On-Farm Demonstrations of Perennial Biomass Crops for Forage or Bioenergy Plus Ecosystem Services

April 2016 by Agricultural Watershed Institute and Prairie Rivers Network

Harvestable Saturated Buffer:
Tile flow diverted to soil column under buffer. Nitrate in tile flow fertilizes a perennial crop.

Adapted from Dan Jaynes, USDA, 2009.
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Executive Summary

Perennial forage or bioenergy crops able to tolerate wet conditions can play a significant role in achieving the Illinois nutrient loss reduction targets.

Nitrogen and phosphorus are essential nutrients for crop production but excessive nutrient loss from cropland contributes to algae blooms and public health concerns in fresh water bodies and hypoxia (the “dead zone”) in the Gulf of Mexico. The Mississippi River/Gulf of Mexico Hypoxia Task Force set a goal of reducing the size of the dead zone by about two thirds. This is estimated to require a 45% reduction in N and P carried by the Mississippi to the Gulf.

In 2015, the Illinois Environmental Protection Agency and Department of Agriculture issued the Illinois Nutrient Loss Reduction Strategy (INLRS) that is intended to guide efforts over the next 20 plus years to achieve statewide reduction targets for phosphorus and nitrate.

A significant challenge is reducing nitrate lost from row crop fields via subsurface drainage tiles, which are extensive in east Central Illinois. While most phosphorus loss occurs as surface runoff, nitrate is carried under buffer strips by drainage tiles that discharge to ditches or streams.

Nutrient loss per acre from land in perennial crops is estimated to be 90% less than from land in annual grain crops. Some perennial crops tolerate wet conditions better than corn or soybeans. That creates an opportunity to combine such crops with drainage modifications to increase nutrient reduction by a given area of perennial crops. This project explores that opportunity.

Saturated buffers and seasonal wetlands can significantly reduce nutrient loss. This project looks at growing suitable perennial biomass crops in these areas.

This report addresses three innovative concepts to produce a perennial biomass crop and reduce nutrient loss. The area converted to perennial crops in effect treats nutrients lost from nearby row crop acreage that drains across or under the converted area. The systems we propose to demonstrate extend existing concepts by producing harvestable biomass.

The systems that we propose to demonstrate are:

- **Harvestable saturated buffers**: Saturated riparian buffers are a recent innovation that has shown considerable promise in removing nitrate from tile drainage water by redirecting some of the drainage water into the root zone of a perennial buffer. We propose to expand the saturated riparian buffer concept to include biomass harvesting.

- **Harvestable saturated hillsides**: In this system, perennial grasses are planted on a slope along a contour. It expands on the Iowa STRIPS concept by adding biomass harvesting and drainage modifications to redirect tile flow into the soil under the strip.

- **Harvestable seasonal wetlands**: Many Illinois crop fields have areas where water ponds in wet years, resulting in replanting or yield loss. Converting such areas to perennials that tolerate ponding may make economic sense.
In consultation with university and U.S. Department of Agriculture agronomists, we identified and described perennial grasses suitable for forage and/or bioenergy use that have varying degrees of tolerance for wet conditions. The list of potential crops includes well-established forages such as switchgrass, Eastern gamagrass and Virginia wild rye. The list also includes two native prairie grasses that are being improved by agronomists: Kernza intermediate wheatgrass, being developed by the Land Institute as a perennial grain crop; and Savoy prairie cordgrass, being developed at University of Illinois as a bioenergy feedstock.

**We assessed hurdles to overcome before these innovative cropping systems are widely adopted and identified producers and sites for on-farm demonstrations.**

Converting land from row crops to perennial crops would achieve a significant nutrient loss reduction. However, as noted in the ILNRS, “large scale movement to perennial crop production would require dramatic changes in agricultural structure.”

Through fliers, meetings, workshops, Soil & Water Conservation District referrals, and personal networking, the project team shared our vision with owner/operators to recruit cooperators, identify sites, and solicit feedback on logistics and potential barriers to implementation. This report describes lessons learned through this process.

Today, most Central Illinois cropland is used to grow corn and soybeans. Many farmers have little or no experience with alternative crops including perennial forages. The market for hay in Central Illinois is relatively small and there is currently no market for bioenergy feedstock. Early on it became evident that livestock farmers, hay crop operators, and biomass innovators were better suited for the project because of their basic knowledge of and the necessary equipment for forage and biomass production. Knowledge of harvesting methods and timing of grasses, along with marketing experience with forage and biomass crops increased their willingness to explore the potential for perennial crops.

Six sites, representing four owner/operators, were strategically selected from three Central Illinois watersheds: the Sangamon River watershed, the Embarrass River watershed, and the Vermilion River (Wabash River) watershed. Four of the sites are in Champaign County and two are in Macon County.

**We prepared layouts for harvestable saturated buffers or hillsides and harvestable seasonal wetlands on six sites in three Central Illinois watersheds.**

The six sites represent two proposed demonstrations of each of the three systems identified for the project. Data was provided by each owner/operator including drainage patterns, tile maps, and crop yield data for each site. Soil maps were prepared using a USDA web tool. Working with the owner/operators, design features and harvest potential were examined and concepts for the demonstration project layouts were developed.
Layouts were prepared for each site. The layouts identify areas to be planted in cool season and/or warm season perennial grasses. Specific species and varieties to be planted will be determined by the producers to meet their operational needs and preferences. For the saturated buffers and hillsides, the location of a drainage control structures and distribution tile to redirect tile flow into the soil is shown on the layouts. The two seasonal wetlands are not expected to include drainage modifications.

Five of the sites are expected to be planted in perennial grasses suitable for use as forage or animal bedding. One landowner is a Miscanthus grower interested in growing bioenergy feedstock; that site provides an opportunity to demonstrate prairie cordgrass as a bioenergy crop adapted to very poorly drained conditions.

**Costs were estimated for implementation of these on-farm demonstrations. The sites are appropriate for research and outreach on the innovative systems.**

A range of costs to establish the grasses and install proposed drainage modifications was estimated for each site. Seed prices vary for the cool and warm season grass species. It is expected to take two or three years for the grasses to become well-established to be harvested for forage or bioenergy. Year 1 establishment costs, which include seed, were estimated to be between $119 and $317 per acre for cool season grasses and between $144 and $208 for warm season grasses. Year 2 and Year 3 costs were estimated to be about $50 per acre per year for all grasses. Those estimates are based on producers doing their own spraying for weed control. It is common to contract for spraying which would increase spraying costs since there is generally a minimum charge for small areas. A rough estimate of $5,000 per site was used for installation of drainage modifications for the saturated buffers and hillsides.

To compensate producers for lost crop revenue during the establishment period, a land rental payment of $300 per acre per year was included in the overall cost of the demonstration sites. Based on these estimates and preliminary estimates of nitrate removal, the saturated buffers and hillsides would have a cost range between $0.69 and $1.33 per pound of N load reduced, which is less than almost all of the practices considered in the ILNRS.

The landowners/producers that participated in this project were not asked to commit in advance to implementation of the proposed cropping/drainage systems. Following submittal of this grant report, the project team will meet with them to review layouts, perennial crop options, and cost estimates in this report. If they want to proceed, the team will identify potential funding sources, firm up the budget, and apply for funding for the demonstration projects.

All of the sites appear to be well suited for demonstration and outreach for the various systems. Some may be suitable for intensive monitoring and research to assess environmental and economic performance. The team expects to apply for monitoring, research, and outreach funding. As funding permits, the next steps are to proceed with the final design, implementation, and research/outreach phases. This type of research is the first step toward developing design standards and USDA incentives for a new practice.
1 – INTRODUCTION AND PROBLEM / OPPORTUNITY STATEMENT

The State of Illinois lies within the Mississippi River Basin, except for a small part of northeast Illinois that drains to Lake Michigan. Nitrogen and phosphorus are essential nutrients for agricultural production. However, nutrients lost from Illinois farms to surface waters are transported by ditches, creeks and rivers to the Mississippi River and the Gulf of Mexico. Excessive nutrient loads contribute to algae blooms in lakes and seasonal hypoxia (low dissolved oxygen) near the bottom of the water column in the northern Gulf of Mexico off the coast of Louisiana. In lakes used as public water supplies, nitrogen in the nitrate form is a public health concern since it is associated with methemoglobinemia (“blue baby syndrome”) and is not removed by common water treatment processes.

The Mississippi River/Gulf of Mexico Hypoxia Task Force has established a goal of reducing the size of the summertime hypoxia (aka “dead zone”) by about two thirds. This is estimated to require about a 45% reduction in nitrogen and phosphorus flowing down the Mississippi River.

In 2015, the Illinois Environmental Protection Agency and the Illinois Department of Agriculture issued the Illinois Nutrient Loss Reduction Strategy (INLRS) that is intended to guide efforts over the next 20+ years to achieve statewide reduction targets for phosphorus and nitrate. Prairie Rivers Network (PRN) and the Agricultural Watershed Institute (AWI) were involved in development of the strategy and are now involved in early efforts for its implementation.

A significant challenge is reducing nitrate lost from row crop fields via subsurface drainage tiles, which are extensive in east Central Illinois. While most phosphorus loss occurs as surface runoff, nitrate is carried vertically through soil with percolating water to the water table and then laterally into subsurface drainage tiles that discharge to ditches or streams. Figure 1 shows a map of the entire Mississippi River Basin color-coded to indicate annual nitrate yield per unit of watershed area. Much of the extensively-tiled cropland of central Illinois falls in the highest yield range, 1801 to 3050 kilograms per square kilometer, which equals 16 to 27 pounds per acre.

The INLRS estimates 90% less nitrate-N losses from perennial crops compared to corn and soybeans. Thus, converting land that is now in row crops to perennial crops would achieve a significant nutrient loss reduction for the acres converted. However, as noted in the ILNRS, “large scale movement to perennial crop production would require dramatic changes in agricultural structure.”

Today, most Central Illinois cropland is used to grow corn and soybeans. Many farmers have little or no experience with alternative crops including perennial forages. Yet there is some local demand for perennial biomass crops as hay to feed livestock or as animal bedding. There is currently no local demand for bioenergy crops. AWI and other organizations are actively working to develop markets, potentially including the Eastern Illinois University Renewable Energy Center, as well as on-farm biomass use for heating and grain drying. Farmers may be willing to try perennial biomass crops in areas where commodity crop production is unprofitable, such as poorly drained areas, and on highly erodible slopes.
Increased adoption of perennial biomass crops has the potential to provide multiple benefits to the environment and community. Benefits can include a more diversified source of revenue from harvestable crops, improved water quality, reduction in greenhouse gas emissions, more wildlife habitat, increased biodiversity, and greater resilience to a changing climate. Our vision for the future of agricultural landscapes in Illinois includes more diversified farms, including perennial crops and winter annual cover crops, that meet local resource and wildlife needs while minimizing water pollution and other negative externalities.

In May 2015, the Lumpkin Family Foundation awarded a grant to PRN and AWI for a project to assess landowner and producer interest in and acceptance of converting less profitable corn-soybean portions of particular fields under their management to harvestable perennial crops. Our goal was to recruit three to six farmers to engage in planning for establishing perennial grasses in demonstration projects for co-production of harvestable biomass for forage or bioenergy use and ecosystem services, with a special emphasis on reducing soil erosion and nutrient loss.

Figure 4 Average annual nitrogen yields of streams in the Mississippi River Basin for 1980–96 (modified from Goolsby and others, 1999). Source: http://pubs.usgs.gov/fs/2003/fs-105-03/
This report presents the results of those efforts. Implementing and monitoring the resulting plans will likely involve future proposals to Lumpkin and other foundations and governmental agencies for monitoring of water quality and wildlife and providing incentive payments to participating landowners to cover the costs of crop establishment, drainage modifications, and lost crop revenue during the establishment period for the perennial grasses.

For this project, we recruited four farm operators who own and/or manage six fields in which they were willing to consider implementing one of the experimental perennial conservation practices. The fields are located in Central Illinois, three in the Vermilion River watershed (Champaign County), one in the Embarras River watershed (Champaign County) and two in the Upper Sangamon River watershed (Macon County). Figure 2 shows the demonstration site locations and watershed boundaries.

Figure 5 Locations of potential conservation practice on-farm demonstration sites, showing watershed boundaries and flow path to the Mississippi River.
2 – CROPS AND PRACTICES TO BE DEMONSTRATED

The Conservation Reserve Program (CRP) contributes to nutrient loss reduction by converting enrolled areas from annual row crops to perennial vegetation. With limited exceptions, USDA rules for the CRP program do not allow enrolled acreage to be harvested. CRP essentially avoids creating the nutrient losses produced by annual row crops. Additionally, CRP buffer strips along streams are able to filter out some sediment and phosphorus in surface runoff preventing it from entering streams. However, there is relatively little surface runoff from the level or nearly level cropland common in Central Illinois. Most of the drainage from row crops in this region flows through subsurface tile drains that carry high nitrate concentrations in late winter and spring. Traditional streamside perennial buffer strips are unable to remove nitrate from tile drainage water.

In addition to causing problems with drinking water supplies and in aquatic food webs, nutrients carried from farm fields to ditches or streams via surface runoff or subsurface drainage represent an economic loss to farmers, in terms of lost fertilizer. The crops and conservation practices that we focused on in this study are intended to use some of the nutrients lost from row crops as fertilizer for perennial crops that can be harvested, thereby putting the nutrients to a productive use and potentially removing them from the landscape.

Riparian buffers and constructed wetlands are among the Best Management Practices (BMPs) used to reduce nutrient loss in agricultural areas. To date, we have not discovered any relevant research that has examined producing a harvestable crop in riparian buffers or wetlands. The lack of a harvestable product from these areas means that they are economically sustainable only with public subsidies or through landowners voluntarily foregoing revenue from the converted acreage. Incorporating a harvestable crop with buffers and wetlands would give producers a greater incentive to adopt these practices. If the practices prove to be both economically and environmentally favorable, it would produce a win-win situation. But the conditions under which these practices provide both economic and environmental benefits need to be examined.

The Big/Long Creek Watershed TMDL Implementation Plan prepared by AWI and partners in 2014 is an example of a water quality plan that identifies the types and potential locations of conservation practices that farmers can use to reduce the loss of soil and nutrients into streams. In addition to conventional BMPs, that plan includes innovative concepts for perennial biomass crops such as saturation-tolerant prairie grasses to be grown in harvestable saturated buffers and seasonal wetlands. By combining saturation-tolerant perennial crops with drainage modifications, it may be possible to produce harvestable biomass and remove or utilize nutrients lost from row crops higher on the landscape. In effect, the water quality benefit of converting land from row crops to perennial crops can be increased by having the perennials “treat” surface or subsurface runoff from upslope row cropped areas.
2.1 Combining Perennial Crops with Drainage Modifications

This report presents preliminary layouts and cost estimates for three innovative systems that include perennial crops and may also include drainage modifications:

- Harvestable saturated buffers
- Harvestable saturated hillsides
- Harvestable seasonal wetlands

Future phases of this project are proposed to demonstrate and evaluate the agricultural, environmental, and economic performance of each cropping and drainage system.

2.1.1 Harvestable Saturated Buffers

A recent innovation, known as saturated riparian buffers, has shown considerable promise in removing substantial amounts of nitrate from tile drainage water by redirecting some of the drainage water into the root zone of a perennial streamside buffer. The concept was developed by Dan Jaynes at the USDA-ARS National Laboratory for Agriculture and the Environment in Ames, Iowa. In a two year study, Jaynes and Isenhart (2014) showed a 55% reduction in nitrate delivered to an Iowa stream by diverting a portion of the flow to a distribution lateral tile installed under a perennial riparian buffer that was not harvested.

The USDA Natural Resources Conservation Service (NRCS) provided a Conservation Innovation Grant (CIG) to the Agricultural Drainage Management Coalition (ADMC) to examine this practice in 15 additional installations in the Upper Midwest states, including a site in the Upper Sangamon watershed near Cisco (Piatt County). Preliminary results from that CIG study are promising, although performance of the practice was shown to vary depending on soil conditions. The presence of sand and gravel layers or low organic matter soils in the buffer will lead to reduced performance because the nitrate can pass through these layers to the stream with less reduction.

Saturated buffers are still considered to be experimental by NRCS. There is an Interim NRCS Conservation Practice Standard (Code 739). The CIG results may lead to adoption of a final standard. The schematic illustrations in Figures 3a and 3b compare a conventional buffer and a saturated buffer. In the saturated buffer, the water table is artificially raised by diverting subsurface drainage along and under the buffer by installing a water control structure in the main drainage outlet and a perforated distribution lateral along and under the buffer.

The original saturated buffer studied by Jaynes and Isenhart and the additional installations through the ADMC CIG project are in CRP buffers and the vegetation is not harvested. In the present study, we seek to expand the saturated riparian buffer concept to include harvesting of the vegetation in the saturated riparian buffer. Nutrient loss from perennial crops is usually a small fraction (about 10%) of the losses from corn-soybeans because perennial grasses typically require less fertilizer than corn, and perennials are more capable of absorbing available nutrients because of more extensive root systems and a longer growing season.
For each of the proposed harvestable saturated riparian and hillside buffers, a flow control structure will be installed on an existing tile line to divert a portion of the drainage water from corn—soybean fields into the root zone of a riparian buffer planted to cool or warm season grasses. As noted, this is a modified version of the saturated riparian buffer system that did not involve harvesting biomass developed by Jaynes and Isenhart. The removal mechanism for nitrate diverted to the buffer is assimilation by the vegetation or denitrification by soil microbes. For saturated buffers enrolled in CRP, Jaynes and Isenhart estimated that the cost of achieving this reduction was $1 per lb of N over a 20 year period, which is about 50% less than the cost effectiveness of rye cover crops and 80% less than constructed wetlands. However, their economic analysis did not include the cost of establishing the perennial vegetation, which was already in place prior to their study.

Central Illinois has more rainfall and drainage than Iowa, and therefore the performance of saturated buffers in east central Illinois may be less than reported in the Iowa study. Extending the saturated buffer to include biomass harvesting will add to the cost of the practice (harvesting and establishing perennial grasses that have some economic value). But these grasses will also generate some revenue from the sale of the hay. If the grasses are harvested during the growing season, this may reduce the nitrate removal effectiveness of the system, as water and nitrate uptake will be reduced following a harvest. But the additional water and nitrate may also increase the productivity of the grasses. To our knowledge, there is no published literature to evaluate the performance of harvested saturated buffers.

### 2.1.2 Harvestable Saturated Hillsides

We also propose to expand the saturated buffer concept to hillsides with perennial grass strips. A Saturated Hillside, as envisioned, is similar to the Saturated Riparian Buffer but will extend up a slope. This practice focuses on areas on marginal sloping farm ground where perennial strips can be incorporated on the contour in annual row crops. Perennial strips on hill slopes have been shown to substantially reduce nitrogen, phosphorus and sediment loss in surface runoff in the Iowa STRIPS Program (Science-based Trials of Row-crops Integrated with Prairie Strips).
Our proposed demonstrations extend the STRIPS concept in two ways: First, the Iowa STRIPS research and demonstration sites are generally not harvested, although the Iowa State University research team notes that they could be harvested with no loss of water quality benefit. Second, to date the STRIPS sites have been studied only for removal of nutrients and sediment in surface runoff and have not been designed to interact with and treat tile flow. Where hillslopes have subsurface drain tiles, diversion of a portion of the drainage water to the root zone of the vegetated strips could fertilize and irrigate the grass crop to reduce nitrate discharged to streams and increase the productivity of the grasses planted in the strips.

2.1.3 Harvestable Seasonal Wetlands

In wet years, many annual row crop fields include areas where water ponds for several days. Corn and soybeans do not survive extended ponding and these areas need to be replanted at considerable expense, rendering many of these areas unprofitable for corn-soybean production. Converting these areas to perennial vegetation that tolerates ponding may be economically advantageous for the farmer because it would reduce replanting and other input costs, and may produce some income from the harvested biomass. We refer to this practice as harvestable seasonal wetlands, which have the potential to reduce nutrient and sediment losses to streams as well as improving farm profitability and providing wildlife habitat. Depending upon the perennial species utilized and the timing of harvest, perennial grasses create refuges for beneficial insects, pollinators, grassland birds and other compatible species.

Harvestable Seasonal Wetlands will utilize areas in a field that are less reliable and productive for annual crops due to poor drainage conditions. Such areas ranging from a fraction of an acre up to several acres in size may be replanted during a wet planting season. Sometimes the replant is successful but many times the crops in these areas are a total loss or the yield is
significantly reduced. AWI and University of Illinois host an Energy Grass Education Area with small demonstration plots at the Farm Progress Show held in Decatur every other year. Producers have shown interest in considering what could be planted in poorly drained or flood-prone areas besides corn/soybeans that would be tolerant of wet conditions and that could still provide a monetary return. In order for such areas to be planted to a perennial grass crop the acreage should be large enough to justify harvesting and have access for management without damaging the grain crops.

In some cases drainage modification can be used to create the saturated conditions to help treat the tile water before it discharges into a water body. At the present time there are several standards for wetlands in the USDA programs, however, they do not allow harvesting any material from the wetland.

2.2 Harvesting and Use of Perennial Biomass Crops

The three systems we propose to demonstrate and research are intended to provide farmers with opportunities to produce a biomass crop that can be sold or used by the farm operation for forage or heat. Cool season and warm season grasses are included in the proposed systems. Cool season species are expected to be grown as forage crops. The native warm season grasses can be grown for either forage or bioenergy. Harvest timing differs depending on intended use of the harvested biomass.

Harvesting will begin in early to mid-May for the cool season grasses and end in late August through mid-September, depending on regrowth. Growth of cool season species typically drops off and may stop during the hot summer months of July and August.

Harvest of warm season varieties for forage begins around June 1 for Eastern Gamagrass and ends in mid to late August. Switchgrass usually can be cut from late June through mid to late August and Big bluestem from early July through late August. The last harvest should be early enough in late summer to allow for adequate regrowth for nutrient relocation. Six to eight inch stubble should be left after cutting to help ensure adequate regrowth. Depending on the variety and weather conditions, two or three cuttings for hay can be expected. Nutrition value of warm season grass hay can vary considerably with the timing of harvest.

One difference between harvesting cool and warm season grasses is that tractor speed for harvesting warm season grasses may be slower because the ride will be rougher for clump grasses. This may be affected by the crop and the type of bale. For example, one experienced local hay farmer told us he has no issues in baling forages other than Eastern gamagrass and ground speed is about the same when baling large rounds. However, for small square bales of Eastern gamagrass he slows down due to the roughness and the quantity of material. He also stated, raking is usually not required because of the higher stubble left during mowing. Warm season perennial grasses managed for bioenergy feedstock rather than as forage are generally harvested much later in the year, usually through a single cutting in late fall or winter. For bioenergy use, lower moisture biomass with more stems and less leafy material is
preferable. Since animal nutrition is not a goal, waiting until nutrients translocate to the roots after a killing frost is typical to minimize the nutrients removed with the harvested biomass.

The proposed practices for this project are examples of multifunctional cropping systems for co-production of agricultural goods and environmental services. Our objective is to produce harvestable biomass in sloping or poorly drained soils and also significantly reduce nutrient losses. Multifunctional agriculture by definition involves synergies and tradeoffs since it is generally not possible to maximize multiple desired outcomes simultaneously.

### 2.3 Candidate Perennial Biomass Crops for Seasonally Wet Conditions

In selecting grasses for this project, a basic consideration is the expected market or on-farm use for the harvested biomass. This could be for forage, bioenergy, or both. The authors appreciate information on potential species provided by Jerry Kaiser, USDA Elsberry (MO) Plant Material Center; Drs. DoKyoung Lee and Adam Davis, University of Illinois; Dr. Lee DeHaan, The Land Institute; and the Eastern Gamagrass Company. The following table summarizes characteristics of various native grasses that may be considered for forage or bioenergy feedstock production and water quality enhancement when grown in the scenarios envisioned for this project.

<table>
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<th>Variety</th>
<th>Cool/Warm Season</th>
<th>Forage Value</th>
<th>Bioenergy Value</th>
<th>Saturation Tolerance</th>
<th>Expected Yield (tons per ac)</th>
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<td>Perennial Rye Grass</td>
<td>Cool</td>
<td>Fair*</td>
<td>Low</td>
<td>Moderate</td>
<td>3 to 5</td>
</tr>
<tr>
<td>Virginia Wild Rye</td>
<td>Cool</td>
<td>Good*</td>
<td>Low</td>
<td>Moderate</td>
<td>3 to 5</td>
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<tr>
<td>Reed canarygrass**</td>
<td>Cool</td>
<td>Good</td>
<td>High</td>
<td>Very High</td>
<td>6 to 8</td>
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<td>Intermediate wheatgrass</td>
<td>Cool</td>
<td>(see text)</td>
<td>Moderate</td>
<td>Moderate</td>
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</tr>
<tr>
<td>Big Bluestem</td>
<td>Warm</td>
<td>Good</td>
<td>High</td>
<td>High</td>
<td>3 to 5</td>
</tr>
<tr>
<td>Switchgrass</td>
<td>Warm</td>
<td>Good</td>
<td>High</td>
<td>High</td>
<td>3 to 5</td>
</tr>
<tr>
<td>Eastern gamagrass</td>
<td>Warm</td>
<td>Excellent</td>
<td>High</td>
<td>Moderate</td>
<td>7 to 8</td>
</tr>
<tr>
<td>Prairie cordgrass</td>
<td>Warm</td>
<td>Poor***</td>
<td>High</td>
<td>Very High</td>
<td>5 to 7</td>
</tr>
</tbody>
</table>

* Forage value will increase with addition of Alsike Clover and/ or Red Top.
** Not recommended due to invasiveness risk. See text for further discussion.
*** New growth may be grazed before leaves become serrated.

Table 1. Summary of perennial grass crops for seasonally wet conditions.
2.3.1 Cool Season Species

Cool season perennial grasses and legumes grown for hay or grazing green up in early spring and grow best in spring and fall with slower growth or dormancy in hot weather. Common cool season forages such as tall fescue and orchardgrass are unsuited to wet conditions and therefore not adapted to the practices addressed in this report. For purposes of nutrient uptake in spring when nitrate loss via drainage tiles is typically high, cool season grasses would be desirable as a forage crop to maximize water quality benefits. Jerry Kaiser recommended perennial ryegrass and Virginia wild rye as cool season perennial forages with some tolerance of saturated conditions. Two other cool season grasses, reed canarygrass and a new cultivar of intermediate wheatgrass, with potential for use in a system designed for agricultural production and water quality enhancement are also discussed.

Perennial Ryegrass withAlsike Clover: Perennial ryegrass does fairly well in wet conditions and has yield potentials of 3 to 5.5 tons per acre. To help improve its forage quality Jerry Kaiser recommends a companion planting of Alsike Clover. However, if the forage is going to be used for horse feed the Alsike Clover should be substituted with a different legume since it causes photosensitivity.

- Seeding rate recommendations for this mixture are 9.13 lbs/acre (Pure Live Seed – PLS) for the perennial rye and 4 lbs/acre (PLS) for the alsike clover.
- Producer can work with their local seed dealer to determine which cultivars are adapted for this area.

Virginia Wild Rye (Elymus virginicus L.) with Red Top andAlsike Clover: Virginia wildrye is palatable and nutritious to all classes of livestock and can handle wetter conditions, unlike other common cool season grasses. This mixture has yield potentials of 3 to 5 tons per acre. Jerry Kaiser recommends a mixture of Virginia Wild Rye, Redtop, and Alsike Clover for forage use. However, if the forage is going to be used for horse feed the Alsike Clover should be substituted with a different legume since it causes photosensitivity.

- Seeding rate recommendations for this mixture are 18.8 lbs/acre (PLS) for the Virginia Wild Rye, 2.1 lbs/acre (PLS) for the Redtop, and 4 lbs/acre (PLS) for the Alsike Clover.
- Cuivre River Germplasm is a Virginia Wild Rye cultivar for this area that was released in 2002 from the USDA Plant Material Center in Elsberry, Missouri, for use as a companion species for forage production.

Reed canarygrass (Phalaris arundinacea): May be grown for permanent hay or pasture on sites too wet for good performance of other forage plants, but also performs well on drier soils. This species is not generally recommended due to its highly invasive habit. Reed canarygrass is considered an invasive species and must be managed effectively to avoid its spread. The species is very aggressive and will choke out other perennial vegetation. It should not be used along or streams, ditches, or ponds. It can be a high-yielding forage in wet conditions where other cool season varieties could not survive. The characteristics of reed canarygrass make it a potential candidate for a selection or breeding program to develop and test cultivars with properties suited for forage production and water quality enhancement but
with reduced invasiveness. When planted for forage, reed canarygrass should be grazed or mowed prior to heading for nutritional quality and palatability; this management also reduces the risk of invasive spread by preventing seed production. On-farm demonstration of reed canarygrass in portions of fields that are subject to ponding may be appropriate with active involvement of scientists with expertise in management to prevent spread of potentially invasive plants.

Kernza™ Intermediate wheatgrass: This is a new cultivar developed by scientists at The Land Institute as part of that organization’s program for perennial grain crops. It is their first variety that is beginning the big transition from research plots to working farms and from farm to table. Land Institute plant breeder Lee DeHaan has said that it has some ability to tolerate saturated soils, but not ponding. One 9-acre plot of Kernza was planted in 2012 on an organic farm near Pana, Illinois. AWI and other members of the Green Lands Blue Waters partnership are working with The Land Institute to increase the acreage planted and assist in the commercialization process. That process includes assessing how the perennial wheat variety fits into farming operations and its yield of both grain and biomass. It has three potential economic uses: grain, forage, and bioenergy. An on-farm demonstration in a saturated buffer scenario would add to the body of knowledge associated with bringing this new multi-purpose crop to working farms. The following photo series by The Land Institute compares the root system of Kernza (on the right) with annual wheat throughout the year.

![Comparison of root system of annual wheat and perennial intermediate wheatgrass.](image)

Figure 5. Comparison of root system of annual wheat and perennial intermediate wheatgrass.
2.3.2 Warm Season Species

The big native warm season grasses of the American prairie are coming to be viewed as potential crops for forage, bioenergy, and bio-based products. Selection and breeding to improve the plants' agricultural attributes is underway in various places including the University of Illinois. Established varieties of prairie grasses have traditionally been planted mainly in non-harvested nature preserves and conservation areas. With the exception of Eastern gamagrass, there is limited experience in Illinois with native warm season grasses managed for production of forage or bioenergy feedstock. The proposed demonstration sites will provide an opportunity to expand this knowledge base and to test new varieties developed for agricultural production.

**Big Bluestem** (*Andropogon gerardii*), the official Illinois State Prairie Grass, is an erect, robust, perennial bunchgrass and the iconic grass of the tallgrass prairie. It produces foliage in late spring from buds at basal nodes and from short, scaly rhizomes. Growing points stay close to the ground until late-summer. Seed heads appear in August and September. Big bluestem grows 3 to 6 feet tall and often is reddish-purple at maturity. The seed head consists of two or three racemes which arise from a common joint of the seed stalk, resembling a turkey's foot. It is considered more palatable than switchgrass or Indiangrass, especially after maturity.

- Big Bluestem can be utilized for pasture or hay. Forage production occurs from May to September with yields ranging from 4 to 6 tons/ac.
- Planting dates occur from March to May at a seeding rate recommendation of 5 to 10 lbs/ac. (PLS).
- Rountree cultivar is the preferred variety for hay production, adapted statewide. Good seedling vigor and forage productivity. Origin: Iowa

**Switchgrass** (*Panicum virgatum L*) is a tall, rhizomatous perennial that grows 3 to 5 feet tall. It appears bunch like, but the short rhizomes may produce a coarse sod. The early growing point is the developing seed head that terminates in a large spreading panicle by mid-July.

- During the growing season, leafy regrowth develops from basal shoots emerging along the lower stems at leaf nodes. In the immature stage, leaves and stems of switchgrass have good forage value and are readily grazed by livestock.
- Planted for many purposes including livestock grazing and haying, wildlife cover, and as a biofuel crop.
- Palatability and nutrient content of stems decline rapidly after heading.
- Several native cultivars are adapted to our area, Cave-in-Rock and Sunburst, and will yield between 3 to 5 tons/acre.
- Higher-yielding cultivars including the Blade™ switchgrass pictured here have been developed for bioenergy or forage production.
• Seeding rate recommendations of 5 to 6 lbs/acre (PLS) are suggested.
• Switchgrass is not recommended for horse consumption since it causes photosensitivity.

**Eastern Gamagrass (Tripsacum dactyloides (L.)L.)** is a native, perennial, warm-season bunchgrass. This tall, robust grass has long been recognized as a highly productive forage grass of the eastern prairie with a photosynthetic rate that is among the highest reported in scientific literature for any species. Some refer to Eastern Gamagrass as the “Queen of Grasses” and others have stated that it is the “Ice Cream of Forage”.

• A unique characteristic of gamagrass is its ability to green up earlier in the spring and exhibit faster first year seedling growth than other common warm-season bunchgrasses.
• It is nutritious and readily eaten by all classes of livestock. High potential forage yields and palatability combine to make it a superior grass for haying or grazing.

**Prairie Cordgrass (Spartina pectinate)** is also known by the common names freshwater cordgrass, tall marsh grass, and slough grass. It is native to much of North America, including central and eastern Canada and most of the contiguous United States except for the southwestern and southeastern regions.

• This grass has hard, sturdy, hollow stems that may reach 10 feet in height. They grow from a network of woody rhizomes and tough roots that form a sod. The roots penetrate over 10 feet deep into the soil. The leaves have sharp, serrated edges. The panicle may be up to 20 inches long and may have many branches. Each spikelet is up to 1 inch in length. This grass can spread via its rhizome, producing large monotypic stands.
• It is a facultative wetland species, most often found in wet habitats such as fens, wet prairies, rivers, floodplains, and ponds. The grass is tolerant of water, but it does not tolerate prolonged flooding. Its dense root network stabilizes soil, even in areas where it would be eroded by flowing water.
• Livestock may graze on this plant when it is young, but once it matures it becomes very coarse and unpalatable.
• This species has been investigated as a possible source of biofuel.
• Dr. D. K. Lee, pictured here in a cordgrass research plot, has developed improved varieties for maximum yields and flood tolerance. His Savoy cultivar is available on a limited basis for on-farm demonstrations.
• Seeding recommendation of 8-10 lbs/acre (PLS). Native cordgrass can be hard to establish from seed. Dr. Lee’s work is in large part intended to overcome that issue for easier use as a bioenergy crop.
3 – COOPERATOR RECRUITMENT AND SITE SELECTION

3.1 Study Site Selection

Site selection involved finding a producer/landowner with conservation values and suitable sites for the proposed practices. Site topography played a key role in selection of saturated buffers and saturated hillsides along with soil types and existing drainage systems on site that could be used and modified.

The selection of sites for harvestable seasonal wetlands was less connected to topography and site conditions and more importantly tied to the site location within an existing cropping system and the willingness of the producer to try alternative crops. Some sites may not be economically feasible to drain for maximum crop production therefore drainage modifications would not be necessary. Other sites may have subsurface drainage installed where drainage modifications could create saturated conditions if the producer is willing to set aside a few acres to control nutrient loss from his crop ground.

3.2 Recruiting Cooperators

At the outset of the project, AWI and PRN staff attempted to identify suitable sites and contact information for potential landowner cooperators through various state and federal USDA agencies including NRCS and Soil and Water Conservation Districts, farm management agencies, various workshops on BMPs, and perennial biomass innovations, but a number of uncertainties arose making it difficult to access the necessary information for targeting cooperating farmers. Challenges included identifying areas suitable for each of the cropping strategies to be tested, timing of the project with harvest meant many farmers and NRCS and SWCD staff were not readily available during the outreach phase, and project staff found the need to further clarify the perennial species available and information about markets for these perennial products. Recruitment strategies included fliers, workshops, meetings, and farm visits. Through direct contacts with farmers, the team recruited 4 teams of farmer cooperators who agreed to provide 6 different study field sites distributed in the three targeted watersheds: 3 sites in the Vermilion watershed, 2 sites in the Sangamon watershed, and 1 site in the Embarras watershed.

The 6 project sites are owned/managed/operated by 4 operator teams, two of which are multi-generational family teams, with most teams owning centennial farms. One of these teams controls 3 of the implementation sites. The remaining sites are owned/managed/operated by separate operator teams. The operator team members are all male and range in age from young farmers (age 20-35) to seasoned producers (age 86+), with the majority in mid to late career (36-85). All the producers own some of the land they farm, ranging from a 3 acre homestead to 1300 acres. Most of the cooperators also rent or crop share additional land with another landowner. Each proposed project involves the primary decision maker as a member of the cooperators. These farmers produce corn, soybeans, wheat, beef cattle, hay and miscanthus on the study sites.
3.3 Cooperator Motivations and Attitudes

To better understand the motivations of the cooperators, we implemented a brief survey with each cooperator team to determine their rationale for interest in perennial grasses and their general attitudes toward innovative practices, including other BMP’s they may be implementing on their farms.

Most of the members of the cooperator teams report that they view themselves as innovators who like to try new ideas. One cooperator noted that “innovation and fabrication have been the two aspects that drive our farm and our farming practices.” Most have integrated conservation as a regular practice in their farming operation.

These farming teams are concerned about reducing nutrient loss to avoid government regulation, ensuring there is adequate funding investments in new best management practices and innovative cropping systems, future water restrictions that may come with climate change, and the disconnection between absentee landowners and the land with the pressure to increase farm size to be economically viable, and the succession of their farm to the next generation.

In addition to trying harvestable perennial crops on their lands, these farmers are trying strategies such as transitioning to organic practices (2), cover crops (3), incorporating riparian buffers (2), switching less productive areas to pasture and hay (1); pond-fed irrigation and other water conserving practices (2). Reasons they offer for trying these innovative practices include: economics/better bottom line, reducing erosion, improving soil structure, better nutrient utilization, and staving off government regulation. In addition these lands include recognized best management practices for nutrient management, including CRP, buffer strips, grassed waterways, filter strips, 10 acre wetland area, no till conservation tillage, spring applied N, slow release N, and variable rate technology (VRT) for fertilizer.

Generally, these cooperators, while motivated by economics, are innovators with a strong conservation ethic who are concerned about reducing nutrient losses in order to avoid future government regulation. Their farms are not just their livelihood, they represent their family’s commitment to and stewardship of the land in E. Central Illinois.

3.4 Barriers/Liabilities to Implementing Alternative Crops and Practices

In the initial stages of the project, seeking suitable sites and connecting with associated landowners was difficult due to the confidentiality of USDA-FSA (Farm Service Agency) records. Not having access to local USDA agency records required reliance on SWCD staff assistance in site locations and identifying associated landowners. In an already tight state budget environment it was difficult for busy SWCD staff to devote the necessary time to provide the information we were seeking.
Time being valuable to everyone, asking farmer/operators, landowners, and farm managers to make time to consider introducing a new practice into their operation, especially for a pilot project without incentives, was also challenging. Further requirements of working with researchers and project developers to evaluate appropriate sites, discuss plans on the ground, and provide farm records and financial history for a five-year cycle tapped precious time and resources of potential participants.

For row-crop farmers, the logistics of moving into the perennial system was another hurdle. With a majority of farmers involved in row crop farming in this region today, finding producers interested in forage or biomass production was mostly limited to livestock operators or others already involved in forage or biomass production which is limited in this area. Forage and biomass operations have different machinery requirements from planting to harvest and storage and many operators do not have the necessary equipment to participate in this project.

Harvest timing and logistics of perennial biomass crop production needs to be coordinated with other farming operations. Conventional row crop farmers today have moved into heavy spring and fall work cycles around planting and harvest. Many producers hire out herbicide and fungicide applications. Without livestock, there is less pressure on mid-summer workloads unless wheat is incorporated into the rotation which is also uncommon. With USDA promoting cover crops for soil health and water quality benefits this trend may change slightly as farmers consider introducing more rotations into their management plan, but introducing perennials will require many operators to adjust their work cycles.

The technical transition from row crop to perennials on the ground is another consideration. If a farmer/landowner/farm manager is motivated and interested in the project, they may willingly put in the extra time and effort necessary to establish a test plot, but it can be a hard sell. Row crop farmers may have little or no experience in perennials, while livestock/forage/biomass producers have the basic skills required. Establishment of native species can be difficult. Warm season perennial grasses generally require a period of approximately three years to establish. Weather patterns or other unforeseen circumstances may affect establishment outcomes or result in even longer establishment periods. Weed suppression during transition is critical and labor intensive. Mowing or herbicide spraying of unfavorable plants will be required and invasive species will need to be controlled.

During site selection and design, soil types and characteristics must be examined to insure that the site is suitable for both Saturated Buffers and Hillsides. The soil must have a carbon source to help with the denitrification process. Heavy clay soils such as Miami may not be suitable for drainage modifications. Soil borings should be conducted on the Saturated Buffer sites to ensure that there are no sand and gravel veins that would lead to rapid bypass flow of the tile water through the buffer without much nitrate removal.

As discussed in Section 2.2, harvest methods and timing are another concern. The clumping nature of some perennial species creates rough fields for machinery to maneuver during harvest, and the plant material may add additional challenges, especially if harvest is delayed.
by rain. Tougher and larger amounts of biomass may not feed through conventional harvest equipment well. On-farm demonstrations as proposed in this report will explore these technical aspects.

Markets for forage and biomass and profitability are significant limiting factors to enrollment in this project. Limited hay markets exist regionally, but pricing is inconsistent. Multiple harvests and critical harvest timing for optimal feed value are not guaranteed in the climate of Central Illinois. Marketing hay requires more time and effort than corn or soybeans, and at this time there appears to be no foreseeable market for biomass locally. In addition, harvest timing to maximize feed value or optimum biomass for premium price may be challenging in the current Illinois climate.

And finally, no matter how well you present the project, with the current interest in cash rent leases, tenant farmers are reluctant to enter into conservation programs requiring a significant amount of investment of their time, income, and sweat-equity unless there is a long-term lease agreement with the landowner. Perennial crops are long-term investments that demand long-term strategies between all decision-makers in the farm operation.

The four producers (with six sites) that were recruited for the project are from families that PRN and AWI already know and have worked with previously. Each of the proposed sites is owned by the producer’s family, which simplifies arrangements compared to potential sites on rented land. In each case, the producers are conservation-minded and willing to demonstrate new ideas that they view as having a good chance of success. Three of the farm operations produce hay for their own livestock or for sale. One landowner is a grower and proponent of Miscanthus for bioenergy feedstock and was willing to try a saturation-tolerant native grass in a wet area.
This project seeks to demonstrate and evaluate the agricultural, economic, and environmental performance of the three innovative systems described in Section 2.1. Six sites have been identified, including two sites for demonstration of each cropping and drainage system:

<table>
<thead>
<tr>
<th>Site/Watershed</th>
<th>County</th>
<th>Perennial Crop System</th>
<th>Expected Biomass Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sangamon #1</td>
<td>Macon</td>
<td>Harvestable Saturated Hillside</td>
<td>Forage or bedding</td>
</tr>
<tr>
<td>Sangamon #2</td>
<td>Macon</td>
<td>Harvestable Saturated Hillside</td>
<td>Forage or bedding</td>
</tr>
<tr>
<td>Vermilion #1</td>
<td>Champaign</td>
<td>Harvestable Saturated Buffer</td>
<td>Forage or bedding</td>
</tr>
<tr>
<td>Vermilion #2</td>
<td>Champaign</td>
<td>Harvestable Saturated Buffer</td>
<td>Forage or bedding</td>
</tr>
<tr>
<td>Vermilion #3</td>
<td>Champaign</td>
<td>Harvestable Seasonal Wetland</td>
<td>Forage or bedding</td>
</tr>
<tr>
<td>Embarrass #1</td>
<td>Champaign</td>
<td>Harvestable Seasonal Wetland</td>
<td>Thermal bioenergy</td>
</tr>
</tbody>
</table>

Table 2. List of proposed sites for on-farm demonstrations of perennial crop systems.

The three Vermilion River Watershed sites are part of one family farming operation. Each of the other sites is farmed by a different landowner/producer. The proposed demonstration sites therefore represent four landowners. Each site is farmed by the landowner, rather than rented.

The mix of proposed cropping/drainage systems achieved the desired representation of each practice. The geographical distribution includes three Central Illinois watersheds, which will provide good locations for purposes of field days if the systems are established as proposed. The original intent was to have sites in the Upper Sangamon, Embarras, and Upper Kaskaskia watersheds. We did not identify any cooperators in the Kaskaskia Watershed. The Vermilion Watershed sites are suitably located to demonstrate the crop and drainage systems in sites with characteristics common throughout east-central Illinois.

All sites except Embarras #1 are expected to be planted in perennial grasses suitable for use as forage or animal bedding. In general, forage is a higher value use but if harvest occurs after optimal nutritional value, bedding is an appropriate alternative use. The Embarras #1 landowner is a Miscanthus grower interested in demonstrating production and use of bioenergy feedstock.

This section presents site descriptions and layouts and soil information for each of the proposed on-farm demonstrations. Soil maps and legends for each site were generated in the NRCS Web Soil Survey (WSS), which provides soil data and information produced by the National Cooperative Soil Survey. [http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm](http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm)

Cooperators for this project were not asked to commit to implementation of the proposed systems. Landowners may opt to implement the cropping system and related drainage modifications as proposed here or with any changes they want to make. They may also opt not to proceed with the proposed system. If they wish to proceed, AWI and PRN will work with them to seek funding to establish the systems and monitor performance as discussed in Section 5.
4.1 Sangamon #1 – Saturated Hillside

This site is located in Section 21 of Oakley Township in Macon County in the Upper Sangamon Watershed. The landowners/producers are a multigenerational family with experience in on-farm research and demonstrations of new management practices and cropping systems. The family plans to begin raising cattle and is in the process of converting some land from row crops to pasture or hay production. The owners plan to construct a pond on this site for the purpose of irrigating the adjacent crop ground. The Saturated Hillside will be installed above the proposed waterline elevation of the pond with the distribution line running parallel to the pond. This site will allow us to demonstrate the Saturated Buffer concept on a hillside and evaluate the performance of this practice for nutrient reduction and forage production. The proposed buffer includes both cool season and warm season grasses.

![Figure 6. Sangamon #1 layout of harvestable saturated hillside.](image)
The soils in which the Sangamon #1 buffer will be installed appear to have adequate organic carbon for denitrification. Prior to implementation of a buffer on this site soil borings should be conducted in order to determine if any strata of sand and gravel are present.

Figure 7. Soil map and legend for Sangamon #1 site.
4.2 Sangamon #2 – Saturated Hillside

This site is located in Section 18 of Long Creek Township in Macon County in the Upper Sangamon Watershed. The owners have implemented other BMP's on his ground. They have been trying different crops on his acreage to be more diversified than a corn/soybean rotation. They do not have livestock but they do have experience producing hay for sale. This site will allow us to demonstrate the Saturated Buffer concept on a hillside and evaluate the performance of this practice for nutrient reduction and forage production. The proposed buffer includes both cool season and warm season grasses.

Figure 8. Sangamon #2 layout of harvestable saturated hillside.
The soils in which the Sangamon #2 buffer will be installed appear to have adequate organic carbon for denitrification. Prior to implementation of a buffer on this site soil borings should be conducted in order to determine if any strata of sand and gravel are present.

Figure 9. Soil map and legend for Sangamon #2 site.
4.3 Vermilion #1 – Saturated Buffer

This site is located in Section 7 of S. Homer Township in Champaign County in the Vermilion River Watershed. The landowners/producers have both livestock and grain operations. They have expressed willingness to demonstrate the innovative concepts proposed in this project and assess how they fit into their farming operation. The sites for proposed Vermilion #1, #2, and #3 are all owned and farmed by the same family. The ground adjacent to the drainage ditch is enrolled in the USDA Conservation Reserve Program and has an established grass filter strip. If implemented, this site will provide a demonstration of a Harvestable Saturated Buffer for warm season forage adjacent to a CRP buffer that is not harvested.

Figure 10. Vermilion #1 layout of harvestable saturated buffer.
The soils in which the buffer will be installed appear to have adequate organic carbon for denitrification. Prior to implementation of a buffer on this site soil borings should to be conducted in order to determine if any strata of sand and gravel are present.

Map Unit Legend

<table>
<thead>
<tr>
<th>Map Unit Symbol</th>
<th>Map Unit Name</th>
<th>Acres in AOI</th>
<th>Percent of AOI</th>
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<td>Planagan silt loam, 0 to 2 percent slopes</td>
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<td>171B</td>
<td>Catlin silt loam, 2 to 5 percent slopes</td>
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<td><strong>10.6</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

Figure 11. Soil map and legend for Vermilion #1 site.
4.4 Vermillion #2 – Saturated Buffer

This site is similar to Vermillion #1, however, the adjacent crop ground is a lot flatter, for that reason this site was chosen. If implemented, this site will allow us to evaluate the agricultural and environmental performance of a Harvested Saturated Buffer in a relatively flat field. Since level or nearly level topography in fields adjacent to drainage ditches is common in central Illinois, a successful demonstration in these conditions could indicate that harvestable saturated buffers may be widely applicable. The proposed layout includes both cool season and warm season grasses, which is expected to increase plant uptake of nitrogen in early spring.

Figure 12. Vermilion #2 layout of harvestable saturated buffer.
The soils in which the buffer will be installed appear to have adequate organic carbon for denitrification. Prior to implementation of a buffer on this site soil borings should to be conducted in order to determine if any strata of sand and gravel are present.

Map Unit Legend

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<tr>
<th>Map Unit Symbol</th>
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<th>Percent of AOI</th>
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<td><strong>Totals for Area of Interest</strong></td>
<td></td>
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<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

Figure 13. Soil map and legend for Vermilion #2 site.
This site represents a poorly drained area within a crop field, which is common in Central Illinois prime farm ground. Such areas often occur in prairie soils including Drummer silty clay loam that have shallow circular depressions where water ponds in wet years. These soils are highly fertile and produce high yields under favorable conditions; however, ponding or a high water table in wet years may damage corn and soybean crops. It may be impractical or uneconomical to install surface or subsurface drainage to reduce such crop damage. If implemented, this site will provide an opportunity to evaluate the feasibility and economics of an alternative perennial crop within a corn—soy field and the capability of a harvestable wetland to capture and use nutrients lost from cropland draining to the wetland area to grow a forage crop.

**Figure 14. Vermilion #3 layout of harvestable seasonal wetland.**
The soils in which the proposed Harvestable Seasonal Wetland will be installed appear to have adequate organic carbon for denitrification. Prior to implementation of a wetland on this site, soil borings are recommended in order to determine if any strata of sand and gravel are present.

Figure 15. Soil map and legend for Vermilion #3 site.
4.6 Embarras #1 – Harvestable Seasonal Wetland

This site is located in Section 32 of Crittenden Township in Champaign County near the headwaters of the Embarras River. The landowner/producer is actively promoting Miscanthus as a bioenergy crop and has already planted Miscanthus on the ground adjacent to a drainage ditch with a CRP buffer. However, like soybeans and corn, Miscanthus cannot tolerate extended periods of wetness. A small area of the plot is located on a slight slope with groundwater seepage that has stunted the Miscanthus. Replanting this area in Prairie cordgrass, a saturation-tolerant native warm season grass producing high biomass yield, is proposed as a demonstration of bioenergy feedstock production in poorly drained soils. This site has a recently installed subsurface tile system. Depending on the outcome of the initial 0.5 acre demonstration, the area planted in cordgrass could be expanded with drainage modifications to increase the removal and utilization of nitrate and phosphorus for research purposes.

![Embarras #1 layout of harvestable seasonal wetland](image)

Figure 16. Embarras #1 layout of harvestable seasonal wetland.
The soils in which the proposed Harvestable Seasonal Wetland will be installed appear to have adequate organic carbon for denitrification. Prior to implementation of a wetland on this site, soil borings are recommended in order to determine if any strata of sand and gravel are present.

Figure 17. Soil map and legend for Embarras #1 site.
5 – RESEARCH / DEMONSTRATION PROJECT APPROACH AND BUDGET

The practices addressed in this project are new concepts that extend saturated buffer and wetland practices by introducing the harvest of a forage or bioenergy crop. None of these practices are currently cost-shared through NRCS. This section presents estimated costs for the demonstration projects including (1) crop establishment, (2) drainage modifications, and (3) incentives so that producers do not lose income by participating in on-farm demonstrations. These costs and an estimate of nutrient reduction are then used to estimate the cost per unit of nitrate and total phosphorus reduction of the scenarios. Monitoring and research cost to measure actual nutrient reduction by these new systems and related outreach activities are estimated separately.

5.1 Demonstration Project Cost: Perennial Crop Establishment

Establishment of cool or warm season grasses usually takes 2 to 3 years before vegetation can be harvested for forage or other uses. Preparing the site for planting the grasses can vary considerably from site to site depending on the present use of the ground and other factors. Most costs are similar for cool or warm season grasses, except for the cost of the seed. Many factors play into the average cost of perennial grasses per acre such as spraying cost depending on whether the operator will have to contract for this service, chemicals used, how many mowings will be required, and seed selection. The following tables show a range of estimated average costs per acre for establishing the perennial grasses in the proposed systems.

<table>
<thead>
<tr>
<th>Year #1</th>
<th>Cool Season Grasses</th>
<th>Warm Season Grasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity</td>
<td>Cost per Acre</td>
<td>Cost per Acre</td>
</tr>
<tr>
<td>Seedbed Preparation</td>
<td>$22.00</td>
<td>$22.00</td>
</tr>
<tr>
<td>Planting</td>
<td>$19.60</td>
<td>$19.60</td>
</tr>
<tr>
<td>Spraying</td>
<td>$5.00*</td>
<td>$5.00*</td>
</tr>
<tr>
<td>Chemicals</td>
<td>$4.00 to $12.00</td>
<td>$4.00 to $12.00</td>
</tr>
<tr>
<td>Mowing(1)</td>
<td>$18.70</td>
<td>$18.70</td>
</tr>
<tr>
<td>Seed</td>
<td>$50.00 to $240.00**</td>
<td>$75.00 to $150.00**</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$119.30 to $317.30*</td>
<td>$144.30 to $208.60*</td>
</tr>
</tbody>
</table>

* Spraying and total cost estimates assume spraying is done by the producer; commercial contractors may charge a minimum of $200 per site for custom spraying.

** Cost per acre for seed depends on varieties and mixtures to be planted.

(1) Mowing is a vital part of controlling weed competition in the establishment process. A control burn in the spring can also be used to reduce weed competition; trained personnel and permits are needed for burns.

Table 3. Estimated perennial grass crop establishment cost, Year 1.
<table>
<thead>
<tr>
<th>Year #2 &amp; #3</th>
<th>Cool &amp; Warm Season Grasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity</td>
<td>Cost per Acre per year</td>
</tr>
<tr>
<td>Spraying</td>
<td>$5.00*</td>
</tr>
<tr>
<td>Chemicals</td>
<td>$4.00 to $12.00</td>
</tr>
<tr>
<td>Mowing(1)</td>
<td>$37.40</td>
</tr>
<tr>
<td>Total</td>
<td>$46.40 to 54.40*</td>
</tr>
</tbody>
</table>

* Assumes spraying is done by producer; commercial contractors may charge a minimum of $200 per site for custom spraying.

(1) Mowing is a vital part of controlling weed competition in the establishment process. A control burn in the spring can also be used to reduce weed competition; trained personnel and permits are needed for burns.

Table 4. Estimated perennial grass crop establishment cost, Years 2 and 3.

5.2 Demonstration Project Cost: Drainage Modification

Drainage modifications for saturated buffers or hillsides typically include installing a water control structure and a 4” plastic tile distribution line approximately 1000’ in length. Cost may vary depending on location and layout of the project. An estimated average cost of $1750.00 should cover the installation of the water control structure and a cost of 2.50/ft. for the distribution tile. Mobilization of the drainage contractor’s equipment would be an additional cost and will vary by location. Total estimated cost for drainage modifications for each Harvestable Saturated Buffer or Hillside is about $5000.

Drainage control structures and possibly additional tile drains may be installed for Harvestable Seasonal Wetlands to allow management of the water elevation. Total estimated cost for a control structure is about $2000, including installation and contractor mobilization cost. Other drainage costs for a seasonal wetland with water level controls would need to be estimated case by case. No drainage modifications are proposed for the wetlands in this report – Vermilion #3 and Embarras #1.
5.3 Demonstration Project Cost: Land Rent and Total Estimated Cost

For producers to be willing to convert annual row crops to perennial crops, it is expected that financial incentives will be needed to ensure that the change from row crops to the proposed perennial cropping system does not result in a reduction in net income for the field. Since establishing perennial grasses is expected to result in two or possibly three years with little or no crop revenue, incentives to offset monetary losses during the establishment period are included. A simple way to compensate for lost revenue is to provide a cash payment based on cropland rental rates. We used $300 per acre. This figure may be adjusted as appropriate for each site.

We used the above cost information to estimate a range of costs for implementing the crops and practices described above on the six planning sites. We considered the highest cost of grass establishment (most expensive seed and herbicide and custom herbicide application) and the lowest cost of grass establishment (least expensive seed and herbicide and non-custom herbicide application), estimated cash rent for three years and drainage modification costs.

<table>
<thead>
<tr>
<th>Site</th>
<th>Perennial crop area</th>
<th>Grass Establishment Cost ($/ac)</th>
<th>Cash Rent</th>
<th>Drainage Modification Cost</th>
<th>Estimated total cost first three years</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>3</td>
<td>$213</td>
<td>$611</td>
<td>$300</td>
<td>$8,338</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$9,533</td>
</tr>
<tr>
<td>S2</td>
<td>3.13</td>
<td>$213</td>
<td>$603</td>
<td>$300</td>
<td>$8,483</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$9,704</td>
</tr>
<tr>
<td>V1</td>
<td>7.5</td>
<td>$213</td>
<td>$491</td>
<td>$300</td>
<td>$13,346</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$15,433</td>
</tr>
<tr>
<td>V2</td>
<td>5</td>
<td>$213</td>
<td>$531</td>
<td>$300</td>
<td>$10,564</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$12,156</td>
</tr>
<tr>
<td>V3</td>
<td>15</td>
<td>$213</td>
<td>$451</td>
<td>$300</td>
<td>$16,692</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$20,267</td>
</tr>
<tr>
<td>E1</td>
<td>0.5</td>
<td>$213</td>
<td>$1611</td>
<td>$300</td>
<td>$556</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$1,256</td>
</tr>
</tbody>
</table>

* High estimate includes $600 per site for 3 years of custom spraying.

Table 5. Estimated costs incurred during the first three year for establishing the practices at each site.

5.4 Estimated Cost for Nutrient Reduction

For preliminary estimates of the cost of reducing nitrate delivery to streams from these practices, we assumed after the third year, revenues from hay or biomass sales would cover the costs of cash rent and other input costs. Based on previous research we assume that tile drained areas lose 30 lb N per acre per year through the tile system and estimate that harvestable saturated buffers and hillslopes could remove about 40% of that nitrate loss. Harvestable seasonal wetlands will treat surface runoff which has a much lower nitrate concentration compared to tile drainage and so we assumed the incoming nitrate load was 3 lb
N per acre per year and that the wetland could reduce this load by 40%. For both practices, we assumed that the area converted from corn-soybean to perennial vegetation would have 90% less nitrate loss. We also assumed a 20 year planning horizon.

<table>
<thead>
<tr>
<th>Site</th>
<th>Drainage Area (acres)</th>
<th>Estimated N loss over 20 years (lb N)</th>
<th>Estimated N loss reduction (lb N)</th>
<th>Estimated total cost Low ($)</th>
<th>Estimated cost per lb of N loss reduction Low ($/lb)</th>
<th>Estimated total cost High ($)</th>
<th>Estimated cost per lb of N loss reduction High ($/lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>40</td>
<td>24,000</td>
<td>9,681</td>
<td>$8,338</td>
<td>$0.86</td>
<td>$9,533</td>
<td>$0.98</td>
</tr>
<tr>
<td>S2</td>
<td>30</td>
<td>18,000</td>
<td>7,285</td>
<td>$8,483</td>
<td>$1.16</td>
<td>$9,704</td>
<td>$1.33</td>
</tr>
<tr>
<td>V1</td>
<td>80</td>
<td>48,000</td>
<td>19,402</td>
<td>$13,346</td>
<td>$0.69</td>
<td>$15,433</td>
<td>$0.80</td>
</tr>
<tr>
<td>V2</td>
<td>60</td>
<td>36,000</td>
<td>14,535</td>
<td>$10,564</td>
<td>$0.73</td>
<td>$12,156</td>
<td>$0.84</td>
</tr>
<tr>
<td>V3</td>
<td>35</td>
<td>2,100</td>
<td>1,245</td>
<td>$16,692</td>
<td>$13.41</td>
<td>$20,267</td>
<td>$16.28</td>
</tr>
<tr>
<td>E1</td>
<td>300</td>
<td>133.5</td>
<td></td>
<td>$556</td>
<td>$4.17</td>
<td>$1,256</td>
<td>$9.40</td>
</tr>
</tbody>
</table>

Table 6. Estimated costs per pound of nitrate-N removal from implementing the practices described above.

With these assumptions, it appears that harvestable saturated buffers (sites S1, S2, V1 and V2) may provide a cost of reducing N loads to streams ranging from $0.69 to $1.33 per pound of N load reduced. These costs are similar to the estimate by Jaynes and Isenhart (2014) for Iowa, and less than almost all of the practices considered in the Illinois Nutrient Loss Reduction Strategy. The only less costly practice in the INLRS was the cost of reducing N fertilizer application amount to the economically optimal levels. Adjusting N fertilizer quantities and timing was expected to reduce N loss across the state by less than 10%, which will not achieve the nutrient loss reduction goals.

Our estimates of the costs of nitrate removal for the harvestable wetlands (sites V3 and E1) are considerably greater than for harvestable saturated buffers because these practices treat surface water which has a much lower nitrate concentration than tile drainage water. None of these estimates include nutrient loss reduction that occurs from harvesting of N or P in the perennial grasses. Furthermore, these cost estimates do not include any revenues generated from hay sales that exceed the costs of production and land rent. Nor do these estimates consider reducing the economic losses from planting and replanting corn and soybeans on low yielding cropland. These additional benefits are difficult to estimate because of a lack of relevant research on the agronomic and economic performance of these systems. The cost of nitrate loss reduction is likely to be even less than we estimate in settings where these benefits are significant.
Using the average 2013-2016 estimated costs and revenues for Central Illinois from the University of Illinois Department of Agricultural Economics, it appears that the breakeven yields in central Illinois are 214 bushels per acre for corn and 61 bushels per acre for soybeans, assuming a land rent of $300 per acre per year. There are many areas in central Illinois that have lower yields and/or higher rents, and thus negative economic returns. Converting these areas from corn-soybean to perennial grass could reduce economic losses on those areas as well as reducing nutrient losses.

5.5 Monitoring Equipment and Research Costs

The cost for the monitoring equipment to collect flow and nitrate data from the sites will range from $4,700 to $5,100. If an automated system is desired additional cellular charges would also be occurred. These prices do not include the cost of the PVC monitoring wells and/or the cost of sampling supplies.

If we can secure funding for implementation and monitoring this practice, we will follow protocols developed in the previous studies of saturated buffers. V-notch weirs will be used in the flow control structures in conjunction with pressure transducers to measure water depth and tile flow from the corn-soybean field and the proportion that is diverted to the saturated buffer. Water samples will be collected periodically and nitrate concentrations measured. The combination of nitrate concentrations and water flow will allow us to calculate the amount of nitrate being discharged from the corn-soybean field, and the amount being diverted to the saturated buffer.

Three groundwater well transects will be installed between the lateral distribution line and the stream to determine the fate of the nitrate diverted into the saturated buffer. Groundwater samples will be drawn from these wells every other week while the tiles are flowing. If the groundwater nitrate concentrations approach zero in the well closest to the stream, then we can conclude that all of the nitrate diverted into the buffer was either taken up by the vegetation or converted to gas rather than contaminating the stream, the Mississippi River and the Gulf of Mexico. If the nitrate concentrations in the groundwater below the buffer are not zero, then we will estimate the amount of nitrate removal as proportional to the reduction in nitrate concentration. This will be a conservative estimate of the nitrate removal of the buffer because it will not include nitrate and water uptake by the vegetation which is difficult to measure.

We will quantify the costs of establishing and harvesting the perennial grasses, as well as the revenues derived from harvesting the biomass. Combining this information with the amount of nitrate consumed in the riparian buffer, we will be able to calculate a cost of nitrate loss reduction by this practice.
A preliminary estimate of the effectiveness of a harvestable saturated riparian buffer can be generated by assuming an average of 30 lb N/ac per year lost from typical tile drained corn-soybean field. If we assume the saturated buffer system is capable of removing 40% of the nitrate on average, this will prevent 12 lb/ac per year from entering a stream. If the proposed buffers are implemented, the economics of achieving nitrate reduction by means of harvested saturated or hillside buffers can be calculated based on monitoring results, actual costs of system installation, and farm costs and revenue.
6 – PROJECT SUMMARY AND NEXT STEPS

This project is an initial step toward on-farm demonstration and monitoring of innovative perennial cropping systems to produce harvestable biomass and reduce nutrient losses. In each scenario, nutrients lost by annual row crops can be taken up by perennial crops or be removed by other mechanisms, including phosphorus adsorption to soil particles and denitrification by soil microorganisms. The drainage modifications in the harvestable saturated buffers and hillsides are specifically intended to reconnect tile flow containing nitrate to the soil column to address one of the most challenging aspects of nutrient loss reduction in tile-drained cropland. The harvestable wetlands in this report do not include drainage modifications and consequently may have less nitrate removal potential than a design with a drainage control structure and diversion of tile flow to the wetland area. Even without drainage modifications, the proposed wetlands would allow a test of perennial crops integrated into poorly drained areas within a corn—soy field.

Implementation of the proposed systems with or without water quality monitoring would allow producers to assess how well the cropping and drainage systems fit into their operations and gather information about the farm economics of the systems. Implementation of the various systems can proceed even if funding is not available for water quality monitoring. However, performance monitoring and analysis is important to assess the potential role of these systems in meeting the objectives of watershed scale or statewide water quality plans.

The Lumpkin Family Foundation grant for this project was for the planning phase consisting of identification of sites and cooperators and development of layouts and cost estimates. The next steps for this project are to

1) Meet with the landowners/producers to review layouts, perennial crop options, and cost estimates in this report;
2) If they decide to proceed with implementation, identify potential funding sources, firm up the budget, and apply for funding for the demonstration projects;
3) Apply for monitoring, research, and outreach funding, which may be from the same or different sources than the implementation funding;
4) Proceed with the final design, implementation, and research/outreach phases.

Nutrient loss reduction is the principal environmental benefit addressed in this report. It should be noted that the proposed perennial crops can provide additional conservation benefits including soil erosion reduction, increasing soil organic carbon, and enhancing wildlife habitat. We will explore the interest of landowners and scientists to add assessment of such additional benefits to the research phase.

Monitoring of these initial systems can help to refine the cropping and drainage systems and lead to wider testing of these or similar with the goal of adding to the menu of options available for meeting nutrient loss reduction targets on a watershed or statewide basis. Such perennial cropping systems could, with adequate research results, become NRCS practices eligible for cost-share or other incentives through Farm Bill conservation programs for working lands.
This project will test innovative ideas to improve environmental outcomes of agriculture while maintaining or increasing net farm income. This type of on-farm R&D is expected to become increasingly important in coming years as Illinois and the United States address the critical issues of Gulf hypoxia and climate change mitigation and adaptation. Systems that provide significant environmental benefits while also producing revenue from harvested perennial crops may be more readily adopted on a voluntary basis by producers with appropriate incentives for ecosystem services. To achieve the goals of the Illinois Nutrient Loss Reduction Strategy, this may well be a desirable, cost-effective approach.

As part of the effort by Illinois and other states to achieve the goals of the INRS, new economic tools are, or soon will be, available to help farmers and landowners evaluate the economic value of BMPs. For example, the Precision Conservation Management Program (PCM) is designed to help farmers apply the voluntary fertilizer management BMPs suggested in the Illinois Nutrient Loss Reduction Strategy. The University of Illinois, the Illinois Corn Growers Association, and 30 other partners with agricultural interests have developed PCM to help farmers make important conservation management decisions. The CPM software will give farmers the opportunity to review agronomic and financial records simultaneously to answer important management questions about sustainability, areas of strength and weakness, and ultimately determine if programs and investments addressing soil loss and water quality are good investments. This tool could provide to be of use in evaluating the economics of a saturated buffer system.

Another tool is the Profit Zone Manager (PZM) program developed by AgSolver Inc. that is now commercially available. We wish to acknowledge the participation in the current project of David Muth and Dan Bahe of AgSolver. They used input and yield data provided by the Vermilion #3 producer to assess sub-field scale profitability of the site with the PZM tool. This software can be used to identify areas of a field that are or are not profitable and evaluate alternative management scenarios such as adding drainage or changing cropping systems to improve profitability. In broad terms, their analysis tended to support our conclusion about the reasonableness of converting a poorly drained area of the Vermilion #3 field from row crops to perennial crops. In a future project, PZM could be used on a larger scale to evaluate the farm economics of harvestable wetland or saturated buffer concepts. Economic and water quality data about the performance of the on-farm demonstrations in the current project could be used to refine the PZM program. AgSolver is currently involved in a large sustainable bioenergy landscape design project in Iowa funded by the U.S. Department of Energy. PZM will be applied to help producers decide whether and where to harvest crop residues or grow bioenergy crops.

The current project proposes to demonstrate innovative multifunctional agriculture concepts in which perennial crops are selected and managed for co-production of agricultural goods and environmental services. Our specific objective is to produce harvestable biomass on sloping or poorly drained soils while also significantly reducing nutrient losses from annual crops. By definition, multifunctional agriculture involves synergies and tradeoffs since it is generally not possible to maximize multiple desired outcomes simultaneously. We hope that the proposed harvestable buffers and wetlands will lead to many more on-farm trials of perennial systems that enhance the social, economic, and environmental outcomes of Midwestern agriculture.
REFERENCES

