경운방식이 환경에 미치는 영향평가를 위한 EPIC 모형의 적용

Application of EPIC model to assess the environmental impact of tillage methods

*정세웅(한국수자원공사)
*Chung, Se-Woong

Abstract

The EPIC model was applied to assess the environmental impacts of two contrasting tillage systems (conventional versus ridge tillage). The model was calibrated with field data and validated with another set of data. The errors between the 12-year predicted and observed means or medians were less than 10% for nearly all of the environmental indicators, with the major exception of a nearly 44% over prediction of the N surface runoff loss for Watershed 2. The predicted N leaching rates, N losses in surface runoff, and sediment loss clearly showed that EPIC was able to simulate the long-term impacts of tillage and residue cover on these processes.

Ⅰ. Introduction

The Erosion Productivity Impact Calculator (EPIC) was originally designed to simulate the impacts of erosion on soil productivity (Williams et al. 1984). Current EPIC can also produce indicators such as nutrient loss from fertilizer and animal manure applications, and climate change impacts on crop yield and soil erosion. The flexibility of EPIC has led to its adoption within the Resource and Agricultural Policy System (RAPS), an integrated modeling system designed to project shifts in production practices and evaluate the resulting environmental impacts, in response to agricultural policies implemented for the North Central United States. The EPIC applications within RAPS is to provide nitrogen loss and soil erosion indicators in response to variations in crop rotation, tillage, soil, fertilizer applications, and environmental conditions. The objectives of this research are to confirm that EPIC can replicate the impacts of the two different tillage systems on water balance, sediment, nutrient loss, and crop yields.

Ⅱ. Materials and Methods

The EPIC was tested using long-term data sets collected by the USDA-ARS at two field-sized watersheds denoted as Watersheds 2(WS2) and 3(WS3) located in southwestern Iowa, USA. Water balance, sediment, and nutrient loss data have been collected from both watersheds, which have been cropped with continuous corn (*Zea Mays L.*) and managed with contrasting tillage systems (conventional in WS2 versus ridge tillage in WS3) for at least two decades.

The EPIC was calibrated using field data of 1988-94. The calibration process focused primarily on the infiltration and runoff partition at the soil surface and the effects of

---

2002년도 한국농공학회 학술발표 논문집(2002년 10월 12일)

soil residue on the soil evaporation portion of evapotranspiration (ET). The SCS curve number method is used to partition precipitation between infiltration and runoff volume in EPIC, with modifications incorporated for slope and soil profile water distribution effects as described by Williams (1995). Standard runoff curve numbers (CN2) represent conventional tillage practices and need to be reduced to reflect the impacts of conservation tillage (Rawls et al. 1980; Rawls and Richardson 1983). Adjustment of residue impacts on the soil evaporation portion of ET was also performed in the calibration phase. EPIC computes soil water evaporation and plant transpiration separately by an approach similar to that of Ritchie (1972). The depth distributed estimate of soil water evaporation may be reduced according to the following equation if soil water is limited in a layer.

$$SEV_l^* = SEV_l \ \exp\left(\frac{parm(12)(SW_l - FC_l)}{FC_l - WP_l}\right), \quad SW_l < FC_l \qquad (1)$$

$$SEV_l^* = SEV_l, \quad SW_l \geq FC_l \qquad (2)$$

where SEV_l is the potential soil evaporation for layer l (mm), SEV^* is the adjusted soil water evaporation (mm), SW is the soil water content for layer l (mm), FC is the field capacity (mm), and WP is the wilting point (mm). The *Parm(12)* is a parameter that governs the rate of soil evaporation from upper 0.2 m of soil as a function of residue cover. The effect of the WS3 residue cover on soil water evaporation was simulated by adjusting *parm(12)*, as discussed in the calibration results section.

Ⅲ. Results and Discussion

1. Model calibration

The *CN2* and *parm(12)* values were adjusted until the percentage error between the observed and simulated average values were less than 5%(Table 2). The calibration process for WS 2 resulted in a *CN2* value of 74, a slight reduction from the standard value of 75. The WS2 calibration also resulted in a *parm(12)* value of 4.0, a slight increase over the EPIC default value of 2.5. The WS3 calibration resulted in a curve number of 61, which is a reduction of about 19% from the standard value of 75. Rawls et al. (1980) analyzed surface runoff data from small watershed and plot areas managed under different tillage systems, to determine appropriate *CN2* adjustments for different residue coverage levels. They showed a

Table 2. Hydrologic indicator summary statistics during calibration.

Watershed	Variables	Observed		Simulated		Statistics	
		Mean	Std. Dev.	Mean	Std. Dev.	%Error	r^2
Watershed2	Precipitation	790.0	283.3	730.0	283.3	-	-
	Surface runoff	51.7	66.9	53.2	40.3	+2.8	0.92
	Seepage flow	155.2	123.1	148.9	200.5	-4.2	0.42
	ET	583.1	200.9	581.2	39.8	-0.3	0.76
Watershed3	Precipitation	784.1	274.3	784.1	274.3	-	-
	Surface runoff	32.5	48.8	32.0	31.4	-1.7	0.83
	Seepage flow	210.3	125.5	214.0	213.9	+1.8	0.74
	ET	541.3	159.4	538.1	36.1	-0.6	0.83

maximum *CN2* reduction of 10% would occur for conservation tillage systems leaving greater than 60% residue cover. A *parm(12)* value of 14 was selected based on the WS3 ET calibration, reflecting the effect of greater residue cover on ET.

2. Model validation

The calibrated model was validated against a second set of observed data for 1976-87. The summary statistics of observed and simulated 12-year average hydrologic variables are compared in Table 3. The predicted mean surface runoff, seepage flow, and ET are in good agreement with observed values for both watersheds. The percentage error of each estimated indicator is within 5% of the corresponding observed level, except for the WS2 mean seepage flow. Observed and simulated 12-year median, median absolute deviation(MAD), percent error, and r^2 values are listed in Table 4 for the N loss, erosion, and crop yield indicators. The predicted 12-year medians are in close agreement with the measured values for each variable. However, the WS2 surface runoff N loss was overpredicted by about 44% and the WS3 soil erosion was overpredicted by roughly 19%. The r^2 values are generally weak; only the predicted soil erosion and WS3 N leaching indicators explain greater than 50% of the annual variability. The calibrated model accurately captured the effects of ridge tillage, predicting less soil erosion and greater N leaching for WS3 relative to WS2.

Table 3. Hydrologic indicator summary statistics during validation.

Watershed	Variables	Observed		Simulated		Statistics	
		Mean	Std. Dev.	Mean	Std. Dev.	%Error	r^2
Watershed 2	Precipitation	843.6	178.2	869.1	178.2	-	-
	Surface runoff	74.4	39.3	76.0	39.3	+2.1	0.62
	Seepage flow	141.6	57.4	155.7	82.8	+10.0	0.37
	ET	627.6	144.9	612.0	35.4	-2.5	0.69
Watershed 3	Precipitation	812.5	143.5	812.5	143.5	-	-
	Surface runoff	40.0	23.7	40.1	21.7	+0.2	
	Seepage flow	218.8	82.2	211.7	93.1	-3.2	0.48
	ET	553.7	100.2	560.9	35.9	+1.3	0.44

Table 4. Observed and simulated annual environmental indicators summary statistics, based on the annual values for the 1976-1987 validation period.

Watershed	Variables	Observed		Simulated		Statistics	
		Median	MAD	Median	MAD	%Error	r^2
Watershed2	NO_3-N runoff (kg/ha)	1.6	0.8	2.3	1.2	+43.8	0.42
	Leached NO_3-N (kg/ha)	8.0	5.9	7.3	6.8	-8.8	0.35
	Soil erosion (Mg/ha)	11.7^{**}	15.3^{**}	$58.8^{\$}$	$37.8^{\$}$	-	-
	Crop yield (Mg/ha)	7.4	2.1	7.7	0.5	+4.1	0.30
Watershed3	NO_3-N runoff (kg/ha)	2.7	1.8	2.7	1.4	0.0	0.36
	Leached NO_3-N (kg/ha)	32.2	25.3	33.7	36.8	+4.7	0.69
	Soil erosion (Mg/ha)	1.1^{**}	1.4^{**}	$3.6^{\$}$	$1.5^{\$}$	-	-
	Crop yield (Mg/ha)	7.9	0.5	7.8	0.8	-1.3	0.29

**Observed soil erosion measured at headcut; $Simulated soil erosion at the source of watershed.

Graphical time series comparisons between the predicted and measured annual levels of N losses in leaching and surface runoff are shown in Figures 2.

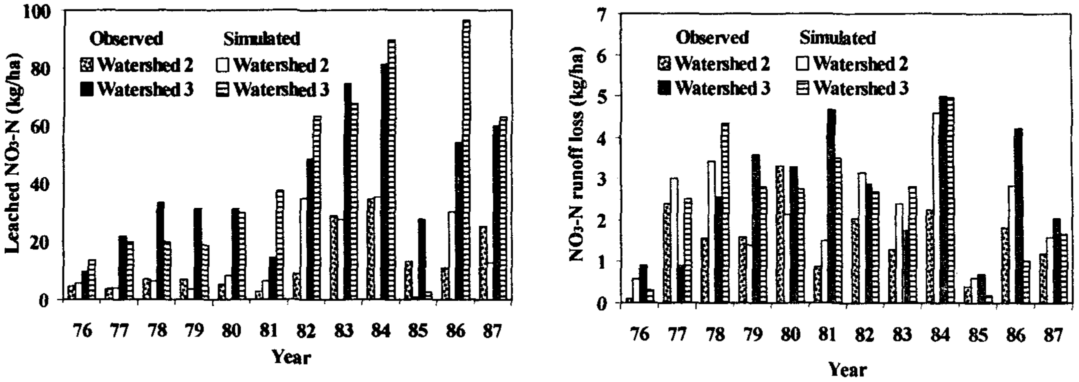

Fig. 2 Observed and simulated NO3-N losses for WS2 and 3 for the validation period

Ⅳ. Conclusions

The large differences observed in soil erosion and nutrient leaching between the two tillage systems were clearly reflected by the calibrated EPIC model. Overprediction of N loss in surface runoff by more than 40% for WS2 was the weakest model response. *However, the corresponding estimated surface N runoff loss was greater for WS3,* mirroring the general observed trends between the two watersheds. Overall, the output shows that EPIC was able to replicate the long-term relative differences between the two tillage systems, which is the major emphasis in applying the model within many integrated systems including RAPS. The results presented here confirm earlier studies by Rawls et al. (1980) and Rawls and Richardson (1983) that standard tabulated CN2 values (Mockus 1969) should be reduced to represent the impacts of residue cover on the partition of precipitation between surface runoff and infiltration. The large reduction (19%) required for this study is likely an extreme; reductions of 10% or less should be adequate for the majority of conservation tillage systems as determined previously by Rawls et al. (1980).

References

Rawls, W. J., C. A. Onstad and H. H. Richardson. 1980. Residue and tillage effects on SCS runoff curve numbers. Trans. ASAE 23:357-361.

Rawls, W. J. and H. H. Richardson. 1983. Runoff curve number for conservation tillage. J. Soil and Water Conser. 38:494-496.

Ritchie, J.T. 1972. A model for predicting evaporation from a row crop with incomplete cover. Water Resour. Res. 17(1):182-190.

Williams, J.R. 1995. The EPIC Model. In: Computer Models of Watershed Hydrology (Ed.: V.P. Singh). Water Resources Publications, Highlands Ranch, CO.