# Developing a 100-year Retrospective Carbon Budget for the Sooke Watershed, Vancouver Island, BC.

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## Abstract

Boreal and temperate forest ecosystems are significant components of terrestrial carbon (C) cycling and play an important role in the global C cycle. Understanding C cycling processes at the landscape or watershed scale is a prerequisite for upscaling results to higher orders of analysis at the national, continental and global scale. As well, modeling the baseline C budget of a landscape enables a comparison between different management and disturbance regimes. To address the role that deforestation through reservoir creation as well as forest harvest and natural disturbance, have had on watershed level forest C budgets, historic spatial, inventory and disturbance data were assembled for lands of the Sooke watershed in the Greater Victoria Water Supply Area (GVWSA). A retrospective C budget for the watershed for the period 1910 to 2012 is being developed using the spatially-explicit version of the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3). CBM-CFS3 is an inventory-based C budget modelling tool that has been used to simulate forest C dynamics at national, regional, and operational scales and has the capability to include lateral transfers of dissolved organic C (DOC) to aquatic systems. Water quantity and DOC monitoring data from three subwatersheds in the Sooke will be used to estimate annual C fluxes to the reservoir and data used to parameterize DOC transfers in the model. Alternative disturbance scenarios and sensitivity analysis of DOC fate will be examined with the model to determine the relative importance of disturbance regimes and lateral DOC transfers on watershed level C budgets.

## Background and Relevance

Northern forest ecosystems play an important role in global C cycling and are currently considered to be a net C sink for atmospheric C (IPCC, 2007). Whether forested regions or landscapes are net C sources or sinks depends primarily on the degree and type of disturbance (fire, harvest, insect infestation, deforestation etc.) (IPCC, 2007). A disturbance is defined as "any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability or the physical environment"(Pickett & White, 1985), affecting biogeochemical interactions in general and C cycling processes in particular (Liu, et al., 2011). Many terrestrial ecologists believe that substantial C dioxide ($CO_2$) emissions have occurred from the disturbance and destruction of terrestrial vegetation and soils (Schlesinger, 1997).

This study will address a gap in current forest C budget research ie. the relative importance of including dissolved organic C (DOC) as a dynamic C export mechanism from the terrestrial system. Also, as a contemporary C budget has not been conducted for the Sooke watershed, this consolidated forest cover/disturbance dataset which will include all known anthropogenic disturbances, will present a baseline management scheme from which alternative management scenarios can be compared to. The Capital Regional District's (CRD) strategic mandate to improve the understand of the potential effects that climate change may have on forest ecosystems and water quality/hydrology as well how forest management plans could amplify or reduce these impacts will be partly addressed by this research. The high value placed on the Sooke watershed as the primary source of water for the region, as well as the prevalence of old growth stands and unique disturbance history culminate in an appealing and topical case study of the impact reservoir creation can have on the C budget of a watershed.

In 1910 the 8500 ha Sooke watershed was dominated by old-growth and mature Douglas-fir forests, when land clearing around the existing 372 ha Sooke Lake began, with dam completion and formation of the 452 ha Sooke reservoir in 1915. Dams were raised and the reservoir was subsequently expanded in 1970 to 608 ha, 1980 to 672 ha, and again in 2002 to 812 ha, resulting in further land clearing for the reservoir and dam infrastructure. While conversion of forest to reservoirs means a decrease in forest area able to sequester C, reservoir sediments can also potentially serve as a sink for terrestrial C transported in streams, which might otherwise be respired if it remained in the stream. Such an aquatic DOC flux is an important gap in terrestrial C budget models and currently in CBM-CFS3 the flux assumed to be nil.

While some localized forest harvest occurred in the 1920s and 1930s, more widespread forest harvest began in 1954 and over the next 43 years over 2600 ha of forest was cut and replanted or permanent roads installed. All forest harvesting for timber production ceased in the late 1990s and besides the final reservoir raising in 2002, no large scale disturbance have occurred.

## Methods and Data

In order to ascertain the forest cover history (and potentially disturbance type) of polygons that have experienced a disturbance event, a series of historical inventories or maps will be used. The CRD has recently received an updated 2012 forest cover inventory; this dataset will be the primary source of information for all stands that have not been disturbed (i.e. old forest). The 1996 inventory was done prior to the clearing for the 2002 reservoir raising and therefore it will provide forest typing information of the cleared/harvested land that has not been retained in the 2012 inventory. A 1975 forest cover inventory was collected to thorough standards relative to the a 1964 forest cover map, however the 1964 map preserves the forest typing and disturbance information for the areas that were flooded in 1970 and therefore will also be required. The BC Ministry of Forests has provided a series of 1955/56 forest cover maps that will aid in determining disturbance dates and forest cover types for that time period. Also, an engineering map of Sooke Lake in 1911 that describes the original lake shore and area to be cleared for the initial raising will be instrumental in delineating those initial disturbance events. Forest cover information will also be supplemented and inferred using a series of historical airphotos of the watershed (air photo dates to be used included 1930, 1957, 1968, 1984, 1998, 2002 and 2012).

These data sources will be digitized and georeferenced (if not already) and brought into a GIS (ArcGIS 10.0/10.1) for processing. Forest cover attributes including stand establishment date, species composition, site index, and volume estimates will be used during the selection of growth and yield equations that are primary inputs into the CBM-CFS3. Disturbance date, disturbance type, non-productive land information and regeneration type will be retrieved from the series of forest cover inventory maps and will be used to parameterize the C transfers and describe the flow of C between the donating (pre-disturbance) and receiving (post-disturbance) pools (Trofymow et al. 2008; Kurz et al. 2009). These spatial datasets will be overlayed together creating a combined forest cover-disturbance mosaic over the full extent of the study area. By compiling the spatial forest cover data into a combined geodataset this process will result in each individual polygon having a unique disturbance history encompassing the time span 1910 to 2012.

Using DOC concentrations collected intermittently for three Sooke subwatersheds over the last 15 years and regular water flow measurements for the same subwatersheds, a sensitivity analysis will be performed within the CBM-CFS3 investigating the aquatic flux of C from the terrestrial landscape and the fate of this allochthonous C in the inland aquatic environment.

## Results

Preliminary results include the combined disturbance-forest cover dataset which will describe the natural and anthropogenic disturbance and forest cover history, included deforestation events due to reservoir raising and changes in forest cover attributes through disturbance within the Sooke Watershed. Future results will be a current and historical baseline C budget for the Sooke Watershed.

## Conclusions

Mapping historical disturbances and forest cover changes across the Sooke watershed will allow us to construct a current and retrospective C budget in order to ascertain the impact that past management practices have had on the C budget of the land base over time. This baseline spatially explicit C budget can inform future land management plans that may strive to maximize the C stored on these water supply lands.

While modeling C dynamics at the national and global scales is a substantial objective, understanding and modeling C exchange at the watershed level will prove useful in explaining the higher order interactions. Integrating C budgets between the terrestrial and inland aquatic components is important because as much of the C lost from flowing streams has its origins within the terrestrial ecosystem, this terrestrial respiration can occur meters to kilometers away from where the C was originally fixed (Cole, et al., 2007). Therefore, if only one component of the C cycle within a watershed is measured or modeled, there exists a missing mechanism for C export out of the ecosystem.

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