Understanding Land-Use Feedbacks and Ecosystem Service Trade-Offs in Agriculture

Lisa A. Schulte and John C. Tyndall

PART II – Creating a Watershed to Meet Established Environmental Goals

Approximate time requirement: 120-180 minutes

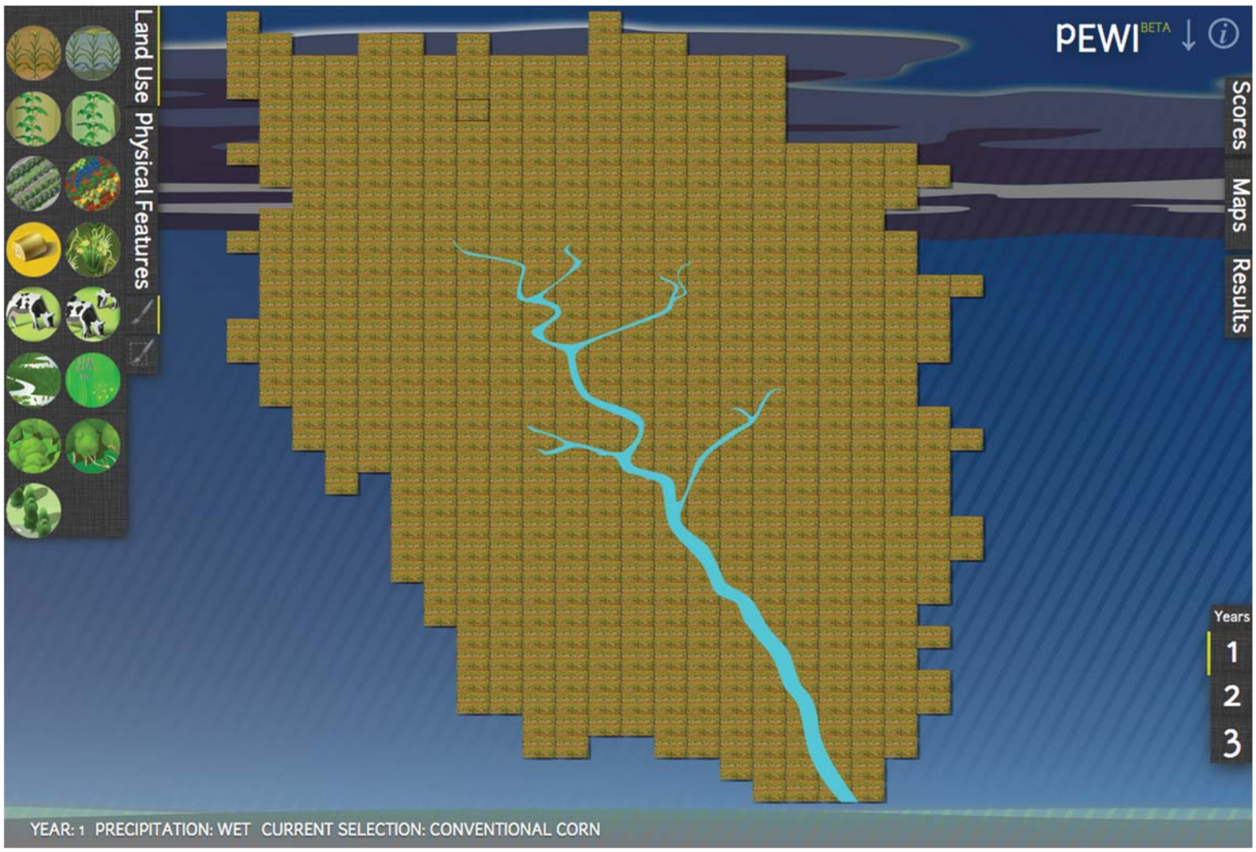
Background: One of the key challenges in agriculture is finding an acceptable balance between production output (the four "F's": food, feed, fiber and fuel) and environmental outcomes. Importantly, this balance must be found within the same land base. The challenge arises from the distinct disparity in land use skills, knowledge, and available economic incentives between production agriculture and environmental management. Row crop production management in the Corn Belt region has upwards of (and for some crops beyond) 100 years of accumulated knowledge, research, development, market infrastructure and extension; whereas, collective understanding of pathways for improved environmental conditions in agricultural landscapes is based on comparatively new science and technology. Agricultural scientists and farmers are however turning to an expanded understanding of landscape ecology and hydrologic function to guide planned land use (also known as targeting) that can enhance ecosystem function at multiple scales. This approach strategically integrates conservation practices, perennial vegetation, and commodity production in ways that broaden the array of landscape or watershed scale ecosystem goods and services (and minimize negative outcomes like non-point source pollution).

As a way to jump-start this approach to strategic land use, the State of Iowa enacted the Iowa Nutrient Reduction Strategy (IA NRS). The IA NRS is a science and technology-based framework to assess and guide a state-level reduction of nutrients and sediment to Iowa waters and the Gulf of Mexico (the state-level goal from agricultural lands is a 41% and 29% reduction in N and P, respectively). The strategy promotes different land use practices that farmers throughout Iowa can implement individually or collectively to improve overall environmental quality as mediated by the land they manage; all the while maintaining or even increasing the commodity output so critical to the region's economy. Below is a scenario that uses the goals of IA NRS to set the stage for bio-physically (Part II) and then economically (Part III) exploring how strategic land use can be a path forward to balancing production and environmental quality.

PEWI Scenario: Start with a PEWI 2.0 watershed that is 100% conventional corn (not an unusual situation in parts of the U.S. Corn Belt. Imagine the USDA Natural Resources Conservation Service has selected your PEWI watershed to test an experimental land use conservation program. The program is designed to comprehensively analyze alternative land-use designs to determine the best way to minimize delivered sediment, nitrate and phosphorus leakage (at levels amenable with the IA NRS) increase carbon sequestration and improve biodiversity *at the lowest cost and resulting in the highest watershed-scale market value relative to current commodity corn production.*

Step 1: Using the PEWI 2.0 model, you are to study the physical characteristics of the watershed (e.g., topography, soil type, sub basin delineation) and apply your basic knowledge of the effects of land use on: surface/subsurface hydrology (including tiling), nitrogen (N) and phosphorus (P) dynamics, the carbon cycle, and biodiversity ecology to strategically design land-use patterns that result in the following improvements in “environmental quality” at the lowest cost (relative to the baseline scenario).

Start with a Year 1 watershed that is 100% conventional corn; for example, see figure below. Run through the years 1-3 and examine the results (see “results” tab). Determine which year has the “worst” baseline data (collectively, which year has the highest levels of the pollutants of concern? Use your best judgment; some years may be similar in outcome). Using that watershed year only, write your RESULTS TABLE 2.1 below; note you’ll only be filling in the “Conventional Corn Baseline” column in this step.



RESULTS TABLE 2.1	**Conventional Corn Baseline***	**Step 2 Results**	**Step 3 Results**
Erosion Control (Gross Erosion; tons)			
Sediment Control: In-stream delivery (tons/yr)			
Phosphorus: In-stream loading (tons/yr)			
Nitrate Pollution Control: In-stream concentration (PPM)			
Carbon sequestration ("new" carbon accumulated; tons)			
Biodiversity (1-100 unit-less scale or points out of 10)			
Bioenergy yield (total tons/yr)			
Average corn yield/ acre			

* Note: every team's baseline conditions will be a little different due to different precipitation.

Step 2: Design and redesign the watershed as needed to fulfill the following environmental and production objectives. This way, if you make the watershed "environmentally sound" for the most challenging year as determined by precipitation, your watershed is assumed to be *resilient* across time – make sense? For fun: spend some time thinking about the concept of "resilience". What does this concept mean? How might the concept be measured? Record your results in RESULTS TABLE 2.1 above.

Ecosystem Services	Improvement goals relative to conventional corn baseline	Target limits
Erosion Control (Gross Erosion; tons)	≥ 70% reduction	To be determined
Sediment Control: In-stream delivery (tons/yr)	≥ 60% reduction	TBD
Phosphorus: In-stream loading (tons/yr)	≥ 30% reduction	TBD
Nitrate Pollution Control: In-stream concentration (PPM)	--	≤ 6.5 PPM
Carbon sequestration ("new" carbon accumulated; tons)	≥ 4500 tons	≥ 4500 tons
Biodiversity (1-100 unit-less scale or points out of 10)	≥ 4.5 points; or a score of 45	≥ 4.5 points or score of 45
Bioenergy yield (total tons/ year)	≥ 43,000 tons	≥ 43,000 tons

Step 3: Once you find a land use design that meets the environmental objectives, test which of the environmental goals are the most "constraining" by strategically putting acres back into row crop production (this will require giving up some chosen perennial land cover but it also may involve trading one perennial land cover choice for another; that is, do some land cover choices do more functionally than others, thus allowing for more land to be dedicated to production?); do this until you no longer can meet the target limits. Record your results in Results Table 2.1 above.

In the text box below, describe your process for creating a "targeted" watershed design. Consider the following questions:

- Which environmental goals are most constraining? Which are the least constraining? Why do you think this is the case?
- Did you substitute one land cover choice for another in an attempt to remain environmentally compliant? If so, what guided your choices and what happened?
- What are the various ways that your redesigned watershed is "different" from the baseline watershed? Think about the agronomic, ecological, economic, and social issues associated with this situation.
- What data were most useful in your land use choices?
- What other data or tools may have been helpful to you as tried to target?

Step 4: Once you have your watershed in place and you've had time to consider your design process and outcomes, pair up with another watershed designer and share your designs and overall thoughts on the process. Be ready to discuss your findings with the whole class.

Step 5: Turn in your completed lab packet and submit your targeted watershed design electronically to your instructor.

References and Supporting Reading:

- *Brauman, K.A., G.C. Daily, T.K.E. Duarte, and H.A. Mooney. 2007. The nature and value of ecosystem services: an overview highlighting hydrologic services. Annual Review of Environment and Resources 32:67-98.*
    - This paper will introduce students to the concept of ecosystem services, focusing on services associated with water and watersheds, and also introduces the concept of ecosystem service valuation. It should be understandable to junior- or senior-level undergraduates as well as graduate students.
- *Lovell, S.T., and D.M. Johnston. 2009. Creating multifunctional landscapes: how can the field of ecology inform the design of the landscape? Frontiers in Ecology and the Environment 7:212–220.*

    - This paper will introduce students to concepts and tools used in landscape design. The authors use a real world landscape similar to PEWI's virtual one as a case study used to exemplify the use of design processes in agricultural settings. It should be understandable to junior- or senior-level undergraduates as well as graduate students.

- *Mississippi River/Gulf of Mexico Watershed Nutrient Task Force. 2008. Gulf Hypoxia Action Plan 2008 for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico and Improving Water Quality in the Mississippi River Basin. Washington, DC.*
    - This report provides basic information on water quality issues on the Midwestern US and the Gulf downstream. It is highly readable and contains highly illustrative graphics.