AGRICULTURAL WATER MANAGEMENT 95 (2008) 633–644

available at www.sciencedirect.com

ScienceDirect

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

Summer cover crop impacts on soil percolation and nitrogen leaching from a winter corn field

R. Muñoz-Carpena [a,*], A. Ritter [a,b], D.D. Bosch [c], B. Schaffer [d], T.L. Potter [b]

[a] Agricultural and Biological Engineering Department, University of Florida, 101 Frazier Rogers Hall, PO Box 110570, Gainesville, FL 32611-0570, USA
[b] Instituto Canario de Investigaciones Agrarias (ICIA), Apdo. 60 La Laguna, 38200 Tenerife, Spain
[c] USDA-ARS, SEWRL, 2375 Rainwater Road, PO Box 748, Tifton, GA 31794, USA
[d] Tropical Research and Education Center, University of Florida, 18905 SW 280 Street, Homestead, FL 33031, USA

ARTICLE INFO

Article history:
Received 8 August 2007
Accepted 7 January 2008
Published on line 20 February 2008

Keywords:
Nitrogen leaching
Deep percolation
Cover crop
Maize
Crotalaria juncea
Sunn hemp
WAVE model
Vadose zone
Modeling
Groundwater pollution
Water management
Irrigation

ABSTRACT

The impacts of a leguminous summer cover crop (sunn hemp; *Crotalaria juncea*) on nitrogen leaching from a corn (*Zea mays* L.) field was evaluated by direct measurements of soil water content and nitrogen balance components, complemented by direct and inverse modeling as an exploratory tool to better understand water flow and nitrogen balances in the soil. Water and nitrogen inputs and outputs were measured during winter corn production in an experimental field located in the south Miami-Dade basin in southern Florida (USA). Data from the last two seasons (2001–2002 and 2002–2003) of a 4-year study are presented. The field was divided into six 0.13 ha plots. One-half of the plots were rotated with sunn hemp (CC plots) during the summer while the remaining plots were kept fallow (NC plots). Sweet corn management was uniform on all plots and followed grower recommended practices. A numerical model (WAVE) for describing water and agrochemical movement in the soil was used to simulate water and nitrogen balances in both types of plots during the corn seasons. The hydrodynamic component of WAVE was calibrated with soil water data collected continuously at three depths, which resulted in accurate soil water content predictions (coefficients of efficiency of 0.85 and 0.91 for CC and NC plots, respectively). Measured components of the nitrogen balance (corn yields, estimated nitrogen uptake, and soil organic nitrogen) were used to positively assess the quality of the nitrogen simulation results. Results of the modeled water balance indicate that using sunn hemp as a cover crop improved the soil physical conditions (increase in soil water retention) and subsequently enhanced actual crop evapotranspiration and reduced soil drainage. However, nitrogen simulation results suggest that, although corn nitrogen uptake and yields were slightly higher in the CC plots than in the NC plots, there were net increases of soil N content that resulted in increased N leaching to the shallow aquifer. Therefore, the use of sunn hemp as cover crop should be coupled with reductions in N fertilizer applied to the winter crop to account for the net increase in soil N content.

* Corresponding author.
E-mail address: carpena@ufl.edu (R. Muñoz-Carpena).
0378-3774/$ – see front matter
doi:10.1016/j.agwat.2008.01.005

1. Introduction

Agriculture in southern Florida is an important economic activity that competes for land and water resources with ongoing environmental restoration efforts and Miami's urban sprawl. The south Miami-Dade County agricultural region occupies an environmentally sensitive area between the Everglades and the Biscayne National Parks. While agriculture in the area was once perceived as a threat to the fragile natural ecosystems in the National Parks, it is now considered to be a viable alternative to establishment of exotic weeds or Miami's urban sprawl (Ritter et al., 2007). Crop production (vegetables, ornamental and landscape plants, and tropical fruits) in this area occupies approximately 32.4 km^2 located south of the city of Miami (Florida), between the National Parks. The marine subtropical climate of south Florida is conducive to the development of crop diseases and its proximity to South America and several Caribbean countries favors the introduction of new insect pests and invasive plants (Klassen et al., 2002). However, increased pests and low native soil fertility (Potter et al., 2007) have resulted in growers' strong dependence on pesticides and fertilizers to achieve economically sustainable yields.

The shallow unconfined Biscayne aquifer, which underlies the entire region, provides potable water for most of the population residing in southeastern Florida. The aquifer is made of Miami oolite limestone that exhibits extremely high effective hydraulic conductivity values (Fish and Stewart, 1991). The unsaturated zone thickness varies seasonally in the area from 1 to 2 m. Beneath the soil, the limestone is present down to about 12 m where a semi-confining layer is found. The hydrogeology of the area and high rates of fertilizer and pesticide use suggest that farming may be a significant source of non-point source of aquifer pollution. To better understand the environmental costs and benefits of agriculture in this area, the impact of agrochemicals on water resources must be clearly defined. Vegetable growers in Florida's South Dade Basin are commonly advised to maintain vegetative cover crops (CCs) on fields between crops seasons as a best management practice (BMP), and to turn the CC residues into the soil prior to planting (Wang et al., 2002; Li et al., 2006). Sunn hemp (*Crotalaria juncea*) has excellent potential as a CC for this area, because in addition to providing nitrogen fixation as a legume, it has a very rapid growth rate in this climate, thus providing large biomass and a dense cover (Li, 1999). Although it is considered a non-native exotic plant species, sunn hemp does not set seeds in south Florida during the time allotted as a summer CC (from initial seed sowing to mowing). Thus, its potential for becoming an established naturalized species is limited. Benefits attributed to the use of sunn hemp and other CCs are mainly related to the improvement of the soil hydrological and microbiological properties caused by increased soil porosity, reductions in rain drop energy impact at the soil surface, and an increase in soil organic matter content (Reeves, 1994; Rao and Li, 2003; Simonne and Hochmuth, 2003). As a result, herbicide leaching and groundwater contamination may be reduced (Bottomley et al., 1999; Gaston et al., 2003; Harman-Fetcho et al., 2005). Potter et al. (2007) found that the sunn hemp used as a summer crop in rotation with corn in the area effectively reduces atrazine leaching by enhancing rapid and extensive atrazine degradation in soil.

Field-tested computer models can be useful tools for assessing nutrient leaching and devising or demonstrating the efficacy of BMPs to control and reduce negative water quality impacts relative to current practices. In particular, when data is scarce or of limite reliability, physically-based numerical models for water and solute transport can be useful exploratory tools to understand the complexity of these processes and to quantify nitrogen (N) leaching as a consequence of fertilizer practices. However, the use of such models is not an easy task, since they contain a large number of parameters that must be identified before the model can be applied to a specific scenario. The model predictions and associated uncertainties strongly depend on the identification of parameters and model sensitivity to these parameters (Ritter et al., 2003).

The purpose of this study was to evaluate the effectiveness of a summer CC (in this case, sunn hemp) as a BMP to reduce nitrogen leaching from a winter sweet corn crop using a combination of field data and modeling results. The numerical model WAVE (Vanclooster et al., 1996) was selected to simulate water fluxes and nitrate transport through the soil profile to the aquifer. A combination of soil water content time series obtained at different depths and measured components of the nitrogen balance were used to evaluate the model predictions.

2. Materials and methods

2.1. Experimental site

The study was conducted in Homestead (80.50°W, 25.5°N), just south of Miami (Florida) on a 4-ha field at the Tropical Research and Education Center (TREC) of the University of Florida (Fig. 1). The topography is essentially flat. The soil is classified as a gravelly loam Krome series (loamy skeletal, carbonatic, hyperthermic, Lithic Udorthents) (Nobel et al., 1996), with average pH of 7.6, electrical conductivity measured in saturated paste extract of 0.33 $dS\ m^{-1}$, and a low average organic carbon content around 10 $g\ kg^{-1}$ (Potter et al., 2007). This is an artificial shallow soil created by ''rock-plowing'' the underlying porous Miami oolite limestone bedrock. Fruit and vegetable fields as well as urban and residential development are found on Krome soils.

2.2. Experimental setup

Six experimental plots (47 m $\times$ 27 m each) were established on the 4-ha field, with three blocks randomly selected for each BMP treatment (CC) and no cover (NC) crop blocks (Fig. 1). Sweet corn (*Zea mays* L.) was cultivated for a 4-year period in all the plots during the winter months (November to March). Sunn hemp (*C. juncea*) was used as a summer CC. Sunn hemp was planted each year in April to May, after the sweet corn crops were harvested and was tilled into the soil about 1 month prior to planting the sweet corn (October to November). This study focused only on the last 2 years of 4 years of sweet corn/CC rotation, when the nitrogen build-up from the CC