Determining when waterways work best, and art and a science

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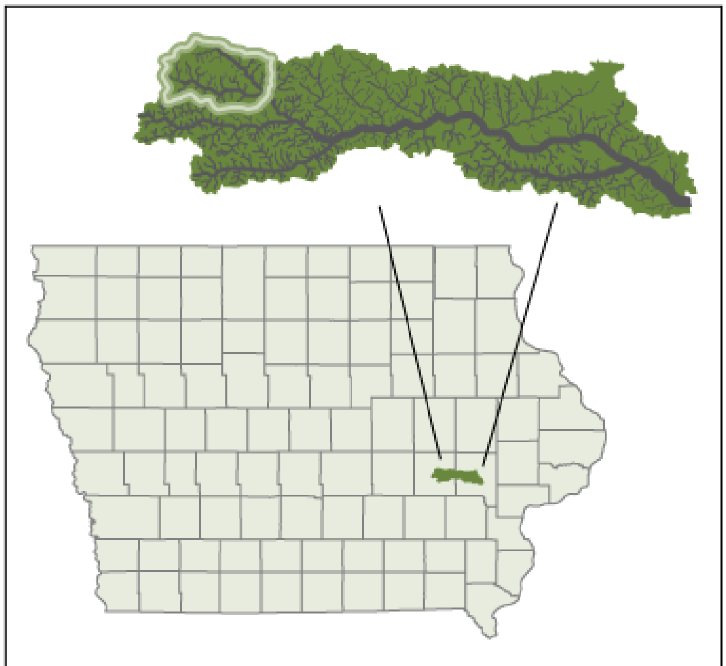
"Essentially, all models are wrong, but some are useful."
– George E. P. Box, Professor Emeritus of Statistics, University of Wisconsin-Madison

Both federal and state policymakers use numbers from computer models to help inform conservation and land-use policy decisions. Long before policy makers see them, technicians enter site-specific agronomic and geographic data into the program; through a series of complex mathematical equations, the model then simulates the agroecological impact of the specific scenario. Most models have been designed to provide a specific kind of analysis and a certain kind of information for the user.

Thanos Papanicoloau, a University of Iowa hydroscience engineer with a flair for integrating models and mathematics, and Lee Burras, an Iowa State University professor of agronomy with a passion for the soils of Iowa and how they change over time and with use, decided to join forces and see what they could contribute to our working knowledge about using a popular NPS (non-point source) model, WEPP—Water Erosion Prediction Model. Their work is being funded by a joint Leopold Center Ecology-Policy Initiative project, "Impacts to the land-water-human system of rural Iowa from high-intensity continuous maize production."



The South Amana Catchment is part of the Clear Creek Watershed. The larger watershed is located in Iowa and Johnson counties.

In 2008, when the investigators were considering this project, farmers were experiencing record high corn prices, due in part to increased demand from the biofuel industry. Because of the high prices, analysts were predicting that more Iowa farmers would be inclined to break the "standard" corn-soybean rotation in favor of planting corn in fields where corn was planted in the prior year—a continuous corn rotation.

Though some agricultural benefits could be derived from continuous corn rotation—increased soil organic matter resulting from corn residue left on the field—much more fertilizer would need to be applied. This arguably could result in reduced downstream water quality due to the amount of runoff typically found in a corn-cropping system. (In this case, runoff refers to any water that exits the field by moving above or below the soil surface.)

In order to address runoff concerns, many farmers in southeastern Iowa install grassed waterways. These are areas where water from neighboring fields collects into a single flow. The waterways are planted with grasses, which reduce runoff, sediment transport, and gully formation. They function by slowing the water as it leaves the field, trapping sediment and absorbing nutrients from the runoff.

The current specifications for grassed waterways in Iowa are well tested and consistently applied. They specify width, depth, slope, acceptable types of grasses, etc. Interestingly, they do not address waterway length. It has largely been assumed they should extend to the head of the swale, with "head" being somewhat vague. As a result, uncertainty exists about optimal waterway lengths. Field-testing to determine the most effective length can be costly, and the results are site specific. Computer models, which can simulate area hydrology as well as grassed waterway lengths, require careful integration by a modeling expert, but the resulting integration can be applicable to a wide variety of models and modelers.

Updating guidelines

Given the potential for changing agricultural land use in Iowa, the Leopold Center acknowledged the need for updated guidelines and funded the study by Papanicolaou and Burras to address the issue.

Papanicolaou started by calibrating a well-established model, the Water Erosion Prediction Model (WEPP) to a section in Iowa County's Clear Creek Watershed, the South Amana Catchment (SAC). Calibration involves collecting site-specific field data as well as historical data from different agencies and sources. Basic input requirements for the computer-based model include climate, topography, soil and land management.
Papanicolaou calibrated the program to the SAC and honed in on the grassed waterways.

What waterway length offers the best conservation benefits? In other words, which works best to reduce the greatest volume of water and sediment leaving a given field? In the SAC, grassed waterways are generally 250 meters on .2-6 percent slopes for drainage areas less than 12 ha. Papanicolaou tested waterways in six different lengths: 100, 200, 300, 400, 500 and 600 meters. He assumed brome grass as the cover in the waterway.

He found, in storm events with the greatest volume of rainwater, 500 meters is a critical length for reducing sediment loss, and a 600-meter length provides the greatest reduction in runoff volume. He also learned that if the drainage area gradient was above 3 percent, the hydrology of the hill slope and soil saturation were the main considerations in determining the effectiveness of the waterway.

What results mean for farmers

According to Papanicoloau, findings such as these aid officials as they make predictions and develop guidelines and policy for famers and landowners.

"I think policy decision-makers are very much paying attention to similar modeling efforts." he said. "They use reliable models such as the ones we are using. The information [we generate] is conveyed to the USDA decision-making people who then coordinate with the NRCS offices and then to the farmers."

According to John Sellers, Jr.,

Knowing the differences: Equations, models and indexes

Example of an equation

- Runoff Curve Number (RCN): This algebraically generated number has been used by engineers for decades to estimate the amount of water that will leave a given field.

Examples of computer-based agroecosystem models

- Annualized Agricultural Non-Point Source (AnnAGNPS): This predicts average annual fluxes of water, sediment, nutrients and pollutants in watersheds ranging from 200 to 1650 km2
- Water Erosion Prediction Project (WEPP): This predicts the amount of erosion (tons per acre) that will occur each year from a given agricultural field into a small watershed.
- CENTURY Soil Organic Matter Model (CENTURY): Simulates carbon, nitrogen, phosphorus and sulfur dynamics through plant/soil interactions for different ecosystems through an annual cycle over time scales of centuries to millennia.

Examples of indexes (the final measure)

- Soil Conditioning Index (SCI): An index used to evaluate the effects of management practices on soil organic matter. (This information can be generated by a model.)
- Water Quality Index (WQI): An index used to evaluate water quality in Iowa water bodies. The scale ranges from 0-100; 0 = poor, 100 = excellent. (This information can be generated by a model.)

Putting it all together – the flow diagram

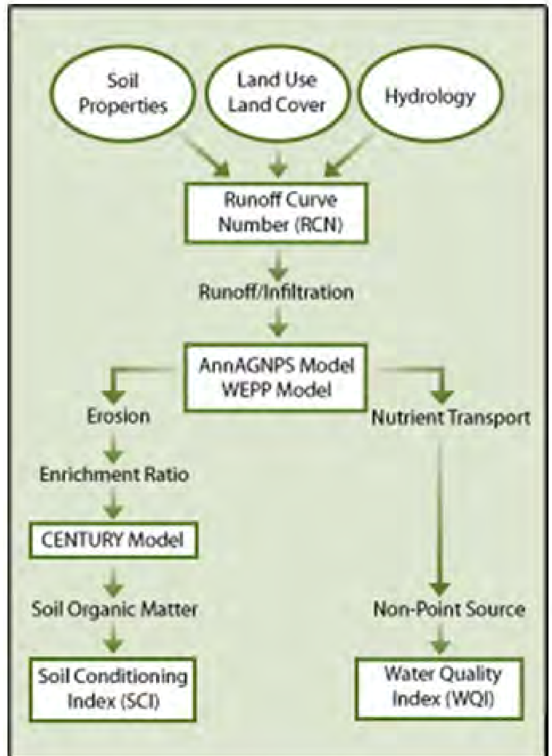
Some inputs and models that experts may use have a flow diagram to arrive at one number that describes water quality and / or soil quality. See example above.

Corydon-area farmer and Leopold Center Advisory Board member, farmers in southern Iowa could have trouble implementing the guidelines.

"There are not many fields in southern Iowa that are large enough for a 500-meter grassed waterway. Most of our focus is on waterways with sufficient width and slope," says Sellers.

If a grassed waterway is currently installed the length of the field and is less than the recommended 500-600 meters, Papanicoloau recommends site-specific waterway modifications that can reduce runoff and sediment loss.

"Depending upon the characteristics of a given field, you can play with the width and gradient of a waterway. The shape of the channel can also be adjusted to better fit the situation."



A model may be used with other equations and parameters to generate user-friendly indexes. See box below for definitions of these tools.

Universal application

Those working with computerized agricultural models will definitely find this work valuable. Though the specific findings regarding threshold waterway lengths are only directly applicable to southeastern Iowa and parts of western Illinois, the mathematics used to operate the model are universal and can be used in a variety of models in locations across the United States.

This is one step toward fine-tuning a model to make it more robust and useful, and it is important because a lot of expensive decisions can be based on the model predictions. But, investments in the models will never pay out in conservation benefits unless the practices actually go on the land. Conservation performance is as much economics and community culture as model precision.

A grassed waterway in Iowa. Photo courtsey of NRCS.

Sellers agrees with this concept: "It's a hard sell on $5,000/acre ground no matter how you design it. And if grandpa and dad didn't do it, I probably won't either. In the end, it's really about a conservation ethic."

The second year of the funding for the project will more directly involve Burras. He plans to expand on Papanicoloau's findings. Given the emphasis on predicted reductions in runoff volume and sediment yield, Burras will step back and ask how changing soil conditions in Iowa might or might not impact these model predictions.

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