A Review of Mapping Support Tools - Carbon

Action for Adaptation

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Executive Summary

The Action for Adaptation Project is being delivered by UBC Botanical Garden, the Coastal Douglas-fir Conservation Partnership (CDFCP) and UBC Okanagan. The project is focused on supporting local governments and First Nations in south-west British Columbia (BC) that are looking to accelerate how they mitigate and adapt to the effects of climate change through direct land protection, restoration of degraded habitats, and development of new or enhanced nature-based solutions.

This report is part of a series that presents the results of conversations and a review of mapping layers currently used for planning and decision making. Local government and First Nations representatives have indicated that there are six mapping layers that are currently missing at a resolution that they can use and this report series focused on four of these layers: terrestrial carbon; ecosystem connectivity; land cover; and species at risk and culturally significant species and places.

This report is specifically focused on currently available terrestrial carbon mapping layers. The review had the following objectives:

- To identify through conversations what elements of mapping improved user experience.
- To identify mapping layers that are actively used in decision making and have features that enhance the user experience.
- To identify mapping layers that have led to a change in behaviour and management of the natural environment.

Through conversations and the review of existing terrestrial carbon mapping the following issues were identified:

- There is inconsistency and lack of consensus in relation to the methods being used to map carbon storage and sequestration.
- LiDAR is the best technology for mapping above ground biomass, but it is expensive to collect. Therefore, the best method is to map biomass accurately once and then track change using remote sensing imagery.
- Remotely-sensed methods to quantify carbon are still in development and requires on the ground quantification of biomass / carbon.
- Carbon plots are biased as they are often undertaken where the licensees are operating and are consequently of low value to local governments.
- Artificial Intelligence (AI) is being used to track land use change from satellite imagery, but there is still the need for human review.

This review highlights the currently available tools that estimate above and below ground carbon storage and existing approaches for mapping carbon sequestration. The review also highlights how the scale of modelling and mapping (e.g. 10 m vs 250 m) and methods impacts the overall carbon quantification accuracy (e.g. WWF vs Metro Vancouver).

The approach to biomass modelling presented by 3GreenTree could provide detailed estimates of above ground carbon now and in the future, reflecting the impact of local government and First Nation decision making but it will not be able to fill the gap relating to historical changes of carbon stores from 2007 to

present currently needed for carbon accounting. Ideally changes to terrestrial carbon due to land use change will be provided by the province through the Community Energy and Emissions Inventory (CEEI).

Contents

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1 Introduction

1.1 Background

The Action for Adaptation Project is being delivered by UBC Botanical Garden, the Coastal Douglas-fir Conservation Partnership (CDFCP) and UBC Okanagan. The project is focused on supporting local governments and First Nations in south-west British Columbia (BC) that are looking to accelerate how they mitigate and adapt to the effects of climate change through direct land protection, restoration of degraded habitats, and development of new or enhanced nature-based solutions.

In 2022 and 2023 conversations were undertaken with representatives from federal, provincial and local government, First Nations, not for profit conservation organisations, carbon developers, consultants and ecosystem services finance companies. The purpose of the conversations was to identify gaps and opportunities relating to policy, decision making tools and incentives.

These discussions highlighted the need for specific mapping layers and guidance on the integration of nature-based solutions into local and regional government and First Nations plans and strategies. To meet the needs of the targeted end users Action for Adaptation is working on the production of a Biodiversity Atlas and a Regional Climate Adaptation Plan.

1.2 Study Area

The study area for the Action for Adaptation project is indicated in **Figure 1** by the blue line boundary. The layers reviewed in this report are not limited to those developed in the area of interest.

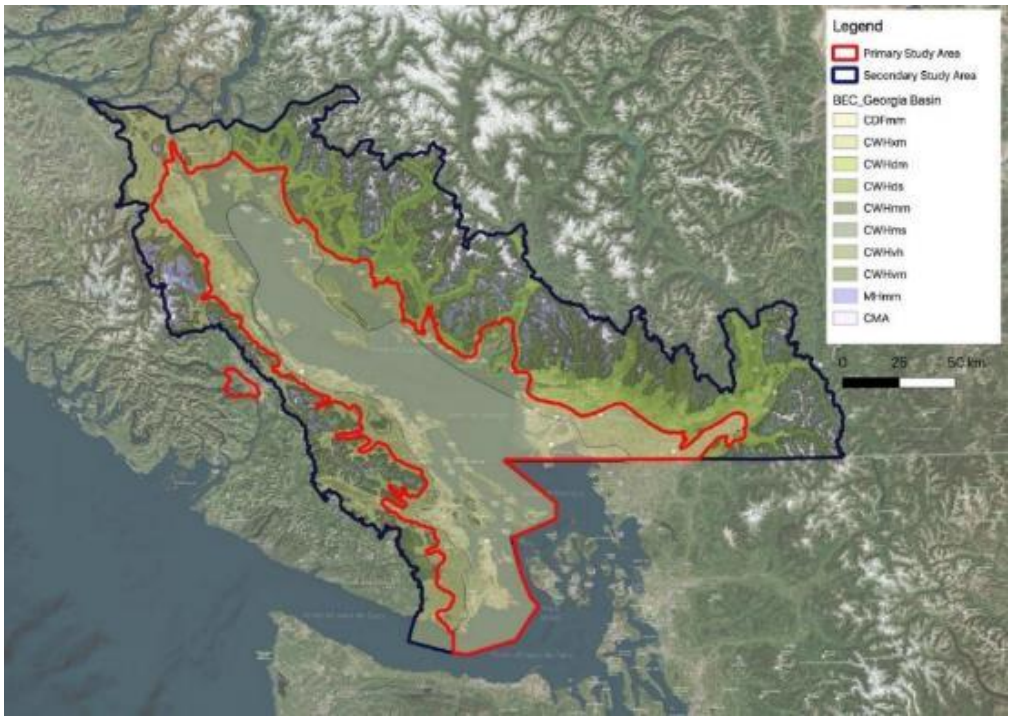

Figure 1. The red line boundary represents the CDFCP area of interest which incudes the CDFmm and CWHxm1. The blue line boundary represents the Action for Adaptation boundary which includes the catchments that feed the ecosystems in the CDFmm and CWHxm1.

1.3 Purpose of this Report

This report is part of a series that presents the results of conversations and a review of mapping layers currently used for planning and decision making. Local government and First Nations representatives have indicated that the mapping layers that are currently missing at a resolution that they can use are:

- Terrestrial carbon
- Landcover and land cover change
- Environmentally Sensitive Areas (ESAs)
- Ecosystem Connectivity
- Species at Risk and Culturally Significant Species and Places
- Hydrologically sensitive ecosystems.

This report is specifically focused on terrestrial carbon mapping layers. The review had the following objectives:

- To identify through conversations what elements of mapping improved user experience.
- To identify mapping layers that are actively used in decision making and have features that enhance the user experience.
- To identify mapping layers that have led to a change in behaviour and management of the natural environment.

This report should be read in conjunction with the following reports:

- A Review of Decision Support Tools that Protect Nature-Based Solutions.
- A Review of Mapping Support Tools – Landcover.
- A Review of Mapping Support Tools – Ecosystem Connectivity.

2 Terrestrial Carbon

Mapping layers have been developed to help with the quantification of carbon storage and sequestration. This review looks at the benefits and limitations of these tools (refer to **Appendix A, Table A1** for summary information). These mapping layers reviewed may present a quantification of carbon for:

- Above ground carbon or biomass stored in woody matter such as stem, bark, branches and twigs;
- Below ground carbon or biomass stored in soil and roots; or
- Both, sometimes referred to as total carbon or total biomass.

2.1 Summary of Conversation Comments

Conversations in 2022 and 2023 identified the following gaps and opportunities in relation to available carbon mapping (CDFCP, 2022 and CDFCP & UBC Botanical Gardens 2023):

- There is inconsistency and lack of consensus in relation to the methods being used to map carbon storage and sequestration.
- LiDAR is the best technology for mapping above ground biomass, but it is expensive to collect. Therefore, the best method is to map biomass accurately once and then track change using remote sensing imagery.
- Remotely-sensed methods to quantify carbon are still in development and requires on the ground quantification of biomass / carbon.
- Carbon plots are biased as they are often undertaken where the licensees are operating and are consequently of low value to local governments.
- Artificial Intelligence (AI) is being used to track land use change from satellite imagery, but there is still the need for human review.
- Modelling and tracking of carbon emissions is a new science and there isn't consensus on the best overall approach to carbon storage and sequestration mapping.
- Carbon mapping should be produced for decision makers to consider how their policy decision will affect carbon stores.
- Local government carbon accounting (to meet carbon neutrality goals) does not take into consideration the loss of carbon caused by land conversion.
- First Nations are not tracking GHG emissions as their impact has been minimal compared to colonisers.
- Biodiversity and carbon storage is being taken into consideration by First Nations in relation to forestry management.

2.2 World Wildlife Fund-Canada and McMaster University Carbon Mapping

The World Wildlife Fund-Canada and McMaster University quantified and mapped above and below ground carbon throughout Canada at a 250 m resolution using models that pulled on satellite data and existing field plots (**Figure 2**). The individual layers can be downloaded from a research data portal. The WWF have an interactive map of the total carbon layer. The map is broken down into 10 km hexagons and the user can click on a hexagon to obtain an estimate of the carbon stored per hexagon. The resolution of the interactive map would not provide the detail that planners and decision makers need when trying to understand GHG emissions in relation to land use change.

The downloadable layers have a higher level of precision (250 m), but the calculations are based on a national model, meaning that local calculations may provide a different estimates of carbon stores.

Benefit: Estimates of above and below carbon in 2021 for all ecosystems in Canada.

Considerations for use:

- It is a national model at 250m resolution.
- Local models may produce different numbers, particularly if backed of with additional field data.
- Changes in carbon can be tracked going forward when cross referenced to land cover change, but it could not be used to quantify changes to carbon stores back to 2007, which is needed for carbon accounting.

Figure 2 McMaster WWF Canada Interactive map of carbon stores for Vancouver Island - 10 km resolution.

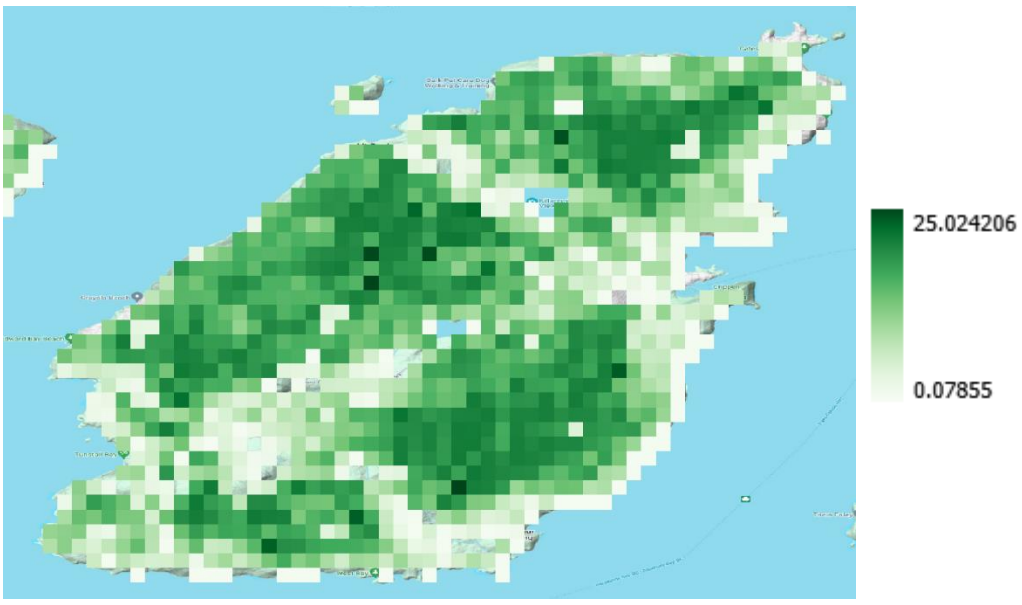

Figure 3 McMaster WWF Canada forest carbon mapping at 250m, excluding below ground carbon.

2.3 CDFCP Carbon Project Feasibility Assessment

In 2022 the CDFCP commissioned a carbon developer called 3GreenTree to undertake a carbon feasibility study of land within the CDFCP boundary. This generated several GIS layers that enable total carbon per land parcel to be estimated. This project produced a simplified land cover map (water, cut block, non forested vegetation, urban, coniferous and deciduous) from Sentinel-2 imagery at a 10 m resolution. A map classifying forest age was produced using a machine learning algorithm that was trained using the spectral signatures of forest pixels and the age classes within the Vegetation Resource Inventory (VRI). The project then estimated biomass within the forest from Sentinel-2 data using the VRI as training data for the model. The GIS layers can be obtained from the CDFCP (**Figure 4**).

Benefits: Predictions of above ground biomass are completed at a resolution that local government and First Nations could use to assess the impacts of their decision making on above and below ground carbon stores.

Considerations for use:

- Biomass estimates are focused on forested ecosystems.
- The dataset has limited spatial coverage e.g. CDFCP boundary.
- The dataset has not been peer reviewed.
- The dataset is not available online but can provided on request.
- The dataset is a snapshot in time so could be used for carbon accounting going forward but couldn't be used to quantify changes in carbon since 2007.

Figure 4 3GreenTree - Predicted biomass on Bowen Island using Sentinel-2 imagery at 10 m.

2.4 Vegetation Resource Inventory (VRI) Biomass

The mapping completed by 3GreenTree drew on the VRI to train their models, but it is also possible to produce estimates of above ground carbon directly from the VRI. The VRI includes estimates of stem, branch, bark and foliage biomass for each of polygon. This can be converted to above ground carbon by multiplying total biomass by 0.5[1] (**Figure 5**). The VRI does not include information relation to below ground carbon (soil and roots).

Benefit: Provides biomass estimates for all forested land in BC. The VRI can be downloaded from the BC Data Catalogue.

Considerations for use:

- The dataset doesn't provide estimates of carbon this information is extrapolated from biomass.
- Biomass estimates are for forested ecosystems only.
- Biomass figures are for above ground carbon only.
- Mapping has been undertaken at different time periods and might not reflect recent harvesting.

Figure 5 Example of using VRI biomass to estimate above ground carbon on Bowen Island.

2.5 Local Government Carbon Mapping

Local governments have produced carbon storage maps for their jurisdiction including the Islands Trust (2014) and Metro Vancouver (2019). The assessment of carbon was undertaken on behalf of the Islands

[1]Patersson, H, Hom, S, Stahl, G, alger, D, Fridman, J, Lehtonen, A, Lundstrom, A, Makipaa (2012) Individual tree biomass equations or biomass expansion factors for assessment of carbon stock changes in living biomass – A comparative study. Forest Ecology and Management. Volume 270 pp 78-84.

Trust used a model called FORECAST. The approach taken for Metro Vancouver pulled on several sources of biomass and carbon information including:

- Vegetation Resource Inventory (VRI).
- Land cover classification / LiDAR.
- Sensitive Ecosystem Inventory.
- Agricultural soil carbon mapping.

Reports for these layers are available online but the layers themselves could not be found to view them. It is anticipated that they can be accessed by local government staff.

Benefits: Produced at a scale that is meaningful to local government.

Considerations for use:

- Static approach to mapping.
- Approaches to mapping carbon are evolving and may have changed since 2014 and 2019. Mapping not accessible online.

2.6 Greenprint Net Carbon Sequestration

The Maryland Department of Natural Resources (DNR) tool called Greenprint includes several layers that were generated as part of a program called Accounting for Maryland's Ecosystem Services (2017). These layers include a Net Carbon Sequestration (mT per yr) layer which quantifies yearly net carbon sequestration in Maryland's forests and wetlands. The calculation was completed in 2017 (**Figure 6**). The location of forested ecosystems was identified through a LiDAR derived tree canopy layer and a land-use / land cover layer at a resolution of 30 m. The carbon sequestration potential of these forested ecosystems was calculated using values within the US Forestry Services i-tree landscape online tool. The location and extent of wetlands came from a DNR dataset. The sequestration and emissions rate for wetlands was taken from literature. The areas on **Figure 6** that indicate a loss of carbon through the year are freshwater wetland and river ecosystems.

Benefits: Produced at a scale that is meaningful to regional government and First Nations (30 m). It may also be useful to municipal government. Visually appealing and easy to understand. The layer presents net carbon sequestration rather than only stored carbon, which is potentially a better representation of the fluxes of carbon.

Considerations for use:

- Static approach to mapping so it is unlikely to be useful for historical carbon accounting, but it would enable an assessment of the impact of future changes.
- Calculations of carbon are based on carbon emissions factors.

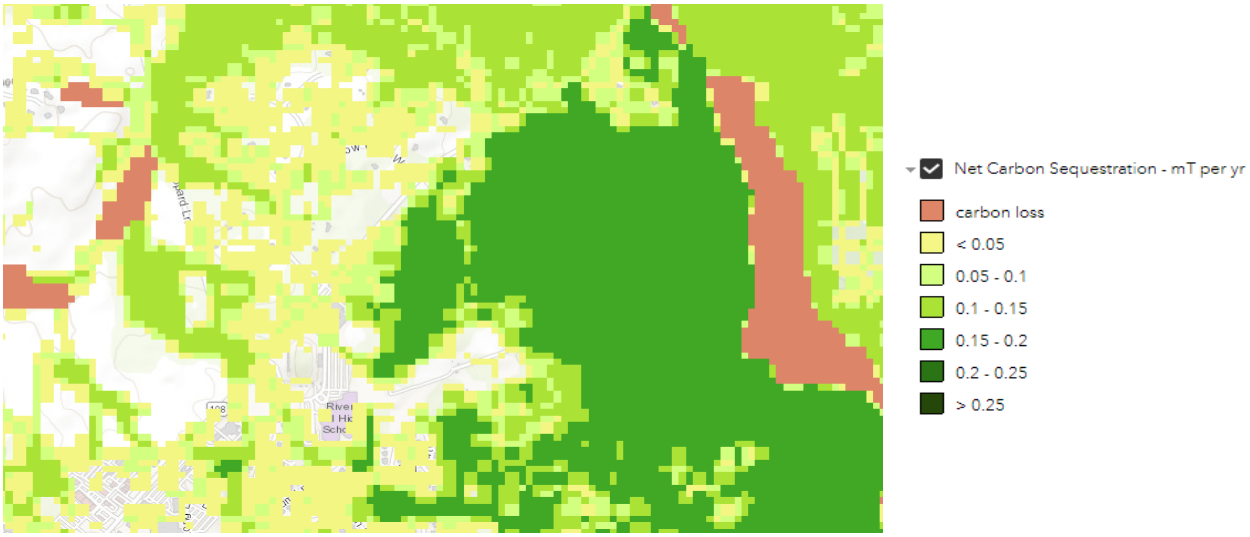

Figure 6 Greenprint Net Carbon Sequestration mapping layer.

2.7 UN Biodiversity Lab- Irrecoverable Land Carbon and Biomass Carbon Density

The UN Biodiversity Lab includes 10+ layers presenting estimates of terrestrial and marine carbon. One of the mapping layers that can be viewed has been developed by Noon et al (2022) and is called irrecoverable land carbon (**Figure 7**). This mapping presents the location of natural carbon stores that are vulnerable to release due to human activities and if lost could not be restored by 2050. The mapping is completed at a 1 km resolution. It represents biomass and soil carbon per hectare. This mapping illustrates that there is high irrecoverable carbon density in the Pacific Northwest of North America.

Benefits: Illustrates that the loss of carbon (trees / soil) in the study area will have an impact on the worlds ability to meet its GHG 2050 emissions reductions targets.

Considerations for use:

- The 1 km resolution will impact on local governments and First Nations ability to use this tool for local planning, but does indicate that at a policy level there should be a focus of preventing the loss of ecosystems that store high levels of carbon.

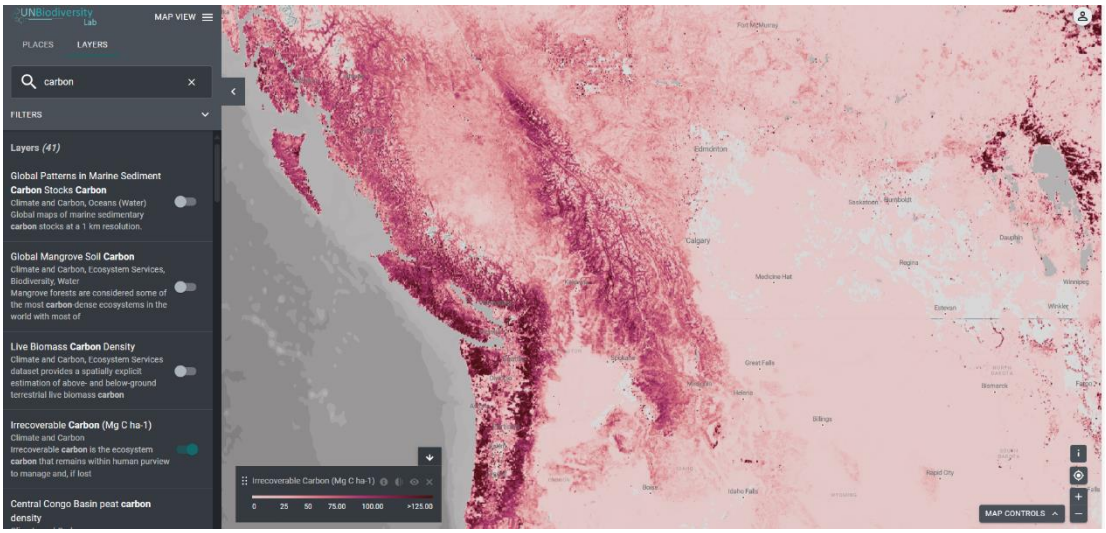

Figure 6 UN Biodiversity Lab – Irrecoverable land carbon[2].

The UN Biodiversity Lab also hosts two layers called above ground biomass carbon density (**Figure 7**) and below ground biomass carbon density. These layers have been generated from datasets that are temporarily consistent and harmonised globally in 2010. The above ground biomass map integrates remotely sensed land cover for woodland, grassland, cropland and tundra biomass. The below ground biomass map is modeled from the above ground information. The resolution of these datasets is 300 m.

Considerations for use: The 300 m resolution will impact on local governments and First Nations ability to use this tool for local planning.

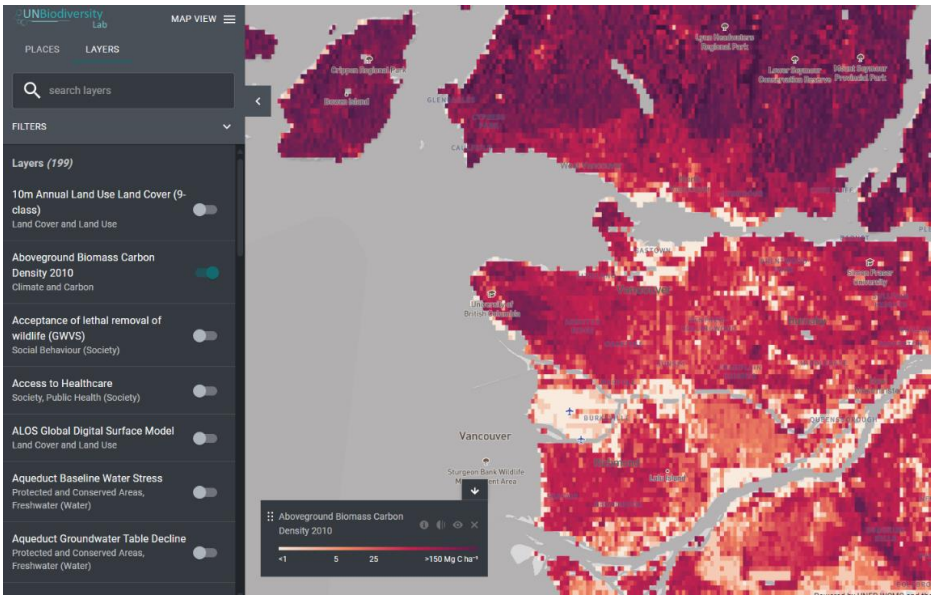

Figure 7 UN Biodiversity Lab decision support tool – above ground biomass carbon density 2010, 300 m resolution.

[2] Irrecoverable carbon refers to the vast natural stores of carbon that are vulnerable to release due to human activity and, if lost, could not be restored by 2050. This layer shows tons of irrecoverable carbon per hectare in both biomass and soils. Data are displayed at a 1 km resolution. Source: Noon et al., 2021.

2.8 Local Government GHG Inventories

In the study area Regional Districts (e.g. Capital Regional District, Sunshine Coast Regional District etc.) have completed GHG Inventories in accordance with the Global Protocol for Communities (GPC). This includes an assessment of emissions from Agriculture, Forestry and Other Land Uses (AFOLU). However, the consultant(s) did not include land use change in the total emissions due to concerns around the accuracy of the data. The consultant highlighted that these inaccuracies occurred due to inconsistent land use mapping for the period of interest 2007 – present. This was caused by:

- Mapping being completed at different resolutions.
- Timing of collection increased uncertainty of classifications of land uses e.g. leaf on or leaf off.

In addition, the consultant found limitation with quantifying GHG emissions resulting from land use change based on national and international carbon emissions factors they had access to.

Considerations: The exclusion of AFOLU emissions from the regional district total emissions calculation removes the pressure from local government to consider the effect that their land use decisions are having in relation to GHG targets.

2.9 Community Energy and Emissions Inventory (CEEI)

The Community Energy and Emissions Inventory (CEEI) was established by the province of BC to support local governments meet their Climate Action Charter commitments. The province still provides data through the CEEI, but the data provided has changed since reporting began in 2007.

To date reporting through the CEEI has occurred in 2007; 2010; 2012 and 2021. The province is currently working to automate the provision of community data relating to utilities (electricity, natural gas and piped propane), municipal solid waste and on-road transportation data, which will help inform decisions in relation to climate adaptation.

The CEEI reports in 2007 and 2012 included estimates for carbon emissions from land use change - deforestation. This snapshot illustrates that local government and First Nations land use decisions impact on their annual GHG emissions, but it doesn't provide trend data and it doesn't reflect the carbon sequestered by the forest and other ecosystems.

Consideration: The CEEI tool if expanded and automated could provide an effective way for local governments and First Nations to understand the impact of their land use decisions. Local governments have indicated through the Local Government Climate Action Program (LGCAP) annual reports that they need additional support in relation to carbon accounting (CDFCP, 2024[3]).

2.10 Provincial Inventory of Greenhouse Gas Emissions

The province of BC has been producing a provincial inventory of greenhouse gas emissions each year since 1990. This is based on the National Inventory Report prepared by the federal government. The reports include emissions data that is two years old, due to the lag in data analysis. Therefore, the current report presents data from 1990 – 2021.

[3] CDFCP (2024) A Review of Local Government Climate Action Plans: Nature-based Solutions.

This allows general trends to be viewed for BC, but the information could not be used by local governments and First Nations to understand how their decisions are impacting on carbon emissions and sequestration as reporting is on a BC scale.

The data illustrates that from 1990 to 2021 emissions from deforestation have decreased from 4.5 to 2.6 $MtCO_2e$ per annum. The inventory also presents emissions that are excluded from the provincial total emissions as summarised in **Table 1** for 2021. This illustrates the impact that wildfire can have on emissions in comparison with deforestation.

Table 1 Emissions from forestry management excluded from total provincial emissions.

Description	Emissions 2021 $MtCO_2e$	3 Year Trend (%)
Forest growth minus decay	-0.2	-112%*
Slash pile burning	2.7	-40%
Wildfires	133.2	-32%**
Decomposition of harvested wood products	41.5	-13%

*numbers suggest sequestration rate of forests has declined since 1990.

**the frequency of large burns has increased in the last 10 years.

3 Recommendations Carbon Mapping / Accounting

Carbon accounting for local government and First Nations remains a challenge. This is due to:

- a lack of detailed landcover mapping for the inventory period (2007 – present) preventing the tracking of land cover change.
- an absence of LiDAR data for the same period, which can be used to quantify biomass.
- a lack of published local carbon factors for all ecosystems leading to the use of national or international factors.
- there needs to be a clear definition of what should be included or excluded from a local government / First Nation GHG inventory.

It is considered that the Net Carbon Sequestration layer generated by the Maryland DNR and the 3GreenTree biomass layers are at a resolution that could be used to support decision making in relation to development. The Maryland layer is also presented in a decision support tool that is easy to use.

However, these layers provide a snapshot in time and could be challenged in relation to accuracy due to the age and inaccuracies of mapping or the carbon emissions factors used for the calculations.

Appendix A – Overview Table

A1- Overview of Carbon Mapping Layers

Table A1 Review of mapping tools that present stored **carbon.**

Name of Product	Single (S) or multiple (M) layers	Resolution	Date Range	Above ground forest carbon	Soil Carbon	Wetland Carbon	Marine Carbon	Description
WWF / McMaster	S	250 m	2022	Yes	Yes	Yes	No	Downloadable mapping presents above and below ground carbon at a 250 m resolution for all of Canada. Online interactive mapping presents total carbon at resolution 1 mile^2 or greater. There are multiple carbon layers that can be downloaded and it can be confusing as to how to interpret the information within them.
CDFCP Carbon Feasibility Mapping by 3GreenTree	M	10 m	2023	Yes	No	No	No	Coverage is restricted to the CDFCP boundary and the work has not been peer-reviewed. The work generates an estimate of carbon per parcel.
Vegetation Resource Inventory	S	-	Multiple	Biomass	No	No	No	VRI provides estimates for biomass which can be used to calculate carbon – Biomass x 0.5 = carbon.
Greenprint - Accounting for Maryland's Ecosystem Services	M	30 m	2017	Net sequestration	No	No	NO	Easy to access layer that visually illustrates where high carbon sequestration is occurring and places a economic value on it.