ANNAGNPS EPHEMERAL GULLY EROSION SIMULATION TECHNOLOGY

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1. Introduction

The National Resources Inventory (NRI), conducted by the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS), in cooperation with Iowa State University's Center for Survey Statistics and Methodology, reported that there has been a 42% decrease in sheet and rill erosion in the U.S. between 1982 and 2003. Erosion control practices within agricultural watersheds have a significant impact on reducing the sheet and rill source of sediment to the streams. While these practices have significantly affected sheet and rill erosion, they do not appreciably affect ephemeral gully erosion. Ephemeral gully erosion is becoming a dominate source of cropland erosion simply because sheet and rill erosion is decreasing.

Most ephemeral gullies that develop within croplands are tillage-induced; i.e., certain tillage operations weaken the top layer down to the maximum depth disturbed by this mechanical process during a rotation. What makes a tillage-induced ephemeral gully different from other gullies is the assumption that a non-erosive layer develops at the maximum tillage depth from operations during the management rotation cycle. Ephemeral gullies may form into the soil profile that are greater than tillage depths if the tractive stresses exceed the critical tractive stress of the more resistant bottom layer below the tillage layer. A management operation in the rotation cycle may also remove the gully, by filling in the gully through mechanical soil disturbance, but the gully may reform when conditions are again sufficient to produce ephemeral gully erosion.

Sheet and rill erosion conservation management technologies, such as the Revised Universal Soil Loss Equation (RUSLE, Renard et al, 1997), have provided valuable tools in reducing cropland erosion, but have not considered the impact of ephemeral gully erosion. NRCS has requested improvements in USDA Agricultural Research Service (ARS) technologies to account for watershed sources of sediment from ephemeral gully erosion through the USDA Annualized Agricultural Non-Point Source model (AnnAGNPS, Bingner and Theurer, 2001). AnnAGNPS has been developed to determine the effects of conservation management plans and provide sediment tracking from all sources within the watershed. Technology is also needed to identify where ephemeral gullies may form in the watershed using geographic information system (GIS) technology.

2. AnnAGNPS Model Description

AnnAGNPS is a watershed conservation management planning tool developed by USDA as a partnership between ARS and NRCS. RUSLE technology is used within AnnAGNPS to determine sheet and rill erosion. The model has the capability to track sediment from any source to any point in the watershed for sheet and rill erosion, as well as other sediment sources such as classical gullies and channels. The inclusion of ephemeral gully processes within AnnAGNPS has become a major model developmental need identified by NRCS for conservation planning on croplands.

3. AnnAGNPS Ephemeral Gully Model Enhancements

Although not satisfactorily achieved, the only USDA technology available to assess ephemeral gully erosion on an agricultural field for many years has been the Ephemeral Gully Erosion Model (EGEM, Woodward, 1999). Gordon et al. (2007) has extended the capabilities of EGEM through the Revised EGEM (REGEM) as a stand-alone program, by: (1) adding a new algorithm which estimates the migration rate of the headcut; (2) adding an algorithm which creates the initial headcut's knickpoint; (3) refining some of the existing EGEM components; and (4) developing additional components into a revised and further enhanced algorithm.

The integration of REGEM technology into AnnAGNPS led to other additions to simulate tillage-induced ephemeral gully erosion including: the capability to repair gullies through tillage that defines when an ephemeral gully can again initially form; the influence of prior landuse as defined from RUSLE-technology; utilization of HUSLE (Theurer and Clarke, 1991) components for sediment transport determination; enhanced gully width calculations; and the determination of the amount of scour hole erosion. These enhancements and the inclusion of REGEM-technology have led to the Tillage-Induced Ephemeral Gully Erosion Model (TIEGEM) within AnnAGNPS to provide a watershed-scale assessment of management practice effects on sediment production from ephemeral gully erosion within croplands.

This technology provides an integrated approach in simulating ephemeral gully erosion as the headcut is induced and moves up the length of the pathway with varying widths, depths and migration rates as a result of management practices, watershed characteristics, and climatic effects. Examples of sheet and rill erosion and ephemeral gully erosion control conservation practice assessments include simulations from the conversion of cultivated fields to the Conservation Reserve Program (CRP), from conventional-till to no-till farming practices, or from the use of grassed waterways for ephemeral gully erosion control. Sediment

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from ephemeral gully erosion, as well as from sheet and rill erosion, that eventually reaches the edge of a field (sediment yield), can then be separately tracked as sediment moves further downstream from the utilization of AnnAGNPS.

4. Potential Ephemeral Gully Identification

The identification of where ephemeral gullies occur on a landscape is typically determined through visual observation based on field reconnaissance or from aerial photographs. When there are many fields within a watershed this can be tedious and time consuming to determine. Parker et al. (2007) has developed a topographic analysis technique based on digital elevation models (DEM) that is combined with Geographic Information System (GIS) technology to characterize the location of potential ephemeral gullies and their downstream mouth throughout a watershed system. This approach may provide an automated estimate of the location of potential ephemeral gullies, especially the knickpoint that, when combined with AnnAGNPS, can be used to determine the extent of actual ephemeral gully erosion within a watershed resulting from management practices.

5. Current Model Limitations

The integration and transformation of EGEM to REGEM into TIEGEM within AnnAGNPS has identified several model limitations because little is known about several critical components. Some of the more important limiting components are the identification of and relationships for: (1) ephemeral gully width; (2) soil resistance to gully erosion including a definition for non-erosive layers; (3) the effect of root mass and above ground vegetation on erosion resistance; (4) ephemeral gully networks; and (5) the effect of subsurface flow on ephemeral gullies. Currently, these components are represented through widely divergent to non-existent algorithms, which at best have a heuristic basis.

6. Study Locations

6.1. Ohio–Upper Auglaize Watershed Study

The Upper Auglaize Watershed agricultural non-point source modeling project (Bingner et al, 2006) was an interagency effort to use a GIS-based modeling approach for assessing and reducing pollution from agricultural runoff and other non-point sources that eventually discharges into the Toledo, Ohio Harbor. This watershed is also part of the USDA Conservation Effects Assessment Project (CEAP). A significant source of sediment was identified from ephemeral gully processes and an approach was needed to assess this and determine its contribution to the total sediment load entering the harbor. This project applied AnnAGNPS with EGEM estimates of ephemeral erosion to the Upper Auglaize River Watershed to produce sheet and rill, and ephemeral gully sediment source simulations. Through this approach, sediment load reductions throughout the watershed were evaluated when no-tillage conservation practices were used instead of conventional practices. This produced an overall watershed sediment loading reduction of 60%, with a 70% sediment load reduction from ephemeral gullies.

6.2. Kansas–Cheney Lake Watershed Study

The Cheney Lake Watershed is also part of the USDA CEAP Project, located in south-central Kansas, and is a major source of the fresh-water supply to Wichita, Kansas. Improved drinking water can be created if pollutants entering the lake are reduced. AnnAGNPS was also applied to this watershed where ephemeral gullies were identified as a significant source of sediment. Potential ephemeral gullies were identified in over 1000 unique sites that AnnAGNPS then was used to simulate their impact. Over 35% of the sediment load was determined to originate from ephemeral gully erosion. Only 10% of the drainage area produced 76% of the entire sediment load from the watershed, with this 50% of this from ephemeral gully erosion.

7. Conclusions

Tillage-induced ephemeral gully erosion has been shown to be a significant and sometimes dominant source of sediment within a watershed. An approach has been developed within AnnAGNPS to assess the impact of conservation practices on ephemeral gully erosion as well as sheet and rill erosion. Conservation management treatments should include targeting practices specific for ephemeral gullies differently than for sheet and rill erosion. Within watersheds, gullies are becoming the dominate source of cropland erosion unless preventative conservation practices are installed.

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