Assessing the Impact of Land Use Change on Agricultural Runoff Using MIKE SHE

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Introduction

The transport of nutrients and pollutants from agricultural lands by surface runoff has been identified as a major contributor to the impairment of receiving waters in the Midwest U.S. Extreme storm events, such as the 2008 flood in Iowa, could also have enormous damage, which has been partially linked to the increased row-crop acreage during the past decades. Many croplands planted to perennial grasses under the Conservation Reserve Program are being returned to crop production, and with potential consequences for water quality. There is a continuing need to advance our understanding how land use change impacts surface runoff on tile-drained soils. The objectives of this study were to simulate the runoff flow in agricultural watersheds using the MIKE SHE model and assess the impact of land use change on runoff generation.

Materials and Methods

- The experimental site is the Four Mile Creek watershed, which is contained within the Iowa-Cedar River basins in Eastern Iowa (Figure 1).
- The watershed is typical of the heavily cropped areas of Iowa with about 75% being in corn and soybeans. Drain tile have been well developed along the waterways.

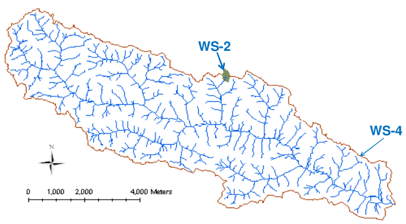

Figure 1. Four Mile Creek watershed

- The MIKE SHE model is a deterministic, fully distributed and physically-based model that allows for simulation of the major processes occurring in the land phase of the hydrologic cycle (Figure 2).
- The MIKE SHE model was validated using measured daily surface runoff in the growing season during 1976-1980. The year 1976 was used as a "warm up period" to establish initial conditions for MIKE SHE.
- Two nested watersheds were simulated: the 6.4-ha WS-2 watershed and the 5055-ha Four Mile Creek watershed (WS-4) (Figure 1).
- The model performance was quantified using the Nash-Sutcliffe (NS) model efficiency coefficient and coefficient of determination (r^2).

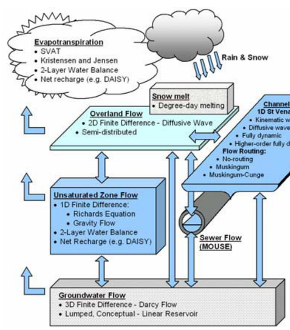

Figure 2. MIKE SHE model (DHI, 2004)

Model Construction

- Meteorological data: Precipitation, daily solar radiation as well as daily maximum and minimum air temperatures for the period April through October of each year was monitored at the experimental site.
- Land use: A corn-soybean rotation system was adopted in the watersheds.
- Overland flow: A value of 10 recommended for Manning's number on cropland with a conventional tillage system was used.
- Unsaturated zone: Van Genuchten parameters were estimated by the neural network program in the Rosetta model for each soil layer based on the ISPAID soil database.
- Saturated Zone: The subsurface tile drainage system was included as a component of the saturated zone at a depth of 1.06 m below the ground surface.
- Channel flow in WS-4 was modeled using MIKE 11.

Results

- A large variation of rainfall during the growing season was observed for the study period, ranging from 455 mm in 1976 to 827 mm in 1979 (Table 1). As a result, the measured surface flow also showed a higher variation from year to year.

Table 1. Annual rainfall and surface flow during the growing season

		WS-2		WS-4	
	Rainfall	Measured	Simulated	Measured	Simulated
	mm				
1976	455	21	/*	76	/*
1977	712	1	1	19	35
1978	698	22	26	121	77
1979	827	127	137	233	269
1980	648	66	18	104	177

* "Warm-up period" for MIKE SHE

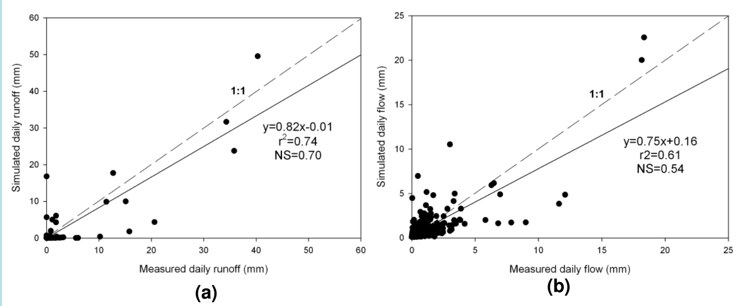

Figure 3. Measured vs. simulated flow for (a) WS-2 and (b) WS-4

- Overall, the model showed a good performance in simulating daily surface runoff/flow at both watersheds with different scale, as indicated by the values of NS and r^2. The NS values were 0.70 and 0.54 for WS-2 and WS-4, respectively. Generally, predictions with model efficiency greater than 0.5 indicate a good model performance. The r^2 values are 0.74 and 0.61 for WS-2 and WS-4, respectively (Figure 3).
- Some storm runoff flow during the early growing season was underestimated, likely due to the snow melting process which might not be well simulated by the model.
- The model had a better performance for the WS-2 than WS-4, partly because of the limited spatial information on the land use of the entire Four Mile Creek watershed for the study period. A uniform row-crop agriculture was used for WS-4 without considering the small percentage area of permanent grass and woods.
- After converting row-crop agriculture to grassland in the model, the predicted surface runoff at both watersheds was greatly reduced by 85-90%. The simulated runoff after land use change was comparable to the measured runoff in a small grassed watershed, 5.9-ha WS-3, within the Four Mile Creek watershed (Table 2).

Table 2. Predicted runoff during the growing season after conversing cropland to grassland

	WS-2	WS-3*	WS-4
	mm		
1977	0	0.9	3.2
1978	0.9	1.6	3.1
1979	26.1	27.7	33.6
1980	4.5	4.5	6.5
Total	31.5	34.6	46.4

* Measured runoff in grassed WS-3 watershed

Conclusion

- MIKE SHE preformed reasonably well in predicting surface flow on agricultural land at the two watersheds with difference scale.
- Converting row-crop agriculture in the areas with relatively high slope to more conservative grassland could greatly reduce surface flow.