BIOENERGY FROM RESERVE PRAIRIES IN MINNESOTA: MEASURING HARVEST AND MONITORING WILDLIFE

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Abstract
Conservation of land is valued by society and nurtured by policy that should be informed by science and technology. Over 1.5 million acres are in the Conservation Reserve Program in Minnesota alone. This and similar programs provide ecosystem services, but as prices of commodity crops increase, along with costs of farm operations, many reserve lands may revert to cropland, potentially reducing quality of soil, water, climate, and habitat.

In this study we investigated whether reserve lands could reliably be harvested to yield high quality renewable bioenergy while concurrently preserving resident wildlife populations. Implications can inform policy on earning opportunities from harvested bioenergy while maintaining or expanding conservation lands.

This paper broadly outlines our ongoing, six-year study on production-level harvesting of over 1000 acres of re-established Minnesota prairie. It and its on-line supplementary material (www.cbs.umn.edu/wildlife) focus on protocols, methods, and management practices that have emerged. Results and statistical analyses from this study will be reported in subsequent publications. We describe the logistics of managing a landscape-scale bioenergy research program, with emphasis on harvesting, sampling, and coordination with land managers. In addition, in supplementary material we offer specific protocols to survey small mammals, birds, reptiles, amphibians, and invertebrates. These protocols are intended for researchers to assess whether wildlife populations are affected by various harvesting regimes for bioenergy, and the quality and quantity of bioenergy that can be expected.

The pursuit of principles integrating conservation biology, ecology, agronomy, and energy production, as described here, is an intrinsic part of establishing a viable domestic bio-based economy.

Keywords: bioenergy, wildlife conservation, ecosystem services, multiple use CRP

Introduction
Minnesota grasslands continually produce biomass that largely goes untapped. A properly restored and managed field of mixed grasses, legumes, and other flowering plants offers key ecosystem services including carbon sequestration, enhanced water quality, biodiversity, and wildlife habitat (Foley *et al*. 2005). It also offers flexibility for use as animal feed or forage (Sanderson and Adler 2008). In general, contemporary

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energy crop fields, such as soybean and corn, and some other feedstocks such as miscanthus and switchgrass, support lower levels of wildlife than do diverse grasslands (Robertson e*t al*. 2010; Meehan *et al*. 2010; Gardiner *et al*. 2010). Suitable wildlife habitat in such cases may be reduced by simplification of the landscape, complete harvest of all cover, wetland drainage, chemical application, mechanical injury, and other causes.

But what of restored native grasslands? Can they be harvested sustainably and still provide suitable wildlife habitat? We considered principles of wildlife ecology to design an experiment testing the effects of harvest patterns, edges, and unharvested refuges on production-scale fields within restored native grasslands. We surveyed birds, small mammals, reptiles, amphibians, and invertebrates, including insects and spiders. We also conducted several specialized pilot surveys. This paper outlines the project thus far, five years into a six-year study, to summarize lessons learned. Detailed results and statistical analyses from this study will be reported in subsequent publications.

Site Selection and Logisitics

A common criticism of biomass production is that it uses land that might otherwise be used for food production, leading to increased greenhouse gases, among other outcomes (Fargione *et al.* 2008; Searchinger *et al*. 2008). However, mixed grassland biomass is an exception in that it can be established or restored on marginal land that is either not suitable for typical crop production (Cai *et al.* 2011), or as is more often the case, has been taken out of production because of low yields. For this study, we selected three regions of representative climate, soil, and wildlife composition in western Minnesota spanning the state's latitudinal gradient (Figure 1). These were re-established prairies, restored no less than five years earlier, held in federal, state, or private conservation under fire and weed management appropriate for their region.

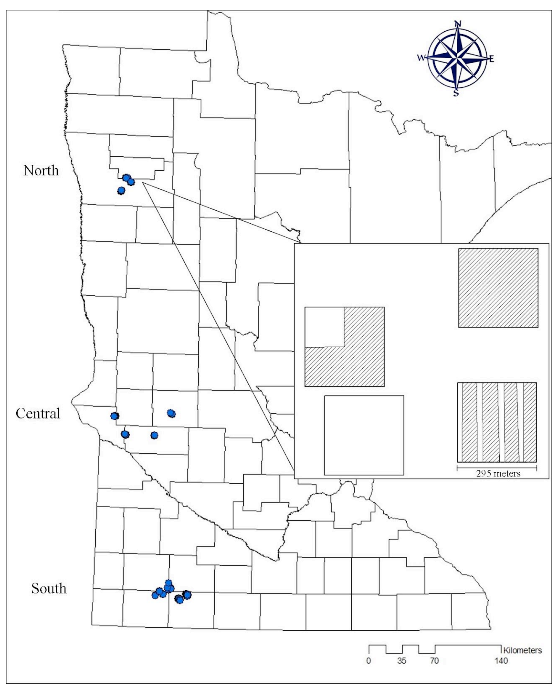

Fig. 1. Three regions in Minnesota where restored grasslands were studied to evaluate effects of biomass harvesting on grassland wildlife. Inset shows one block of four 20-acre plots with one unharvested control and three different harvest plans.

Locating landscapes with enough contiguous, re-established prairie to establish replicated, consistently-sized production scale plots was challenging. We were able to accomplish this goal with plots averaging 20 acres each, organized into study blocks of an average three-mile radius. The blocks within a region were close enough for harvesting efficiency and delivery to potential biomass consumers. This also kept the soil and climate within each region similar enough to support a randomized block design. We chose plots using detailed maps that included soil and elevation parameters, wetland delineation, and land cover from aerial images, then visited potential locations to determine plot suitability.

Plot distributions within fields required detailed attention. Removing bales would become difficult and expensive if plots were further into fields and away from roads. Wetness and slope were considered as well, especially since the fields used in this study did not have drain tiles. We recognized these as challenges in using marginal agricultural or non-agricultural land for harvesting. Given those constraints, sufficient land for this study was located and partnerships with federal, state, and local agencies and private entities were secured largely within the first year of the project, but required some care and effort.

Wildlife

We evaluated wildlife with biological field crews surveying birds, small mammals, reptiles, amphibians, and invertebrates. Each of these taxa required distinct protocols, detailed in supplementary material (www.cbs.umn.edu/wildlife). Any single survey does not define the response of the landscape to bioenergy harvest, but together these surveys characterize outcomes of harvest management. We identified wildlife to species level where possible, but several taxa were only identified to order, family, or genus (*e.g.* invertebrates, some genera of small mammals).

Invertebrate sampling techniques included sweep nets, pitfalls, and bee bowls. We also developed a new quantitative invertebrate sampling technique (QuIST) to collect all invertebrates within a grassland canopy and calibrate conventional sweep net measurements. Our measurements of invertebrates examine their important roles as food for wildlife and as beneficial predators and pollinators. Small mammals were surveyed because they occupy a central role in grassland ecosystems, consuming invertebrates and plants lower in the food web and in turn becoming food for larger predators. We conducted small mammal surveys in late summer using Sherman live-traps. Reptiles and amphibians are sensitive and susceptible to environmental disturbances and therefore are important indicators. We surveyed them throughout summer using funnel and pitfall live-traps. Grassland birds are of widespread interest, not only for activities such as bird-watching and hunting, but because their populations have declined more precipitously than any other bird guild. We used area-based search methods to survey birds throughout the entire plot, using both auditory and visual cues.

In addition to the wildlife surveys, we conducted vegetation surveys throughout the growing season. These surveys tracked the presence and absence of a variety of plants, percent cover at randomly placed quadrats, and also which plants were blooming and providing resources for pollinators. Other surveys were piloted for special purposes, including winter pellet surveys for deer, artificial nest and predator surveys using trail cameras, snow depth measurements, and nesting waterfowl surveys.

Harvesting

Biomass harvesting was organized in six treatment patterns: 50% harvest in strips, 50% harvest in blocks, 75% harvest in strips, 75% harvest in blocks, 100% harvest, and 0% harvest. Patterns were designed to test for the importance of unharvested areas in providing wildlife refuges, connectivity, edges, and landscape complexity. Harvesting was guided by semi-permanent bamboo poles placed in the plots. Following harvest, we traced the edges on all-terrain vehicles using global positioning systems (GPS) to record actual harvested areas, which occasionally differed from the plan due to temporary wetlands or other obstructions. We collected sample cores from biomass bales and analyzed them for minerals and other factors (Jungers *et al*. 2011).

We did not employ custom equipment for harvesting. A discbine with multiple small spinning heads was used for all cutting. After the biomass was cut, it was roller-conditioned and dispensed to form windrows. The discbine head worked well for cutting the various plant types in the project and cut both wet and dry material. It also allowed greater ground speed. However, it can be expensive to repair if damaged by rocks or other debris, which can occur on marginal lands targeted for this study.

During the first harvest season (2009), the discbine head was mounted on a two-wheel-drive, self-propelled, swathe-type cutter, but this was suboptimal because the unit was difficult to transport between plots, and it got stuck in wet ground. Accordingly, in 2010 and later, we mounted the discbine on a four-wheel drive tractor, which solved the transportation problem and also provided the versatility of another tractor on site. A high capacity wheel V-rake worked well to combine two windrows of cut biomass into one windrow and also to flip the material to speed drying. If conditions were dry, the biomass did not have to be raked.

We tested both round and square balers. Both produced large bales of similar size. In 2009, the large square baler produced 4'x 4' x 8' twine-tied bales weighing around 1,000 pounds at 15% moisture. They stacked, hauled, and transported well—better than round bales—and had no tendency to roll on slopes. However, they were not as resistant to rain. The square baler was effective but heavy for its tire size and difficult to load for transport. In 2010, we switched to a round baler, which produced a 4' wide by 6' high bale wrapped with plastic net. That size allowed easy hauling by truck to final destinations. Round, net-wrapped bales can be left outdoors for up to three years or more without cover, allowing storage in the field, where costs are lower.

Available time windows for harvesting were relatively short, due in part to regulations of land managers, but also to weather conditions. For example, many wildlife management areas by regulation cannot be harvested before November 1, sometimes leaving little available time before snowfall. Occasionally, wet conditions or snow prevented a complete fall harvest. Where possible, harvesting was then completed the following spring. The best method for transporting bales from the field was tractors with front and rear-mounted bale spikes. With these, bales can be placed a safe distance from the roadside for future transport or loaded directly onto trucks.

A practical consideration for geographically broad studies like this is preventing the spread of weeds, so for this project transportation equipment carried on-board air compressors to clean machinery before departing any plot.

Public Involvement

Ultimately policy flows from the public, and with that in mind we dedicated part of the project to meetings and demonstrations for agencies, landowners, news media, and the general public. During multiple fall harvest seasons, we advertised in local media and moved a representative set of harvesting equipment to one of our 20-acre plots that was close to a roadway with safe parking nearby. We presented the ideas of ecosystem services from multiple concurrent uses of land and conducted discussion and feedback sessions. Conditions permitting, we demonstrated the harvesting process to those not familiar with issues of harvesting non-agricultural land. Attendance was good and responses were enthusiastic, though more people interested in land management and wildlife attended than those interested purely in bioenergy. These sessions were then distributed more broadly through news reports and photos in local newspapers.

Discussion

With proper planning, diverse, re-established grasslands can provide multiple benefits to conservation lands and to agricultural lands used for bioenergy (Tilman *et al.* 2006). Harvesting can provide an easier and less expensive management alternative to prescribed burning on conservation lands. As riparian buffers, prairies can be planted and subsequently harvested alongside waterways, with bioenergy revenues potentially making such buffers profitable and allowing them to be wider than they otherwise could be. Wet and mesic prairies could be established to catch drain-tile runoff of food-crop fields and remove nitrogen and other nutrients before they reach natural watersheds, increasing bioenergy yields in the process. Integrating animal production for food onto grassland bioenergy fields may offer further opportunities for managing a multifunctional system. For example, if grazers use mixed-species grasslands in the spring and consume cool-season grasses, that could maximize the growth of warm-season grasses and bring higher bioenergy yields. Lower potential yields than heavily managed monoculture grasses are offset by putting to use land that is not suitable for heavy management, and providing broad conservation services to society across the landscape.

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