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Integration of water, nutrient an carbon cycling under diverse annual perennial plant community systems in agricultural landscapes

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Abstract
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Disciplines
Agriculture | Hydrology | Soil Science

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Principal Investigator:

Heidi Asbjornsen
Formerly at Iowa State University

Co-Investigator:
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Agricultural and Biosystems Engineering
Iowa State University

Budget:
$25,000 for year one
$25,000 for year two
$25,000 for year three
$25,000 for year four
$25,000 for year five

Q How much perennial plant cover is needed to achieve significant improvements in water quality?

A Results suggest that placing as little as 10 percent perennial cover in the lower (toe) portion of a watershed can substantially reduce sediment loss by greater than 90 percent.

ECOLOGY

Background

This project addresses the problem of increasing surface and subsurface water and nutrient transport from agricultural land uses that flows into streams and rivers in the Midwest. These alterations in hydrologic functioning have had dramatic impacts on flood events and nutrient and sediment loading in aquatic systems, leading to a lower quality of life for people in the region and downstream. Further, in the associated terrestrial systems, almost complete conversion of native perennial vegetation to row crop agriculture has affected floral and faunal diversity, soil physical and chemical properties, and overall ecosystem productivity.

The two main objectives of the project were to:

- Quantify the influence of different proportions and landscape configurations of annual (e.g., corn and soybean) and perennial (e.g., prairie, savanna, agroforestry) plant communities on the storage, cycling, and output of nutrients, water, and carbon and the biodiversity of diverse taxa (birds, insects, and plants) at the field and catchment scale.
- Catalyze change on the landscape by promoting greater understanding among diverse groups of people (i.e., the public, policy makers, farmers, environmentalists) that agroecosystem production and environmental stewardship are compatible when appropriate combinations and configurations of perennial and annual plants are established.

Approach and methods

The first objective focused on field experimentation to examine the main hypothesis that strategic integration of perennial plant communities in agricultural landscapes will disproportionately improve nutrient, carbon and water fluxes—thereby reducing nutrient loads and movement of precipitation to surface waters and groundwater—while maintaining high productivity of the annual crop systems and promoting native biodiversity. Researchers at Iowa State University (Agronomy, Agricultural and Biosystems Engineering, and Natural Resource Ecology and Management) and the USDA Forest Service North-Central Station and the USDA Agricultural Research Service National Laboratory for Agriculture and the Environment conducted the field experiments.

Prairie strips integrated into the soybean field with monitoring station at the bottom of the watershed.

The second objective involved transferring key information to targeted groups and individuals to influence decisions and behavior, using learning processes that encourage new thinking and understanding about complex issues and promote active engagement among a broad range of stakeholders. A network for promoting research-policy linkages, comprised of representatives from key government agencies, non-governmental organizations, and other private and public groups, was created to work with the project team to achieve these goals. Educational and outreach activities were conducted annually, using the Neal Smith National Wildlife Refuge as a demonstration site and opportunity for participatory learning.

Results and discussion

Results suggest that placing as little as 10 percent perennial cover in the lower (toe) portion of the watershed can substantially reduce sediment loss by greater than 90 percent. Furthermore, a total of 83 plant taxa were identified, while total plant cover in the perennial strips was >80 percent by the first year, of which 17.6 percent was comprised of native species. Forty-eight bird species were recorded using the watersheds, and bird abundance was found to be significantly greater in watersheds containing the perennial strips relative to the watersheds with 100 percent annual crops. Over 2,000 insects were collected from the watersheds, many of which are known to be important for ecosystem services such as pest regulation and pollination.

Approximately 30 percent of the farmers participating in the Willingness to Accept (perennial strips) group responded positively; this unexpectedly low acceptance rate was potentially due to the high degree of uncertainty in the commodity markets and, subsequently, farmers' preference to opt for the status quo.

Findings from the soil respiration study indicated that soil respiration was lowest under the annual crop and increased with the age of prairie reconstruction. Predominant controls on soil respiration were the interaction between soil temperature and root biomass. These findings suggest that soil respiration is an important variable to consider when assessing potential long-term impacts of prairie reconstructions and perennial-based conservation practices on carbon sequestration and ecosystem carbon balance.

The research on the effects of plant species diversity and composition on nutrient cycling showed that the aboveground biomass of polycultures did not exceed that of monoculture of the best performing component species, although polycultures exhibited superior performance relative to monocultures for annual net primary productivity. These findings have implications for selecting and combining species when designing conservation practices involving the integration of perennial plant cover within agricultural landscapes.

Conclusions

The results thus far suggest that small amount of perennial cover strategically placed within the landscape can lead to significant improvements in reducing both

STRIPs stakeholder group views runoff monitoring station including H-flume and auto sampler.

surface runoff and sediment and nutrient loss from row-crop dominated watersheds. Although additional data collection over multiple seasons and climatic conditions is needed before making conclusive recommendations, the initial two years of post-treatment data suggest that optimal results are obtained by placing as little as 10 percent perennial cover in the lower portion of the watershed. In contrast, distribution of that same 10 percent of perennial cover crops across the watershed in contour strips does not seem to enhance performance relative to water quality.

Impact of results

These results have important implications for the (re)design of agricultural systems that are capable of providing multiple ecosystem services to society, particularly clean water and regulation of hydrologic flows, but also biodiversity for pest regulation, disease control, and pollination services, recreational opportunities, and spiritual and cultural value. Perhaps the best indication that the results of this project already are having an impact on the thinking of a broad range of people is the significant amount of attention and interest that the project has attracted. Active participation among members of the stakeholder committee remains high and is characterized by enthusiastic discussion and questions.

Education and outreach

Publications

- Ridley, A., M.J. Helmers, I. Fillery. The adoptability of perennial-based farming systems for hydrologic and salinity control in dryland farming systems in Australia and the United States. *Australian Journal of Agricultural Research* (to be renamed *Crop & Pasture Science* from 2009)
- Maher, R., H. Asbjornsen, R. Kolka, J. Raich. Comparative soil respiration and rooting dynamics in a restored prairie and soybean field in Central Iowa. *Ecosystems*.
- Schulte, L., H. Asbjornsen, R. Atwell, C. Hart, M. Helmers, T. Isenhart, R. Kolka, M. Liebman, J. Neal, M. O'Neal, S. Secchi, R. Schultz, J. Thompson, and J. Tyndall. 2008. A targeted conservation approach for improving environmental quality: multiple benefits and expanded opportunities. PMR 1002. Iowa State University Extension, Ames, IA.
- Arbuckle Jr., J.G., M. Helmers, M. Liebman, and L. Schulte. 2008. From vulnerability to resiliency: Iowa agriculture in the age of biorenewables. Iowa State University Extension, Ames, IA. On-line at: http://www.extension.iastate.edu/bioeconomy/biocon2/WP6-Arbuckle.doc.
- Asbjornsen, H., G. Shepherd, M. Helmers, G. Mora. 2008. Patterns in depth of water uptake and soil moisture dynamics under contrasting annual and perennial systems in the Midwestern U.S. *Plant and Soil*. 308(1-2):69-92.
- Secchi, S., J. Tyndall, L. A. Schulte, H. Asbjornsen. 2008. High crop prices and conservation: Raising the stakes. *Journal of Soil and Water Conservation*. 63(3):69-73.
- Asbjornsen, H., M. Tomer, M. Gomez-Cárdenas, L.A. Brudvig, K. Schilling. 2007. Sap flux patterns and transpiration of a bur oak savanna undergoing woody encroachment and restoration in Central Iowa. *Forest Ecology and Management*. 247(1-3):209-219.

- Asbjornsen, H., L.A. Brudvig, M.D. Tomer. 2007. Ecohydrological implications of restoring Midwestern bur oak savannas after woody encroachment. *Ecological Restoration.* 25(1):58-59.
- Schulte, L.A., M. Liebman, H. Asbjornsen, T. Crow. 2006. Unplowing the land: Restoring agroecosystem health and function through perennialization. *Journal of Soil and Water Conservation*. 61(6):165-169.

Twelve presentations were given on the project. Among the most prominent:

- Two symposia were organized at the EcoSummit in Beijing, China in May, 2007 (Ecohydrology of managed landscapes: from plants to watersheds; Embracing complexity in agricultural landscapes: linking ecosystem services and biodiversity), in which presentations were given by Helmers and Asbjornsen on results from the Neal Smith project.
- In 2008, an invited presentation was given by Helmers at the Second International Salinity Forum, Adelaide, South Australia, March 30-April 3, entitled: "The adoptability of perennial-based farming systems for hydrologic and salinity control in dryland farming systems in Australia and the United States." A peer-reviewed publication has resulted from this work with collaborators in Australia.
- In April 2009, an invited presentation was given by Asbjornsen at the Annual Meeting of the International Association for Landscape Ecology, entitled: "Enhancing biophysical and socioeconomic functions of agroecosystems in the Midwestern through strategic integration of perennial plants," as part of a symposium organized by the Coupled Human-Natural Systems Network.
- This project was featured as part of an Associated Press article. The story was picked up by about 100 papers nationwide and inquiries have been received from numerous states including Nebraska and Ohio. The story also was featured online by *Farm Journal*.

Leveraged funds

Additional funds leveraged by this grant included:

College of Agriculture and Life Sciences, Iowa State University, $66,000
Iowa Department of Agriculture and Land Stewardship, $54,128
USDA Forest Service North-Central Research Station, $12,000
ISU – Natural Resources Ecology and Management Department, $3,641
National Science Foundation, Biocomplexity in the Environment, (Dynamics of Coupled Human-Natural Systems), $99,998
The Land Institute, Natural Systems Agriculture Program, $4,500
ISU College of Agriculture Agricultural Systems: Management and Performance Initiative, $110,000
University Research Grant Program, Iowa State University, $15,825
USDA Forest Service, Grand Rapids Research Station, $192,000
USDA Forest Service, North-Central Research Station, Iowa State University, $145,000

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