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Research Brief

From the Southwest BC Bioregion Food System Design Project

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Carbon Stocks and the Impact of Agricultural Expansion in a Regionalized Food System

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Abstract

The carbon stored in woody perennial vegetation is an important tool for agricultural climate change mitigation. These carbon stocks are at risk of being lost to agricultural land conversion, releasing their carbon into the atmosphere. There are a number of on-farm carbon storage practices, such as hedgerows and riparian buffers, which can allow more carbon stocks to co-exist alongside food production. Farmland in the Southwest BC bioregion is 39.7% non-production perennial vegetation, primarily in the form of large, contiguous stands of trees. The carbon stocks are equivalent to 19.4 MT CO_2e (carbon equivalents). When agriculture is expanded in Southwest BC, 84.3% of carbon stocks are potentially lost to deforestation. The planting of hedgerows and riparian buffers would compensate for only 27.7% of the loss however. Carbon stock loss represents a large trade-off with agriculture expansion. The most effective way to protect carbon stocks is the preservation of large areas of forest in addition to utilization of other on-farm carbon storage practices.

Planting and maintaining non-production perennial vegetation on farmland can help reduce the diminuition of carbon stocks from agriculture while still allowing food to be produced.

What are carbon stocks?

An ecosystem service is an ecological process that occurs naturally and benefits human communities. One valuable ecosystem service plants provide is pulling carbon from the atmosphere through the process of photosynthesis and storing it in their tissues (Chapin et al., 1990). The most substantial carbon storage occurs in perennial woody plants, which do not fully die back every year. Their wood is primarily made of carbon-based compounds and these perennials hold onto this carbon for decades or even centuries, longer than many other forms of carbon storage (Morgan et al., 2010). This attribute of woody perennial plants makes trees and forests an invaluable sink for atmospheric carbon, which is referred to as carbon stocks (Chapin et al., 1990).

The capacity of the landscape to sequester and store carbon is enhanced by maintaining patches of forest or stands of trees and shrubs. As land is cleared, forests are removed and their wood begins to decompose. During decomposition, the carbon that had been accumulating in the plant, often for decades, is released back into the atmosphere. The expansion of farmland poses a risk to forests and has the potential to cause the release of a large amount of carbon into the atmosphere (Chaplin-Kramer et al., 2015). The United Nations has initiated several programs, such as REDD+, to help countries collect data on their valuable carbon stocks and prevent deforestation due to human activity (Strassburg et al., 2010). Planting and maintaining non-production perennial vegetation (NPPV), using carbon storage practices such as hedgerows and riparian buffers, on farmland can help reduce the diminution of carbon stocks from agriculture while still allowing food to be produced (Schroeder, 1994). Carbon stock assessment is a useful way to measure the climate change mitigation potential of forests as well as the negative impacts of deforestation.

In the Southwest BC bioregion, there have been limited studies on carbon stocks. Studies such as Wilson's (2010) and the Vegetation Resource Inventory (BC Ministry of Forests Lands and Natural Resource Operations, 2013), have largely focused on the extensive forests surrounding the bioregion's farmland while agricultural land use inventories in the region have focused on farm activities providing only coarse data about vegetation on farmland (Ministry of Agriculture, 2014). There is currently no clear data on the distribution of NPPV on the Southwest BC Bioregion's agricultural land. The objective of the Carbon Stock indicator is to better understand the trade-off between expanding local food production and aboveground carbon stocks by mapping current NPPV, simulating scenarios of NPPV loss as a result of agriculture expansion and estimating resultant carbon stock rate changes.

Methods

A land cover map of Southwest BC bioregion's NPPV was developed through a combination of satellite data and existing land cover maps. Agriculture & Agri-Food Canada (AAFC) 2011 crop maps were augmented with 2013 RapidEye satellite images and used to distinguish NPPV from farm fields and urban/ suburban areas. Existing spatial data on roads, railways, water bodies, and wetlands were used to improve the accuracy of the land cover map. The resulting map provided the total area of NPPV as well as information on the size and location of these vegetated areas (Rallings, 2016). NPPV was categorized using patch size and location and types per Javorek & Grant (2011) (Table 1).

Land use scenarios were developed to model the potential impact of changes to agricultural land use in Southwest BC Bioregion. Dorward (2016) describes the methods used to develop the following land use configurations for 2050:

1. Baseline – 2011 Baseline land cover
2. Expand Land – NPPV located on farmable land is removed
3. Mitigate Impacts - NPPV located on farmable land is removed, however, Hedgerows and Riparian Buffers are either preserved or implemented wherever possible.

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Table 1: Categorizes of non-production perennial vegetation (NPPV), modified from Javorek & Grant (2011), and their assigned carbon density per ha. Definitions of NPPV describe the method of differentiating the category in the land cover map

NPPV CATEGORY	DEFINITION	CARBON (TONNES/ HECTARE)
Large Stands	> 9 ha (as per woodlands, with interior in Jarovek & Grant, 2011)	87.5
Small Elements	< 9ha (as per woodlands, no interior in Jarovek & Grant, 2011)	61.3
Riparian Buffers	Within 30m of waterways	87.5
Hedgerows	Small Elements within 6m of roadways/parcel boundaries	61.3
Peatland	Located on organic soil*	5.0
Wetlands	Located on wetlands or swamps**	5.0

**Soil classified from National Soil Database (Agriculture and Agri-Food Canada, 1998).*
***Wetlands classified from BC Freshwater Atlas (Integrated Land Management Bureau, 2009).*

To determine total aboveground carbon stocks in each scenario, carbon per hectare values were assigned to each category of mapped NPPV (Table 1). Per existing (forestry) literature, a mean value of biomass per hectare was calculated using the high and low forest biomass values found in the Southwest BC Bioregion (Penner et al., 1997). Wetland NPPV was assigned a lower biomass value due to the sparse nature of aboveground vegetation. Biomass values were converted to carbon using a factor of 0.55, as carbon on average constitutes 55% of plant tissues (Ponce-Hernandez et al., 2004). These carbon stocks were reduced by 30% for Small Elements and Hedgerows as per the findings of Czerepowicz et al. (2012) wherein smaller on-farm NPPV tended to have lower carbon content due to management by landowners.

Carbon per hectare values were multiplied by the area of NPPV (per type) to provide the total megatons carbon (MT C) in the Southwest BC bioregion. The high and low value estimates reflect the potential range of carbon stock. The carbon stocks estimate did not include soil carbon in NPPV areas or soil carbon in agricultural soils. Future work could do so.

Results and Discussion

NPPV covered 39.7% of the Southwest BC bioregion in the baseline land cover analysis. This value is greater than those previously reported in other local farmland assessments, such as the Agricultural Land Use Inventory (Ministry of Agriculture, 2014). Although 62.8% of the vegetation was in the form of large, contiguous stands of trees (Large Stands), small, fragmented patches of trees and shrubs (Small Elements & Hedgerows) collectively contributed the next largest portion, followed by Riparian Buffers (Figure 1). Baseline carbon stocks amounted to 5.3 MT C (± 2.6 MT C) (Figure 2).

The high error is attributable to the wide range of potential vegetation types and age classes found in the Southwest BC bioregion. The distributions of carbon stocks mirrored the land cover indicated in Figure 1 with the exception of Peatlands and Wetlands & Swamps, which contributed little aboveground carbon relative to their area. The amount of carbon stored in the aboveground NPPV was equivalent to 19.4 MT Carbon Dioxide Equivalent (CO2$_e$) (± 9.6 MT CO2$_e$); an amount equal to that emitted by nearly 4.1 million cars driven for one year

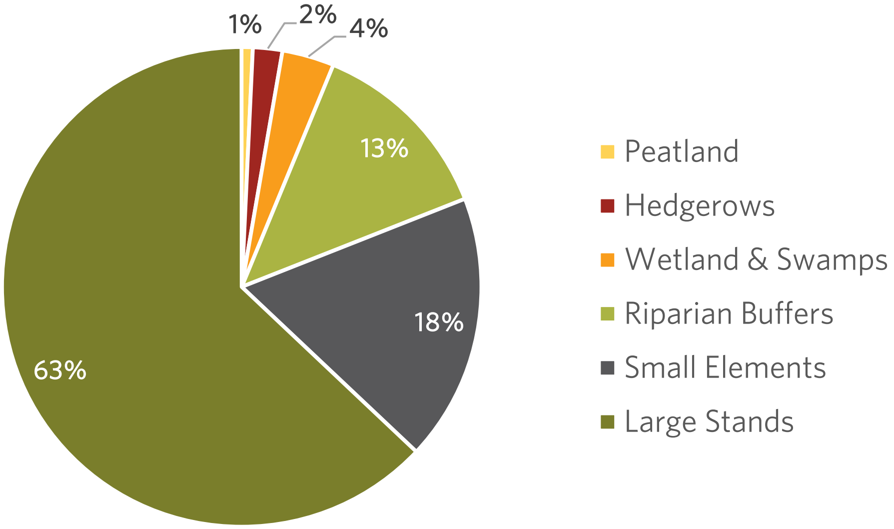

Figure 1: Distribution of Baseline NPPV land covers in the Southwest BC bioregion

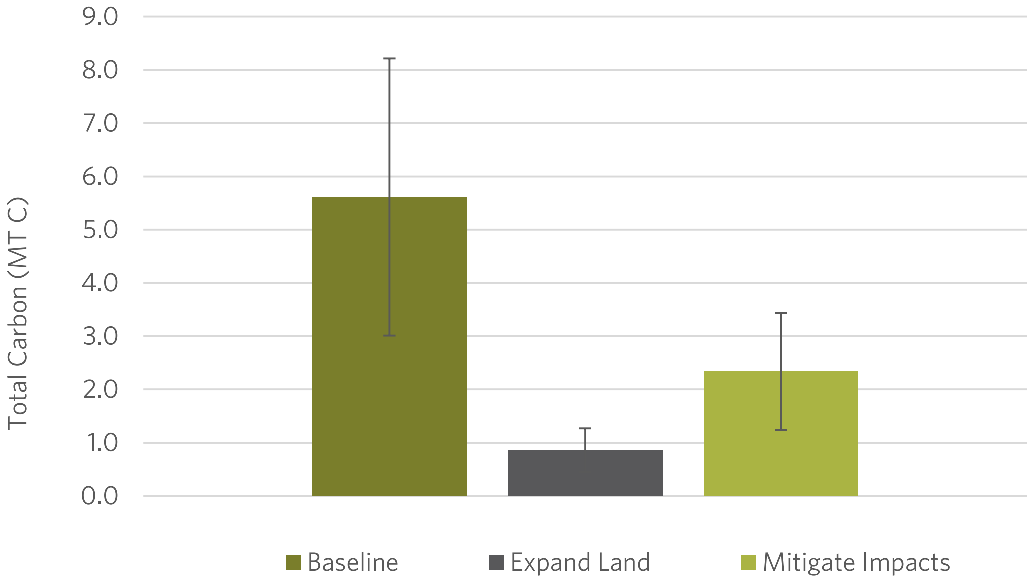

Figure 2: Total megatons carbon (MT C) in Southwest BC by land use scenario

(EPA, 2014). If the current Southwest BC agricultural footprint remained stable, these NPPV carbon stocks could be protected regardless of the food produced.

In the Expand Land scenario where agricultural land use is greatly increased, there is an estimated loss of 84.3% of aboveground carbon stocks, leaving only 0.83 MT C (± 0.41 MT C) on non-arable lands or conservation areas (Figure 2). The greatest losses come from diminished Large Stands, Small Elements and Hedgerows, which collectively had an 80% decrease in area. Between 2013 and 2050, the loss of NPPV carbon would annually contribute an average of 0.44 MT CO_2e to the bioregion's GHG emissions. The likely conversion of these carbon stocks to agricultural production is driven by the arability of the land on which they are located.

When NPPV is augmented with habitat mitigation in the same scenario (Mitigate Impacts), NPPV area is nearly tripled, increasing the total aboveground carbon stocks to 2.3 MT C (± 1.1 MT C) (Figure 2). The planting of new NPPV would mitigate the bioregion's annual emissions of GHGs by an average 0.27 MT CO_2e per year during a 20-year vegetation maturation period. Despite these improvements with the use of habitat mitigation, the total carbon stock increases only range from 4.3% to 12.0% of the 2011 baseline.

The expansion of agricultural production presents a substantial trade-off with the bioregion's carbon stocks due to the potential loss of extensive forested lands within the ALR. Large Stands account for 57.0% of carbon stocks in the bioregion.

To minimize the loss of carbon stocks as agricultural production expands, it would be most effective to prevent the loss of existing NPPV stands, especially Large Stands, whenever possible, in addition to planting hedgerows or riparian buffers. If farmland is cleared for food production, other measures to mitigate associated loss of stored carbon should be implemented. Examples of mitigation measures include: increasing soil organic matter, planting new hedgerows or riparian buffers, and maintaining existing perennial vegetation along parcel boundaries and waterways.

References

Agriculture and Agri-Food Canada. (1998). Canada Land Inventory, National Soil Database. Ottawa, Ontario. Retrieved from http://sis.agr.gc.ca/cansis/nsdb/cli/index.html

BC Ministry of Forests Lands and Natural Resource Operations. (2013). Vegetation Resource Inventory. Retrieved from https://www.for.gov.bc.ca/hts/vri/

Chapin, F. . S. I., Schulze, E.-D., & Mooney, H. A. (1990). The Ecology and Economics of Storage in Plants. Annual Review of Ecology and Systematics, 21, 423–447.

Chaplin-Kramer, R., Sharp, R. P., Mandle, L., Sim, S., Johnson, J., Butnar, I., … Kareiva, P. M. (2015). Spatial patterns of agricultural expansion determine impacts on biodiversity and carbon storage. Proceedings of the National Academy of Sciences, 112(24), 7403–7407. doi:10.1073/pnas.1406485112

Czerepowicz, L., Case, B. S., & Doscher, C. (2012). Using satellite image data to estimate aboveground shelterbelt carbon stocks across an agricultural landscape. Agriculture, Ecosystems & Environment, 156, 142–150. doi:10.1016/j.agee.2012.05.014

Dorward, Caitlin, Sean Michael Smukler, and Kent Mullinix. 2016a. “A Novel Methodology to Assess Land-Based Food Self-Reliance in the Southwest British Columbia Bioregion.” Renewable Agriculture and Food Systems: 19.

EPA. (2014). Greenhouse Gas Equivalencies Calculator.
Integrated Land Management Bureau. (2009). BC Freshwater Atlas. Retrieved from http://geobc.gov.bc.ca/base-mapping/atlas/fwa/index.html

Javorek, S. K., & Grant, M. C. (2011). Trends in wildlife habitat capacity on agricultural land in Canada, 1986-2006. In Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 14. Canadian (p. 46). Ottawa, Ontario: Canadian Councils of Resource Ministers.

Ministry of Agriculture. (2014). Metro Vancouver Regional District Land Use Inventory. Abbotsford, BC. Retrieved from http://www.al.gov.bc.ca/resmgmt/sf/gis/lui_reports/MetroVan-Regional2010_11_ALUIReport.pdf

Morgan, J. A., Follett, R. F., Allen, L. H., Del Grosso, S., Derner, J. D., Dijkstra, F., … Schoeneberger, M. M. (2010). Carbon sequestration in agricultural lands of the United States. Journal of Soil and Water Conservation, 65(1), 6A–13A. doi:10.2489/jswc.65.1.6A

Penner, M., Power, K., Muhairwe, C., Tellier, R., & Wang, Y. (1997). Canada’s Forest Biomass Resources: Deriving Estimates from Canada’s Forest Inventory (No. BC-X-370). Victoria, BC.

Ponce-Hernandez, R., Koohafkan, P., & Antoine, J. (2004). Assessing carbon stocks and modelling win-win scenarios of carbon sequestration through land-use changes. Rome, Italy.

Rallings, A. (2016). Evaluating potential impacts of hedgerow and riparian buffer management options on habitat and carbon stocks within the Agricultural Land Reserve of the Lower Fraser Valley, British Columbia. University of British Columbia.

Schroeder, P. (1994). Carbon storage benefits of agroforestry systems. Agroforestry Systems, 27, 89–97.

Strassburg, B. B. N., Kelly, A., Balmford, A., Davies, R. G., Gibbs, H. K., Lovett, A., … Rodrigues, A. S. L. (2010). Global congruence of carbon storage and biodiversity in terrestrial ecosystems. Conservation Letters, 3(2), 98–105. doi:10.1111/j.1755-263X.2009.00092.x

Wilson, S. J. (2010). Natural Capital in BC’s Lower Mainland: Valuing the benefits from Nature. Vancouver, BC. Retrieved from http://www.davidsuzuki.org/publications/downloads/2010/DSF_lower_mainland_natural_capital.pdf

About ISFS

The Institute for Sustainable Food Systems (ISFS) is an applied research and extension unit at Kwantlen Polytechnic University that investigates and supports regional food systems as key elements of sustainable communities. We focus predominantly on British Columbia but also extend our programming to other regions.

About the Southwest BC Bioregion Food System Design Project

The Southwest BC Bioregion Food System Design project was conceptualized at ISFS in 2012 and concluded in 2016. The project was conceived as a "research project within a research project," with the broad goals of developing a method to delineate the interconnected economic, food self-reliance, and environmental stewardship potentials of a bioregional food system and applying the method to the Southwest BC bioregion. To our knowledge, this project is the first of its kind. Project research briefs are one means used to present project findings. They are intended to report detailed, topic specific project methods and results. For other research briefs from the project, as well as the project report and summary, and peer-reviewed publications, please visit kpu.ca/isfs.

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