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Abstract

The root zone water quality model (RZWQM V.3.25) was calibrated and evaluated using four years (1993-96) of field data to simulate the effect of swine manure application on NO3-N losses with subsurface drainage water under a corn-soybean production system. The RZWQM was calibrated for corn and soybean crops separately using crop-specific calibration parameters. The main crop specific parameters of maximum nitrogen uptake rate (g/plant/day), proportion of photosynthesis to respiration, and amount of biomass (g) needed to obtain leaf area index of 1.0 were calibrated to 2.0, 0.12, 10.0 for corn and 0.5, 0.005 and 1.5 for soybean, respectively. The predicted subsurface drain flows and NO3-N concentrations in the drainage water were compared with the measured values. The predicted subsurface drain flows followed the pattern of measured drain flows, giving an average difference of about +2.0% and –9.7% for corn and soybean, respectively. The predicted NO3-N concentrations in tile water were in good agreement with the measured values for all simulation periods (overall average difference was less than 1%). The evaluation of the model for validation years (1995 and 1996) showed correlation coefficients of 0.66 and 0.57 between predicted and measured NO3-N concentrations for corn and soybean, respectively. The overall predicted NO3-N losses were within 5% of the observed NO3-N losses for both cropping systems. This shows that the crop specific parameters of the RZWQM have the potential to simulate satisfactorily the effect of crop rotation and swine manure application in alternate years and N-fixation by soybean on NO3-N losses with subsurface drain flow. To improve model performance, the crop specific parameters need to be tested for above and belowground biomass and grain yield predictions along with NO3-N losses.

Keywords

Water quality, Nitrate-nitrogen, Swine manure

Disciplines

Agriculture | Bioresource and Agricultural Engineering | Water Resource Management

Comments

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SIMULATING THE EFFECT OF SWINE MANURE APPLICATION ON NO_3-N TRANSPORT TO SUBSURFACE DRAINAGE WATER

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ABSTRACT. *The root zone water quality model (RZWQM V.3.25) was calibrated and evaluated using four years (1993-96) of field data to simulate the effect of swine manure application on NO_3-N losses with subsurface drainage water under a corn-soybean production system. The RZWQM was calibrated for corn and soybean crops separately using crop-specific calibration parameters. The main crop specific parameters of maximum nitrogen uptake rate (g/plant/day), proportion of photosynthesis to respiration, and amount of biomass (g) needed to obtain leaf area index of 1.0 were calibrated to 2.0, 0.12, 10.0 for corn and 0.5, 0.005 and 1.5 for soybean, respectively. The predicted subsurface drain flows and NO_3-N concentrations in the drainage water were compared with the measured values. The predicted subsurface drain flows followed the pattern of measured drain flows, giving an average difference of about +2.0% and –9.7% for corn and soybean, respectively. The predicted NO_3-N concentrations in tile water were in good agreement with the measured values for all simulation periods (overall average difference was less than 1%). The evaluation of the model for validation years (1995 and 1996) showed correlation coefficients of 0.66 and 0.57 between predicted and measured NO_3-N concentrations for corn and soybean, respectively. The overall predicted NO_3-N losses were within 5% of the observed NO_3-N losses for both cropping systems. This shows that the crop specific parameters of the RZWQM have the potential to simulate satisfactorily the effect of crop rotation and swine manure application in alternate years and N-fixation by soybean on NO_3-N losses with subsurface drain flow. To improve model performance, the crop specific parameters need to be tested for above and belowground biomass and grain yield predictions along with NO_3-N losses.*
Keywords. *Water quality, Nitrate-nitrogen, Swine manure.*

Properly used, manure can be an excellent natural source of nutrients for crop production. However, improperly used manure can also be a source of pollution of soil and water resources. A few researchers have investigated the fate and transport of nutrients in the soil receiving swine manure applications (Hubbard et al., 1987; Kanwar et al., 1995).

In addition to field and laboratory experiments, computer simulation models provide an opportunity to evaluate the response of the soil and water system to a range of management practices in an efficient and cost-effective way (Zacharias and Heatwole, 1994). The models used for predicting the fate and transport of chemicals through and beyond the root zone range from screening models such as PESTAN (Enfield et al., 1982) to research models such as LEACHM (Wagenet and Hutson, 1986). The models evaluating the effect of agricultural management systems on groundwater quality such as GLEAMS (Leonard et al., 1987) and PRZM (Carsel et al., 1985) are considered to be between the screening and research models, based on the complexity of their simulation processes. Jabro et al. (1993) compared LEACHM and NCSWAP (Nitrogen, Carbon, Soil, Water, and Plant) models for predicting NO_3-N leaching losses below 1.2 m from N-fertilized and manured corn lysimeters. Kanwar et al. (1983) developed a model to simulate the major water and N transport processes occurring in a typical agricultural watershed during the crop growth period. DRAINMOD (Skaggs, 1978) was extended as DRAINMOD-N (Breve et al., 1997) for predicting N-transport, uptake, and transformation in tile-drained soils. Yoon et al. (1994) and Minkara et al. (1995) used the GLEAMS model to predict nitrate and ammonium losses in surface and subsurface runoff from poultry litter application. Verma et al. (1995) modified the DRAINAGE model to simulate NO_3-N concentrations in subsurface drain flows to analyze the impact of N-fertilizer application rates. These models are limited to a narrow range of agricultural management practices and also lack the complete incorporation of the interaction of soil water and heat processes with tillage, residue cover, crop growth and rotation, and chemical fate into agricultural simulation (Hanson et al., 1998). Another soil-water-plant-atmosphere system model called Root Zone Water Quality Model (RZWQM) (USDA-ARS, 1992) was recently developed to evaluate various agricultural management practices on the subsurface movements of nutrients and pesticides.

RZWQM is a physical process-based simulation model that has the capability to evaluate the effects of various management practices on chemical transport. The model is still being evaluated under different agroclimatic

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conditions, although several of its modules have been tested and validated (Ahuja et al., 1993, 1995; Ma et al., 1996; Azevedo et al., 1997; Kumar et al., 1997). Singh and Kanwar (1995) used the modified RZWQM to simulate the effects of various tillage systems on the fate and transport of NO_3-N losses to subsurface drain flows. Kumar et al. (1997) evaluated the RZWQM for predicting NO_3-N losses with subsurface flows from swine manure application under a continuous-corn production system. Therefore, a study was conducted to evaluate the RZWQM for predicting and validating NO_3-N losses from subsurface tile flows for corn-soybean production system receiving swine manure under field conditions. The calibrated and validated crop specific parameters could help frame the guidelines for environment safe application of swine manure. The specific objectives of this study were:

- Calibrate the RZWQM for predicting subsurface drain flow and NO_3-N concentrations using crop specific calibration parameters for corn and soybean.
- Evaluate the performance of RZWQM for predicting NO_3-N losses with subsurface drain flows as affected by liquid swine manure application for corn only under a corn-soybean rotation.

Brief Overview of RZWQM

RZWQM (ver. 3.25) is a one-dimensional, vertical field-scale model that simulates the transport processes of water, nutrients, and pesticides within the crop root zone for a representative point of the area (USDA-ARS, 1994). Besides considering planting and harvesting practices, the RZWQM evaluates the impacts of various management practices such as manure-fertilizer and pesticide application, type and amount of tillage operations, and irrigation methods. Tillage operations change physical properties of the soil based on type, time, and intensity of the tillage operations. The model is an efficient tool for evaluating the system response to various levels of management practices.

The model simulates water flow processes in two phases: (1) infiltration into the soil matrix and macropore flow as a result of excess rainfall and macropore-matrix interaction during a rainfall or irrigation, by using the modified Green-Ampt approach (Ahuja, 1983; Ahuja et al., 1995); and (2) redistribution of water within the soil matrix following infiltration, modeled by a mass conservation numerical solution of Richard's equation (Celia et al., 1990). These two domains of flow, infiltration through the soil matrix and excess rainfall through macropores, interact through walls of macropore channels.

The nutrient processes in RZWQM define carbon (C) and N transformations within the soil profile. Given initial levels of soil organic matter, crop residues, other organic, and NO_3-N and ammonium (NH_4-N) concentrations, the model simulates mineralization, nitrification, immobilization, denitrification, and volatilization of appropriate N forms. A multi-pool approach is used for organic matter cycling. Process rate equations are based on chemical kinetic theory and controlled by microbial population size and environmental parameters such as soil temperature, pH, water content, and salinity. Default values of most of the parameters for the biomass population and organic matter pools, and transfer coefficients between pools, were used from the RZWQM manual (USDA-ARS, 1996).

Nitrate-nitrogen is a conservative chemical with an adsorption coefficient of zero (Ma et al., 1998). Prior to infiltration, NO_3-N concentrations in the mobile (mesopores) and immobile (micropores) waters are assumed to be in equilibrium. During infiltration, only about 50% or less of the mesopores are assumed to be piston-displaced followed by an instantaneous mixing of solution in the mesopores. At the end of infiltration, water and NO_3-N in the mesopores are allowed to equilibrate. The NO_3-N is transported with water from layer to layer. The NO_3-N concentrations in the drainage water are estimated as a function of nitrate concentrations in the saturated soil layers. Singh et al. (1996) described the various hydrological processes of the RZWQM in detail. The details of the other modules of the model including evapotranspiration and plant growth processes can be found in Farahani and Bausch (1995) and the nutrient component of the model (OMNI) can be found in the RZWQM technical manual (USDA-ARS, 1992).

Input Data for RZWQM

The minimum data required by the model are daily air temperature (minimum and maximum) and precipitation. Other climatic variables such as wind speed, short wave radiation, pan evaporation, and relative humidity can be estimated by the model if unavailable. The rainfall data required by the model are in breakpoint format for each individual storm. The temperature and rainfall data for 1993-1995 were used from the study site; whereas, the data on wind speed, short wave radiation, and relative humidity were taken from Charles City, Iowa, about 16 km from the study site. The simulations for 1996 were conducted using air temperature and rainfall data from the study site (minimum data required by the model) because the rest of the data were not available from Charles City.

The model requires discretized soil profiles in horizons based on their lithological characteristics. Each horizon is characterized by its soil type, particle density, bulk density, porosity, and percent sand, silt, and clay. The representative values of water content at field capacity (–0.033 MPa) and lateral saturated hydraulic conductivity for a field, along with texture and bulk density, help the model estimate the remaining hydraulic properties which describe modified Brooks-Corey water retention curves (Brooks and Corey, 1964) and hydraulic functions parameters, used by the model.

The model requires plant management variables and parameters and uses a generic crop growth model to simulate corn and soybean crops. Default values of plant growth parameters were used, as recommended in the user's manual. The model also requires detail of the tillage operations performed, manure and fertilizer management, pesticide use, and irrigation practices.

Materials and Methods

Experimental Site

The experimental site is located at Iowa State University's Northeastern Research Center, Nashua, Iowa. The experimental plots are located on a predominantly Kenyon loam (fine-loamy, mixed, mesic *Aquic Hapludoll*)

Table 1. Selected soil horizon properties of the study plots used as input to the model

Horizon No.	Depth (m)	Bulk Density (Mg/m^3)	Particle Size Distribution (%)			
			Porosity	Sand	Silt	Clay
Kenyon Soil (plot no. 11, 27)						
1	0.0-0.20	1.36	0.49	38	42	20
2	0.20-0.41	1.53	0.43	41	34	25
3	0.41-0.50	1.55	0.42	42	32	26
4	0.50-0.69	1.60	0.40	43	30	27
5	0.69-0.89	1.65	0.38	44	28	28
6	0.89-1.23	1.70	0.36	44	31	25
7	1.23-1.67	1.75	0.34	44	31	25
8	1.67-2.52	1.75	0.34	44	31	25
Readlyn Soil (plot no. 23)						
1	0.0-0.20	1.34	0.49	31	43	26
2	0.20-0.30	1.45	0.45	31	33	26
3	0.30-0.43	1.45	0.45	37	38	25
4	0.43-0.54	1.50	0.43	37	38	21
5	0.54-0.68	1.60	0.40	55	24	26
6	0.68-0.89	1.65	0.38	46	28	26
7	0.89-1.10	1.70	0.36	46	28	26
8	1.10-1.50	1.70	0.36	46	28	26
9	1.50-2.52	1.70	0.36	46	28	26

with 2 to 3% organic matter (USDA-SCS, 1982). The physical properties of the soil profile, reported in table 1, were adopted from Singh (1994) and Sharpley and Williams (1990). These soils have a seasonally high water table. Sixty meters of pre-Illinoian till typically overlay a carbonate aquifer, though bedrock is near the surface in some areas.

The Nashua site has 36 plots (58.5 × 67 m in size each), with fully documented tillage and cropping records for the past 19 years. These 36 plots have been allocated to seven different crop management systems under a Randomized Block Design. System 5 was selected for this study which comprised of plots 11, 23, and 27. Only System 5 represents corn-soybean rotation plots fertilized with liquid swine manure in alternate years for which the study was designed. There is very little difference in the hydraulic properties of plots 11 and 27 in comparison with soils of plot 23. Therefore, there was no need to incorporate these minor differences in the overall design of the experiment. A schedule of management practices for the three plots is given in table 2.

Each plot is drained separately. Each plot has tile lines installed at a depth of 1.2 m and a spacing of 28.5 m. The tile lines are intercepted at the end of plots and are connected to individual sumps for water sampling. The sumps are equipped with a 110 V effluent pump, water flow meter, and an orifice tube to collect water samples for chemical analysis. Data loggers, connected to water flow meters, record tile flow data continuously as a function of time. A detailed description of the automated subsurface drainage system is given by Kanwar et al. (1995). Cumulative subsurface drain flows were monitored on alternate days. Subsurface drain flow data were linearly interpolated for the missing days based on values before and after the missing day interval if the data loggers did not work.

Table 2. Schedule of management activities of the study plots

Corn		Soybean		
1993	1995	1994	1996	Activities
15 Nov.*	17 Nov.*	-	-	Fall application of manure
20 Nov.	22 Nov.	4 Nov.	8 Nov.	Primary tillage (chisel plow)
17 May	16 May	17 May	30 May	Planting
21 July	14 June	-	-	Cultivation
1 Sept	7 Sept.	2 Sept.	5 Sept.	Approximate maturity
25 Oct	22 Sept.	6 Oct.	8 Oct.	Harvesting

* Fall of the preceding year.

Table 3. Characteristics of swine manure applied to corn

Characteristics	Fall 1992	Fall 1994
Avg. application amount (mm)	2.70	4.60
Depth of injection (mm)	254.00	254.00
Total solids (%)	6.21	6.73
Total N content (%)	0.54	0.49
Organic N content (%)	0.25	0.04
Ammonia content (%)	0.04	0.06
Phosphorous content (%)	0.21	0.21
Organic phosphorous content (%)	0.04	0.03
Organic matter content (%)	0.14	0.14

Table 4. Application rates of N, P_2O_5, and K_2O for corn-soybean rotation plots from swine manure applications for 1993 and 1995

Application Rates (kg/ha)	1993	1995
N	73	195
P_2O_5	53	78
K_2O	71	104

An experimental field study was initiated in 1993 to evaluate the NO_3-N leaching losses with subsurface drainage flows under continuous-corn and corn-soybean rotation as affected by swine manure application. Swine manure was obtained from a manure pit under a growing/finishing building. Table 3 presents the characteristics of the swine manure used for the experiment. The application of manure to achieve the required nitrogen levels was difficult because of the non-uniform quality of manure. Table 4 gives the actual application rates of N to corn-soybean rotation plots.

Subsurface drainage water samples were collected three times a week for NO_3-N analysis. Measured data for tile flow and their NO_3-N concentrations from three plots under corn-soybean rotation were used to calibrate and validate the model for 1993-1996.

Initial Conditions

The initial soil conditions (both physical and chemical) for the soil system of the RZWQM must be input for each specified horizon of the discretized soil profile. Soil moisture content, soil temperature, soil equilibrium chemistry, nutrient chemistry, and pesticide concentrations are required as initial input to the model. These initial estimates were adopted from the literature, model user's manual, or the data collected at the experiment station. Initial water table depth was set equal to the tile line depth of 1.2 m. The initial soil temperature profile was adopted from Hillel (1982; fig. 9.4) for the spring season. The initial NO_3-N concentrations in the soil profile were adopted from Singh and Kanwar (1995).

Model Calibration and Evaluation

The simulation periods for the entire growing seasons were: day of year (DOY) 70-300 for corn and DOY 121-300 for soybean (Singh, 1994). The model was calibrated for subsurface drain flow simulations using tile flow data for 1993. The input parameters were obtained from field experimental data and through a calibration procedure. The goal of calibration was to minimize the difference between measured and predicted cumulative drainage flow along with timely peak response to the measured data. The calibration period used for corn and soybean was their growing season. Effective porosity (difference between porosity and field capacity) was adjusted until the predicted tile flow hydrograph matched the volume and peaks of the measured tile flow hydrograph. The peaks of the hydrographs were also matched by changing the lateral saturated hydraulic conductivity (Singh et al., 1996). The initial moisture contents of the soil profile played an important role in the beginning of the tile flow simulations.

NO_3-N losses with subsurface drainage were calibrated after tile flow calibrations. For corn, the model was calibrated using the 1993 data and was verified using 1995 data. For soybean, the model was calibrated using 1994 data and was verified using 1996 data. NO_3-N concentrations were calculated by dividing the NO_3-N mass ($\mu g/mm^2$) by the drain flow (mm/day) to find daily NO_3-N concentrations in mg/L. The main criterion used to calibrate the nutrient component of the model was to minimize the difference between the measured and predicted annual average NO_3-N concentrations and annual NO_3-N losses in the tile water. To compare the model performance with a 1:1 best fit line, the simulation data for corn and soybean (1995, 1996) were pooled only for those days for which the measured NO_3-N concentrations data were available. The remaining days' data were not included in making comparisons. The main crop specific calibration parameters of maximum nitrogen uptake rate, proportion of photosynthesis to respiration and amount of biomass needed to obtain a leaf area index of 1.0 (USDA-ARS, 1996) were calibrated to predict the effect of crop rotation and swine manure application on NO_3-N losses with subsurface drain flows.

Results and Discussion

NO_3-N Concentrations in Subsurface Drain Flows

The calibrated values of maximum nitrogen uptake rate, proportion of photosynthesis to respiration and amount of biomass to obtain a leaf area index of 1.0 were significantly different for corn and soybean because soybeans fix N (table 5). Table 6 shows the cumulative measured and simulated subsurface tile flows for the simulation periods of 1993 through 1996. The lateral saturated hydraulic conductivity for the three simulated plots was 35 mm/h for both crops; whereas, the effective porosity varied from 0.17 to 0.20 for corn and soybean, respectively, because of changes in amounts of rainfall for the calibration years. For 1993, the model underpredicted tile flow at the beginning of the growing season and overpredicted it at the end. The study plots may have had more runoff after harvesting, thus reducing the measured tile flow. The model overestimated tile flow during 1993 and underestimated it for 1995 because 1993 was a wet year (1020 mm rainfall) compared with 1995 (800 mm rainfall). The average difference between the measured and simulated tile flow for corn was about +2.0% for 1993 and 1995. The graphical display from figures 1a to 4a for 1993-1996 show good agreement between the measured and simulated tile flow values. The model response for 1994 was not as consistent as for other years. The average simulated tile flow for 1994 was 14% less than the measured tile flow. This difference could also be due to macropore flow, which was not considered in this simulation study. For 1996, model simulations were satisfactory underpredicting the measured tile flow by 5%. The model underpredicted the tile flow compared with measured values for the entire growing season of soybean (1994 and 1996) by 9.7%.

Table 5. A list of crop and site-specific calibration parameters for corn-soybean simulations

Parameters	Corn	Soybean
Maximum nitrogen uptake rate (g/plant/day)	2.00	0.50
Proportion of photosynthesis to respiration	0.12	0.005
Amount of biomass needed to obtain leaf area index of 1.0 (g)	10.00	1.50
Plant density	60,000.00	395,000.00
Age effect for propagules as proportion of photosynthesis	0.80	0.25
Age effect for seed as proportion of photosynthesis	0.60	0.30
Normal maximum root system depth (m)	2.00	1.00
Dry mass of the residue on the surface (MT/ha)	4.30	3.50
Albedo of the dry soil	0.21	0.30
Albedo of the wet soil	0.11	0.12
Albedo of the crop at maturity	0.20	0.25

Table 6. A list of calibrated parameters of the study plots, and measured and simulated tile flows for the simulation period (1993-1996) under corn and soybean

Corn									
Plot No.	Soil Type	LKsat* (mm/h)	EP† (mm^3/mm^3)	1993 Flow (mm) Observed	Predicted	% Diff.	1995 Flow (mm) Observed	Predicted	% Diff.
11	Kenyon	35	0.17	336.0	351.0	+4.5	75.0	61.0	–18.6
23	Readlyn	35	0.18	319.0	373.0	+16.9	97.0	90.0	–7.2
27	Readlyn	35	0.17	128.0	173.0	+35.1	26.0	26.0	0.0
	Average	35	0.17	261.0	299.0	+14.5	66.0	59.0	–10.6
Soybean									
Plot No.	Soil Type	LKsat (mm/h)	EP (mm^3/mm^3)	1994 Flow (mm) Observed	Predicted	% Diff.	1996 Flow (mm) Observed	Predicted	% Diff.
11	Kenyon	35	0.20	73.0	61.0	–16.4	42.0	40.0	–4.8
23	Readlyn	35	0.20	81.0	75.0	–7.4	49.0	48.0	–2.1
27	Readlyn	35	0.20	37.0	30.0	–18.9	19.0	18.0	–5.3
	Average	35	0.20	64.0	55.0	–14.1	37.0	35.0	–5.4

* Lateral saturated hydraulic conductivity.
† Effective porosity.

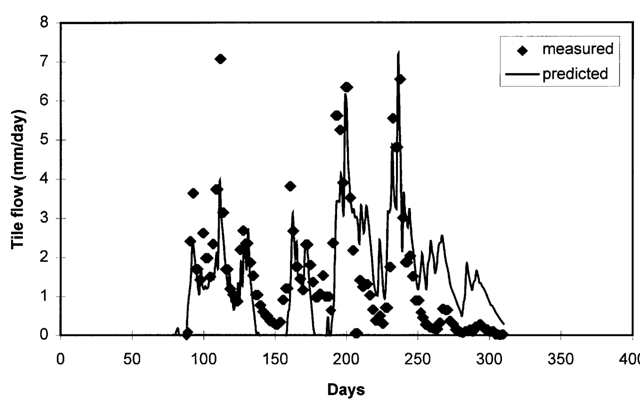

Figure 1(a)–Measured and simulated tile flows for plot no. 11 (1993).

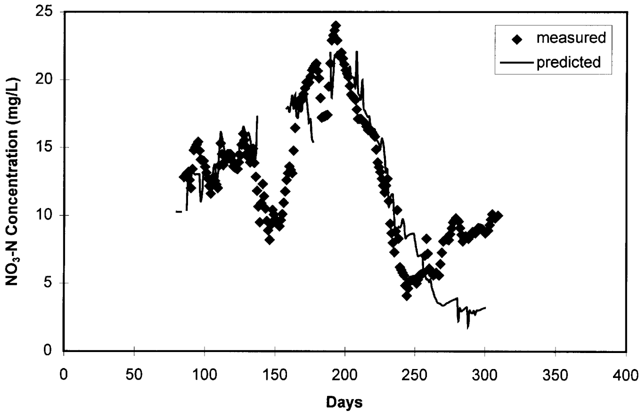

Figure 1(b)–Measured and simulated NO_3-N concentrations for plot no. 11 (1993).

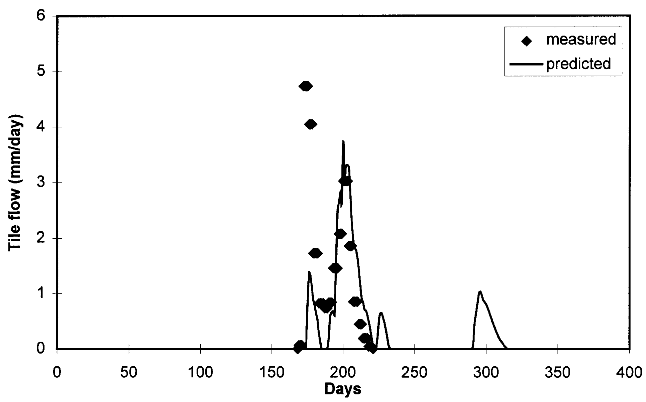

Figure 2(a)–Measured and simulated tile flows for plot no. 23 (1994).

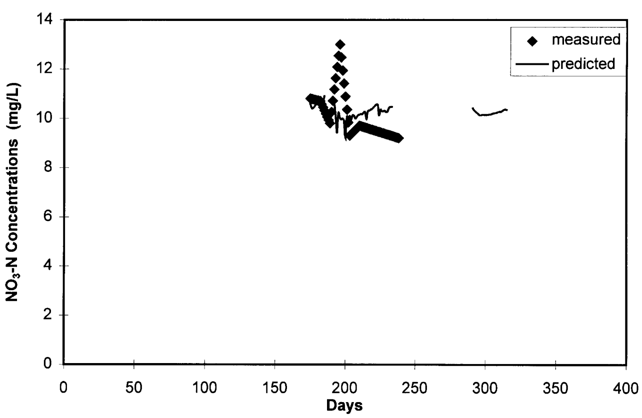

Figure 2(b)–Measured and simulated NO_3-N concentrations for plot no. 23 (1994).

Average annual NO_3-N concentrations for the measured and simulated flows are shown in table 7. The simulated NO_3-N concentrations in the tile water followed the pattern of measured NO_3-N concentration effectively, with an overall average difference of <1% for the entire simulation period of 1993-1996 (table 7). For 1993, the model predicted NO_3-N concentrations very close to the measured values except at the end of the growing season (fig. 1b). The NO_3-N concentrations at the end of the growing season were affected by the higher tile flow simulated by

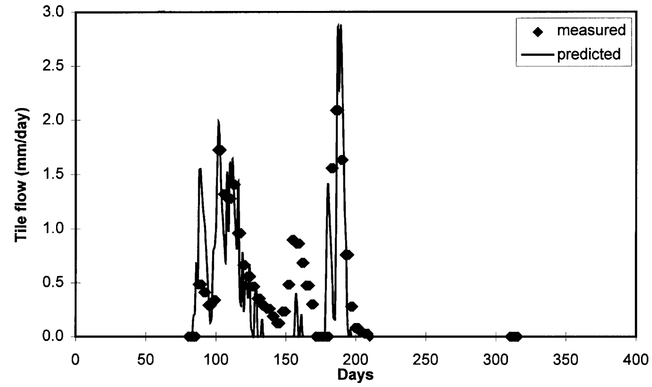

Figure 3(a)–Measured and simulated tile flow for plot no. 11 (1995).

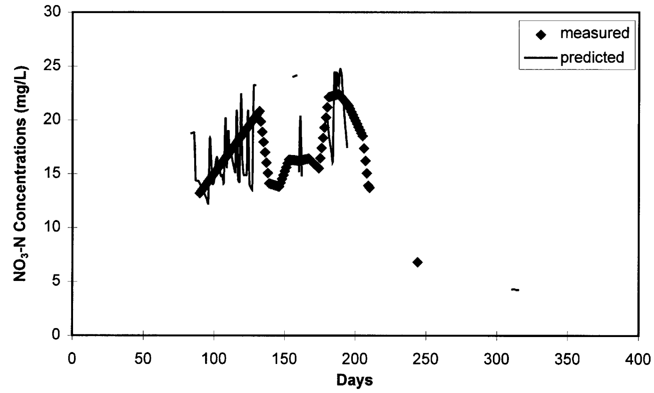

Figure 3(b)–Measured and simulated NO_3-N concentrations for plot no. 11 (1995).

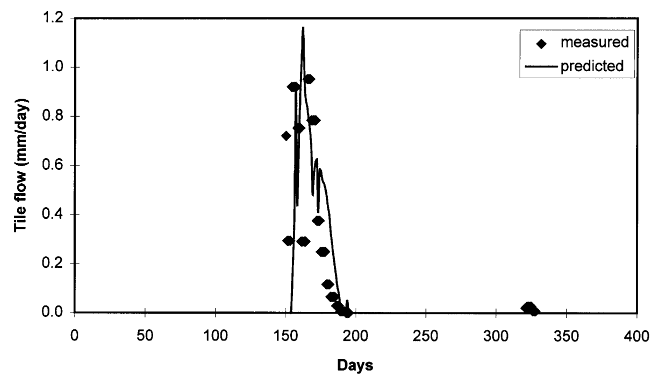

Figure 4(a)–Measured and simulated tile flow for plot no. 27 (1996).

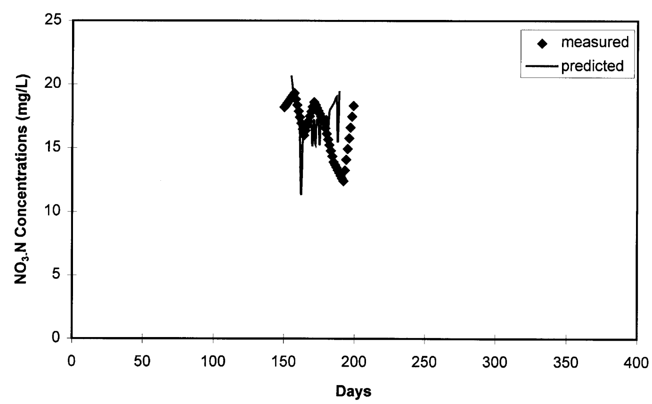

Figure 4(b)–Measured and simulated NO_3-N concentrations for plot no. 27 (1996).

Table 7. Average measured and simulated NO_3-N concentrations in subsurface tile flow of the study plots

		Average NO_3-N Concentrations (mg/L)								
		Plot No. 11			Plot No. 23			Plot No. 27		
Year	Rain-fall (mm)	Mea-sured	Pre-dicted	% Diff.	Mea-sured	Pre-dicted	% Diff.	Mea-sured	Pre-dicted	% Diff.
1993	1027	12.9	12.4	–3.8	12.1	11.3	–6.6	9.3	7.2	–22.4
1994	733	10.3	11.1	+7.8	10.1	10.3	+1.9	7.7	7.5	–2.6
1995	802	17.3	17.8	+2.8	12.6	12.1	–3.9	14.4	14.7	+2.1
1996	683	16.7	17.3	+3.6	21.4	22.7	+6.1	16.5	17.2	+4.2
	Average	14.3	14.6	+2.1	14.0	14.1	+0.7	11.9	11.6	–2.5

the model. Otherwise, model simulations were very close to the measured values (figs. 1b to 4b). The average difference between the measured and predicted NO_3-N concentrations was <5% for Plots 11 and 23. Response from Plot 27 was not similar to that from Plots 11 and 23, likely due to that plot's steeper slope and observed larger spatial variability in soil properties.

The NO_3-N concentrations in tile flow for 1994 were affected by the poor predictions of the tile flow. However, the annual average predicted NO_3-N concentrations were close to the measured values, giving 2.4% difference between the measured and predicted values for 1994. For 1995, the model predicted NO_3-N concentrations very close to the measured values under corn production with an average difference of <1%. The NO_3-N concentrations in tile water decreased in 1994, because heavy rains in 1993 flushed large amounts of NO_3-N. The NO_3-N concentrations in tile water again increased in 1995 due to reduced leaching losses of NO_3-N in 1994 and overapplication of swine manure in the fall 1994 (table 4). The model was able to simulate these effects on NO_3-N concentrations in tile flow.

For 1996, the model predicted both the tile flow and its NO_3-N concentrations satisfactorily perhaps due to a better availability of weather data. The average difference between the simulated and measured NO_3-N concentrations was <5%. The model predicted the peak tile flows for all three plots closer to the measured values. The model predictions for NO_3-N losses were in close agreement with the observed values and followed the pattern of measured losses (table 8). The predicted NO_3-N losses were <5% of the observed values for both cropping systems. The model showed good potential in simulating the effect of crop rotation and swine manure application on NO_3-N losses.

Table 8. Measured and simulated NO_3-N losses (kg/ha) in subsurface drain flow of the study plots

	NO_3-N Losses (kg/ha)								
	Plot No. 11			Plot No. 23			Plot No. 27		
Year	-Mea sured	Pre-dicted	% Diff.	Mea-sured	Pre dicted	% Diff.	Mea-sured	Pre-dicted	% Diff.
1993	49.48	47.06	–4.89	49.93	46.17	–7.53	13.42	14.56	+8.49
1994	6.37	6.23	–2.19	7.14	7.57	+6.02	1.97	2.31	+17.25
1995	13.43	11.18	–16.70	14.58	13.28	–8.91	4.24	3.90	–8.02
1996	7.28	6.02	–17.30	10.76	10.53	–2.13	3.13	2.83	–9.58
Total	76.56	70.49	–7.93	82.41	77.55	–5.89	22.76	23.60	+3.69

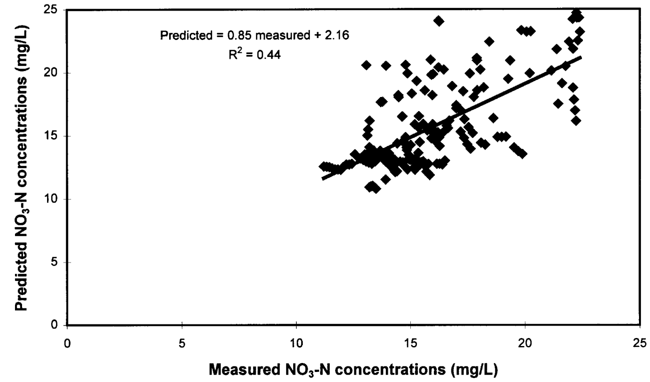

Figure 5(a)–Model evaluation for NO_3-N concentrations simulation for corn (1995).

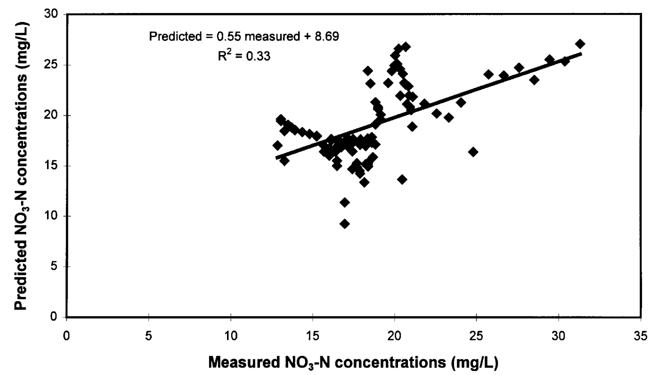

Figure 5(b)–Model evaluation for NO_3-N concentrations simulation for soybean (1996).

Figure 5 evaluates the model performance in predicting NO_3-N concentrations for validation years of 1995 and 1996. Figure 5 gives slopes of 0.85 and 0.55 with correlation coefficients of 0.66 and 0.57 for corn and soybean, respectively. The trend of the best fit lines show that the model has the capability to predict NO_3-N concentration in the tile water for a corn-soybean rotation system of production, as affected by swine manure application. There are some discrepancies in the data, as shown by the best fit line. The NO_3-N concentrations were found to be affected by both the amount and distribution of rainfall, the rate of swine manure application and crop rotation.

Summary and Conclusions

The RZWQM (ver. 3.25) was calibrated and validated using data from 1993-1996 to look for the effect of crop specific calibration parameters for corn and soybean on NO_3-N losses with subsurface drain flows when swine manure was applied in alternate years for corn. The key parameters of effective porosity and lateral saturated hydraulic conductivity were effective in matching the size and shape of the predicted tile flow hydrograph with the measured values. The simulation period comprised both wet and dry years. The model overpredicted subsurface drain flow for wet years and underpredicted it for dry years. The overall predictions of subsurface drain flow for the two cropping systems from 1993-1996 were 5% higher than the observed flow.

The main crop specific calibration parameters accounting for the effect of crop rotation and manure application on NO_3-N losses included the maximum nitrogen uptake rate, proportion of photosynthesis to respiration and amount of biomass needed to obtain leaf area index of 1.0. The model underpredicted NO_3-N concentration at the beginning of the growing season and overpredicted it at the end of the growing season. The error in subsurface drain flow simulations at the end of the growing season also affected the NO_3-N concentration for this period. Some discrepancies exist in predicting the drain flow and NO_3-N concentration for wet and dry years and during the beginning and the end of the drain flow hydrograph. The use of a macropore flow component which was not considered in this study may overcome these limitations. The regression analysis showed that the model underpredicted NO_3-N concentrations for validation years of 1995 and 1996. The overall average predicted NO_3-N concentrations were in close agreement with the observed values (average difference less than 1%). The overall simulated NO_3-N losses were <5% of the observed values for both cropping systems. The analysis shows that the crop-specific parameters of the model were able to predict the effect of corn-soybean rotation and swine manure application on NO_3-N losses with subsurface drain flow satisfactorily. Further verification of the crop specific parameters for predicting above and belowground biomass and grain yield along with NO_3-N losses could help frame the guidelines for environment safe application of swine manure.

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