Modeling Sheet, Rill, and Ephemeral Gully Erosion with RUSLER and EphGEE

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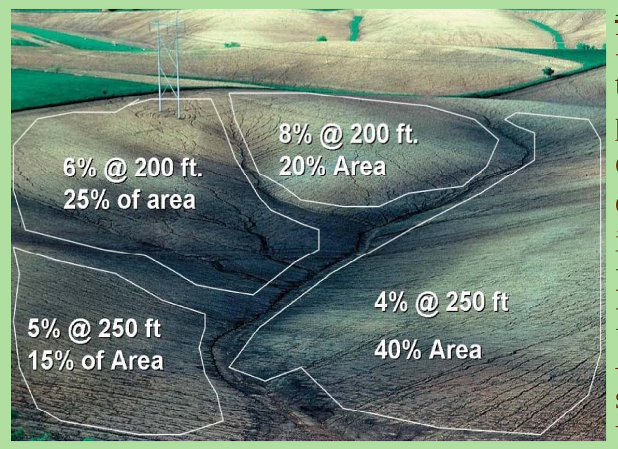
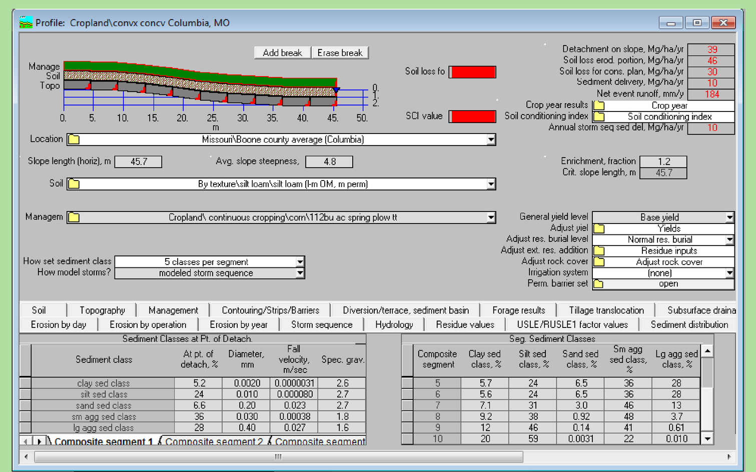
Abstract

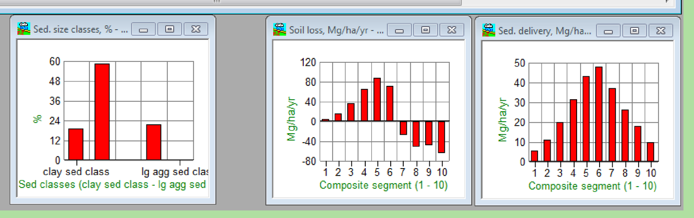
A new modeling system is being developed to provide spatially-distributed runoff and soil erosion predictions for conservation planning. Ephemeral gully erosion is not included in predictions made with the Revised Universal Soil Loss Equation, version 2 (RUSLE2). A new distributed application called RUSLER (RUSLE2-Raster) predicts distributed runoff and soil loss and its output can be linked with the new Ephemeral Gully Erosion Estimator (EphGEE). Digital representations of the area of interest are created using high-resolution topography and data retrieved from established databases of soil properties, climate, and agricultural operations. The system utilizes a library of terrain processing tools to deduce surface drainage from topography, determine the location of potential ephemeral gullies, and subdivide the study area into catchments for calculations of runoff and sheet-and-rill erosion using RUSLER. EphGEE computes gully evolution based on local soil erodibility and flow and sediment transport conditions. These models were applied to a 6.3 ha research watershed near Treynor, IA, where runoff and sediment yield were measured from 1975 – 1991. Using a 3-m raster DEM, results indicate that ephemeral gully erosion contributed about one-third of the amount of sheet and rill erosion, and that considerable deposition of sediment originating from both sources occurred within the grassed waterway. For ambient conditions, predicted annual average watershed sediment yield was 17 Mg ha^{-1} year^{-1}, 20% greater than the measured value of 15 Mg ha^{-1} year^{-1}.

RUSLE2 - sheet and rill erosion



RUSLE2, the Revised Universal Soil Loss Equation version 2, is used by USDA-NRCS thousands of times every day for conservation planning and to determine farm program eligibility. It is supported by a vast national database and supports many other systems, including: AnnAGNPS, Purdue's Manure Management Planner, Wisconsin's SNAP-PLUS nutrient management planning system, AGREN's 2-D erosion calculator, DOE's sustainable residue harvesting tools, the USDA-NRCS Natural Resources Inventory.





RUSLE2 calculates erosion, transport, and deposition or coarse (sand and large aggregate) sediment fractions on complex one-dimensional hillslope flow paths, called "profiles".

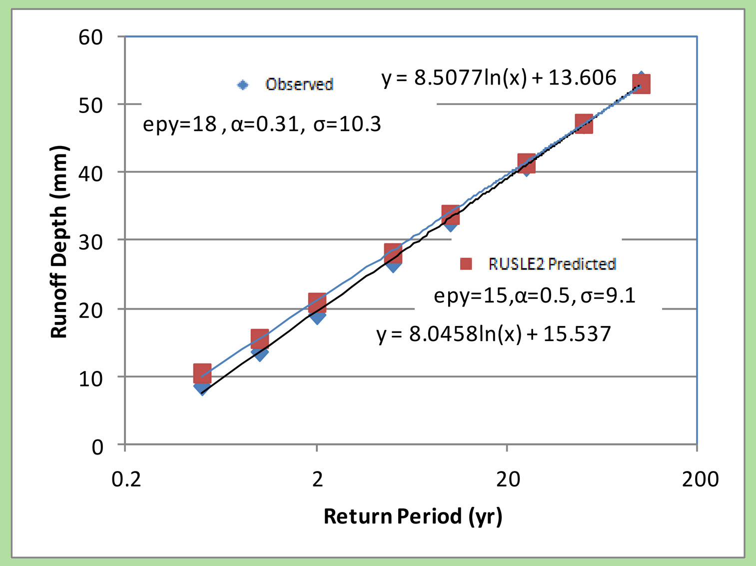
RUSLE2 runoff is not calculated from a rain event sequence; rather an annual channel forming runoff event sequence are calculated from average monthly climate data, soil properties, and land management information.

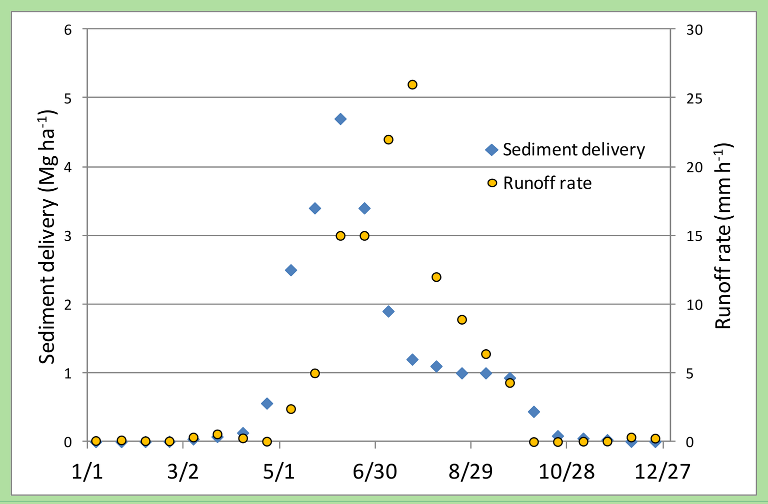
Estimates calculated:

- Average monthly runoff
- Number of runoff events per year
- Statistical distribution parameters describing runoff event depths

Maximum runoff event in the annual event sequence is $R_{1y,24h}$

RUSLE2 then determines event sequence dates and depths (totaling annual runoff) and scales event durations (averaging 60 minutes) based on expected rainfall intensity (erosivity density).

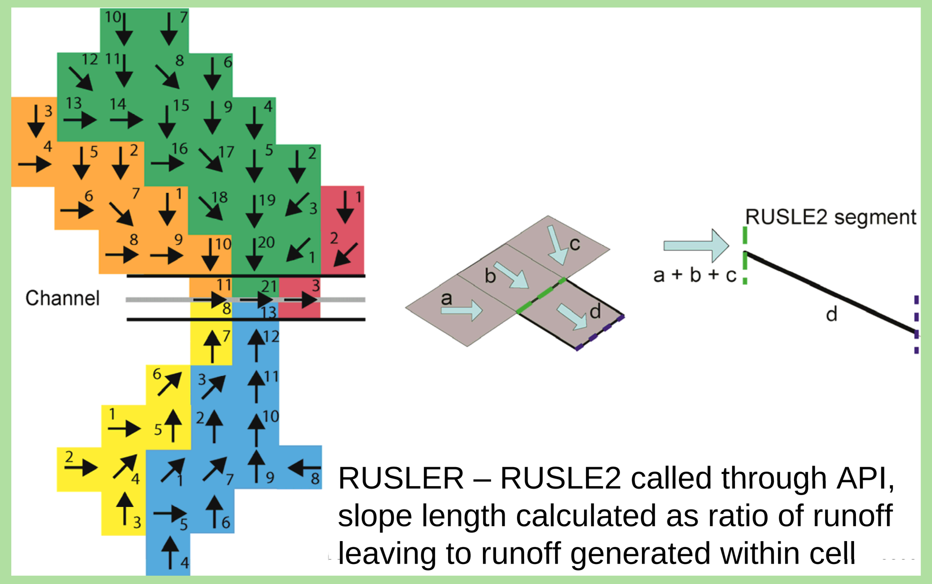




RUSLE2 erosion and runoff event series illlustrated for spring plow corn in Treynor Iowa. Sheet and rill hillslope erosion peaks in May and June; channel forming runoff rates peak in July.

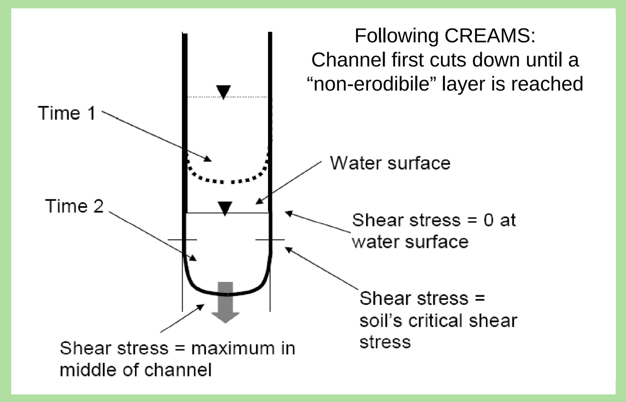
RUSLER short for RUSLE2-Raster

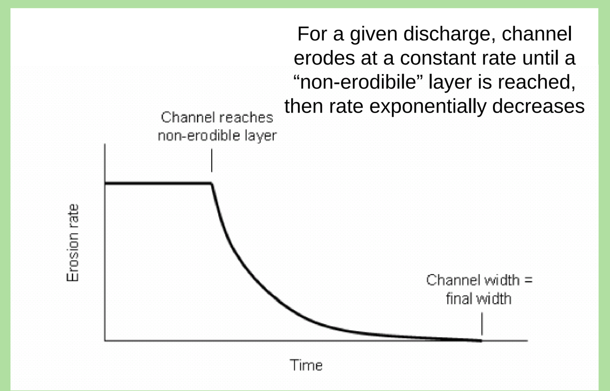
estimates two-dimensional sheet and rill erosion and sediment delivery to field channels.

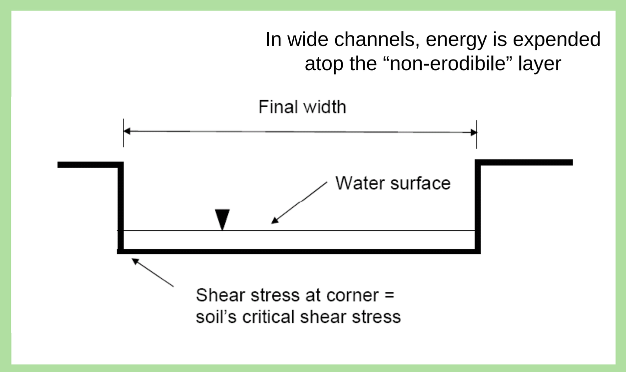


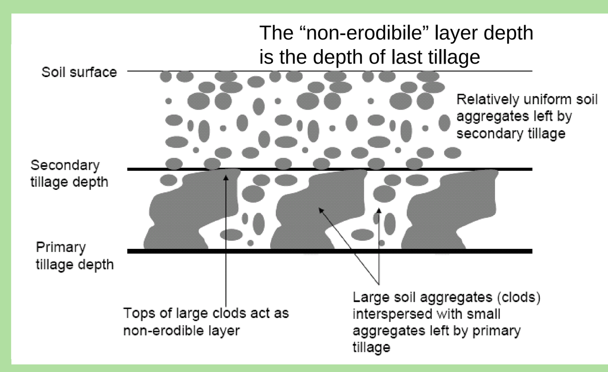
EphGEE - Ephemeral Gully Erosion Estimator

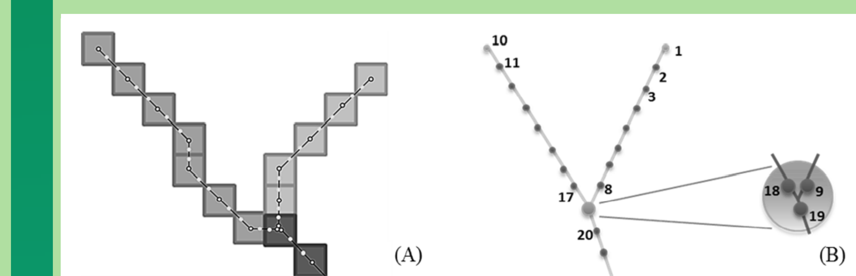
is a one-dimensional numerical model that estimates ephemeral gully erosion by determining detachment due to the shear stress caused by flowing water, and also estimates sediment transport, and dynamic channel dimension changes due to erosion and deposition following Foster's conceptual model.











$$\tau_c = a e^{bC}$$

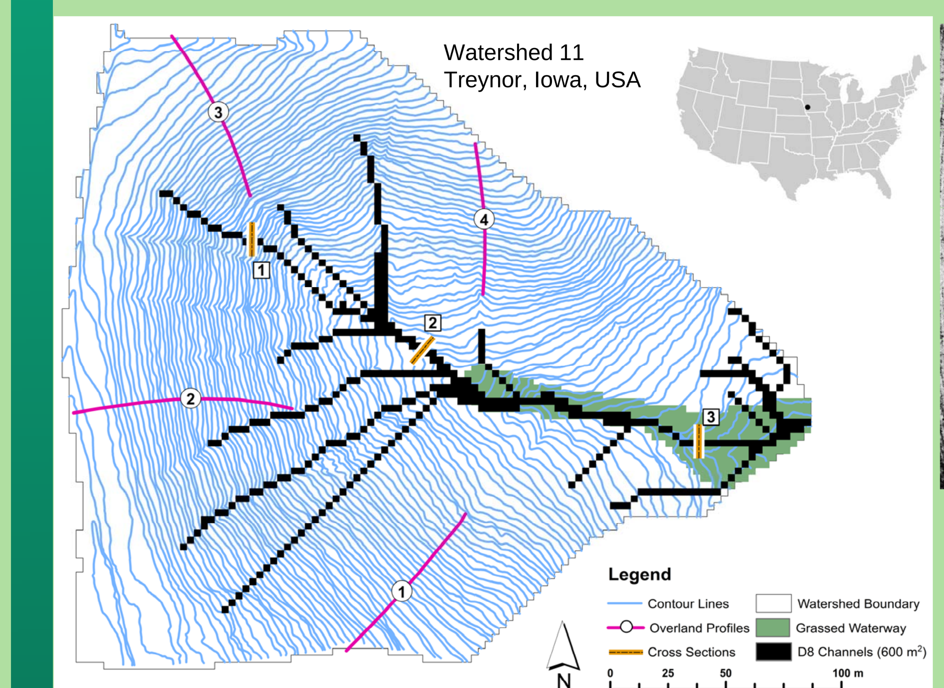
$$a = 0.294 + 0.0075t$$

$$b = 0.0418 + 1.28\times10^{-6}t - 2.79\times10^{-8}t^2$$

$$K = 0.0306 e^{-0.226\tau_c}$$

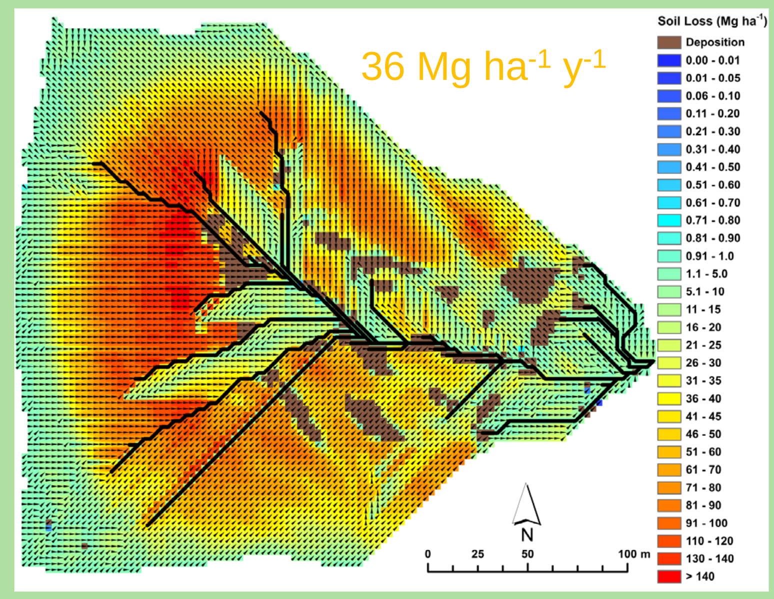
Field Site for Testing

RUSLER and EphGEE simulations without any local calibration were compared with observations on Watershed 11 of the USDA-ARS Deep Loess Research Station located near Treynor, Iowa. The predominant soil was Monona silt loam (fine-silty, mixed, superactive, mesic Typic Hapludolls) with 24% clay. This 6.3 ha watershed was used in the original RUSLE1.04 documentation (Renard et al. 1997) to illustrate the proper selection of four hillslope profiles that end in areas of concentrated flow. A 600 m^2 contributing area resulted in channel network that resembled the gullies observed in aerial photos.



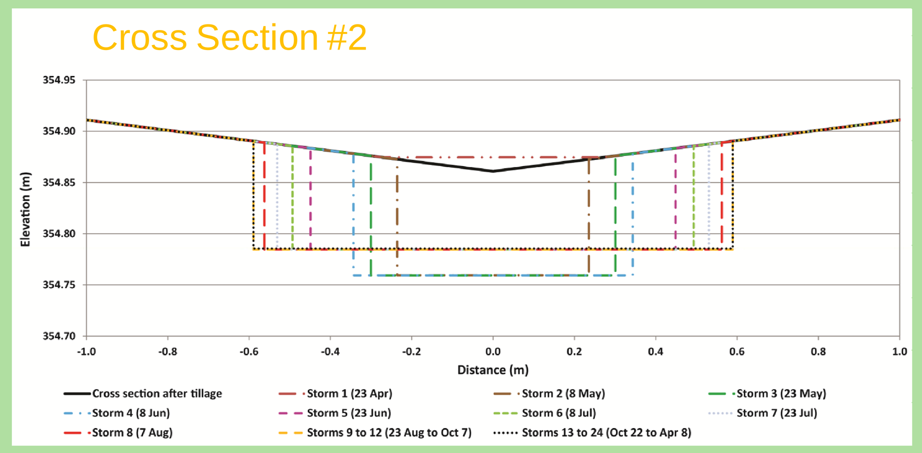
1975 – 1991 contour-plowed corn averaging 7.6 Mg ha^{-1}

Results

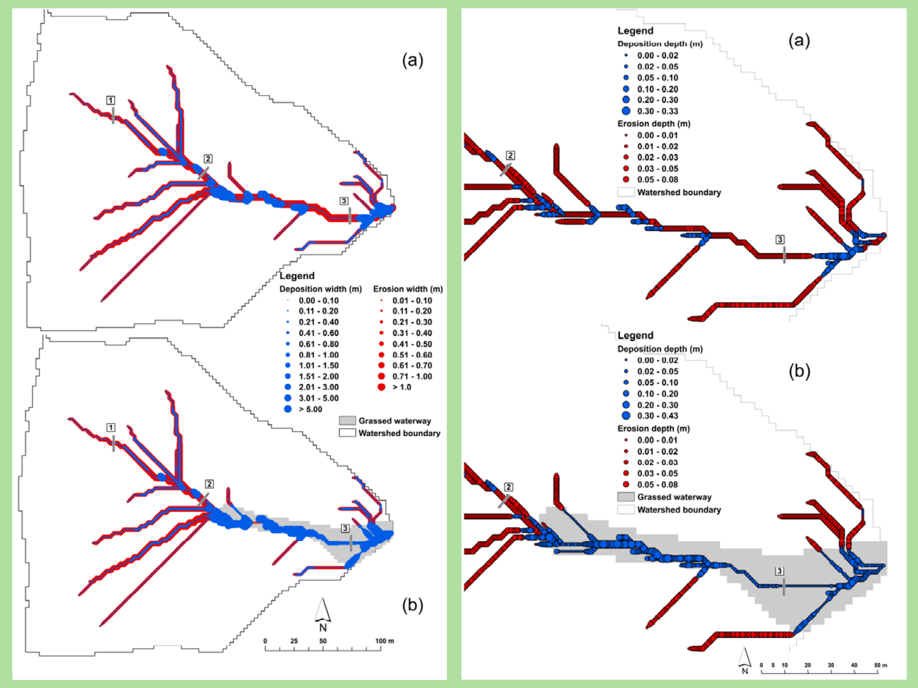


RUSLER estimated hillslope sediment yield to the field channels averaged 36 Mg ha^{-1} yr^{-1}.

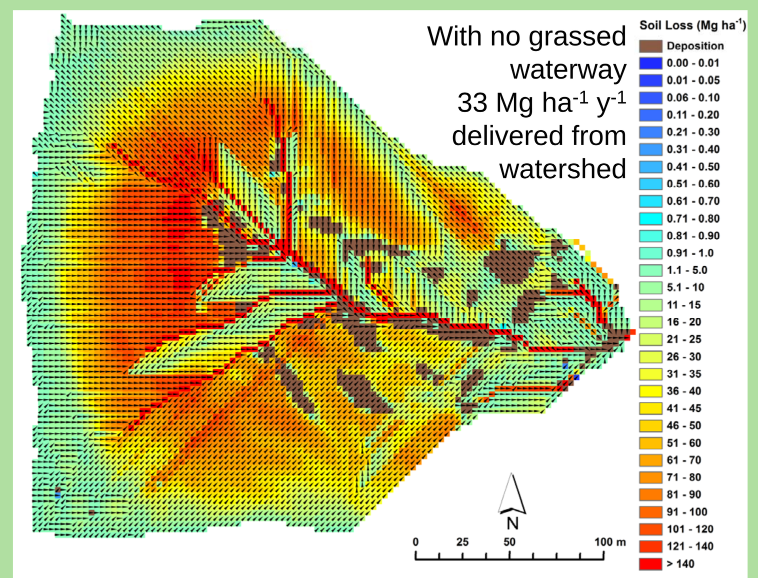
Dabney, S.M., D.C. Yoder, and D.A.N. Vieira. 2012. The application of RUSLE2 to evaluate the impacts of alternative climate change scenarios on runoff and sediment yield. Journal of Soil and Water Conservation 67(5):343-353



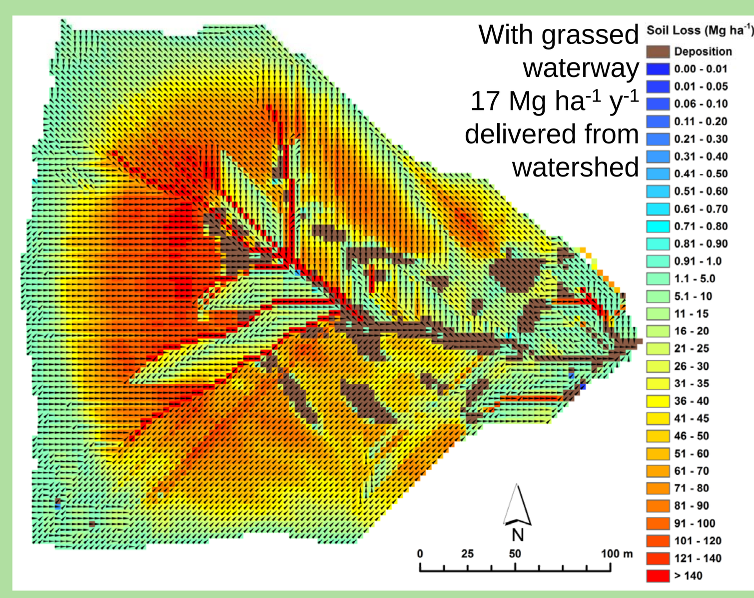
EphGEE estimated ephemeral gully erosion from changes in channel dimensions associated with the RUSLE2 runoff event sequence. Tillage that reset channel dimensions occurred on 15 April (plow, 200 mm depth), 1 May (disk, 130 mm), 5 May (field cultivator, 100 mm), and 10 June (row cultivator, 76 mm)



EphGEE estimated both channel degradation and aggregation. Deposition was common where tributaries met the primary channel due to backwater effects. The grassed waterway caused the main channel to be depositional throughout its last 200 m.



RUSLER/EphGEE estimated watershed sediment yield would have been 33 Mg ha^{-1} yr^{-1} if the grassed waterway had not been in place. Small depositional areas were predicted upslope of the measurement weir due to flat topography.



When the waterway was simulated, estimated sediment yield of 17 Mg ha^{-1} yr^{-1} was about 20% greater than the measured average sediment yield of 15 Mg ha^{-1} yr^{-1}. The grassed waterway reduced sediment yield by about 50% and ephemeral gully erosion contributed about 25% of the sediment delivered from the watershed.

REFERENCE:

Dabney, S. M., D. A. N. Vieira, D. C. Yoder, E. J. Langendoen, R. R. Wells, and M. E. Ursic. 2014. Spatially distributed sheet, rill, and ephemeral gully erosion. Journal of Hydrologic Engineering (in press).