International Soil and Water Conservation Research 5 (2017) 69–75

HOSTED BY

Contents lists available at ScienceDirect

International Soil and Water Conservation Research

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

Original Research Article

The new Caribbean Nitrogen Index to assess nitrogen dynamics in vegetable production systems in southwestern Puerto Rico☆

Miguel Oliveras-Berrocales[a], David Sotomayor-Ramírez[b], Jorge A. Delgado[c,*], Luis R. Pérez-Alegría[d]

[a] USDA-NRCS, Arkansas: 2603 Federal Building, 100 E, 8th Ave, Pine Bluff, AR 71601, USA
[b] University of Puerto Rico, Mayagüez Campus, College of Agricultural Sciences, Department of Agroenvironmental Sciences, PO Box 9000, Mayagüez, PR 00680, USA
[c] USDA-ARS, Acting Research Leader, Soil Management and Sugar Beet Research Unit, 2150 Centre Ave., Building D, Suite 100, Fort Collins, CO 80526, USA
[d] University of Puerto Rico, Mayagüez Campus, College of Agricultural Sciences, Department of Agricultural and Biosystems Engineering, USA

ARTICLE INFO

Keywords:
Nitrogen index
Nitrogen management
Residual soil N
Crop N removal

ABSTRACT

Nutrient loss from agricultural fields is one of the main factors influencing surface- and ground-water quality. Typical fertilizer nitrogen (N) consumption rates in vegetable production systems and horticultural crops in Puerto Rico fluctuate between 112 and 253 kg N/ha. The nitrogen use efficiency of vegetable crops is low, increasing the potential for nitrogen losses and high residual soil nitrate content. Quantification of residual soil N and N losses to the environment can be a difficult task. Simulation models such as the USDA-ARS N Index can be used to identify the relative magnitude of varying N-loss pathways and to identify best management practices. Field studies were conducted to quantify residual soil N and crop N removal, and to validate the Nitrogen Index in onion, tropical pumpkin and tomato production systems in the Lajas Valley in southwestern Puerto Rico. Relationships between observed and simulated values were determined to examine the capability of the model for evaluating N losses. There was good correlation between observed and predicted values for residual soil N ($r = 0.88$) and crop N removal ($r = 0.99$) ($p < 0.05$). In the production systems evaluated, the N volatilization losses ranged from 1 to 4 kg N/ha, the denitrification losses ranged from 18 to 46 kg N/ha, the leaching losses ranged from 155 to 779 kg N/ha, and the residual soil nitrate ranged from 64 to 401 kg N/ha. The N use efficiency ranged from 15% to 39%. The results obtained showed that the Nitrogen Index tool can be a useful tool for evaluating N transformations in vegetable production systems of Puerto Rico's semi-arid zone.

1. Introduction

The Lajas Valley Agricultural Reserve (LVAR) is a large plain in southwestern Puerto Rico located near 17°58′50″ N and 66°54′00″ W, with fertile soils, ample water availability, favorable temperatures for agricultural production, and an irrigation-drainage infrastructure (USDA-SCS, 1965; Lugo-López, 1995). In recognition of its agricultural potential and in response to increasing pressure from urban development, the area was decreed by law as an agricultural reserve (LPRA 277, 1999). The LVAR has a total area of about 41,000 ha and extends from the municipality of Guánica in the east to Bahía de Boquerón in the west (Fig. 1). The western section of the LVAR drains toward Bahía de Boquerón and the remainder toward Guánica Bay in the east. The watershed divide that runs north to south is located 9.5 km east of Bahía de Boquerón near State Road 116. The LVAR's altitude ranges from 1.1 m above sea level (MSL) near what was formerly Guánica Lagoon (currently agricultural land), to roughly 13 m above MSL at the east-west drainage divide. The main crop in the LVAR was sugarcane, but since the crop was gradually phased out in the 1980s, there has been conversion to idle lands, and the main crops that are being grown are naturalized and improved forages for haylage and cattle grazing; rice; and horticultural crops (Sotomayor-Ramírez & Pérez-Alegría, 2012).

From 2009–2010, Puerto Rico's gross agricultural income (GAI) for horticultural crops was estimated at $56.8 M, which represented 13.8% of the total GAI. Vegetables such as onions, pumpkins, peppers, and tomatoes contributed 55% to the horticultural crops' GAI, and farm value increased by 61% over the previous year (DAPR, 2011). Typical fertilizer consumption rates in vegetable production systems and horticultural crops in Puerto Rico, fluctuate from 112 to 253 kg N/ha

☆Peer review under responsibility of International Research and Training Center on Erosion and Sedimentation and China Water and Power Press.

* Corresponding author.
E-mail address: Jorge.Delgado@ars.usda.gov (J.A. Delgado).

http://dx.doi.org/10.1016/j.iswcr.2017.01.001
Received 28 November 2016; Received in revised form 4 January 2017; Accepted 18 January 2017
Available online 15 February 2017

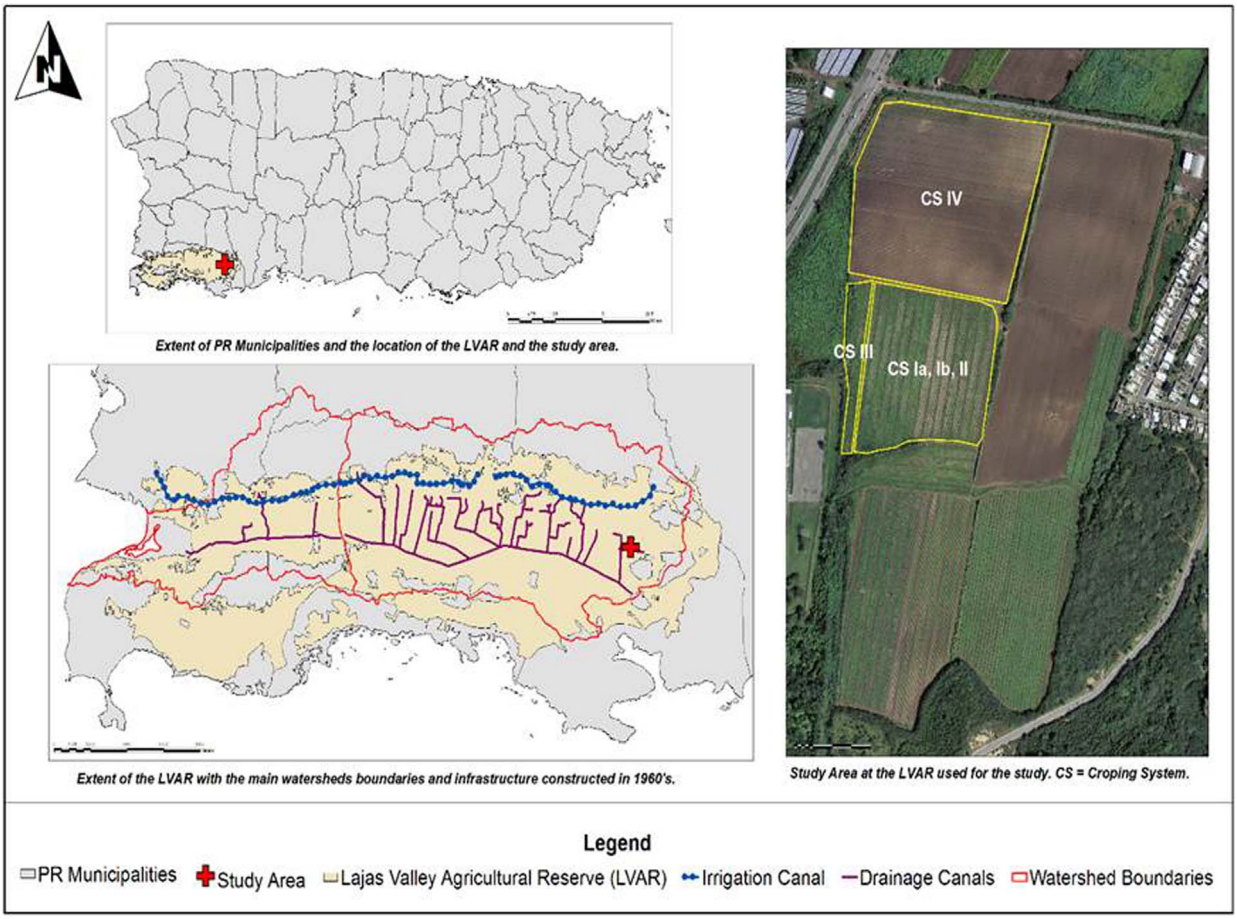

Fig. 1. Location of (A) the Lajas Valley Agricultural Reserve (LVAR) in southwestern Puerto Rico, (B) aerial extent of the area and localization of the study site (red cross), and (C) layout of the fields for each cropping system. Cropping system description is in Table 1.

(Sotomayor-Ramírez & Pérez-Alegría, 2012). Vegetable producers tend to apply high fertilizer nitrogen (N) inputs in efforts to ensure high yields. N fertilizer inputs are necessary to maintain economically viable agricultural production, but N inputs that are higher than necessary increase losses of N via different N loss pathways, impacting groundwater, air, and soil quality (Antweiler, Goolsby, & Taylor, 1996; Follett & Delgado, 2002; Meisinger & Randall, 1991; Mosier, Doran, & Freney (2002). There is limited information on modeling the fate of fertilizer-N in vegetable production systems (De Paz, Delgado, Ramos, Shaffer, & Barbarick, 2009; Delgado, 1998, 2001), especially in systems of the tropics (Sotomayor-Ramirez, Oliveras-Berrocales, & Wessel-Beaver, 2017). Traditional management practices that over-apply fertilizer-N and do not budget N use, increase the potential for N losses to the environment. Traditional farming practices used in vegetable production systems in the LVAR may increase the potential for NO_3-N leaching, which may lead to groundwater contamination.

Negative effects from N losses from agricultural systems have been reported (Hatano, Nagumo, Hata, & Kuramochi, 2005; Hofmann, Brouder, & Turco, 2004; Vagstad, Jansons, Loigu, & Deelstra, 2000). There is a need to assess the effects of N fertilizer management on agricultural N losses to the environment and evaluate best management practices (BMPs) that can reduce the environmental impact in this region (Delgado, 2001; Shaffer & Delgado, 2002). Due to the complexities of the N cycle, it is difficult to quantify N losses from agricultural systems (Delgado, 2002). Nutrient managers that work on agricultural systems need quick tools that could help them integrate large amounts of information on soils, crops, weather, and management practices to identify nitrogen management practices that have lower environmental risk but maintain higher yields.

While tools vary in their level of complexity and the information they provide, tools such as the USDA-ARS Nitrogen Index can be used to assess the fate of N used in agricultural systems and associated management practices. Shaffer and Delgado, (2001, 2002) described different tiers of nitrogen management tools that could be used based on the complexity of the data needed to develop viable field management practices. Nutrient managers can use the Nitrogen Index, a Tier-1 tool, to assess N dynamics in agricultural production systems and evaluate the effect of different management practices to reduce N losses to the environment. A Tier 1 level system would be a system that rapidly conducts an initial qualitative/quantitative screening to evaluate the potential impacts of N losses (Delgado et al., 2006; Shaffer & Delgado, 2002). The Nitrogen Index, an example of a Tier-1 system, ranks the effects of nitrogen management on nitrate (NO_3-N) leaching and atmospheric and surface N losses, and it can be used to conduct a quick comparison of simple scenarios. Different versions of the Nitrogen Index have been tested and validated in various geographical areas, and can assess N losses from agricultural fields (De Paz et al., 2009; Figueroa-Viramontes et al., 2011; Wu et al., 2005; Van et al.,2002). A new version for the Caribbean area was developed by Delgado et al. (2011). This is the first effort to use the Nitrogen Index in Puerto Rico to evaluate N management in vegetable production systems in the LVAR. The objective of this study was to evaluate the performance of the new Caribbean Nitrogen Index in assessing N dynamics in vegetable production systems in Puerto Rico.