Carbon sequestration in riparian buffer systems; influenced by soil texture, vegetation type and age in Ontario, Canada

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Introduction

- Anthropogenic activities such as, burning of fossil fuel and deforestation have resulted in enhanced greenhouse gases (GHGs), mainly CO_2 in the atmosphere causing global warming and it is likely to reach 1.5°C above the pre-industrial era between 2030 and 2052 (IPCC, 2018).

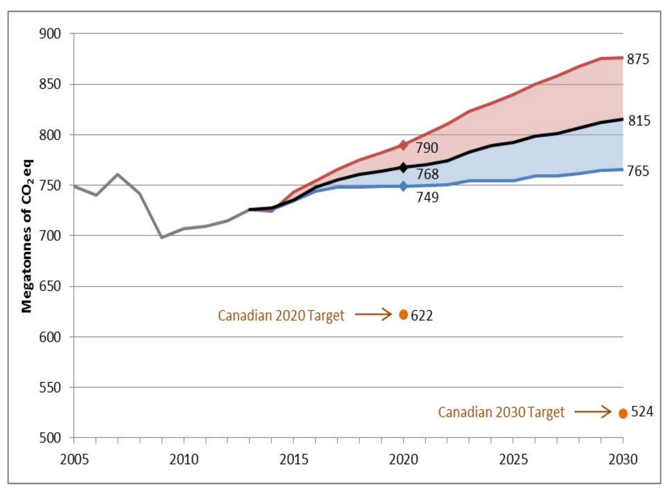

Figure 1: Canada's Emission Projections in 2020 and 2030 (Mt CO_2 eq)
[Environment and Climate Change Canada]

- In Canada, greenhouse gases emission projections under a "with current measures" scenario are projected to be 768 megatonnes (Mt) CO_2 eq in 2020 and 815 Mt CO_2 eq in 2030 and Canada's Federal government has set the target to reduce emissions to 622 Mt by 2020 and to 524 Mt by 2030 (Figure 1).
- Measures should be taken to avoid or mitigate the adverse effects of increased atmospheric CO_2.

- "4 per 1000 initiative" attempts to increase the soil organic carbon (SOC) at an annual growth rate of 0.4% or 4‰ per 1000 in the soil C stocks, which could halt the CO_2 increase in the atmosphere through human activities (https://www.4p1000.org/).
- One of the strategies to reduce CO_2 from the atmosphere is carbon (C) sequestration; the process of taking up CO_2 from the atmosphere and storing it in the stable C reservoirs.

- **Riparian buffer systems (RBS);** a form of agroforestry where strips of perennial plants, shrubs and trees, are mainly used to control non-point source of pollutions reaching the waterways and have the potential to sequester atmospheric CO_2 (Palone and Todd, 1997) (Figure 2). However, the effect of vegetation, their age class and type, and soil texture on soil C sequestration by RBS is not well understood.

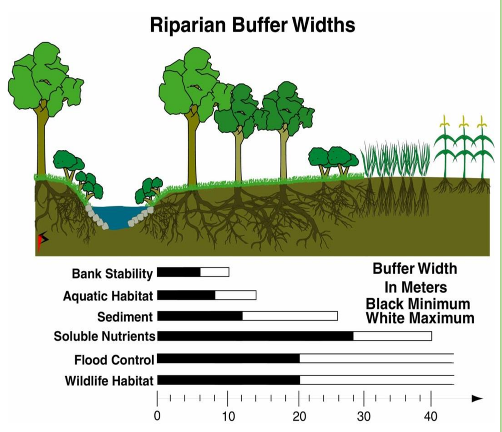

Figure 2: Riparian buffer systems
(https://chainimage.com/stocks/riparian-buffers-can-often-be-identified-by-the-presence-of-sedges)

Objectives

1. To quantify soil organic carbon (SOC) as influenced by soil texture (clay, loam), vegetation type (coniferous, deciduous) and age class [young (<15 years), mature (≥30 years)].
2. To compare land use influence on SOC sequestration potential within RBS and in adjacent agricultural lands.

Materials and Methods

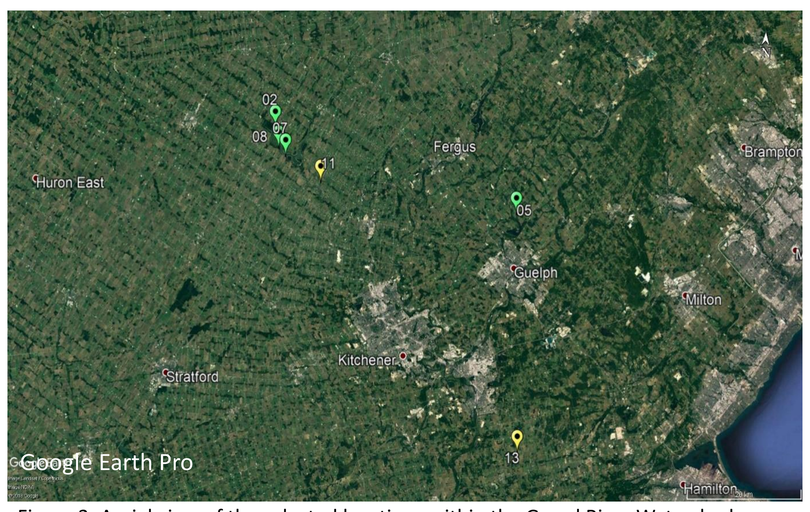

Figure 3: Aerial view of the selected locations within the Grand River Watershed (GRW), Ontario, Canada. **Green symbols**– Mature vegetation sites [02- Mature deciduous loam (MDL), 05- Mature coniferous loam (MCL), 07- Mature coniferous clay (MCC) and 08- Mature deciduous clay (MDC)] and **Yellow symbols-** Young vegetation sites [11- Young deciduous loam (11a - YDL), Young coniferous loam (11b - YCL) and 13- Young deciduous clay (13a - YDC), Young coniferous clay (13b – YCC)].

- The study was executed on selected riparian buffer systems within the Grand River Watershed (GRW), southern Ontario, Canada. A network of replicated riparian buffer treatments (n = 3) comprising of a factorial array of 2 tree types (coniferous vs. deciduous) x 2 tree age classes (<15 years (young) vs. ≥ 30 years (mature)) x 2 soil texture classes (clay vs. loam) were identified within the GRW.

Young deciduous buffer system | Young coniferous buffer system | Mature deciduous buffer system | Mature coniferous buffer system

Figure 4: Photographs of sampled riparian buffer systems

- In each replicated riparian buffer treatment, a strip transect of 150 m^2 (5m x 30m) along the stream was laid out and further, it was divided into ten equal plots (5m x 3m = 15m^2). Five plots (pseudo replicates) were selected randomly within the transect for soil sample collection. With respect to all treatment combinations, 8 sites were selected (4 mature sites and 4 young sites), and adjacent agricultural fields associated with each selected RBS were laid out for soil sample collection.

- Adjacent agricultural fields were treated as control treatment for SOC comparisons with RBS. Transect in agricultural land was laid out perpendicular to the RBS due to the slope effect. RBS are established in the low land along the streams whereas, agricultural lands are located away from the stream in the upland. Therefore, to reduce the slope effect on SOC quantification several soil samples (0-30 cm, 3 samples = 3 samples x 5 locations along the transect = 15 samples) were collected along the transect in the agricultural land, and they were pooled to obtain 5 samples (3 soil samples were pooled to obtain one sample per each location along the transect) per site for C analyses.

- SOC were determined using the dry combustion procedure as outlined in the Leco CR-412 manual (Wang and Anderson 1998).

- Three factor factorial in completely randomized design (CRD) with two levels in each factor were used to conduct this study. The SOC data were analyzed using PROC GLIM in SAS 9.4 package.

Results

- In mature sites, SOC content was greater in deciduous buffers in clay soils (MDC: 177.6 +5.48 Mg C ha^{-1}) and the lowest was in coniferous buffers in clay (MCC: 134.4 +5.10 Mg C ha^{-1}) soils (Figure 5).

- Among the young buffers, SOC content was higher in deciduous buffers in clay soils (YDC: 143.3 +9.29 Mg C ha^{-1}) and the lowest was in coniferous buffers in loam soils (YCL: 94.7 +4.64 Mg C ha^{-1}) (Figure 5).

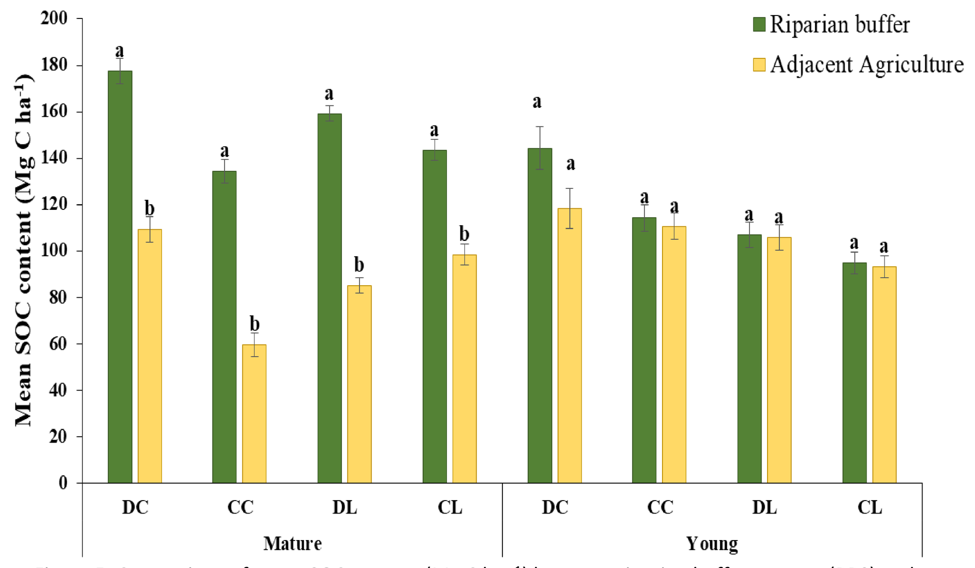

Figure 5: Comparison of mean SOC content (Mg C ha^{-1}) between riparian buffer systems (RBS) and respective adjacent agricultural fields in each site sampled at 0 – 30 cm depth in Grand River Watershed, southern Ontario in 2017-2018. [DC –deciduous clay, CC- Coniferous clay, DL- Deciduous loam, CL- Coniferous loam]. With in a site, means followed by the same letter are not significantly different according to a Tukey's multiple range test (P≥0.05). Error bars indicate the standard error of the mean (n=5).

- All mature buffer systems had significantly higher SOC content than their respective adjacent agricultural fields (Figure 5).

- All RBS, irrespective of their age, had greater SOC content than their respective adjacent agricultural fields (Figure 5).

Discussion

- SOC was higher in the buffers having deciduous trees in both clay and loam soils, which indicates that the deciduous trees have more potential to sequester atmospheric CO_2 in the soil than coniferous trees (Figure 5). It is also interesting to note that the above observation was not influenced by the maturity stage of the deciduous trees. The biomass C sequestration too was found to be higher for deciduous than coniferous trees (results not presented) , which could have resulted in higher SOC sequestration in the soil from the decomposing litter and fine root turnover. However, even though coniferous trees shed needles throughout the year, the amount of the needles is low, and the fact that the needles are highly lignified the coniferous litter may not contribute to SOC accumulation at a higher rate compared to deciduous trees (Krishna and Mohan, 2017.

- Young deciduous clay buffers also had higher level of SOC than mature coniferous clay (Figure 5). These results also suggest that when deciduous trees are grown on clay soils, they have more potential to accumulate / sequester SOC.

- Soil organic matter (SOM) is directly proportional to the total C inputs, hence SOC can be increased with increasing C inputs. In this study, soils under RBS receive continuous C inputs through litter fall, fine root turnover, root decay, root exudates, understory annual and perennial plant inputs etc. Whereas, OM additions in agricultural lands are mainly from crop residues, cover crop residues and through organic manure application during the cultivation. Even though on a unit land area basis agricultural lands can receive more organic C residues as indicated above, due to soil disturbance and surface runoff losses SOC accumulation is limited and thereby resulted in low SOC accumulation in adjacent agricultural fields. Further, as RBS are undisturbed ecosystems SOC sequestration is significantly higher when compared to adjacent agricultural fields.

Conclusion

- SOC sequestration was greater in RBS with deciduous trees in clay soils than coniferous tree buffers irrespective of vegetation age.

- Land use change on SOC
  - All RBS sequestered greater SOC than the respective adjacent agriculture lands.
  - All mature RBS sequestered significantly higher SOC than adjacent agriculture land.

- Grand River Conservation Authority (https://www.grandriver.ca/en/index.aspx) has digitized 11,000 km length of degraded stream in Grand River Watershed. If all streams are planted on both sides; 22, 000 km of RBS can be established.

- This will significantly contribute to Canada's climate change mitigation efforts as there are more than 35 Conservation Authorities in the Province of Ontario alone and therefore significant amount of watershed areas can be planted with riparian buffer systems.

References

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