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Research article

Surface water retention systems for cattail production as a biofuel

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ABSTRACT

Surface water retention systems act to reduce nutrient pollution by collecting excess nutrients within a watershed via runoff. Harvesting aquatic biomass, such as the invasive cattail, from retention systems removes nutrients absorbed by the plant from the ecosystem permanently. Harvested biomass can be used as a renewable energy source in place of fossil fuels, offsetting carbon emissions. The purpose of this research was to simulate cattail harvest from surface water retention systems to determine their ability to provide suitable growing conditions with annual fluctuations in water availability. The economic and environmental benefits associated with nutrient removal and carbon offsets were also calculated and monetized. A proposed upstream and existing downstream water retention system in southern Manitoba were modelled using a system dynamics model with streamflow inputs provided by a physical hydrologic model, Modélisation Environmentale Communautaire - Surface and Hydrology (MESH). Harvesting cattail and other unconventional feedstocks, such as reeds, sedges, and grasses, from retention systems provided a viable revenue stream for landowners over a ten-year period. This practice generates income for landowners via biomass and carbon credit production on otherwise underutilized marginal cropland invaded with cattail. The economic benefits promote wetland habitat restoration while managing cattail growth to maintain biodiversity. Excess nitrogen and phosphorus are also removed from the ecosystem, reducing downstream nutrient loading. Utilizing surface water retention systems for cattail harvest is a best management strategy for nutrient retention on the landscape and improving agricultural resilience.

1. Introduction

Water retention systems are ideal sites for nutrient removal as they act as concentration sites within a watershed for collecting excess nutrient. Another benefit of water retention systems is their capacity to support the growth of plant biomass for bioproducts (Government of Manitoba, 2014). Biomass is beneficial for the production of bioenergy, nutrient retention and extraction, and carbon offsets (Government of Manitoba, 2014; Grosshans et al., 2014). Bioproducts are created from biomass, biological material with stored energy from sunlight (Natural Resources Canada, 2016a). The importance of biomass is growing globally for its use as an energy source, its capacity to be converted into biofuel, and its value in reducing global dependence on fossil fuels (Grosshans et al., 2012a, 2014; Natural Resources Canada, 2016a). Biofuels are a low carbon renewable resource due to biomass' capacity to absorb carbon dioxide from the atmosphere (Grosshans et al., 2012a). Canada has access to a variety of biomass resources through agriculture, forestry, and municipal waste (Natural Resources Canada, 2016b; Tampier et al., 2003). Bioenergy from these resources has become an important renewable energy source in the country. Seventy power plants devoted to bioenergy are scattered across Canada, providing 6% of the country's total energy (Natural Resources Canada, 2016c). As of 2013, Canada was the fifth highest producer of liquid biofuels generating 2% of global biofuel production. The United States, Brazil, the European Union, and China hold the top four spots for biofuel production globally (Natural Resources Canada, 2016b).

Cattails (*Typha* species) are one biomass resource being promoted for their bio production capacity and nutrient management by the International Institute for Sustainable Development (IISD). The IISD have recently illustrated the viability of a commercial cattail biomass market by achieving large-scale cattail harvesting and commercial biomass fuel production in Manitoba, Canada (Grosshans et al., 2016). Cattails can be harvested while still green

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using the same equipment often used for cutting forage crops, a MacDon rotary disc mower. A roll conditioner attachment is used to improve the time required for the harvested cattail to dry (Grosshans et al., 2014). This naturally occurring plant is found in wetlands throughout Canada and the United States (United States Department of Agriculture, 2017). Across North America, significant resources are allocated by landowners towards the management of wetland invasive species (Lawrence et al., 2016). Hybrid cattail has been identified as one of the most difficult wetland invasive species to manage due to its significant impacts on wetland biodiversity and ecosystem functions (Lawrence et al., 2016). Hybrid cattail is prolific, highly adaptable, resists pests, and aggressively regenerates (Pratt et al., 1988). Once a cattail stand has established itself, it is quick to expand, resulting in a reduction in plant diversity and waterfowl habitat within the wetland (Lawrence et al., 2016). The prolific growth of this invasive species has led to exploration of using cattail as a biomass crop (Dubbe et al., 1988; Grosshans et al., 2014; Lawrence et al., 2016; Pratt et al., 1988). The characteristics that make hybrid cattail a difficult species to manage also favorably lend themselves to biomass production. Pratt et al. (1988) found wetland plant crops provided four times more mass per hectare (ha) than typical agricultural crops in north central United States. Research on harvesting cattail as a biomass crop also highlighted its effectiveness as a management strategy for the species (Pratt et al., 1988).

Cattails grow most successfully on marginal crop land and in wet areas and thus do not compete with prime agricultural lands (Grosshans et al., 2014; Maddison et al., 2005; Pratt et al., 1984). Harvesting cattails can subsequently provide landowners with additional revenue on underutilized land (Grosshans et al., 2014; Lake Winnipeg Stewardship Board, 2006; Pratt et al., 1984). Additionally, cattails absorb nutrients via their roots as they grow. Cattail harvest effectively removes these nutrients from the landscape, reducing downstream nutrient loading (Lawrence et al., 2016).

By harvesting wetland plants such as cattails, surface water retention sites gain the additional benefit of providing biomass and increased nutrient management (Government of Manitoba, 2014; Grosshans et al., 2014). Retention systems that hold water in the reservoir throughout the growing season increase the growth potential of cattails. The excess moisture drowns out grasses not adapted to flood conditions that compete with the aquatic cattail while providing improved soil moisture conditions for cattail germination (Grosshans et al., 2014). When compared to other sources of biomass, cattails also have the highest average yield with the lowest time to maturity (Dubbe et al., 1988; Laffont-Schwob et al., 2015; Pratt et al., 1984). Cattails have good densification properties, high quality fibre and high energy density making them suitable for biofuel development (Grosshans et al., 2014). The plant not only absorbs up to 0.02 tonnes/ha of P as it grows, depending on cattail density, but it also removes 0.16 tonnes of captured N/ha while providing 15–20 tonnes/ha of biomass (Grosshans et al., 2014; Lawrence et al., 2016). When mixed plants are harvested from wetlands which includes cattails, nutrient removal is reduced to 0.01 tonnes of captured P/ha, 0.08 tonnes of captured N/ha, and 10 tonnes/ha of harvested biomass (Grosshans, 2016). Table 1 outlines the percentage content of carbon, hydrogen, and nitrogen in seven typical biomass resources.

Biomass burners and pellet stoves can burn pellets created from the harvested cattails. Cattail biomass converted to a solid fuel has a heat capacity of 17–20 GJ/tonne(GJ/t) (Grosshans et al., 2014). Table 2 provides an energy value comparison between cattails and common biomass and fuel sources. While its energy value comparison is similar to other biomass fuel sources, cattails have the benefit of occupying underutilized land and growing rapidly (Svedarsky et al., 2016). Additionally, once cattail pellets are burned, the resultant ash can then be utilized for fertilizer due to its high levels of P (Grosshans et al., 2012b, 2011). The IISD has demonstrated that cattail harvest from 250 ha can remove up to five tonnes of P from the system each year (Grosshans et al., 2014; La Salle Redboine Conservation District, 2013). Wetland habitats also benefit from cattail harvesting as their removal allows for more sunlight to stimulate new plant growth (Grosshans et al., 2011).

Table 1
Cattail carbon, hydrogen, and nitrogen content compared to seven typical biomass resources. Adapted from Grosshans et al. (2012a).

Biomass	Carbon (%)	Hydrogen (%)	Nitrogen (%)
Cattail	39–44	5.4–5.7	0.83–1.3
Wood (various)	48–53	6.0	0.00–0.35
Straw	42	5.1	0.38
Maize stover	44	–	0.61
Coal (Anthracite)	80	–	0.90
Coal (Bituminous)	53–82	–	1.0–1.5
Coal (Lignite)	40	–	0.70
Natural Gas	75	24	0.90

Table 2
Energy value comparison between cattails and common biomass and fuel sources. Adapted from Grosshans et al. (2012a).

Biomass	Calorific Value GJ/t
Cattail	17.3–18.2
Cattail pellet (no binder)	19.9
Cattail pellet (starch binder)	16.8
Wood pellet (standard)	16.9–18.0
Wood (15% mc)	15.0–22.3
Wood chips	10.4
Wheat straw (dry)	17.9
Wheat straw (20% mc)	13.7
Flax straw (dry)	20.0
Flax straw (20% mc)	15.4
Maize stover	17.6
Helianthus annuus (sunflower) hulls	19.7
Propane	46.4
Natural gas	48.0
Fuel oil	37.0
Coal (anthracite)	29.5
Coal (bituminous)	20.9–33.4
Coal (lignite)	15.3

The purpose of this research is to simulate the economic revenue stream created via cattail harvest from surface water retention systems. As well, whether surface water retention systems provide suitable growing conditions for cattail harvest long term. The additional revenue stream cattail harvest creates for the farmer can impact the likelihood of widespread retention system adoption. This in turn, supports a best management strategy for nutrient retention on the landscape.

2. Methods

2.1. Study site

Pelly's Lake is a naturally occurring retention basin in south central Manitoba that flows into the Boyne River, Manitoba (see Fig. 1). The geographic coordinates of Pelly's Lake in decimal degrees are −98.8307, 49.5810. Attempts had been made to drain the land to increase hay production. However, due to the presence of an underground spring, the area remained too wet. Engineering a dike installation at the north-east end of the land allowed for multiple benefits. With this improvement, Pelly's Lake now provides floodwater retention from spring runoff, groundwater recharge when the water is released mid-June, increased hay and biomass crop production, and nutrient removal (Grosshans et al., 2012a;