Landscape-scale Management for Sustainable Plant Production and Ecosystems

A. Scope/audience

Many land management and crop production decisions by private owners/operators or public institutions are made on a piecemeal basis for an individual field or small management unit. With the increasing awareness of long-term environmental and sustainability concerns, a more systematic approach to choosing appropriate management practices for the landscape is needed. The audience, stakeholders, and collaborators for these efforts are broad-based and include: state and federal agencies such as the Natural Resources Conservation Service (NRCS), Indiana Department of Environmental Management (IDEM), Indiana State Department of Agriculture (ISDA), and the Environmental Protection Agency (EPA); agricultural producers; crop commodity associations; agricultural consultants; homeowners; managers of parks and recreational facilities; watershed groups; non-governmental organizations (NGOs) such as The Nature Conservancy; and the general public.

B. Overview & contribution in the past 5 years

Research on sustainable crop production and its underpinnings of soil and water quality has been a mainstay of the Agronomy Department for decades. Examples include research and extension on tillage and planting systems, crop rotations, soil erosion, nutrient management strategies, forage production systems, soil quality, drainage and water use efficiency, and movement of potential agricultural contaminants (manure, fertilizer, pesticides) in surface runoff or subsurface drainage waters. In addition, both research and education activities on turf and the rural-urban interface have broadened the scope of Agronomy to include on-site waste disposal systems, turf for use in recreational facilities, evaluation of land-use transformations from agriculture to urban/suburban, and turf as a contributor to the broader "green" industry in urban and suburban areas. While much of the work has been conducted by teams of researchers, the scale of work has been mainly at the plot or field scale. Notable exceptions at the large scale (multiple field, regional, watershed, etc.) include soil classification studies at the landscape scale, and remote sensing studies. And while much of the work has included multiple functions of a given system (e.g. growing corn while improving soil quality and minimizing negative impacts on air or water quality), those functions have been assessed at one scale only (typically plot or field).

Many of the faculty hired since the last CSREES review were specifically hired to help broaden the impact of our work to larger scales. New expertise in hydrology, climatology, biogeochemical cycling, and remote sensing is enabling the Agronomy Department to apply its expertise in field-scale research to address the larger issues of land and water management at a landscape or watershed scale. Agronomy faculty have a history of serving in advisory roles to state and federal agencies related to agriculture, land use, and environmental issues, and they are committed to research and Extension that has a positive impact in all these areas. There is a strong desire to have the results of this work used at a larger scale to have an impact on the broader citizenry. Future challenges relate to the larger scale, multiple functions, and optimal placement of different management practices within the landscape.

C. Current challenges

There is an ever-increasing competition for land and water resources across all segments of society. Within the agricultural sector there has always been some competition for use for food, feed or fiber production, but with the emerging biofuels emphasis (see Bioenergy white paper), there is potential for greatly increased competition for land. Urban/suburban areas continue to grow, as do demands for recreational areas and preservation of green space. Environmental awareness has increased the demand for cleaner water resources as well as land for wildlife habitat. Recent flooding in the state and region have inspired some calls to rethink our use of floodplains, impervious urban design, landscape drainage, and river engineering schemes, while localized and worldwide water shortages have encouraged water conservation from the other perspective. Water quality concerns include uses for drinking water, recreation, aquatic life habitat, and Gulf of Mexico hypoxia. The revised Hypoxia Action Plan as well as pending State Nutrient Management Criteria and Total Maximum Daily Loads (TMDLs), all put additional emphasis on reducing loads of agricultural contaminants. Clearly there is a great need for the technical knowledge that the Agronomy Department discovers in its research, along with the educational and extension component that our department can deliver for greater implementation of these findings on the landscape.

D. Fundamental issues for next 10 years

The fundamental issues discussed in this section, are intentionally arranged to begin with the small field- or plot-scale issues (#1, 2), and then move up to larger scales of space, time, or functions.

1. ***Improved cropping systems that are sustainable economically, environmentally, and socially despite rapidly escalating global demand:*** This includes work to achieve worldwide food security by ecological intensification of grain crop production systems. It also includes optimization of macro- and micro-nutrient management within the context of high nutrient prices and considerable fluctuations in crop commodity prices. Examples of ongoing or anticipated projects include conservation tillage, nutrient management, crop rotation, soil quality, cover crop, crop management, pest management, and manure management studies in either focused or integrated factor experiments in multiple environments.

2. ***Management of turf for home and business lawns as well as for golf courses and athletic fields and preservation of green space:*** Examples of these projects include nutrient and pesticide management on turf, establishment

methods, stress tolerance, and management practices for both high and low maintenance scenarios.

3. ***How to "scale up" the results from a field scale project, to the landscape or watershed scale:*** For example, if a practice reduces phosphorus (P) losses from a field by 30 percent, how much does it impact P losses at the outlet of the watershed? This involves not only the relative size of the field compared to the watershed, but also the links and intervening processes (see #4).

   The proposed approach would be to develop nested field studies in a few selected watersheds. An example of this already exists to some degree with work in Tippecanoe County. Tile-drained plots at the Water Quality Field Station (WQFS) are used to study the water quality impacts of soil and crop management at the plot scale. Those tile drains contribute to the Box Ditch subwatershed, where another study monitors ditch water for manure constituents from known fields at the Animal Science Farm. These all contribute to Indian Creek and the Wabash River, within which there are some additional measurements. As new field studies are contemplated, a real effort would be made to place them within a watershed where other studies are also located, so that watershed-scale measurements have multiple field-scale detailed measurements contained within them. By the same token, any new watershed study would be considered for watersheds where we have other studies either ongoing or anticipated as part of a plan. Having nested studies will allow for greater use of the data across scales. The nested field study approach would not preclude the need for additional studies under issues #1 and 2 that are at other locations throughout the state, however.

4. ***The connections and processes in the transitional areas and in the larger scale:*** For example, the P or N in the drainage ditch is determined by runoff from the field and drainage from tiles, as well as reactions with sediment already in the ditch, ditch bank sloughing, interaction with ditch vegetation, and interactions with groundwater and baseflow. Many of these connections and transitions are outside the scope of work normally done by the Agronomy Department. In fact, many of them fall "between" numerous departments but not within any of them. There is already some "transitional zone" work being done within our department and others, but in order to really assess the impacts of field-scale BMPs on watershed outflow, greater effort will be needed with these other departments or entities to connect the different scales. Opportunities exist with the National Soil Erosion Research Lab (NSERL), Agricultural and Biological Engineering (ABE), Forestry and Natural Resources (FNR), Indiana Univ.- Purdue Univ.- Indianapolis (IUPUI), and perhaps the U.S. Geological Service (USGS) and NRCS.

   Examples of ongoing projects include measurements of water quality from tile drains, surface runoff, and within ditches and streams; measurements of chemical transformations within ditch water and sediment; modeling the impact of field-scale drainage water management practices or cropping system practices on nitrate loads at a watershed scale.

Issues number 3 and 4 focus on understanding of scale-dependent processes — how does our knowledge of a field translate to understanding of the watershed, and how do processes in those connections between field and watershed outlet affect the result? The next two issues deal with using this understanding to model or predict where we can have the greatest impact on water quality or other desired outcomes in a watershed.

5. ***Optimal placement of various practices for a particular function:*** For example, if one has a suite of practices available to reduce nitrate loads to the river, what is an optimal placement of these practices in different parts of the landscape? Where would particular practices be the best suited and have the most impact? Although most of the land is privately controlled and therefore not subject to following a researcher's "optimal" design, this is not merely an academic exercise. State and federal agencies are focusing some of their cost-share and other landowner assistance programs to specific practices in specific watersheds, and prioritizing funding based in part on perceived effectiveness. Watershed groups and NGOs also try to identify the most critical areas and help fund practices to solve those problem areas. The potential for water quality trading is another driver for some type of optimization analysis.

   A current example of this type of project is a small one recently funded by the Indiana State Department of Agriculture (ISDA) to faculty in the Departments of Agricultural and Biological Engineering and Agronomy. The state will have a new Conservation Reserve Enhancement Program (CREP) that will fund constructed wetlands in strategic locations within agricultural watersheds, to reduce nitrate loads in the Wabash River. The current project will start with a GIS analysis of selected watersheds to determine locations that meet criteria for the program (soils, size, upstream area, no effects on neighbors, etc.) and add estimates of effectiveness and impact. The ISDA will then use the information and analysis to prioritize potential projects and to contact landowners for possible inclusion.

6. ***Optimal placement of multiple functions within the landscape or watershed:*** Given the multiple functions and mixed uses needed in a watershed, where might be the optimal placement of these functions? These multiple functions include flood water storage, nutrient removal, sediment retention, wildlife habitat, recreation, urban needs, confined livestock structures, grazing lands, and agricultural production of food, feed, forage, and biofuel crops.

E. Projects that Purdue and especially Agronomy can develop to address these issues

Many specific projects could be developed from the general ideas listed in the previous section, and a few specific examples were listed in that section.

F. The science team (expertise needed)

As mentioned in Section b, our department has hired many of the people needed to facilitate the transition from field-scale to watershed scale analyses. The science team would include almost all the faculty in the Earth System Science group as well as many in the Crop Sciences group. Some of the remaining gaps in the "transition zones" (discussed in Section D-4) could be filled by greater collaboration with some new faculty in Agricultural and Biological Engineering and Forestry and Natural Resources, and by more collaboration with Indiana Univ. - Purdue Univ. - Indianapolis (IUPUI) and the National Soil Erosion Research Lab. In addition, crop physiology and management expertise needs to be enhanced and more fully integrated with field crop genetic advances (achieved commercially and in our department) to help solve the grand challenges on the landscape scale like drought stress tolerance and improved nutrient use efficiency.

This grand challenge overlaps with several of the others in our department, including Climate Change, Bioenergy, and Chemical and Biological Constituents in the Environment.

G. Time frame

There is a window of opportunity to show how we can help state agencies now, with the great interest in the Hypoxia Action Plan, emerging State Nutrient Criteria, and interest (and funds) within ISDA to improve water quality in the state. The timeframe for most of the research projects needs to be at least 10 years, while ongoing extension projects can have an impact well before the research is "finished."

H. Evaluation of success

A good indicator that our work is having impact would be the use of our results and information and implementation of our recommended practices by agencies, watershed groups, NGOs, and private citizens. Another good indicator would be growth in Midwest farmer adoption of soil and water conservation practices like no-till, strip-till, and cover crops as determined by remote sensing of crop residue cover at critical stages in environmentally sensitive areas. The contribution of crop management research to the joint goals of improving food security and environmental protection can be assessed. An additional evaluation of success would be the influence our work has on future research and extension work of other scientists in our respective discipline areas.

I. Dissemination of information to decision makers/scientific community/public

This is particularly key for work in this grand challenge. Several faculty members have ongoing relationships with state or federal agencies and have the opportunity to communicate some of the findings and ideas even as the landscape scale research is in progress. We also plan to explore new avenues by which we can more regularly and collectively provide timely updates and scientific expertise to state agencies. A variety of extension programming and publication outlets will also be needed, including workshops and meetings, web-based educational modules, and extension factsheets.

J. Resources needed

1. Long-term support of technical support staff (both field and lab) and clerical/technical writer support (write up information, web access and design)
2. Long-term support of key field research facilities (some include WQFS, long-term rotation and tillage plots, Daniel Turf Center, and a few key watershed-scale studies to be initiated in future)
3. Funding in general (grad students, equipment, travel to field sites, ……)
4. Continual long-term availability and support of Purdue's regional research farms in different environments

K. Conclusions/recommendations/vision for future

Many of our current projects could have even greater impact by better linkage with other scales of measurement and modeling. These linkages require time to develop, however, and we often have a shortage of time to discuss these larger ideas and to strategize about ways to link multiple project objectives together. One recommendation would be to discuss all of our current projects in terms of their geographic location, their scale of measurement, and the logical connections that could be made to the next level up or down on the scale. Although we have field projects in many subwatersheds around the state, perhaps we could identify one or two (one logical choice is some subwatersheds of the Wabash River near Lafayette, which could include the Agronomy Center for Research and Education and the detailed work there) where we would focus many of our efforts. Our choices should consider carefully the soil mosaic present in the watershed and subwatersheds by making use of detailed soil survey data that is now available in digital form for the whole state. Much of the work on water quality is already oriented towards reducing nutrient loads to surface waters, and so we might frame the objective as testing ways to reduce nutrient loads (N, P) to surface waters in order to help reduce hypoxia in the Gulf of Mexico and to meet new State Nutrient Criteria and/or TMDLs. This objective would now explicitly consider work at the field scale linked up to the larger scales of ditches, streams, the Wabash River, and possibly the Ohio or Mississippi Rivers.

Another initial goal is to compile available data sets, both old and new, and assemble them in formats available for dissemination and use. These data would be useful for answering some of the questions that arise, as well as for better identifying gaps in knowledge that should be addressed with new research. This goal includes exploring new ways of making data and metadata accessible and should include work with libraries or other evolving data management strategies.