Application of the AnnAGNPS Model to the Walnut Creek, IA CEAP Benchmark Watershed

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Background

The Walnut Creek, IA Watershed in Central Iowa near Ames began to be monitored for water quality and quantity in 1991 as a study site for the Management Systems Evaluation Area (MSEA) program. Representative of a large portion of the Midwest Corn-Soybean Belt, this area is a geologically young landscape with glacial till soil parent material. The soils have a wide range of textures and infiltration rates due to the diverse mix inherent with glacial till, but predominantly are poorly drained due to the landscape's flat topography and an impermeable unoxidized till layer at approximately the 3-m depth. Prairie potholes are ubiquitous and still become inundated with water from peak rainfall and snowmelt events despite being extensively tile drained (see inset). These physical characteristics have resulted in highly variable hydrologic conditions across the landscape and have posed difficulties with many models in efforts to estimate runoff, tile drainage flow, stream flow and contaminant loading and transport. A tile drainage component has recently been added to the Annualized Agricultural Nonpoint Source (AnnAGNPS) pollution model. Therefore, being extensively tile drained, dominated by row-crop land-use and having a continuous long-term database, the Walnut Creek Watershed provides an excellent test to evaluate the performance of this updated version of the AnnAGNPS model.

Summer Ponding, 1998

Methods

To begin, we applied the following inputs and parameters for the AnnAGNPS model:

• 10-m resolution digital elevation model (DEM) of the watershed area with modifications of a 1-m "burned-in" depth for the stream network and a raised watershed perimeter boundary wall 2-m high and 50-m wide to better match the GIS generated watershed area with the known area (Fig. 1a and 1b).

• Soil datasets from the NRCS National Soil Information System (NASIS) and the Iowa Soils Properties and Interpretation Database (ISPAID). Slopes are shown in Fig. 2a.

• Land-use, management and cropping systems/rotations by location were determined from a survey conducted in 1992 (Fig. 2b). For the simulation period all corn fields were set in a corn-soybean annual rotation; all soybean fields set in a soybean-corn annual rotation. All other land-uses remained static.

• Weather datasets from two weather stations within the watershed were used, with dew point data and solar radiation data from other local stations. Solar radiation was converted to percent sky cover via a subroutine program within AnnAGNPS.

• Input values of crop nutrient uptake and content for corn, soybean and oat were made based on related published data.

• A 10 year initialization period based upon the 1992 input data was used to better attain equilibriums for soil water content, soil organic matter, soil plant nutrient contents, etc. at the beginning of the simulation period.

• Appropriate runoff curve numbers and Manning's n coefficient values were determined for each land-use within the watershed from NRCS publication TR-55.

Acknowledgements:
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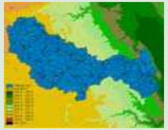
Methods (cont.)

The measured dataset contains nitrate-N concentrations and load losses, but not total nitrogen (TN). The model, however, does not estimate nitrate-N loss, but it does estimate daily dissolved and attached N, and TN. The dissolved N comprised approximately 98% of the model's TN load loss estimates for the entire 1992 – 2003 simulation period. Since nitrate-N typically is the far dominant fraction of dissolved N, we believe it is reasonable to make direct comparisons between measured nitrate-N load loss and the model's estimated TN load loss.

Calibration of the model has not yet be conducted, which will based on the 1992 – 1996 record. Therefore, the model's estimates presented here are pre-calibration.

1a.



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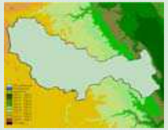


Fig. 1a. Watershed and sub-watershed boundaries determined by the AGNPS/Arc View Interface program with the modified DEM.

Fig. 1b. Watershed area delineated by survey methods from the MSEA program over-laid upon the watershed area determined by the AGNPS/Arc View GIS method.

2a.

2b.

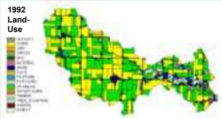


Fig. 2a. Landscape soil unit slope ranges within the Walnut Creek Watershed.

Fig. 2b. 1992 Land-uses within the Walnut Creek Watershed.

* All corn is in the year 1st year of the corn-soybean rotation.
* All soybean is in the 1st year of the soybean-corn rotation.
* All other land-uses remained static by location for all years.

Results and Discussion

The difference in watershed areas between the MSEA delineated boundary and from the AGNPS/Arc View Interface program was minimal, being only a 2% greater area for the later (Fig. 1b).

Monthly total stream flow hydrographs at the watershed outlet of both measured and AnnAGNPS estimates are shown in Fig. 3. Monthly total data were chosen for display due to the difficulty in showing daily flow. On a monthly basis it appears that the model has a phase lag in its discharge compared to measured data, but on a daily basis the model's output actually has a more abrupt cessation of discharge in relation to measured responses to precipitation events. At all time scales the model greatly under-estimated stream flow discharge. For the entire 1992 – 2003 simulation period the model accounted for only 43.8% of the measured discharge flow volume.

Results and Discussion (cont.)

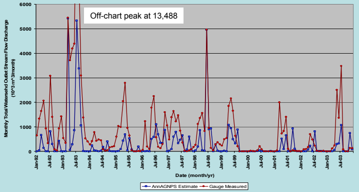


Fig. 3. Comparison of Monthly Total Watershed Stream Flow: AnnAGNPS Estimates vs. Gauge Measured

Preliminary concordance analyses (Lin, 1989) were done as if the data were normally distributed and not auto-correlated, which in both cases is not true. These two factors will be corrected for in final analyses, but doing so will only reflect even worse performance of the model than what was determined with these preliminary analyses. Given this situation for stream flow, concordance (r_c), a test for overall performance of how well modeled output matched the measured data (paired points of the modeled output data vs. measured data) and having a range of 0 - 1.0, equaled 0.35 (P = 0.64; Fig. 5a). At r_c = 1.0, paired data points of modeled vs. measured would fall along on a 45° line of concordance. The mean bias error, a test of the whether or not the differences of the observed (measured) minus the modeled data means (y - x) are zero, equaled 17,234 (P = 1.0). The concordance test also determined that the standard deviation of the measured data was 0.7 of that for the modeled data, indicating a large scale shift. Therefore, based on the three tests for concordance, the model's estimates did not significantly correspond with the measured data for any reasonable predetermined level of significance (i.e., P in 0.05 to 0.15).

Because stream flow volume is a major factor contributing to N load loss and that the model under-estimated flow volume, the model's TN load loss estimates were far less than the measured nitrate-N load loss (Fig. 4). For the entire 1992 – 2003 simulation period, the model accounted for only 3.6% of the actual nitrate-N load. Therefore, the concordance tests for N loss also showed that the model failed to produce estimates that significantly corresponded with the measured data (r_c = 0.005; P = 0.50; Fig. 5b). The mean bias error equaled 269 (P = 1.0) and the corresponding scale shift was 2.4. Again, the modeled estimates failed to significantly correspond to the measured data for all three concordance tests. For both stream flow and TN load a large portion of the bias appears to be from the many days where the model predicts no stream flow nor TN load loss, whereas, discharges were recorded in the measured dataset. This occurred for 2,873 of the total 4,382 days in the 1992 – 2003 record.

With any complex model such as AnnAGNPS there are many factors that may contribute to estimate error. We suspect that the main problems lie within how the model simulates tile drainage and related soil-water infiltration rates, water volumes routed to baseflow and to runoff, and possibly evapotranspiration. The model does not account for water infiltrating below 1.5-m (routing it to deep baseflow) nor water that emerges to the stream as its baseflow. Hatfield et al. (1998), using a water balance method, determined that the amount of water available to infiltrate below the depth of the tile lines for this watershed was <5% of the average annual precipitation. Given these factors of the model and the flat topography of the Walnut Creek Watershed, there is a potential for the model to "lose" large volumes of water via its routing of water to baseflow that may actually be transported as tile drainage and a major fraction of the watershed's annual water budget.

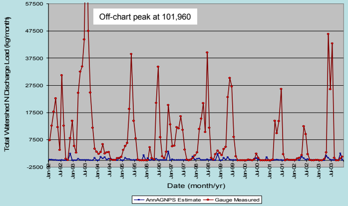
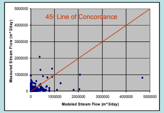


Fig. 4. Comparison of Monthly Total Watershed N Load Loss: AnnAGNPS TN Estimates vs. Gauge Measured Nitrate-N

5a.



5b.

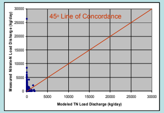


Fig. 5a. Scatter Plot of AnnAGNPS Modeled Stream Flow Output Data vs. Measured Data.

Fig. 5b. Scatter Plot of AnnAGNPS Modeled TN Discharge Data vs. Measured Nitrate-N Discharge Data.

Conclusions

• Calibration procedures and subsequent adjustments in curve values may improve the model's performance.

• Sensitivity analyses need to be conducted on the inputs that are the suspected sources of error relating to stream flow and N dynamics within the model, particularly the inputs that are part of the model's tile drainage component.

• Since AnnAGNPS was originally developed as a model to estimate runoff and that its tile drainage component was recently added, it was not surprising that its estimates did not correspond well with measured stream flow and nitrate-N load loss from this extensively tile drained watershed. These results will guide further development to improve the model.

References

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Lin, L.I.K. 1989. A concordance correlation coefficient to evaluate reproducibility. Biometrics. 45:255-268.