

42. Willow riparian buffer systems for biomass production in the black soils of Elie, Manitoba, Canada

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1. Related practices and hot-spots

Riparian Buffers; Black soils

2. Description of the case study

The case study was conducted in the La Salle Watershed North-West of Elie in the Red River region of southern Manitoba, Canada (Figure 44). The objective of the study was to examine the effects of willow cutting planting density on biomass yield, soil organic carbon sequestration, nutrient runoff mitigation, and biodiversity enhancement using three intra-row planting densities. The willow riparian buffer was planted using *Salix dasyclados* cultivar “India” in a replicated block design using three intra-row spacing treatments: 0.5 m – single row; 1.0 m – single row; 0.75 m – double row Swedish design; and a control grass plot in the Spring of 2013 (Figure 45; Photo 90 and Photo 91). Baseline soil sampling was completed in August of 2013. Soil samples were collected at depths of 0-15 cm, 15-30 cm, and 30-45 cm at a distance of 0.5 m away from the willow buffer planting.

Biometric data was collected on an annual basis in late fall (late October or early November) after senescence: the number of whips/stool, the basal diameter of the largest whip in each stool and the height of the tallest whip in each stool for each of the ten willow stools. Wildlife diversity was recorded using trail cameras installed on the site (Photo 92). Harvesting of willow biomass was completed in 2016 and 2019 in early November by coppicing at approximately three inches above the root collar (Photo 93 and Photo 94). Wet and dry biomass weights were collected to determine the total biomass from each of the field rows, mid-row, and riparian row in the sub-plot of each treatment. All the biomass outside of the sub-plots were removed from the plot and chipped.

In this case study, we are focused on soil organic carbon sequestration and present data from the single row 1.0 m spacing planting treatment only.



Figure 44. Physical location map of case study site (Latitude: 49°57'29"N, Longitude: 97°55'17"W). Inset-map of Canada with blue dot showing geographical location of Elie, Manitoba.

Source: Google Earth and J. Blair English, Fardausi Akhter, Raju Soolanayakanahally, Laura Poppy, Henry de Gooijer, Daniella Giardetti, Rhonda Thiessen, Chris Stefner

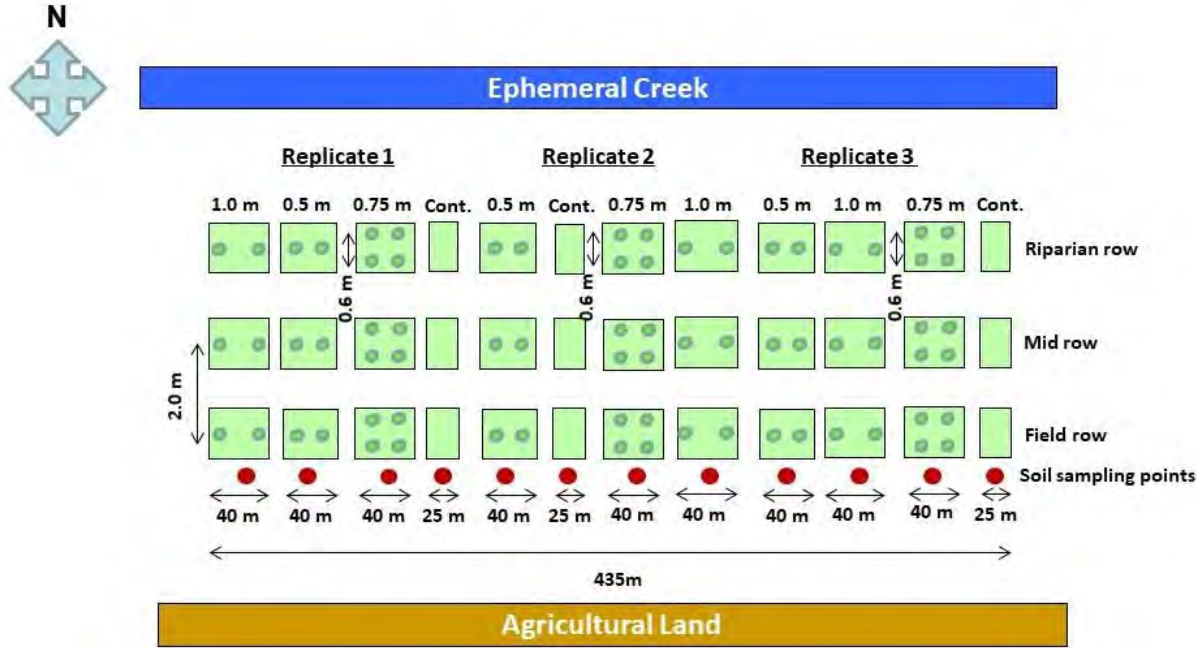


Figure 45. Willow riparian buffer system design layout

3. Context of the case study

Geographic Location: LaSalle Watershed North-West of Elie in the Red River region of southern Manitoba.

Pedo-climatic context: Morris soils in the Canadian System of Soil Classification are described as imperfectly drained Gleyed Solonchic Black Chernozemic soils (Soil Classification Working Group, 1998; Manitoba Soil Series Descriptions (MAFRI, 2010) developed on moderately to strongly calcareous fine-textured lacustrine deposits.

Climate: A sub-humid continental climate in the eastern prairie region of western Canada (Powell, 1978).

Land-use: Dryland annual cropping of mixed grains, oilseeds, soybeans and corn.

Coverage of the case study: Local.

4. Possibility of scaling up

The number of options for edge of field technologies, such as willow riparian buffers, is limited but growing could be scaled up and applied in different geographic areas and climatic conditions. Willow riparian buffers can be used to intercept agrochemicals (above ground drift) and nutrient run-off, create wildlife habitat, and generate revenues from biomass for energy production (Hénault-Ethier *et al.*, 2019). The system can be particularly suitable for marginal lands, jurisdictions with legislated wetland buffers, or areas that cannot be farmed and, therefore, would otherwise not generate income for the farmer. Willow riparian buffer could also be adapted to meet the different site-specific needs of the landowners. For example, the system can stabilize eroding banks or shorelines of adjacent water bodies in a crop field and provide physical separation of agricultural activities from sensitive aquatic areas.

Salix spp. (willow) is a commonly grown species for short-rotation biomass production (3-year harvest cycle). The species responds well to coppicing, is an early successional species with rapid growth and high resprouting capacity (Wilkinson *et al.*, 2007). Recent breeding advances have allowed for more productive, faster-growing, better adapted willow with higher resistance to insects, disease, and environmental conditions (Huang *et al.*, 2020).

5. Impact on soil organic carbon stocks

Baseline soil organic matter varied with soil depth with the highest percentage observed on the 0-15 cm (9.4%) followed by 15-30 cm (6.2%) and 30-45 cm (5.2%). Using the assumption that 58% of organic matter is organic carbon and soil bulk density is 1.07 g/cm³ for Red River Clay soils (MAFRI, 2008), soil organic carbon stock is calculated and presented in Table 174. An increase in SOC is observed at all soil depths, which is consistent with soil N, P and K.

Table 174. Evolution of SOC stocks in the 6-year study

Location	Climate zone	Soil type	Depth (cm)	Duration (Years)	Baseline C stock (tC/ha)	Current C stock (tC/ha)	Additional stock (tC/ha/yr)
Prairie Region (MB)	Cool temperate Moist	Solonetzic Black Chernozem	0-15	6	87.23	144.29	+9.51
			15-30		57.72	89.37	+5.28
			30-45		48.41	73.26	+4.14

6. Other benefits of the practice

6.1. Improvement of soil properties

Changes in soil properties at a depth of 0-15 cm are presented below. In general, an increase in soil macronutrients (N, P, and K) is observed. Salts concentrations decreased over time.

Table 175. Changes in soil properties

Soil Properties	2013	2019
NO ₃ -N (ppm)	1.83 (0.29)	7.67 (5.03)
NH ₄ -N (ppm)	5.63 (0.80)	12.13 (3.82)
P-Olsen (ppm)	31.33 (9.29)	38.33 (20.21)
K (ppm)	280.33 (41.77)	476.67 (35.73)
Ca (ppm)	4452.33 (363.53)	4751.33 (471.57)
Mg (ppm)	1577.33 (247.69)	1713.67 (364.66)
Na (ppm)	94.66 (22.50)	66.66 (4.04)
Cl (ppm)	15.5 (2.78)	11.67 (7.37)
Salts (mmhos/cm)	0.84 (0.36)	0.52 (0.04)
pH	6.43 (0.06)	6.63 (0.25)
CEC (meq)	36.53 (3.15)	39.53 (5.34)

6.2 Minimization of threats to soil functions

Table 176. Soil threats

Soil threats	
Nutrient imbalance and cycles	Sequestration of excess N, P, and K
Soil salinization and alkalization	Reduction of salinization by managing the water table through willow buffer water usage/evapotranspiration
Soil contamination /pollution	Mitigation of agricultural fertilizer runoff

6.3 Mitigation of and adaptation to climate change

Using CBM-CFS3 simulations, the average potential annual rate of carbon sequestration in cumulative harvest was estimated at 5.4 tC/ha/yr for marginal lands on the Canadian prairies (Amichev *et al.*, 2012).

7. Potential drawbacks to the practice

7.1 Decreases in production (Food/fuel/feed/timber/fibre)

Although data is not available for the Prairie region, reduced agricultural output due to land-use tradeoffs was recorded from Eastern Canada (Lantz, Chang and Pharo, 2014). The maintenance of buffer strips is a crucial factor governing their longer-term nutrient retention effectiveness. Without maintenance, buffer strips are known to become a potential source of nutrients rather than a sink (Hille *et al.*, 2019).

8. Recommendations before implementing the practice

Before a willow riparian buffer is implemented, it is necessary to investigate regional regulations and guidelines that may impact the ability to incorporate the buffer (Hénault-Ethier *et al.*, 2019). It is also essential to work with regional experts to receive recommendations on selecting suitable hardy cultivars (Nissim *et al.*, 2013) as well as appropriate planting, maintenance, and management procedures (Truax *et al.*, 2017; Fortier *et al.*, 2010). Proper planning and site preparation will lead to greater success of the planting and investigating the end-use of the biomass, necessary harvesting regime/equipment, and finding local markets before implementing the willow riparian buffer practice.

9. Potential barriers for adoption

Table 177. Potential barriers to adoption

Barrier	YES/NO	
Biophysical	Yes	Suitable willow cultivars that match the site's environmental conditions must be selected to maximize the buffer's effectiveness (Nissim <i>et al.</i> , 2013). Limitations may arise from the regional availability of desired cultivars.
Economic	Yes	Adoption of willow riparian buffers may be limited by costs associated with the loss of land previously used for crop production, initial establishment, and maintenance (Lantz, Chang and Pharo, 2014; Ssegane <i>et al.</i> , 2016).
Institutional	Yes	Local legislation in some jurisdictions may limit the management (harvesting) of riparian buffer strips within legislated buffer zones limiting the removal of above biomass and impact of nutrient removal.
Knowledge	Yes	Knowledge of agroforestry systems by grain and livestock producers, who operate the land, is limited. The use of appropriate management and maintenance practices, including the selection of suitable cultivars, use of black plastic mulching, and regular harvesting, will influence the long-term success of the buffer (Truax <i>et al.</i> , 2017; Fortier <i>et al.</i> , 2010).
Other	Yes	Although the production of biomass can provide financial incentives for land managers, harvesting of small areas may be challenging due to machinery access difficulties (Zak <i>et al.</i> , 2019).

Photos



Photo 90. Paired row willow growth at the end of the 2013 establishment year growing season, August 27, 2013



Photo 91. Vegetation growth after three years of establishment, July 26, 2016



Photo 92. Whitetail deer spotted along Elie Willow Buffer, October 8, 2016



Photo 93. Rhonda Thiessen using Felco shears to harvest willow buffer biomass subplot, November 7th, 2016



Photo 94. AAFC employees harvesting Elie willow buffer biomass - November 18th, 2019

References

- Amichev, B.Y., Kurz, W.A., Smyth, C. & VanRees, K.C.J. 2012. The carbon implications of large-scale afforestation of agriculturally marginal land with short-rotation willow in Saskatchewan. *Global Change Biology*, (4): 70–87. <https://doi.org/10.1111/j.1757-1707.2011.01110.x>
- Fortier J., Gagnon, D., Truax, B. & Lambert, F. 2010. Nutrient accumulation and carbon sequestration in 6-year-old hybrid poplars in multiclonal agricultural riparian buffer strips. *Agriculture, Ecosystems & Environment*, 137(3-4): 276–287. <https://doi.org/10.1016/j.agee.2010.02.013>
- Hénault-Ethier, L., Lucotte, M., Smedbol, É., Gomes, M.P., Maccario, S., Laprise, M.E.L., Perron, R., Larocque, M., Lepage, L., Juneau, P. & Labrecque, M. 2019. Potential Efficiency of Grassy or Shrub Willow Buffer Strips against Nutrient Runoff from Soybean and Corn Fields in Southern Quebec, Canada. *Journal of Environmental Quality*, 48(2): 352–361. <https://doi.org/10.2134/jeq2016.10.0391>
- Hille, S., Graeber, D., Kronvang, B., Rubæk, G.H., Onnen, N., Molina-Navarro, E., Baattrup-Pedersen, A., Heckrath, G.J. & Stutter, M.I. 2019. Management options to reduce phosphorus leaching from vegetated buffer strips. *Journal of Environmental Quality*, 48(2): 322–329. <https://doi.org/10.2134/jeq2018.01.0042>
- Huang, X., Soolanayakanahally, R.Y., Guy, R.D., Shunmugam, A.S.K. & Mansfield, S.D. 2020. Differences in growth and physiological and metabolic responses among Canadian native and hybrid willows (*Salix* spp.) under salinity stress. *Tree Physiology*, 40(5): 652–666. <https://doi.org/10.1093/treephys/tpaa017>
- Lantz, V.A., Chang, W. & Pharo, C. 2014. Benefit-cost analysis of hybrid willow crop production on agricultural land in eastern Canada: Assessing opportunities for on-farm and off-farm bioenergy use. *Biomass and Bioenergy*, 63: 257–267. <https://doi.org/10.1016/j.biombioe.2014.01.027>
- Manitoba Agriculture, Food, and Rural Initiatives (MAFRI). 2008. Manitoba Soil Management Guide [Online]. [Cited 19 December 2020]. <https://www.gov.mb.ca/>
- Manitoba Agriculture, Food, and Rural Initiatives (MAFRI). 2010. Manitoba Soil Series Descriptions [Online]. [Cited 19 December 2020]. <https://www.gov.mb.ca/>
- Nissim, W.G., Pitre, F.E., Teodorescu, T.I. & Labrecque, M. 2013. Long-term biomass productivity of willow bioenergy plantations maintained in southern Quebec, Canada. *Biomass and Bioenergy*, 56: 361–369. <https://doi.org/10.1016/j.biombioe.2013.05.020>
- Powell, J.M. 1978. *Climatic Classifications of the Prairie Provinces of Canada*. Essays on Meteorology and Climatology. Canadian Forestry Service, Northern Forest Research Centre, Edmonton, Alberta.
- Soil Classification Working Group. 1998. *The Canadian System of Soil Classification, 3rd ed.* Agriculture and Agri-Food Canada Publication 1646 (revised), 187 pp.
- Ssegane, H., Zumpf, C., Negri, M.C., Campbell, P., Heavey, J.P. & Volk, T. 2016. The economics of growing shrub willow as a bioenergy buffer on agricultural fields: A case study in the Midwest Corn Belt. *Biofuels, Bioproducts and Biorefining*, 10:776–789. <https://doi.org/10.1002/bbb.1679>

Truax, B., Gagnon, D., Lambert, F. & Fortier J. 2017. Riparian buffer growth and soil nitrate supply are affected by tree species selection and black plastic mulching. *Ecological Engineering*, 106: 82–93.
<https://doi.org/10.1016/j.ecoleng.2017.05.037>

Wilkinson, J.M., Evans, E.J., Bilsborrow, P., Wright, C., Hewison, W.O. & Pilbeam, D.J. 2007. Yield of willow cultivars at different planting densities in a commercial short rotation coppice in the north of England. *Biomass and Bioenergy*, 31(7): 469–474. <https://doi.org/10.1016/j.biombioe.2007.01.020>

Zak, D., Stutter, M., Jensen, H., Egemose, S., Vodder Carstensen, M., Audet, J., Strand, J.A., Fewerbacj, P., Hoffmann, C.C., Christen, B., Hille, S., Knudsen, M., Stockan, J., Watson, H., Heckrath, G. & Kronvang, B. 2019. An assessment of the multifunctionality of integrated buffer zones in northwestern Europe. *Journal of Environmental Quality*, 48: 362– 375.
<https://doi.org/10.2134/jeq2018.05.0216>