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Getting the most from Iowa's forests: Linking forest understory composition to stream water quality and enhancing nutrient capture in forest remnants in agricultural landscapes

Abstract:
Investigators worked to identify and disseminate information to enhance riparian forest understory function through actions that reduce contaminant transport to surface waters and enhance terrestrial and aquatic biodiversity.

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QHow does forest land use affect understory plant community composition and terrestrial nutrient capture, and is there a link between plant communities and stream water/stream habitat quality? What is the potential for reintroduction of key herbaceous species, based on species performance and landowner interest in restoration activities?

AThere were differences in plant community composition: Preserved forests had greater proportions of high-quality, native, specialist plants than grazed or urban forests, and greater biomass production and nutrient capture by understory plants. Stream water nutrient content (especially nitrate concentration) was higher in urban streams compared to grazed or preserved forests. Three key understory species reintroduced to urban forests demonstrated persistence and reproduction within two years, and interactions with forest landowners/forest managers indicated interest in forest restoration activities.

Background

Stream pollution from nutrient and sediment runoff is a chronic problem in Iowa and throughout the Midwest. Forests that remain in this intensively managed agricultural landscape could play an important role by capturing nutrients and sediment to protect water quality in streams and rivers. This project sought to compare the ability of forests under different land uses to reduce pollutant transport to streams and enhance terrestrial and aquatic biodiversity.
The specific objectives were to:

- Compare soil nutrient content and nutrient and sediment loads in headwater streams located within intact forests to those in degraded forests;
- Compare understory composition and nutrient capture by flora in those systems;
- Evaluate aquatic ecosystem integrity in the same streams by assessing macro-invertebrate density and diversity, and relating these to terrestrial system characteristics;
- Evaluate restoration methods for key understory species in forests where they are absent; and
- Conduct outreach and collaborative learning with forest landowners and technical assistance agencies to disseminate project results.

Approach and methods

Project investigation took place in forests of the Lake Red Rock watershed in central Iowa, a 21,070-hectare area that includes the Des Moines metropolitan area and surrounding rural land in 14 counties (project sites were in Polk and Warren counties). Overall, this area is about 6 percent forested, with concentrations along

Michaeleen Gerken measuring flow rate in one of the streams.

rivers and streams in the watershed. Deciduous forest cover is the largest single land cover type within a 30-m distance along first-order streams in this area (32 percent of land cover), followed by grazed grassland (21 percent) and other grassland (17 percent).

Nine research sub-watersheds within the Lake Red Rock watershed were identified as experimental units, three each for urban, grazed, and preserved forest land uses. Urban forests were within the city of Des Moines, grazed forests were embedded in agricultural landscapes, and preserved forests were located in both of these areas. In each sub-watershed, the headwater stream was embedded in forest. All sites met these criteria:

- the forest remnants were mature oak-hickory communities on uplands under the designated land use (urban, grazed, or preserved),
- there was no harvest or other alteration to the stand for 30 years or more, and
- there were no discernible tile outlets or other drainage outlets upstream of the stream sampling point.

The researchers assessed forest understory plant composition by conducting comprehensive species surveys on permanent plots established at each of the nine sub-watershed sites. Plant materials (both aboveground shoots and belowground roots) were sampled from plots at each site in spring, summer and fall to determine the amount of plant tissue produced and its nutrient content. Water samples from each stream were collected once every two weeks between April and October during 2010 and 2011 to assess levels of nitrogen, phosphorus, and sediment. The team examined whether differences in stream water quality could be attributed to differences in understory plant communities. Researchers also examined the ecological integrity of the streams, and sampled invertebrate populations (such as mayflies, damselflies, and diving beetles) to determine whether there were differences in community composition of these organisms that were attributable to different forest land uses.

Investigators tested a protocol for reintroduction of some herbaceous species (known forests where they were absent or uncommon). Three species (wild ginger, Virginia waterleaf, and James' sedge) were transplanted as "plugs" (small plants). Each species was planted at low and high densities (two or five individuals) in plots located in urban forests in fall 2010. The researchers measured the persistence, growth, and reproduction compared to local plant populations over two years.

Finally, the investigators conducted workshops with forest landowners and management professionals, and urban park managers. Participants engaged in discussions about goals, potential obstacles to reaching those goals, and methods of forest management that could enhance landscape-level ecosystem functions of forest land.

Results and discussion

Plant composition differed among these forest land use types, with greater numbers of forest specialists (rich, moist site species) in preserved forests, and greater numbers of non-native and generalist species in urban and grazed forests.

Zachary Keninger keeping plot notes.

Differences in plant community composition translated into differences in biomass production, with preserved forests producing more herbaceous biomass, and capturing greater quantities of nitrogen and phosphorus in plant tissue. Soil nitrogen was slightly higher for grazed sites, and soil phosphorus levels were significantly higher for urban sites compared to grazed or preserved site types.

On average, stream water nitrogen concentrations were higher for urban sites compared to grazed or preserved sites, and delivery (the nutrient concentration multiplied by the stream discharge for the entire upstream area) of nitrogen and phosphorus, to a lesser extent was greater for urban streams compared to the other site types. There was a weak negative association between plant nitrogen content and stream water nitrogen content on a seasonal basis---when plant nitrogen content was high, stream water nutrient concentrations were somewhat lower. The same pattern did not occur for phosphorus; when plant phosphorus content was high, stream water phosphorus concentrations also were high, which was interpreted as evidence of phosphorus saturation; more phosphorus is available than the plants can take up, so it is lost to streams.

The proportion of sensitive invertebrate species was highest for streams on grazed sites, and direct physical habitat factors (especially stream width, but also discharge rate and stream water salt concentrations) were more closely linked to invertebrate community characteristics than to land use type.

All three reintroduced species exhibited persistence and reproduction at both high and low densities, although their performance during the second year (which was relatively hot and dry) was less than that of local plants. It appears that small numbers of these plants are adequate to re-establish populations, and they should be obtained from sources as close to the planting site as possible for best plant performance.

Overall, individual landowner goals were consistent with larger-scale ecosystem goods and services. Land owners and managers were interested in activities that would improve water quality and ecological integrity of forest land, and information collected following the workshops indicated that a number of participants had plans for including planting and restoration to enhance forest lands they own or manage.

Conclusions

As a long-term outcome of this study, restoration of understory flora in disturbed forests could increase landscape-level functions provided by these ecosystems and at the same time support accomplishment of additional forest landowner goals. Increasing herbaceous plant cover and biomass production in urban and grazed forests embedded in the predominantly agricultural landscapes of the Midwest could contribute to increased biodiversity and decreased nutrient “leakage,” creating a more resilient landscape. Forest restoration targeting protection of headwater stream systems is a feasible and useful approach for improving water quality throughout the region.

Impact of results

This work contributes to a growing body of knowledge that will enable landowners and land managers to maximize ecosystem goods and services provided by remnant forests throughout the Midwest, and will support stewardship efforts that lead to more resilient agricultural landscapes. Workshop participants expressed strong interest in opportunities to restore ecosystem function. Based on participant responses to the post-workshop surveys, forest landowners and managers are more knowledgeable and likely to engage in forest restoration actions that will lead to improved water quality.

Education and outreach

Six refereed journal papers, describing the details of the project, are in various stages of preparation. Three graduate student theses (one Ph.D. dissertation and two M.S. theses) were written about the research done for this project. Several popular press articles and fact sheets were generated by the project. Articles appeared in *Field Notes*, *Iowa Sierran*, and *Acreage Magazine*. Two fact sheets were prepared: one on "Linking Forest Communities and Water Quality" and the other on "Species for Iowa Woodland Planting and Restoration." (Available by title at: http://www.leopold.iastate.edu/pubs/alpha)

A number of public presentations were given on the project findings:

- Forest management and water quality: A new twist on an old story. 32 participants (forest landowners). Tri-State Forest Stewardship Conference, Sinsinawa Mounds, Wisconsin, March 2012.
- Forest management and water quality: A new twist on an old story. 30 participants (forest landowners). Forestry Extension Field Day, Lucas, April 2012.
- Forest management and water quality: A new twist on an old story. 36 participants (professional foresters). Iowa-Illinois Chapters of the Society of American Foresters, Rock Island, Illinois, May 2012.
- Forest management and water quality: A new twist on an old story. 16 participants (forest landowners). Camp Wesley Woods, Warren County, Iowa, May 2012.
- Urban parkland forests and water quality: A new twist on an old story. 11 participants (parks management personnel), Iowa Parks and Recreation Association Fall Workshop, Mason City, September 2012.
- Urban parkland forests and stream water quality: Getting the most from our natural areas. 16 participants (parks management personnel). Iowa Parks and Recreation Association Spring Workshop, Des Moines, April 2013.
- Communicating ecology: How research and outreach can better inform the public. Summer of Solutions, Iowa City, July 2012.
- Forest ecosystem functioning in human-impacted landscapes: Opportunities for targeted restoration. EcoSummit, Columbus, Ohio, October 2012.

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