Landcover Mapping by Metro Vancouver and Caslys

A Review of Mapping Support Tools - Landcover

Action for Adaptation

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May 2024

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 coast of British Columbia (BC) that are looking to accelerate how they mitigate and adapt to the effects of climate change by protecting, restoring, and creating 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 for planning and decision making. 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 landcover 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 land cover mapping, it was identified that the following factors can influence the level of accuracy of a land cover mapping layer, and consequently any modelling or mapping completed from it (e.g. terrestrial carbon);

- The resolution of imagery used for mapping and the number of land cover classification types can impact the accuracy of mapping.
- The more classifications used for mapping the greater the potential for missing classification of a land cover type when automised.
- The definitions of each land cover classification can alter the output - e.g., a tilled field could be classed as barren; soil; or agricultural land.
- Transitional landcover types - e.g. a residential property with a forested garden, can affect the quantification of landcover change.
- International mapping products can include classifications that do not translate well between countries - e.g. rangelands used to classify harvested areas of BC.
- Seasonality can impact on classification - e.g. ephemeral waterbodies and snow are not present in the summer.
- Shadows, cloud cover and fire haze can all mask landcover features.
- Land cover classifications can become obsolete as a result of scale - e.g. mixed forest at 5 m is not required as the classification is down to individual trees.

The conversations and the review of existing land cover mappings tools identified several factors that impact on the accuracy of land cover mapping. Below are recommendations on how mapping could be undertaken in a manner that improves the accuracy and consistency of land cover mapping to be used by local governments and First Nations:

- Use the most up to date, high resolution imagery that can be obtained e.g. Plantscope (3 m) or Sentinal-2 (10 m).
- Use LiDAR collected in the same year as the imagery where possible to aid classification of shrub and herb and to pick up changes from harvesting and development.
- Use sufficient land cover classifications to meet user needs and to reflect natural diversity, while ensuring accuracy is maintained during automated classification (NALCMS plus Metro Vancouver land use categories).
- A resolution of 3 m will remove the need for a mixed forest classification as a single tree canopy is likely to be larger than 3 m.
- A resolution of 3 m will reduce issues with transition habitat e.g. trees in are garden are they forest or urban. They become trees.
- Land cover classifications need clear definitions to ensure accurate mapping by multiple people and an automated classification system. .
- The land cover models need to be developed with clear definitions for each of the land cover classifications. The Action for Adaptation project will develop these during the desk based and field verification as they will be dependent on how the model views the imagery.
- Use imagery from a similar time of year, if tracking land cover change, to maintain accuracy of classification e.g. ephemeral water and snow.
- Cloud and shadow can be an issue with mapping but can be overcome by using a composite image e.g. multiple images through a month. However, fire haze is harder for automation to detect and screen out leading to further processing.

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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 coast of British Columbia (BC) that are looking to accelerate how they mitigate and adapt to the effects of climate change by protecting, restoring, and creating nature-based solutions.

In 2022 and 2023, conversations were undertaken with representatives from federal, provincial and local governments, 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 for the area of interest.

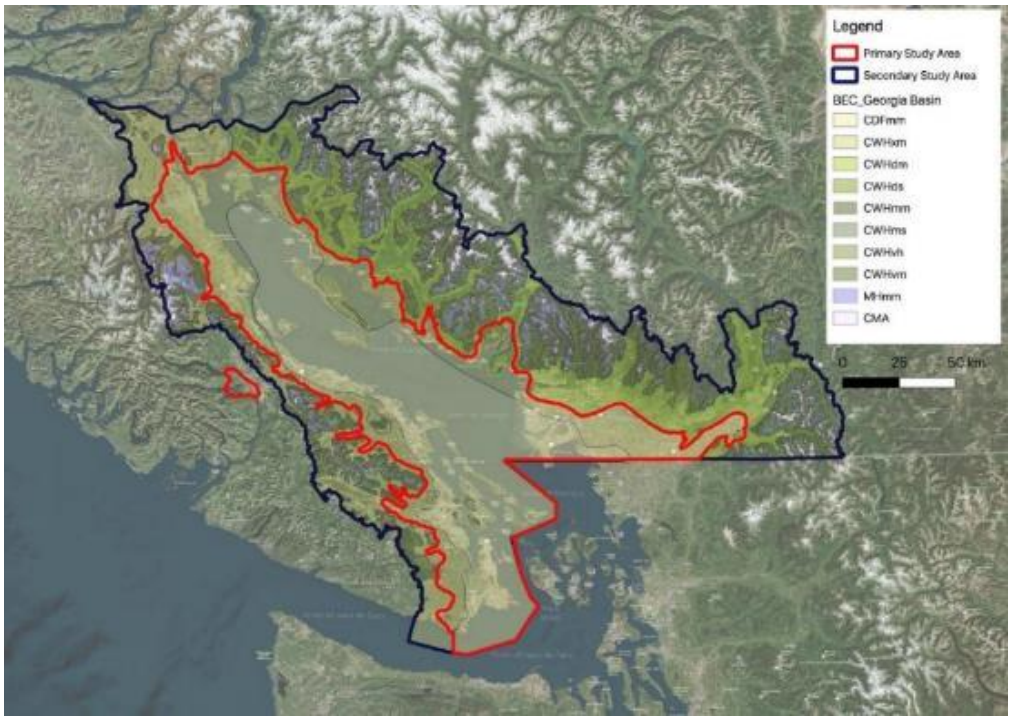

Figure 1. The red line boundary represents the CDFCP area of interest which incudes the CDFmm and CWHxm1 biogeoclimatic zones. The blue line boundary represents the Action for Adaptation boundary which includes the catchments that feed the ecosystems in the CDFmm and CWHxm1.

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 they are currently missing the following mapping layers at a fine enough resolution:

- 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 landcover 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 – Terrestrial Carbon.
- A Review of Mapping Support Tools – Ecosystem Connectivity.

2 Landcover and Forest Landcover Change

Land cover and forest change mapping layers for south-west BC were reviewed. This review discusses the reasons behind why each of the mapping products produces a slightly different map, even though the time periods are overlapping, and discusses the consequence of this when tracking land cover change and consequently carbon emissions and land protection.

2.1 Summary of Conversation Comments

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

- Land cover data is inconsistent across the region, as the land cover products vary in their coverage, land cover categories and spatial resolution.
- First Nation representatives indicated that they would benefit from an easily accessible land cover layer they can download and overlay with mapping layers they have developed.
- LiDAR improves the accuracy of land cover classification, but coverage of LiDAR is not uniform.
- Machine learning models should be trained locally to classify land cover and paired with ground data to improve accuracy.
- Use free satellite imagery to track change in land cover.
- LiDAR and satellite imagery can be used to derive tree canopy cover height at 1-2 m resolution.
- Seasonality (leaf on or off) can impact on land cover classification.

Issues that require consideration during land cover mapping include:

- Spatial resolution - with larger 30 m x 30 m pixels there is a much greater opportunity for mixed land covers within a pixel (e.g. pavement, grass, and building) than with 10 m x 10 m pixels.
- Number of classifications- the number of land cover classification types can impact the accuracy of mapping, e.g. 9 classifications compared to 19 classifications.
- Accuracy of mapping – the more classifications used for mapping the greater the potential for misclassification of a land cover type, e.g. a managed grassland can look very similar to a natural/native grassland at the end of the summer.
- Definitions of each land cover classification can alter the output - e.g. a tilled field could be classified as barren; soil; or agricultural land depending on the criteria used for land cover mapping.
- Seasonality can impact classification - e.g. ephemeral waterbodies and snow are not present in the summer. Therefore, imagery needs to be collected from a similar time of year if making comparisons.
- Transitional landcover types - e.g. a residential property with a forested garden, can affect the quantification of landcover change as a decision has to be made as to whether it is forest or urban.
- International mapping products can include classifications that do not translate well between countries - e.g. ESRI Sentinel-2 Land Cover Explorer identifies recently harvested forest areas in BC as rangelands.
- Clouds, shadows, haze, and snow cover can hinder land cover classifications - e.g. tower block shading forest would make the identification of deciduous and coniferous trees difficult. The frequency of image collection by modern satellites means that composite images can be produced using as many clear-sky images as possible.

- Land cover classifications can become obsolete as a result of scale - e.g. mixed forest at 5 m is not required as the classification is down to individual trees.

The figures presenting landcover mapping in this report are focused on Bowen Island to enable the reader to visually understand the difference between each of the land cover mapping products.

2.2 TerrAdapt and Esri Sentinel-2

Figure 1 and 2 illustrate how the number of classifications (e.g. urban; deciduous forest; grassland etc.) can impact the detail of mapping even when the underlying imagery may be at a higher resolution.

ESRI Sentinel 2 Land Cover Explorer uses imagery with a 10 m resolution but only uses nine categories of classification. This leads to a less detailed image than TerrAdapt mapping that uses imagery at a 30 m resolution but uses 19 categories leading to a more detailed image (**Figure 1 and 2**).

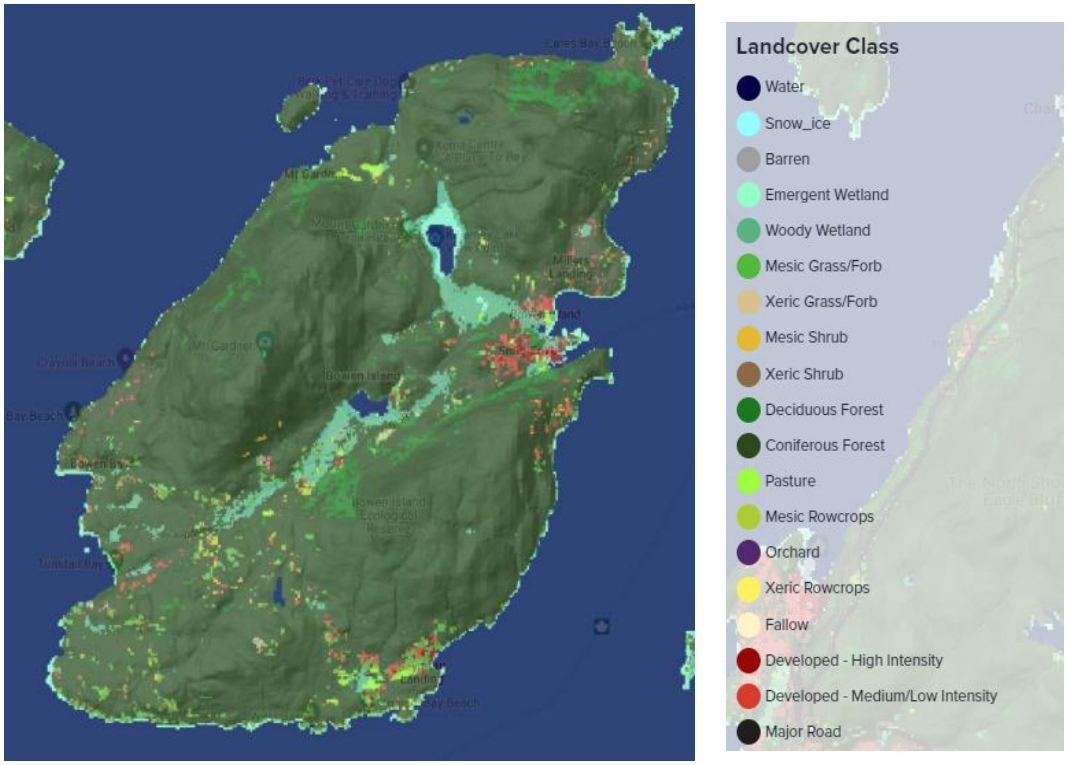

Figure 1 TerrAdapt landcover mapping using imagery at a 30 m resolution but 19 land cover classes.

Figure 2 ESRI Sentinel 2 Land cover explorer using 10 m imagery but only nine land cover classes.

2.3 Metro Vancouver – Landcover Mapping

Figure 3 illustrates a sample of the mapping undertaken by Metro Vancouver which uses Planetscope imagery at a 3 m resolution and using 14 classifications. This achieves one of the most detailed land cover mapping products reviewed. However, Plantscope imagery is expensive, in comparison to Sentinel-2 imagery which is free. In addition, Plantscope imagery does not have the back catalogue of images that earlier satellites provide as it only started collected imagery in 2014, whereas Landsat (30 m) started in 1972.

This may be an issue when governments and First Nations are trying to quantify land cover change and consequently carbon accounting. The BC Government has a legal target to reduce GHG emissions by 80% by 2050, with a baseline year of 2007. Therefore, the change in landcover needs to be accurately tracked from 2007 to the present to understand the effects of land use change on carbon emissions.

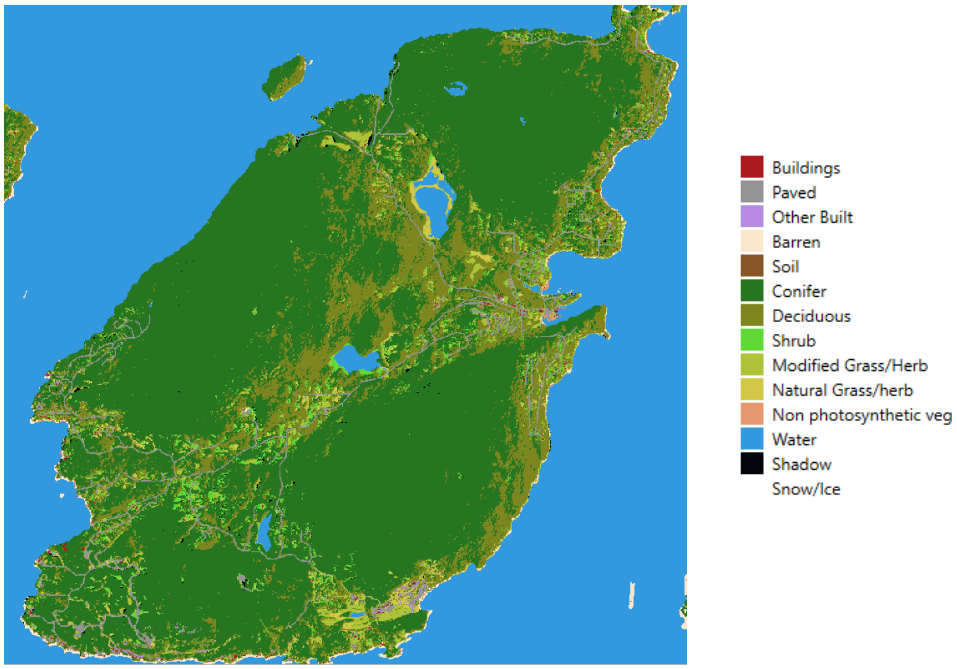

Figure 3 Metro Vancouver land cover mapping using 5 m imagery with 14 classifications.

2.4 North American Land Change Monitoring System (NALCMS)

A key consideration for land cover mapping is alignment with tools that have long term investment and are part of international reporting. The federal government undertakes landcover mapping in accordance with the North American Land Change Monitoring System (NALCMS) using imagery with a 30m resolution with 11 classifications that are relevant to the south-west coast of BC (**Figure 4**). This approach has carefully considered the classifications to increase the landcover mappings accuracy and repeatability in subsequent years, and has tested their application in 2010, 2015 and 2020. This information has been produced on a five-year cycle and will likely continue to provide a long-term data set going forward. However, it's main purpose is to provide data for national reporting and therefore may not reflect the level of detail needed (resolution and classifications) to demonstrate the effect of local, regional, provincial and territorial decisions.

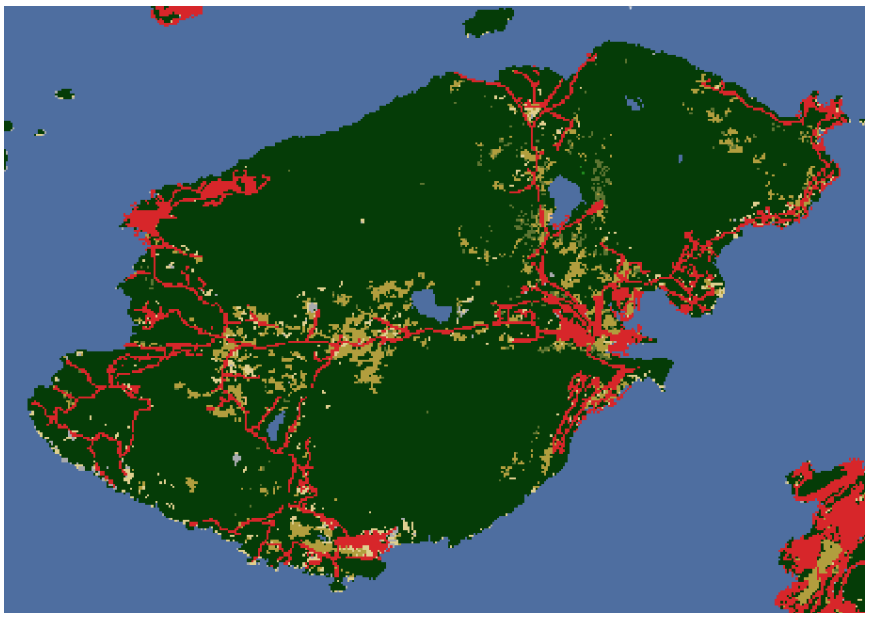

Figure 4 2020 Landcover of Canada 2020 from imagery with a 30 m resolution with 11 classifications.

2.5 Dynamic World

Dynamic World, TerrAdapt and ESRI Sentinal-2 are tools that have been developed to track landcover change. Dynamic World (**Figure 5**) is produced using the Google Earth Engine and AI Platform. It is mapped from imagery at a 10 m resolution with nine land cover classification types.

Dynamic World landcover mapping is updated every 2-5 days and the dataset starts in 2021, but the level of detail of the mapping is low in comparison to TerrAdapt (**Figure 7**) and ESRI Sentinel-2 (**Figure 8**). TerrAdapt presents the highest level of precision of the tools that track landcover change. However, its coverage is limited to the Cascadia region in North America. Whereas, ESRI Sentinel-2 and Dynamic World are international products.

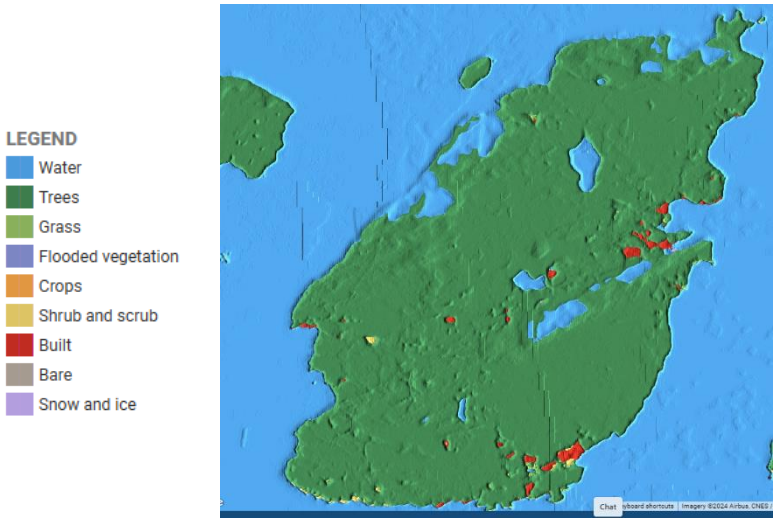

Figure 5 Dynamic World is updating landscape mapping every 2-5 days from Sentinel-2.

2.6 UN Biodiversity Lab – Landcover Layers

The UN Biodiversity Lab includes several land cover layers. This review looked at three of them.

- European Space Agency (SA) and Copernicus Climate Change (CCI) Global Land Cover map series extends from 1992 to 2022 at a 300 m resolution[1]. The mapping includes 22 landcover classes developed by the United Nations (UN) Food and Agriculture Organization (FAO). A new land cover map is produced annually nine months after the beginning of the year and validated within a maximum of three months after release (**Figure 6**).
- ESA Copernicus Global Land Cover (CGLC) map series extending from 2015-2019. The mapping includes 23 land cover classes aligned with UN FAOs classification system. Mapping is undertaken at a 100 m resolution (**Figure 7**).
- CBAS Global Land Cover FCS30 was undertaken at a 30 m resolution in 2020 with 35 land cover types (**Figure 8**).

These tools clearly illustrate how resolution, and the number of classifications can impact the accuracy of the image produced. CBAS Global Land Cover most closely reflects the mapping undertaken by Metro Vancouver, which generated a highly accurate image for local government planning.

[1] Defourny, P., Lamarche, C., Bontemps, S., De Maet, T., Van Bogaert, E., Moreau, I., Brockmann, C., Boettcher, M., Kirches, G., Wevers, J., Santoro, M., Ramoino, F., & Arino, O. (2017). Land Cover Climate Change Initiative - Product User Guide v2. Issue 2.0. http://maps.elie.ucl.ac.be/CCI/viewer/download/ESACCI-LC-Ph2-PUGv2_2.0.pdf

Figure 6 ESA CCI Land Cover 1992 – 2022, 300 m resolution, 22 land cover classifications.

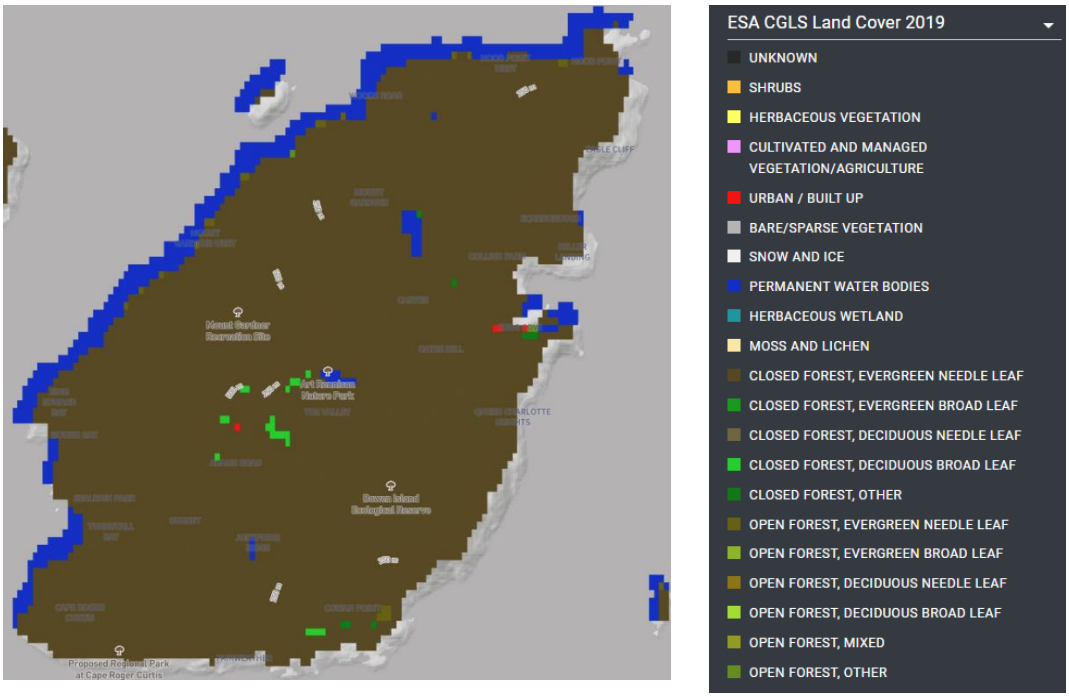

Figure 7 ESA CGLS Land Cover 2015-2019, presenting 2019 land cover, 100 m resolution, 23 land cover classifications.

Figure 8 CBAS Global Land Cover 2020 at a resolution of 30m with 35 land cover classifications.

2.7 Global Forest Watch

An alternative approach to tracking land cover change is to focus on changes to forests. This is particularly relevant in relation to carbon storage and sequestration, and changes in forest biodiversity. A mapping tool developed by Global Forest Watch is often referenced within national and international news articles when discussing forest losses, climate change and biodiversity. **Figure 9** presents a map from Global Forest Watch which illustrates tree losses and gains (trees taller than 5 m) between 2001 and 2022. This image illustrates the effect of harvesting in a 20-year period near Duncan on Vancouver Island. It is difficult to determine from the website the accuracy of mapping within urban centres. The mapping allows you to adjust the tree cover layer according to canopy density (default is 30%), but the quantification of change may not be possible for local governments from this dataset. The dataset highlights that as the resolution of satellite data has improved the scale at which change can be recorded has decreased, leading to the recording of smaller losses that would have previously been missed in the mapping.

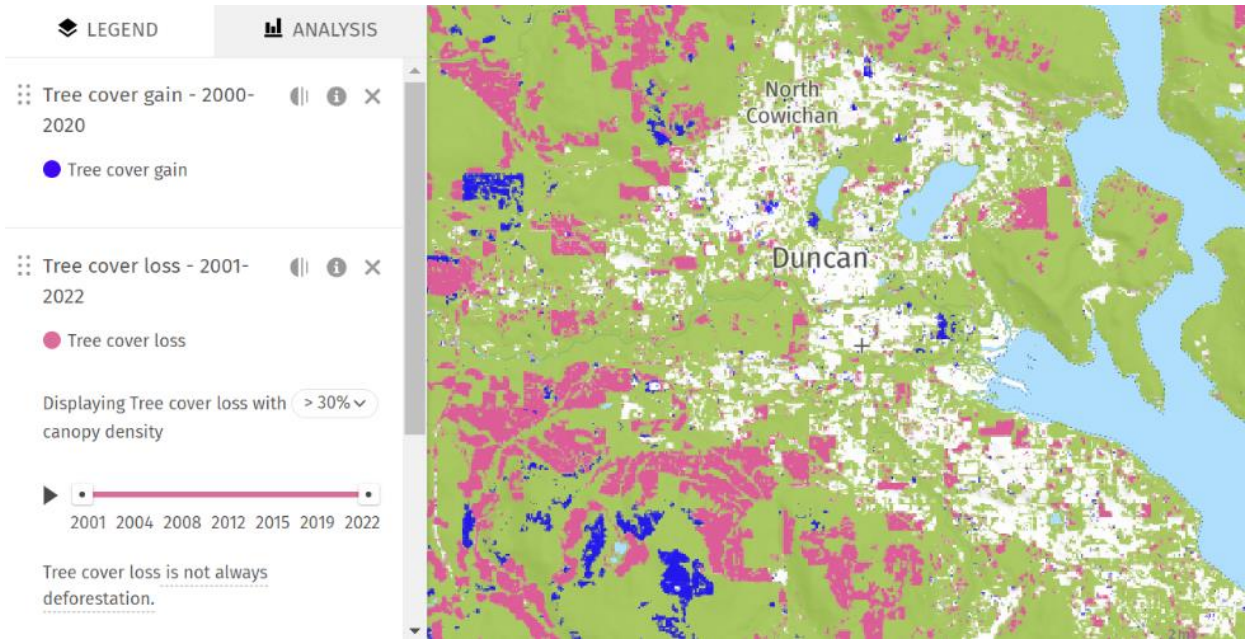

Figure 9 Tree cover gains and losses presented on Global Forest Watch from 2001-2022.

The website also includes a dashboard that can present data for Canada, British Columbia or a specific regional district. This enables the user to see a quantification of tree cover loss per annum. The images indicate at the base of the graph that calculations do not include tree gains, but this information could be missed. Therefore, the user could misinterpret this information as deforestation rather than forest degradation. Most of the tree loss recorded in BC will be re-planted.

2.8 Forest Inventory and Analysis Landscape Data Explorer

Forest Inventory and Analysis Landscape Change Monitoring System (LCMS) Data Explorer developed by the US Forest Service provides landcover change, land use change and the rate of change from forestry between 1985 - 2022 (**Figure 10**). These products are based on a network of field plots, like BC's Vegetation Resource Inventory (VRI), and satellite and aerial imagery with a resolution of 30 m. These datasets can be downloaded as can the field plot data from the online portal. The US Forest Service is also working on a project called BIGMAP which is looking to develop systems to be able to analyse ecological data at a national scale. The initial prototypes of this analysis have included calculations of carbon stores and the classification of forest types. This project is still in development and the aim is to make this information available in a public interface.

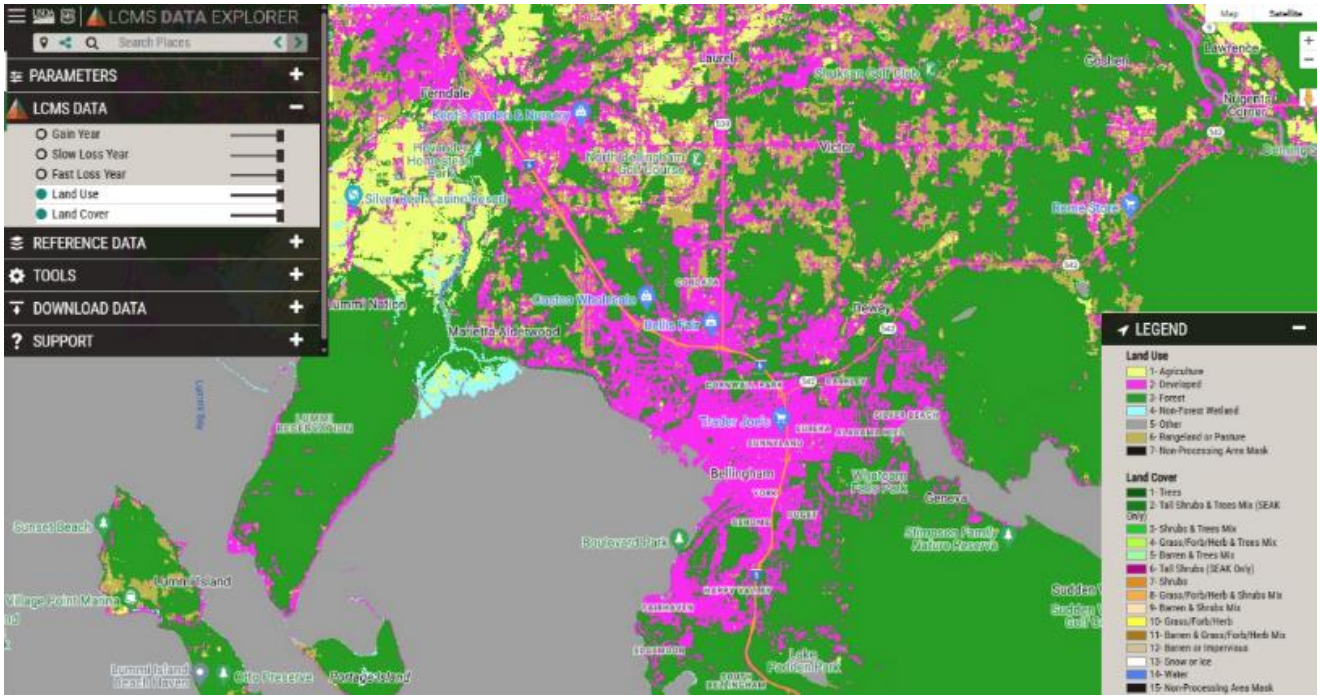

Figure 10 Land use and land cover mapping available from the US Forest Service.

3 Conclusions and Recommendations

The conversations and the review of existing land cover mappings tools identified several factors that impact on the accuracy of land cover mapping. Below are recommendations on how mapping could be undertaken in a manner that improves the accuracy and consistency of land cover mapping to be used by local governments and First Nations:

Imagery resolution, LiDAR and land cover classifications

The age and resolution of imagery from which land cover mapping is completed, the availability of LiDAR and the number of land cover classifications impacts on the accuracy of the land cover mapping product. Ideally for land cover mapping you would use the most up to date, high resolution imagery that can be obtained. Therefore:

- Plantscope at 3 m for which there is a cost; or
- Sentinal-2 at 10 m, which is a free product.

Ideally LiDAR would have been collected in the same year as the imagery used for mapping. The LiDAR is used in the land cover model to differentiate between treed, shrub and herb classifications. If the LiDAR and the imagery are not aligned temporally then harvesting or development may have occurred reducing the accuracy for the model to identify these land cover types. If this is the case then post modelling manual review should be considered / increased.

The Action for Adaptation project is piloting the use of 16 land cover classifications based on the categories used by NALCMS and by Metro Vancouver. The intent is to balance classifications that have

been shown to be accurately modelled while also meeting the additional needs of local governments. Desk based and field verification will be used to test the accuracy of the identification of these classes;

- Treed - Needleleaf
- Treed – Broadleaf
- Shrub
- Herb/Grass – Natural
- Herb/Grass – Anthropogenic
- Pasture / Hay
- Cropland
- Barren – Soil
- Barren – Rocky – Anthropogenic
- Barren – Rocky – Natural
- Urban – Paved
- Urban – Buildings
- Urban – Other
- Urban – Tree Over Pavement
- Water
- Wetland
- Snow & Ice

Obsolete classification and transitional land cover types

Increasing the resolution of imagery to 3 m has two positive impacts on mapping. It will remove the need for a mixed forest classification because there will usually be multiple pixels for each tree, rather than multiple trees within each pixel (e.g. at 30 m resolution), as many tree crowns in the study region are more than 10 m in diameter. In addition, as a result of mapping individual trees differences in mapping transitional habitats are removed. Historically land cover mapping products in BC differed in their approach to mapping trees in a garden as forest or garden. This can have a significant impact on the quantity of forest loss and gain values.

Land cover classification definitions.

The land cover models need to be developed with clear definitions for each of the land cover classifications. The Action for Adaptation project will develop these during the desk based and field verification as they will be dependent on how the model views the imagery.

Table 1 Provides an example of the classifications used by the National Land Cover Database for seven classifications.

Category	National Land Cover Database
Treed - Needleleaf	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
Treed – Broadleaf	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change
Shrub	Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
Herb/Grass – Natural	Areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
Herb/Grass – Anthropogenic	
Pasture / Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
Cropland	Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

Inaccuracy due to seasonality, shadows, cloud and smoke

Land cover classes can change temporally in a year e.g. ephemeral waterbodies and snow. In addition, seasonality can impact on the ability of a land cover model to identify classifications e.g. bare deciduous trees are easy to identify from coniferous trees but later in the summer they can be harder to differentiate.

The issues with seasonality can be over come by ensuring that mapping is completed at a similar time each year e.g. spring / summer. Planetscope imagery has the benefit that it is collecting multiple images in a year so a composite image can be produced. Shadows, cloud and smoke can all impact on classification, by masking the underlying land cover type. It is likely that in this situation the model will

then try an allocate a land cover class on what it thinks it sees. The ability to produce a composite image from Planetscope imagery can reduce the impact of shadow, cloud and smoke, but further processing may also be required.

Appendix A – Overview Table

A1- Overview of Landcover and Forest Cover Change Mapping Layers

Table A1 Review of decision support tools presenting **landcover and forest cover change** information.

Name of Product	Single (S) or multiple (M) layers	Resolution	Date Range	Classifications	Downloadable	Description
TerrAdapt	M	30 m	1984 - 2022	19	No	Multi-layer decision support tool that includes landcover. The tool covers the Cascadia region which includes Metro Vancouver and the Sunshine Coast in Canada. The tool is divided into three parts: monitoring, future projections and prioritisation. Includes a summary dashboard.
ESRI Sentinel 2 Land Cover Explorer	S	10 m	2017 - 2022	9	Yes	Single landcover layer. Includes simple tools that present change over time. Small number of classifications which reduces its value to local government, even though the resolution is high.
2020 Land Cover Canada	S	30 m	2010; 2015; 2020	11	Yes	Single landcover layer. Simple viewer of map. Resolution limits its value to local governments as the impact of their decisions on landcover can not be quantified.
Dynamic World	S	10 m	2015 to present (every 2-5 days)	9	No	Real time 10 m resolution global land use / land cover dataset, produced by deep learning, developed by Google and World Resources institute
BC 1:250,000 Geobase Land Cover	S	30 m	2014	13	Yes	Single landcover layer. Produced in 2014 and not updated. Produced at a 30m resolution so its value to local governments is limited.

Name of Product	Single (S) or multiple (M) layers	Resolution	Date Range	Classifications	Downloadable	Description
Metro Vancouver	M	5 m	2014; 2020	13	Yes	Landcover layer is being used to generate additional layers such as Sensitive Ecosystems Inventory;
Global Forest Watch	M	30 m	2001-2022	N/A	Some downloads are available but dated	The focus of this tool is on forest loss and gains. The mapping does not differentiate between deforestation and areas that have been harvested and replanted as forestry. However, the dashboards do include this information for Canada.
Global Forest Change	S	30 m	2000-2022 Losses 2000-2012 Gains	N/A	Yes	This tool developed by the University of Maryland focuses on forest loss and gains, but the datasets do not align for the full time period. The mapping is completed using Landsat imagery.
Forest Inventory and Analysis Landscape Change Monitoring System (LCMS) Data Explorer.	M	10 m	1985 - 2022	15	Yes	Land cover change, land use change, rate of gains and loss are all presented through time lapse from 1985-2022. This information is generated from Landsat and Sentinel-2 imagery using Google Earth Engine for all of the US