 2008). In tropical regions, such a change in land use can have a higher impact than in less humid areas because the magnitude and duration of precipitation can increase nutrient losses from the land as well as the vulnerability of soils to erosion (Pringle et al. 2000). In addition, implementation of regulations and conservation practices are usually poor, increasing the impacts of human activities (Ramírez et al. 2008). Since changes in land use in these regions probably will result in greater impacts on nutrient loading to streams, it is important to understand how land use at the catchment level influences nutrient export and concentration in streams.

In this study, the relationship between landscape variables and spatial patterns in nitrate and phosphorus were examined in the Guare catchment in Venezuela. Although a large proportion of the study catchment is covered by forests, human activities have disturbed much of the upper basin, influencing nutrient patterns along the river mainstem and some tributaries. By using multiple linear regression, percent agriculture in the catchment, runoff and slope were identified as predictors of nitrogen and phosphorus levels, suggesting that land use and topography can influence nutrient export in the Guare catchment.

Study area

The Guare River is a tributary of the Tuy River, which drains into the Caribbean Sea in northern Venezuela. The Guare basin has a humid tropical climate with a dry season from October to March and a rainy season from April to September. The Guare catchment covers an area of 182 km^2 and it is located between the interior and the coastal branches of the Coast Mountain Range, exhibiting a hilly topography. The study watershed is heterogeneous in terms of land use, showing different types of vegetation (forest and shrubland), crops (horticulture and pasture) and livestock (cattle and poultry farms) (Carnemolla et al. 1990). Although the watershed is mostly forested (40%), agriculture and pasture represent 10% and 12% of the total area, respectively. Agriculture is primarily concentrated in the upper watershed, representing up to 45% of the area of some headwater catchments. Nickel mining is conducted in the catchment of the Mesia River, one of the main tributaries of the Guare. In addition, the small urban centers of Tácata, Altagracia de la Montaña, Las Dolores and San Daniel account for a total population of 6900 (I.N.E. 2001).

Methods

Fifteen sites were selected to cover spatial variation in land use in the study watershed. The sites were visited between September 2001 and November 2002 to follow seasonal variation in discharge. Sampling was conducted in September and November 2001 and January, March, May, June, July, September and November 2002. All sites were sampled at the same date. Eight sites were located on the mainstem of the Guare River and seven sites on the tributaries Las Dolores, Agua Fría, Quebrada Seca, Emilia and Mesia (Fig. 1). Mainstem sites Guare 1 and 2 represented the conditions prevailing in the upper part of the basin, where agriculture is mostly concentrated, particularly at Las Dolores catchment (Table 1). In contrast, Emilia is less cultivated but a large proportion (74%) of the Guare population is located in this catchment. In Emilia, three sites were sampled so as to detect the influence of urban centers such as Bagre and Altagracia de la Montaña, and the inputs of tributaries draining the west side of the basin, like Quebrada Seca. The Mesia catchment is primarily covered by scrubland and secondary vegetation. Agriculture and pastureland are observed along the Guare mainstem.

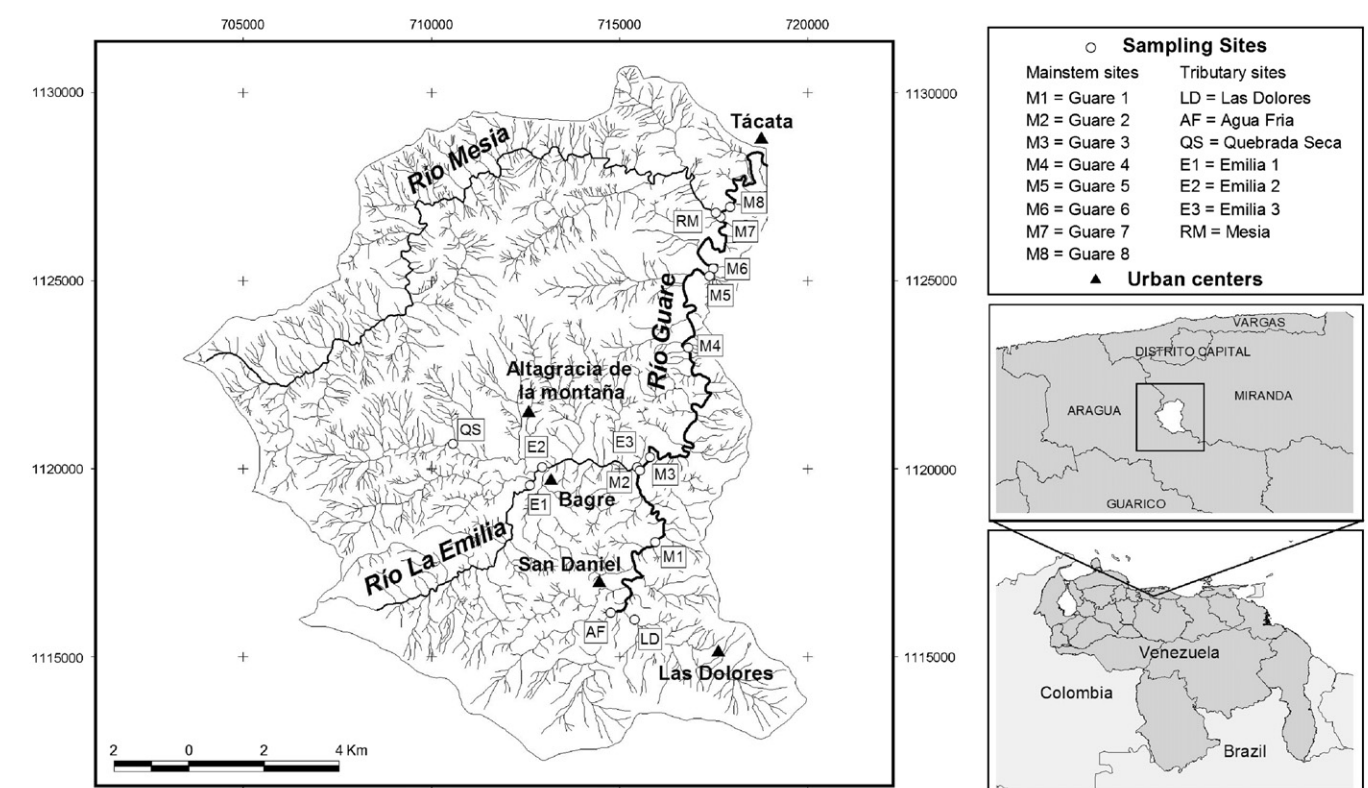

Fig. 1. The catchment of the Guare River, Venezuela. Sampling sites at tributaries and mainstem of the river are shown.