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IMPROVING THE METRO VANCOUVER REGIONAL CARBON STORAGE DATASET Final report

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1 Introduction

In 2016, 3GreenTree was awarded a contract with Metro Vancouver entitled 'Evaluation and application of Metro Vancouver's regional carbon storage dataset'. A resulting report was delivered to Metro Vancouver in March 2017 (File no. OS22624), and in November, 2017, 3GreenTree received confirmation to undertake subsequent work designed to improve Metro Vancouver's existing draft regional carbon storage dataset to better support land use decision-making by local government staff.¹

Project activities occurred over a 1-year interval, culminating in this Final report, along with an electronic copy of the carbon storage database.

The project scope consisted of three tasks:

1. Implement the recommendations contained within the previous report: a. Verify VRI against current conditions and update forest cover mapping where necessary. Have requested relevant data from MetroVancouver; b. Develop, assign and verify carbon analysis units for Metro Vancouver, using imagery, LiDAR and field plots; c. Improve estimates of carbon in wetland ecosystems, including a limited network of field plots; and d. Consider how to create carbon estimates for intertidal and estuarine ecosystems and include if possible.
2. Assess and report on the accuracy of the dataset. The objective is to create a dataset that can provide accurate estimates of carbon stored with a minimum scale of ~50 ha in order to support accurate land use decision-making.
3. Recommend a methodology to update the regional carbon storage dataset over time. This is to include consideration of how efficiencies could be achieved updating the carbon storage dataset simultaneously with other primary mapping datasets maintained by Metro Vancouver (Sensitive Ecosystem Inventory, Land Cover Classification).
4. Potential applications of the carbon storage database.

¹ The authors wish to sincerely acknowledge the support, input, and advice of Josephine Clark, Environment Planner at Metro Vancouver. Any errors and omissions associated with this work remain the sole responsibility of 3GreenTree.

2 Methods

2.1 Implementing the recommendations

The Metro Vancouver carbon storage database is an ArcGIS file Geodatabase consisting of summarized soil and biomass carbon and ecotypes for property parcels within the Metro Vancouver region. The procedures outlined in this section document how the database was constructed (see Figure 1).

2.2 Software

The following list of software was used to carry out the procedures outlined in this document.

- a. Windows 7, 64 bit
- b. ArcGIS 10.x. Spatial Analyst and Image Classification extension.
- c. Python 2.7, 32 bit and 64-bit (ArcGIS Desktop 64 bit Background Geoprocessing)

2.3 Data Sources

2.3.1 Parcels

Metro Vancouver Parcels (2016)

Carbon was summarized by average density and total within parcels to be used by city planners as the primary unit for decision making. Metro Vancouver provided a Geodatabase called Parcel_MV.gdb with feature class Parcel_MV.

2.3.2 Vegetation Resources Inventory (VRI)

BC MOFLNRO Vegetation Resources Inventory (2017)

The VRI contains above-ground biomass data from which biomass and soil carbon was estimated. The VRI dataset has been updated to include changes to forested areas that have been removed due to urban development and forestry harvesting (see Section 2.4.1). The latest updated dataset is called VRI2018_3GT.

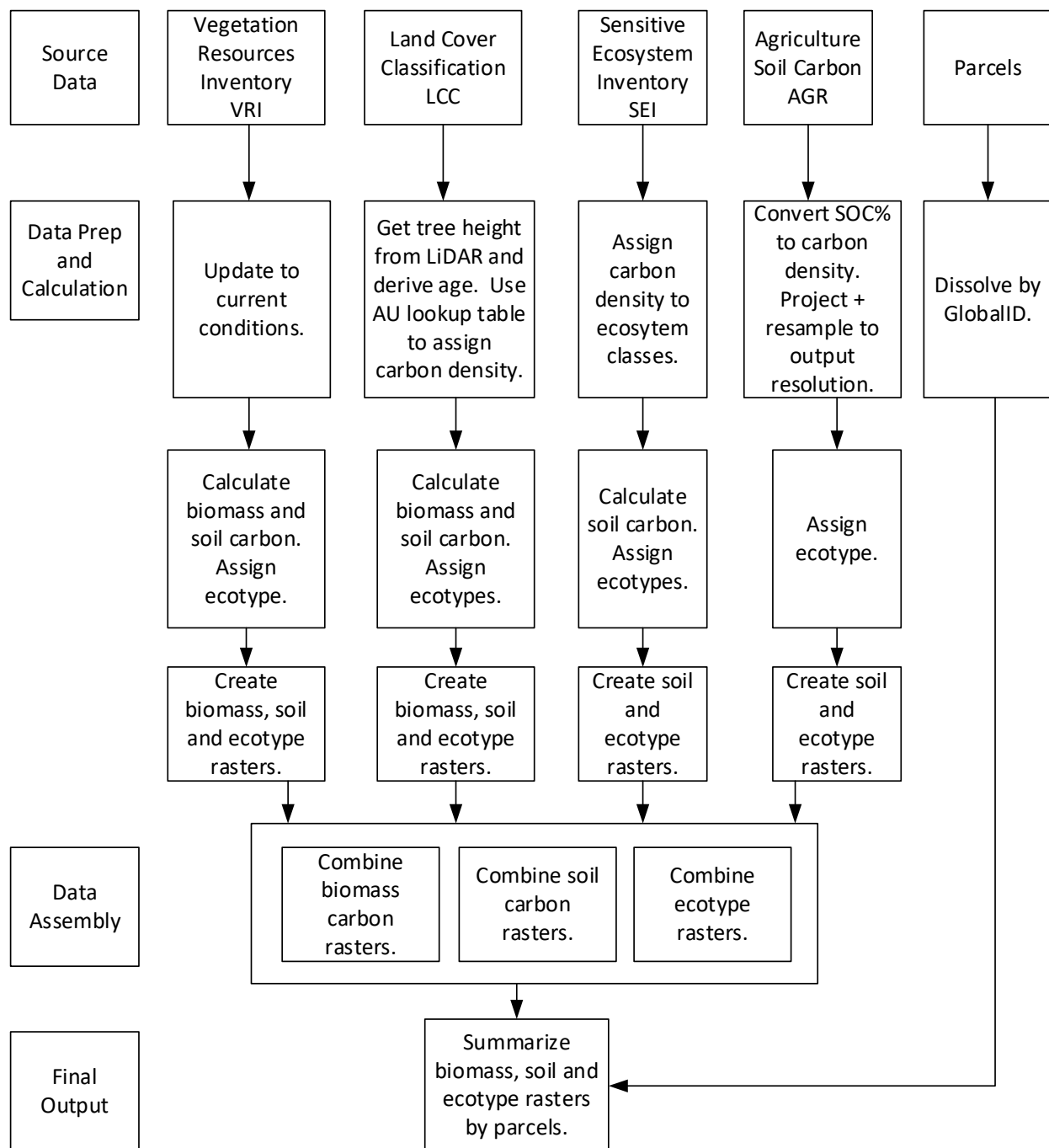


Figure 1. Flow chart of steps to create carbon database.

2.3.3 Land Cover Classification (LCC)

The Land Cover Classification dataset was developed for Metro Vancouver by Coombes (2012). This raster dataset was updated in 2016 from an analysis of 2014 multispectral satellite photos with a 5m*5m cell size. Cells within the LCC include two forested categories that are used to identify coniferous and deciduous tree types. These were used in conjunction with canopy height data as the basis to estimate carbon content (see Section 2.4.2). Metro Vancouver provided two raster images called LCC2014_2m_LiDAR.tif and LCC2014_5m_LiDAR.tif.

2.3.4 Sensitive Ecosystem Inventory (SEI)

Metro Vancouver Sensitive Ecosystem Inventory (2014)

A Sensitive Ecosystem Inventory (SEI) was conducted for Greater Vancouver Regional District (Metro Vancouver) and Abbotsford from January 2010 – May 2012. Sensitive, relatively unmodified, ecosystems including wetlands, older forests and woodlands were identified and mapped using high-resolution orthophotos largely from 2009. In addition, ecosystems such as seasonally flooded agricultural fields and young forests, which are human modified but still have ecological value and importance to biodiversity were included in the mapping process. The project area totaled 367,000 ha, consisting of over 330,000 ha of terrestrial lands plus several thousand hectares of rivers, freshwater bodies, intertidal and estuarine zones.

A polygon-based spatial database was produced as a result of the work. The original database was updated after 5 years, using 2014 orthophotos. The database is described in detail in a technical report (Meidinger, et al., 2014).

2.3.5 Delta agriculture soil organic carbon

A digital map of soil organic matter content in the agricultural fields of Delta was developed in 2016 by the Sustainable Agricultural Landscapes Laboratory at UBC. The map was created using field measurements and various remote sensing data. The data were provided as a 30m raster containing percent organic carbon in surface soil layers. These were converted to carbon density using local soil bulk density and soil depth. The name of the dataset provided by Dr. Smukler in the Faculty of Land and Food Systems at UBC was SOC_Delta().tif².

² For further analysis of this dataset, see Paul et al. (2020)

2.3.6 Orthophoto Imagery

A high resolution orthophoto (7.5 cm) of the entire Metro Vancouver Region taken in 2016 was provided by Metro Vancouver as an MrSID 3-band color image. It was reclassified into vegetated and non-vegetated type classes using supervised classification and used as a reference to the VRI polygons to identify recent removal of forested areas due to urban development or harvesting. The identified polygons were updated manually by digitizing a new border between the forested and non-forested areas (see Section 2.4.1).

2.3.7 Light Detection and Ranging (LiDAR)

LiDAR data were provided for various municipalities and areas where available by Metro Vancouver. These included: Burnaby (2014), Surrey (2013), Vancouver (2013, <https://data.vancouver.ca/datacatalogue/LiDAR2013.htm>), Langley (2011), UBC (2010), Burns Bog (2009), Surrey (2009), Coquitlam (2012).

These data were used to determine tree height of forested areas identified by the LCC data and subsequently age was derived from the tree height (see Section 2.4.2).

2.3.8 Building Footprints

Building footprints were obtained from various online municipal data sources and OpenStreetMaps. The building footprints were used to filter out any misclassified LCC forested areas.

2.3.9 Administrative Boundary

Metro Vancouver Administration Boundary (2018)

The Metro Vancouver administrative boundaries were used to define the extent of the study area.

2.4 Data Preparation & Carbon Calculation

2.4.1 VRI Preparation

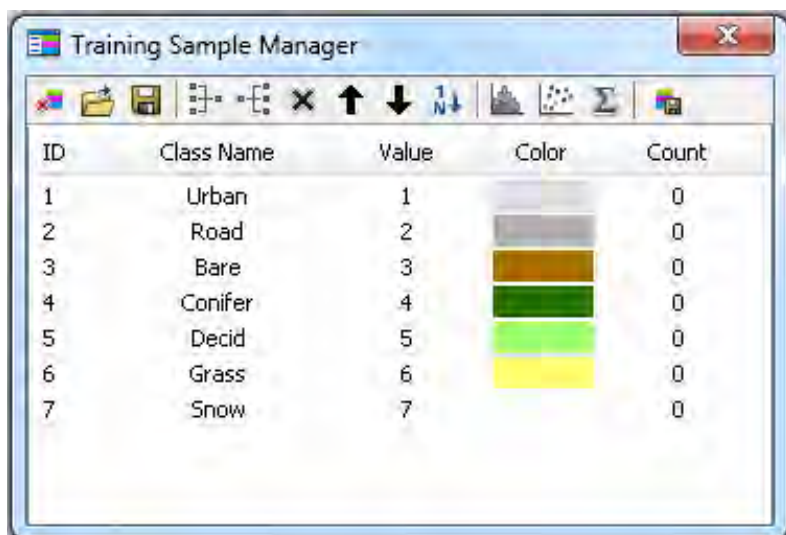
Updating Polygons

The VRI was updated to current conditions (through 2017) by manually comparing the polygon boundaries and attributes against identifiable changes in orthophotography and satellite imagery. Most changes were identified as forested areas removed due to urban development. Supervised classification was used to assist in locating where these changes had occurred. The

sources of imagery that were utilized include 2016 orthophoto supplied by Metro Vancouver and 2017 Google and Bing satellite imagery.

In supervised classification, the user directs how pixels in an image are classified. This is done by selecting pixels that are representative of the land cover type. The selected group of pixels is known as a training sample. The training sample is then used to classify other pixels in the image that have a similar spectral signature. For each land cover type to be identified, a training sample is created.

Training samples sets were created for the following land cover types: anthropogenic (urban, road), forest (conifer, deciduous), shrub (shrub, grass), water, bare and snow (Figure 2). Separate training sample sets were created for the Metro Vancouver orthophoto and the internet-based imagery.



The screenshot shows the 'Training Sample Manager' window in ArcGIS. It contains a table with the following data:

ID	Class Name	Value	Color	Count
1	Urban	1		0
2	Road	2		0
3	Bare	3		0
4	Conifer	4		0
5	Decid	5		0
6	Grass	6		0
7	Snow	7		0

Figure 2. ArcGIS interactive supervised training examples manager.

Figure 3, shows a portion of the original Metro Vancouver orthophoto before classification, while Figure 4 shows the results after running the interactive supervised classification.

The reclassified image was then used to help locate polygons with possible disturbances, which were then compared against the VRI attributes to determine if any updates were required. Only VRI polygons that were previously treed were inspected and updated. This was done by looking at polygons with the following attributes: BCLCS_LEVEL1 = 'V' and BCLCS_LEVEL2 = 'T', BCLCS_LEVEL_5 = 'DE' and including BCLCS_LEVEL_5 = 'OP'.



Figure 2. Metro Vancouver orthophoto before classification.



Figure 4. Metro Vancouver orthoimage with pixels classified using supervised classification.

Figure 4, shows an example of a treed VRI polygon that contains urban development, but has not been updated with these changes. A new VRI polygon was manually digitized around this area and an island was created for the inner patch of trees as seen in Figure 5. The resulting, updated VRI data with new polygons is shown in Figure 6.



Figure 3. Treed VRI polygon that has not been updated with recent urban development (inside red polygon)



Figure 6. The updated VRI layer with added polygons (purple).

Three levels of inspection were used to determine which polygons were inspected based on VRI BCLCS_LEVEL1, BCLCS_LEVEL2, BCLCS_LEVEL5 and the size of the non-forested areas determined by the supervised classification.

1. Vegetated areas that were densely or openly treed where supervised classification non-forest% > VRI non-veg% AND supervised classification non-forest area > 1ha
2. Vegetated areas that were densely or openly treed where supervised classification non-forest% > VRI non-veg% AND supervised classification non-forest area between 0.5ha to 1ha
3. Vegetated areas that were densely or openly treed where supervised classification non-forest% > VRI non-veg% AND supervised classification non-forest area between 0.25ha to 0.5ha

For each selected polygon, the given percentages from the following fields were visually compared against the orthophoto to determine if updating was necessary.

SHRUB_CROWN_CLOSURE, HERB_COVER_PCT, NON_VEG_COVER_PCT_1,
NON_VEG_COVER_PCT_2 NON_VEG_COVER_PCT_3

If the percentage of the cover type did not visually match, the polygon was updated by delineating the boundary of the non-forested elements.

In all, about 5000 polygons were inspected and about 500 were updated. For updating the attributes, copies were made of the WHOLE_STEM_BIOMASS, BRANCH_BIOMASS, FOLIAGE_BIOMASS, BARK_BIOMASS fields (tB) and then set to 0 for the updated polygons (where B = dry biomass). The copied fields were labelled with a 2 at the end of the name.

Calculating carbon density

To calculate carbon density, the following calculations were performed on the VRI biomass fields.

1. Above-ground Biomass (tB/ha) = WHOLE_STEM_BIOMASS2 + BRANCH_BIOMASS2 + FOLIAGE_BIOMASS2 + BARK_BIOMASS2
1. Total Tree Carbon (tC) = Above-ground Biomass * 1.2 * 0.5
2. Deadwood & BG Litter Carbon (tC) = ((Total Tree Carbon / area ha) * 0.149 + 3.5) * area (ha)
3. Net Ecosystem Carbon (tC) = Total Tree Carbon + Deadwood & BG Litter Carbon
4. Biomass Carbon density (tC/ha) = Net Ecosystem Carbon / area (ha)
5. Soil Carbon density = 125 tC/ha (based on average across all forested sites from FORECAST model)
6. A biomass carbon density raster layer (2m) was created by converting the VRI polygons to a raster format using the carbon density field (BiomTCHa) that was calculated in step 4 (See Fig. 7).
7. A soil carbon density raster layer (2m) was created by converting the VRI polygons to a raster format using the soil carbon density field (SoilTCHa) that was calculated in step 5 (See Fig. 8).

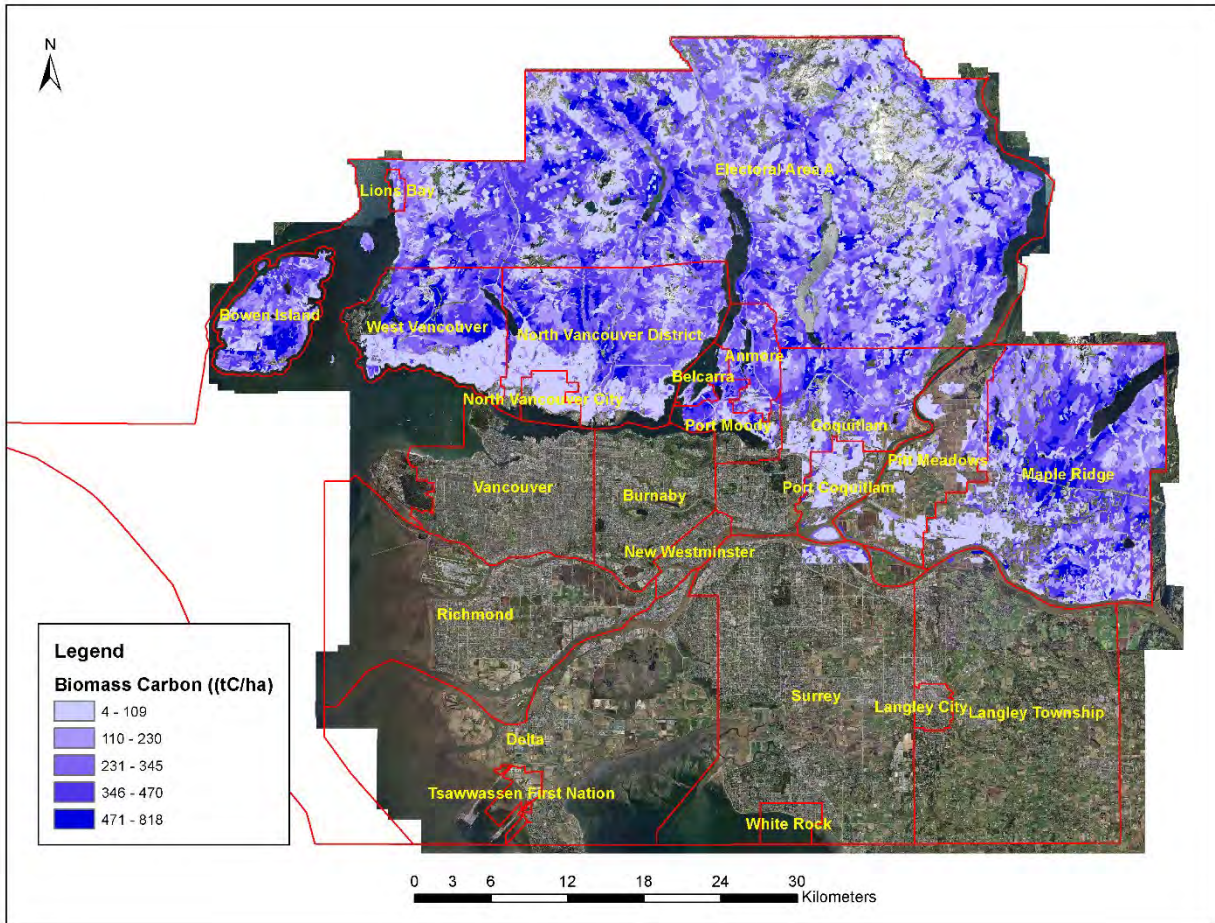


Figure 4. Map showing the spatial distribution of VRI biomass carbon by carbon density class.

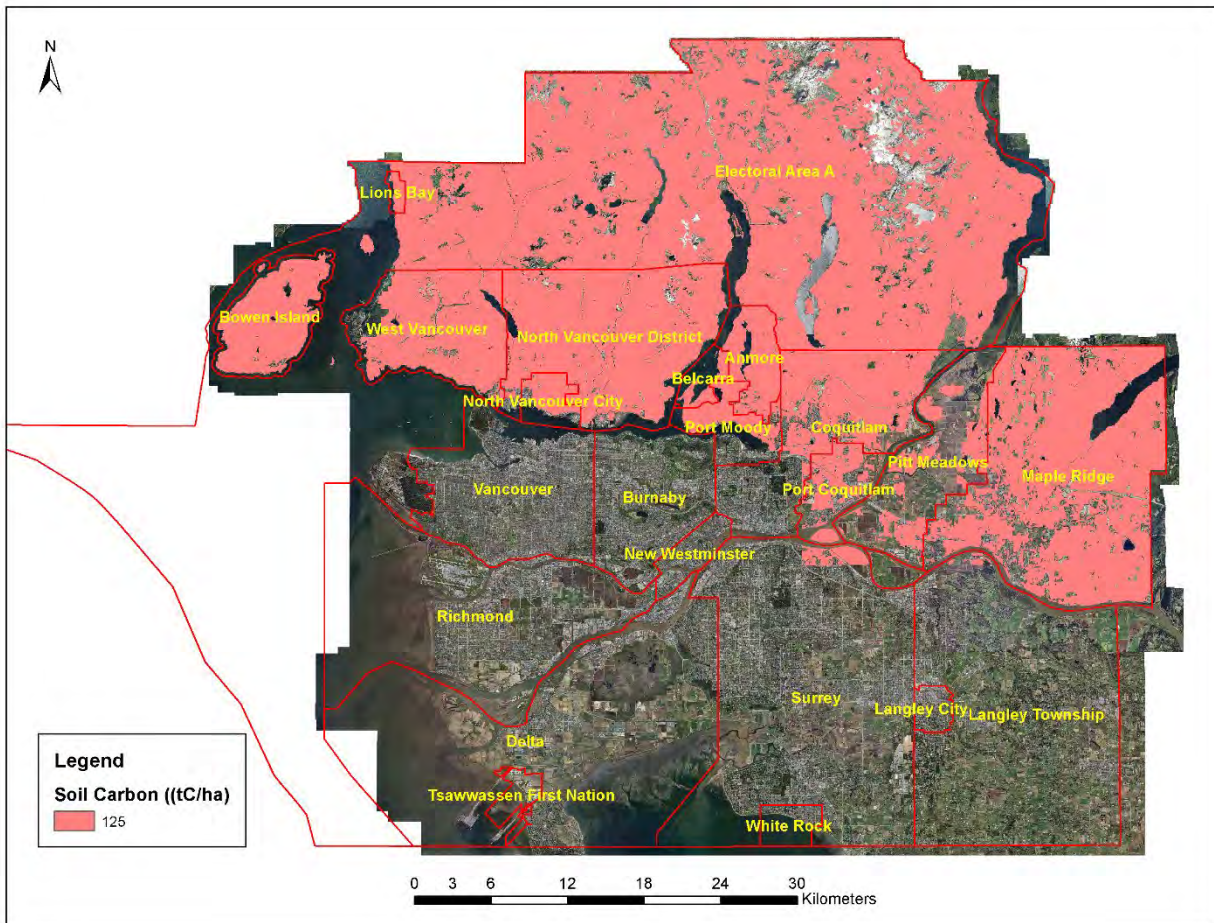


Figure 5. Map showing the distribution of VRI soil carbon by carbon density class.

Ecotype code assignment

To help the user keep track of the source of the carbon data and the nature of the ecosystem with which it is associated, an ecotype code was assigned to each raster cell in the carbon database. Different ecotype codes are associated with the different source data sets as well as different types of ecosystems. A description of all ecotype codes is presented in Table A2 (Appendix 1).

All VRI cells with carbon density data were assigned ecotype code 1 (Fig. 9).

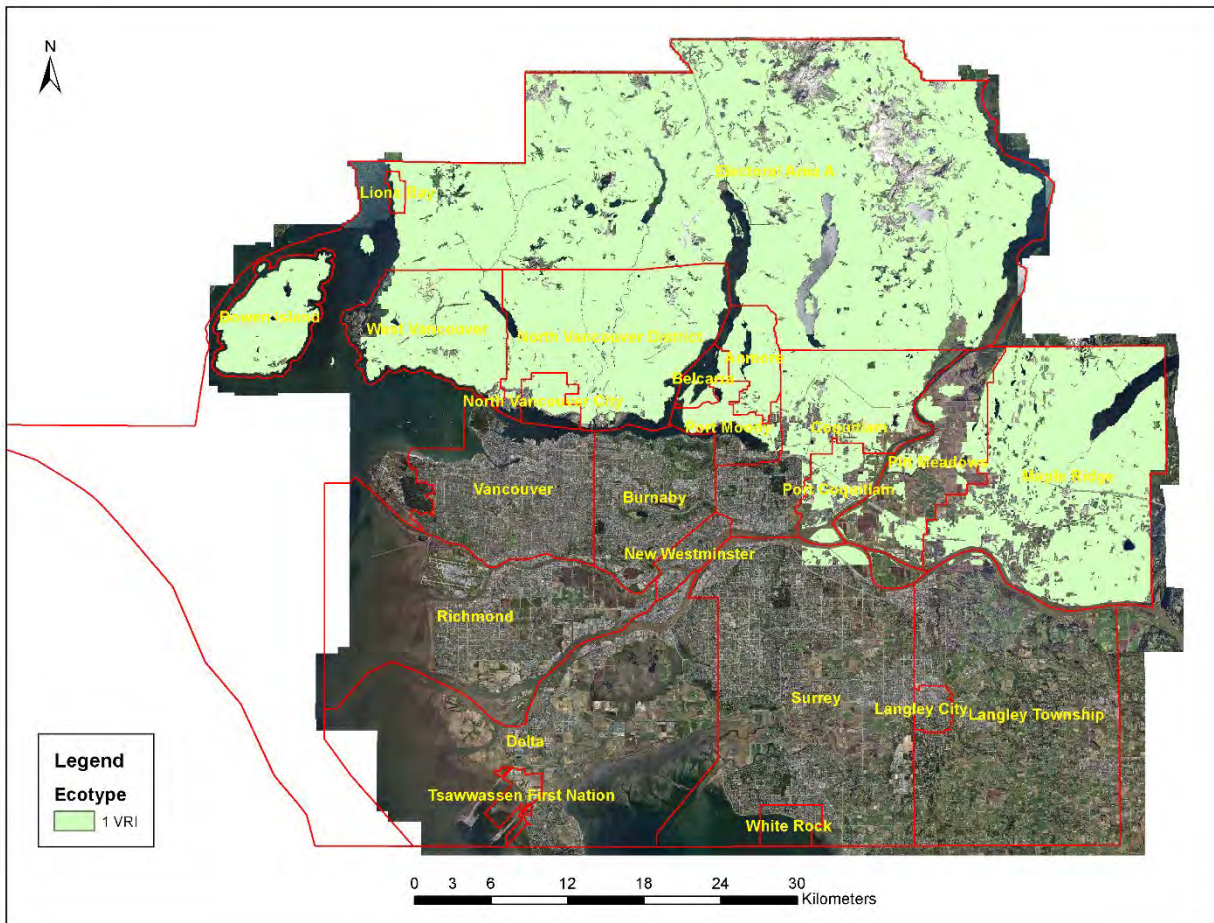


Figure 6. VRI ecotype code.

2.4.2 Land Cover Classification (LCC) Preparation

The LCC data was used to determine the carbon for forested areas for which there were no mapped VRI data. In the LCC, the forested areas are identified as either conifer or deciduous tree types. Biomass and soil carbon were assigned by using a lookup table based on species type and age. Since LCC contains no age information, age was derived from height as explained below.

Merging multi-resolution datasets

The original data was provided as a 5m resolution raster, which covered all of the Metro Vancouver area. An improved 2m LCC raster was also supplied, but its extent was limited to areas that included LiDAR coverage. The lower and higher resolution rasters were combined by first upscaling the 5m raster to 2m using nearest neighbor resampling. Then, the resampled raster

was merged with the improved 2m LCC and any overlapped areas were prioritized by using the improved 2m LCC.

Calculating tree height

Since the LCC data did not contain forest height information, municipal LiDAR datasets (Fig. 10) were used to determine tree top height. A description of the LiDAR data sets is provided in Table 1.

For ground elevation, the LiDAR point files were converted to rasters by using the average value from 2m point binning and voids were filled using linear interpolation with no maximum width limit.

For above-ground elevation, the LiDAR point files were converted to rasters using the maximum value from 2m point binning and no voids were filled. The maximum value was used to capture the top height of trees.

The tree height was calculated by subtracting ground elevation raster from the above-ground elevation raster.

Table 1. Summary of LiDAR data used to develop the carbon database.

Municipality/ Region	Year	Ground Classification ASPRS Code	Veg Classification ASPRS Code
Vancouver	2013	2,8	1,3,4,,5
Burnaby	2014	2,8	1,3,4,5
Surrey	2013	2,8	1,3,4,5
Langley	2011	2,8	1,3,4,5
UBC	2010	2,8	1,3,4,5
Surrey	2009	2,8	First Return
Burns Bog	2009	2,8	1,3,4,5
Coquitlam	2012	Not used because ground points only available	

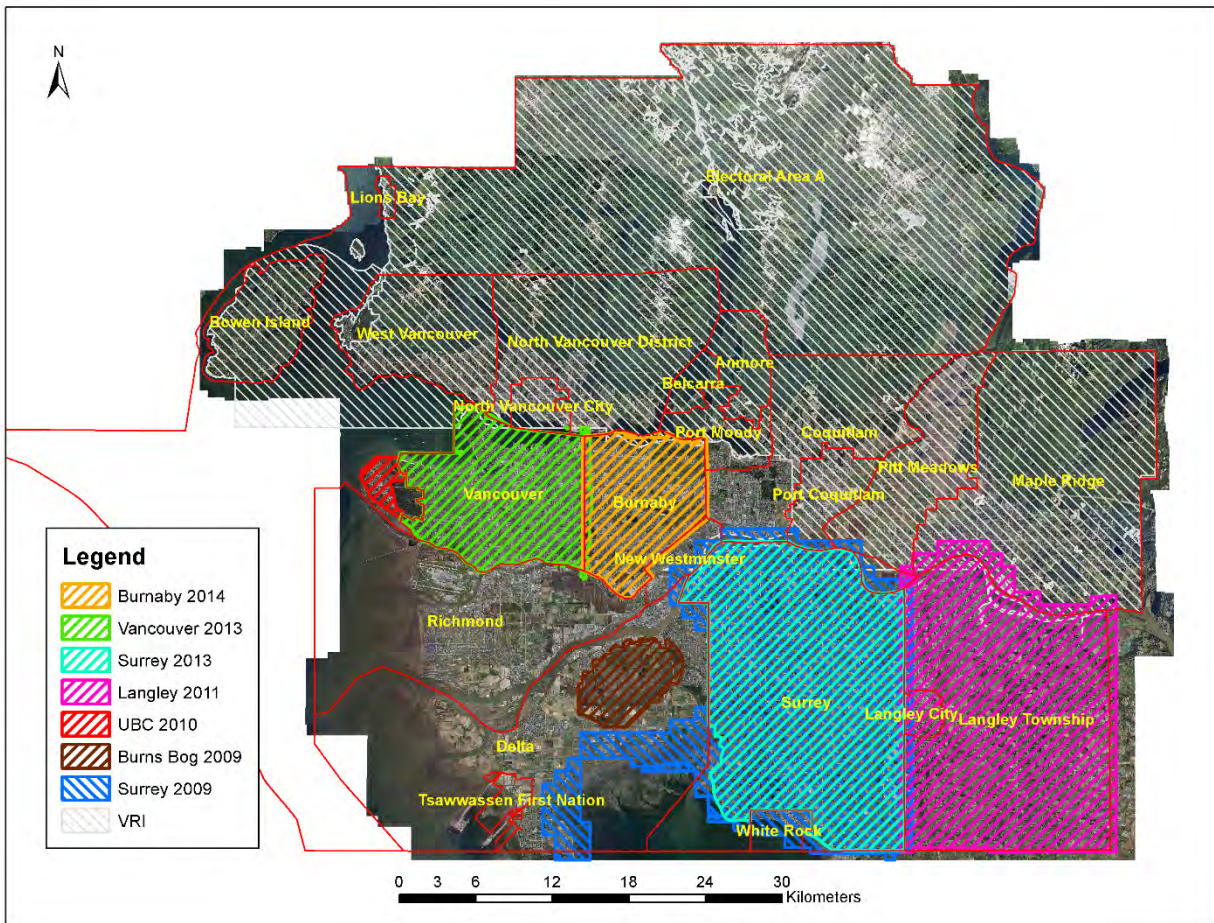


Figure 10. Illustration showing the coverage of LiDAR data available for use in determining LCC conifer and deciduous tree top height. Note, LCC and LiDAR were only used where VRI data were not available.

Deriving age from height

To calculate the carbon density for LCC tree types, age was determined by using general height-over-age curves for conifer and deciduous species based upon a site index of 35m (See Table A3; Appendix 1). As an example, if a cell contained conifer (code 6) and the height was 4.9m, then the age was 10.

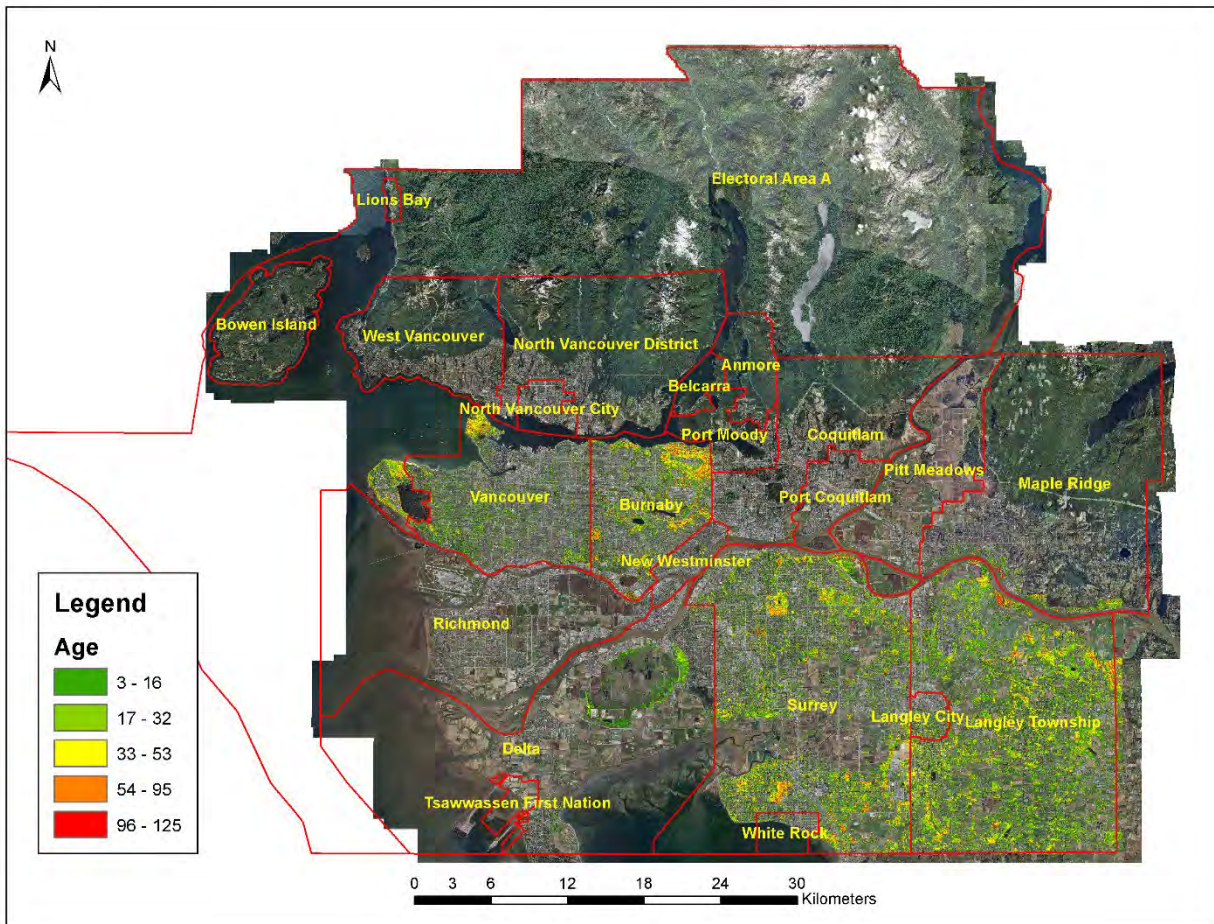


Figure 7. LCC age derived from tree height.

Carbon density calculation

Carbon density for both biomass and soil was determined using carbon density curves indexed by age. The curves for conifer and deciduous species groups were generated using the FORECAST model (Kimmins et al. 1999) calibrated for a general south coastal BC forest type (See Table A4, Appendix 1). As an example, if a cell was identified as conifer (code 6) and age is 10, then the soil carbon density was 124.5 tC/ha and biomass (Ecosystem C) density was 140.7 tC/ha. Spatial maps of carbon density values generated using the LCC data set are shown for biomass (Fig. 12) and soil carbon (Fig. 13). In cases where LCC data were available but LiDAR data were not available, a generic top height based upon the average of all cells with that species group was

assigned and used to index carbon density. The ecotypes associated with LCC-derived carbon density values are described in Table 2 and shown in Figure 14.

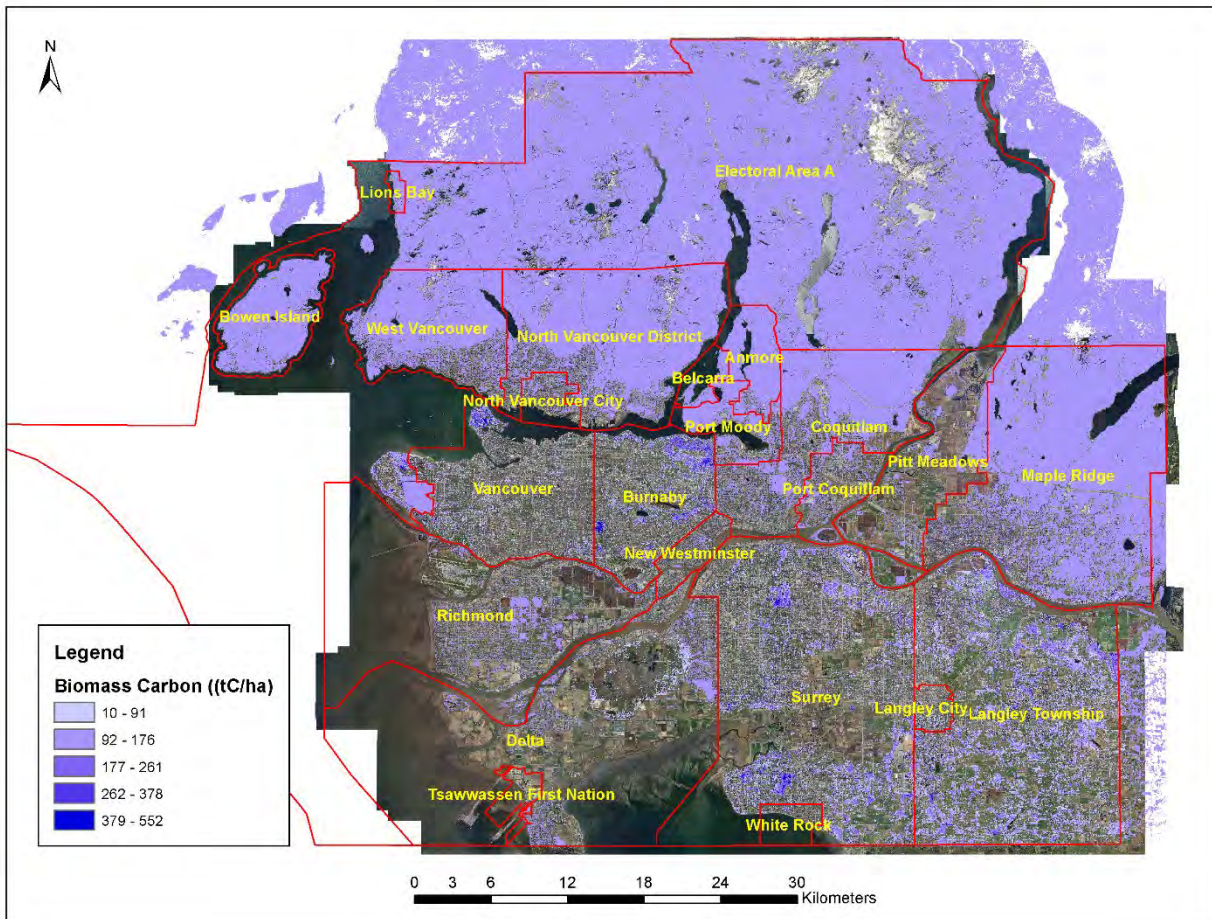


Figure 8. LCC biomass carbon density.

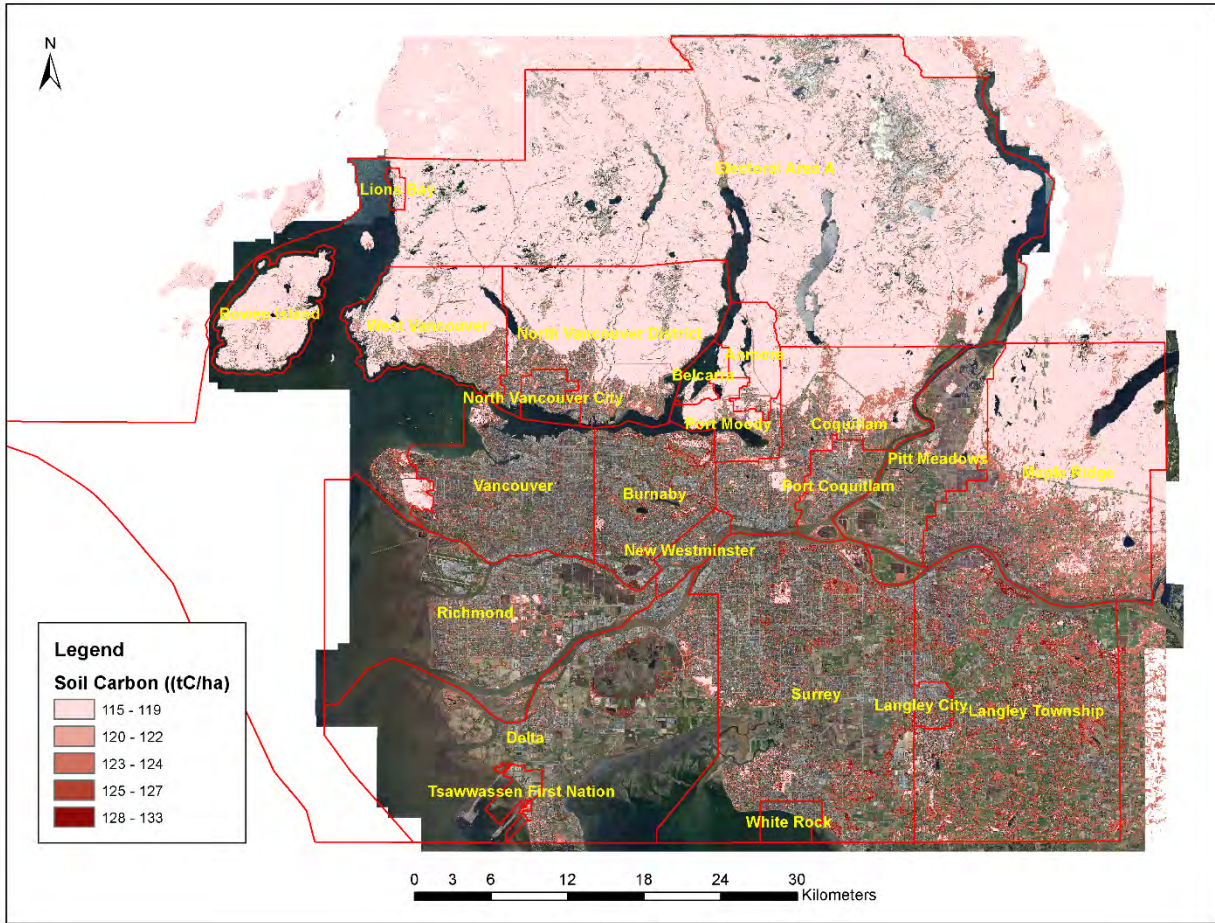


Figure 9. LCC soil carbon density.

Table 2. Ecotype code values associated with LCC derived carbon density values. Codes distinguish between species groups and the presence of LiDAR.

Tree Type	LiDAR Available	Ecotype Code
Conifer	Yes	2
Deciduous	Yes	3
Conifer	No	4
Deciduous	No	5

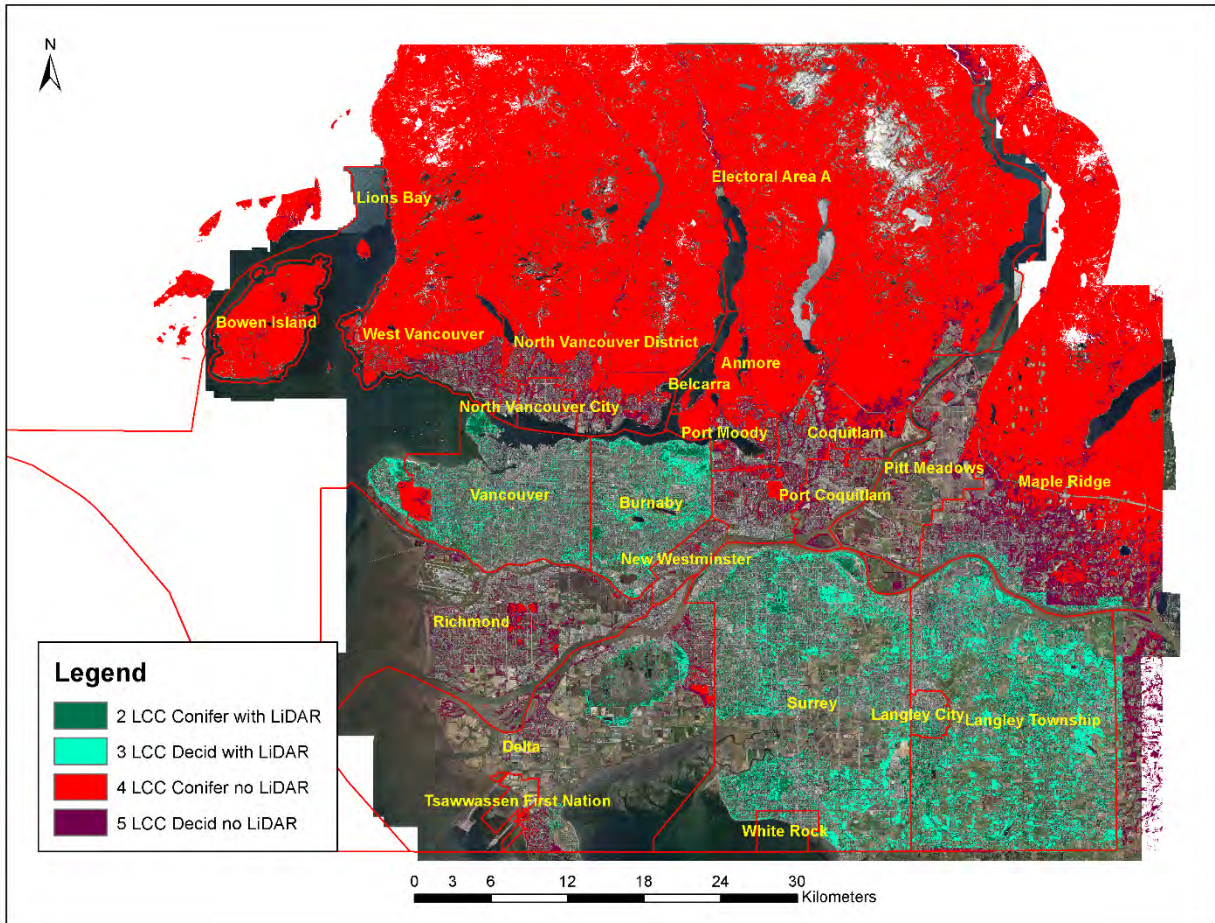


Figure 10. LCC ecotype code assigned to conifer and deciduous with and without LiDAR.

2.4.3 Sensitive Ecosystem Inventory (SEI)

The SEI dataset was used to address gaps in the carbon database associated with ecosystem types with significant carbon contents in non-tree vegetation and soils. Specifically, the SEI dataset facilitates the inclusion of carbon density estimations for estuarine, intertidal, wetland, and riparian ecosystems.

The salinity gradient from freshwater to brackish water to saltwater influences the development of riparian, freshwater wetland, estuarine and intertidal ecosystems. Intertidal and estuarine ecosystems, along with mangrove forests and seagrass meadows, are repositories of ‘blue’ carbon. Organic matter tends to accumulate in these ecosystems, due in part to their high rates of primary productivity, their ability to efficiently trap suspended particles, and their low exposure to wildfire. Moreover, hypoxic (low oxygen) conditions in wetland soils result in slow decomposition of organic matter and thus reduce the remineralization processes by which organic carbon is converted to CO₂ (Mcleod et al. 2011; Duarte et al. 2013). These ecosystems can have rates of organic carbon accumulation in soils (or burial) per hectare an order of magnitude greater than terrestrial forests (Mcleod et al. 2011; Duarte et al. 2013). Of additional importance, is that the presence of abundant sulfate in tidal soils hinders CH₄ production (a greenhouse gas 25 times more potent than CO₂), so these ecosystems are considered to be negligible sources of CH₄ (Chmura et al. 2003). There is also evidence that emissions of the greenhouse gas N₂O are also negligible.

Estuarine ecosystems are found at the confluence of rivers with the sea where freshwater inputs are diluted by diurnal tidal inundation and brackish water. There are about 8,368 ha of estuary in the Metro Vancouver area.

Estuarine ecosystems are distinguished from intertidal ecosystems by the degree of freshwater input – intertidal ecosystems experience saltwater tidal inundation with little to no freshwater input, except by rainfall runoff. The intertidal zone links the marine and terrestrial environments, with a total about 7,969 ha within Metro Vancouver.

Evidence suggests that the influence of salt water intrusion up the Fraser River ends at the mid-point of Annacis Island in the South Arm and at the eastern end of Mitchell Island in the North Arm (Neilson-Welch and Smith 2001). Meidinger et al (2014) also assumed that since saltwater does not penetrate past Mud Bay at the mouth of the Serpentine and Nicomekl Rivers (due to the presence of tidal dams), land types to the east of these areas should be classified as Wetland or Riparian, rather than estuarine or intertidal (see Figure 15).



Figure 15. Salt vs fresh water cut-off points. The freshwater areas to the east of each line are considered either wetland or riparian habitats; areas to the west are either estuarine or intertidal (see text).

A literature search was conducted in an effort to obtain carbon estimates applicable to the intertidal and estuarine ecosystems in Metro Vancouver. The search utilized the Clarivate Analytics Web of Science database. This database allows for a comprehensive citation search and accesses multiple databases that reference cross-disciplinary research, which allows for in-depth exploration of specialized sub-fields within an academic or scientific discipline. The search was conducted in several steps that progressed from general to specific in terms of the search criteria.

Step 1 used following search:

(estuar OR intertidal OR tidal marsh*)*

AND

*(emission OR carbon OR "green*house gas*" OR "GHG*" OR methane OR "organic matter" OR "organic content" OR CO₂ OR CH₄ OR N₂O OR "Nitrous oxide" OR DOM OR DOC OR SOM OR erosion OR depth OR accumulation OR subside* OR wastage OR shrink* OR accret*)*

AND

(flood OR drain* OR restor* OR “grip block*” OR re\$wet* OR plough* OR plow* OR till* OR cutt* OR cut\$over OR ditch* OR drought* OR graz* OR pastur* OR arable OR afforest* OR forest* OR re\$veg* OR extract* OR fertiliser OR fertilizer OR turf\$strip*)*

NOT

(Arctic OR tropic OR subtrop*)*

A total of 6,114 references were elicited. Of this number, the first 250 titles were scanned for relevance, from which a subset of abstracts was also perused.

The second search eliminated all management categories, as well as references from China and mangroves. The latter two criteria were not relevant to Metro Vancouver, while the first criterion was too focused around anthropogenic impacts on carbon storage:

(estuar OR intertidal OR tidal marsh*)*

AND

*(emission OR carbon OR “green*house gas*” OR “GHG*” OR methane OR “organic matter” OR “organic content” OR CO₂ OR CH₄ OR N₂O OR “Nitrous oxide” OR DOM OR DOC OR SOM OR erosion OR depth OR accumulation OR subside* OR wastage OR shrink* OR accret*)*

NOT

(China OR mangrove*OR Arctic OR tropic* OR subtrop*)*

A total of 8,669 references were elicited. Of this number, the first 250 titles were scanned for relevance, from which a subset of abstracts was also perused.

The third search sought to be more specific with respect to carbon within estuarine and intertidal systems:

(estuar OR intertidal OR tidal marsh*)*

AND

(carbon)

NOT

(China OR mangrove*OR Arctic OR tropic* OR subtrop*)*

A total of 7,001 references were elicited. Of this number, the first 250 titles were scanned for relevance, from which a subset of abstracts was also perused.

The next two searches were geographically specific, first by including 'PACIFIC' as a search term, and then 'BRITISH COLUMBIA'.

((estuar OR intertidal OR tidal marsh*))*

AND

(carbon)

AND

(PACIFiC)

NOT

(China OR mangrove*OR Arctic OR tropic* OR subtrop*)*

A total of 301 references were elicited. All were scanned for relevance, from which a subset of abstracts was also perused.

Using,

((estuar OR intertidal OR tidal marsh*))*

AND

(carbon)

AND

(BRITISH COLUMBIA)

NOT

(China OR mangrove*OR Arctic OR tropic* OR subtrop*)*),

a total of 54 references were elicited. All were scanned for relevance, from which a subset of abstracts was also perused.

Despite a reasonably comprehensive set of search criteria, relatively few references were uncovered with respect to carbon density estimates for intertidal and estuarine ecosystems. All references were very general with respect to carbon estimate (ie., they were averages across broad geographic areas) and none provided data for specific subclasses, either for British Columbia or elsewhere. This is likely, in part, because until recently, intertidal and estuarine ecosystems have not received widespread interest from the research community (Laffoley and Grimsditch 2009). By way of a contrasting example, simply replacing the first set of terms in the last search with the word 'FOREST' returned 8 times as many references (433). This is not a phenomenon specific to British Columbia. The same substitution on the first set of search criteria

returned 68,787 returns (versus 6,114) – and this excluded all tropical and subtropical forests, a very active area of research. In their worldwide review, Chmura et al (2003) found only 26 studies that reported soil carbon densities or parameters necessary for calculation of soil carbon density (soil bulk density and percent of soil organic matter or percent of soil carbon) in tidal saline wetlands.

Sensitive ecosystem inventory mapping was used to locate the primary ecosystem classes estuarine, intertidal, wetland and riparian, along with their subclasses. The carbon density that was assigned to each subclass are described in Table 3 and shown in Figure 16. Ecotype code assignments for SEI-derived carbon density estimates are described in Table 4 and shown in Figure 17.

Table 3. Carbon density values assigned to each of the non-tree ecosystem classes included as part of the SEI database.

Ecosystem	Subclass ¹	Carbon content (tC/ha)	Comments
Estuarine (ES)	Meadow (md)	105 (Chastain and Kohfeld, nd) ²	Upper tidal zones. Periodic flooding.
	Marsh (ms)	86.6 (average from Crooks et al. 2014; 71.7) and Callaway et al. 2012; 101.6) ³	Saltmarsh and brackish zones
	Swamp (sp)	86.6	Periodic flooding. Poor drainage. Area included as estuarine marsh.
	Tidal flat (tf)	na (not applicable)	Non-vegetated, soft sediment habitat; no carbon content (Miththapala 2013, Crooks et al. 2014).
Intertidal (IT)	Eelgrass (el)	0.15 ⁴ (McGowan et al. nd)	
	Mudflat (mf)	na	Non-vegetated, soft sediment habitat; no carbon content (Miththapala 2013, Crooks et al. 2014).
	Beach (bs)	na	Non-vegetated habitat; no carbon content.
Wetland (WN)	Bog (bg)	135 ⁵	
	Fen ((fn)	135 ⁵	
	Marsh (ms)	135 ⁵	Bordering open water bodies.

Ecosystem	Subclass ¹	Carbon content (tC/ha)	Comments
	Shallow water (sw)		Included as wetland marsh.
	Swamp (sp)		Included as wetland marsh.
	Wet meadow (wm)		Area insignificant; included as wetland marsh.
Riparian (RI)	Fringe (ff)	47.5 (Rallings 2016)	
	High bench floodplain (fh)	47.5 (Rallings 2016)	
	Mid bench floodplain (fm)	30.3 (Rallings 2016)	
	Low bench floodplain (fl)	17.1 (Rallings 2016)	
	Gully (gu)	na	Non-vegetated habitat; no carbon content.
	Mudflat (mf)	na	Non-vegetated habitat; no carbon content.
	River (ri)	na	Non-vegetated habitat; no carbon content.
	Canyon (ca)	na	Non-vegetated habitat; no carbon content.

¹ See Meidinger et al. 2014, for definitions

² Cored to depth to refusal.

³ Cores to 20 cm (Callaway et al. 2012) and 30 cm (Crooks et al. 2014) depths.

⁴ Average soil organic carbon from data collected in intertidal and subtidal zones, Grice Bay, British Columbia, Canada. Cored to depth of refusal.

⁵ Values for warm, temperate, moist regions to a 30 cm depth (IPCC 2014) were used to standardize measurements and facilitate comparisons. Similar, additional values can be found in a Ducks Unlimited Canada (2015) report. Differences in carbon stocks among and within subclasses can be substantial, as a consequence of peat depth and density, the latter of which varies by depth. Glooschenko et al. (1993), for example, indicate that regional peat depths for coastal BC can be up to 4m for fens, 2m in bogs, and 4-5m in swamps. Another important source of variation, however, is the depth to which the peat is measured. Depths and sampling techniques are not standardized (see, for example, Krüger et al. 2016); some studies only sample the upper layers, while others attempt to sample the entire profile.

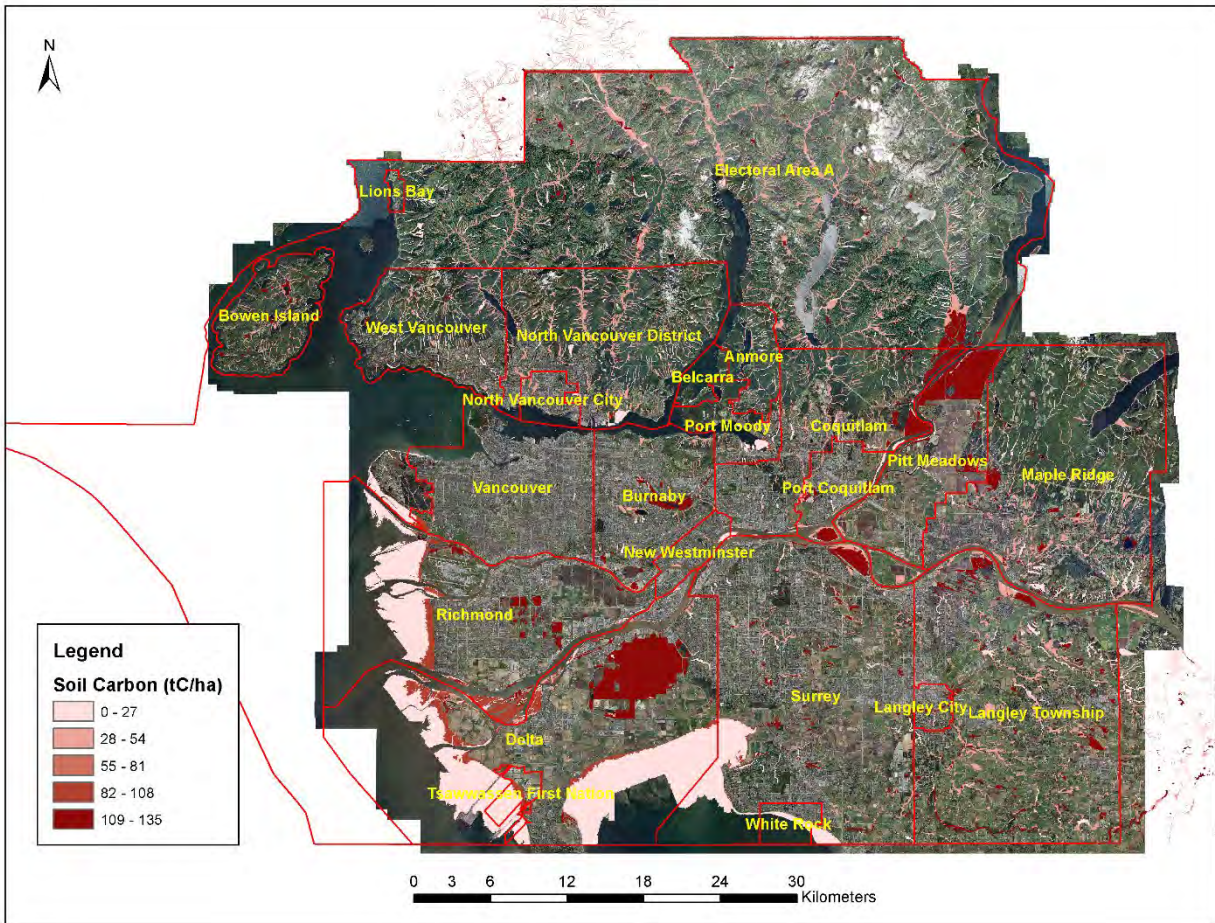


Figure 16. SEI Soil carbon density for estuarine, intertidal, wetland and riparian ecosystem classes.

Table 4. Ecotype codes assigned to the different SEI ecosystem types.

Ecosystem	Subclass	Ecotype Code
Estuarine (ES)	Meadow (md)	6
	Marsh (ms)	6
	Swamp (sp)	6
	Tidal flat (tf)	6
Intertidal (IT)	Eelgrass (el)	7
	Mudflat (mf)	8
	Beach (bs)	8
Wetland (WN)	Bog (bg)	9
	Fen ((fn)	9
	Marsh (ms)	9
	Swamp (sp)	9
	Shallow water (sw)	9
	Wet meadow (wm)	9
Riparian (RI)	Fringe (ff)	10
	High bench floodplain (fh)	10
	Mid bench floodplain (fm)	10
	Low bench floodplain (fl)	10
	Gully (gu)	10
	Mudflat (mf)	10
	River (ri)	10
	Canyon (ca)	10

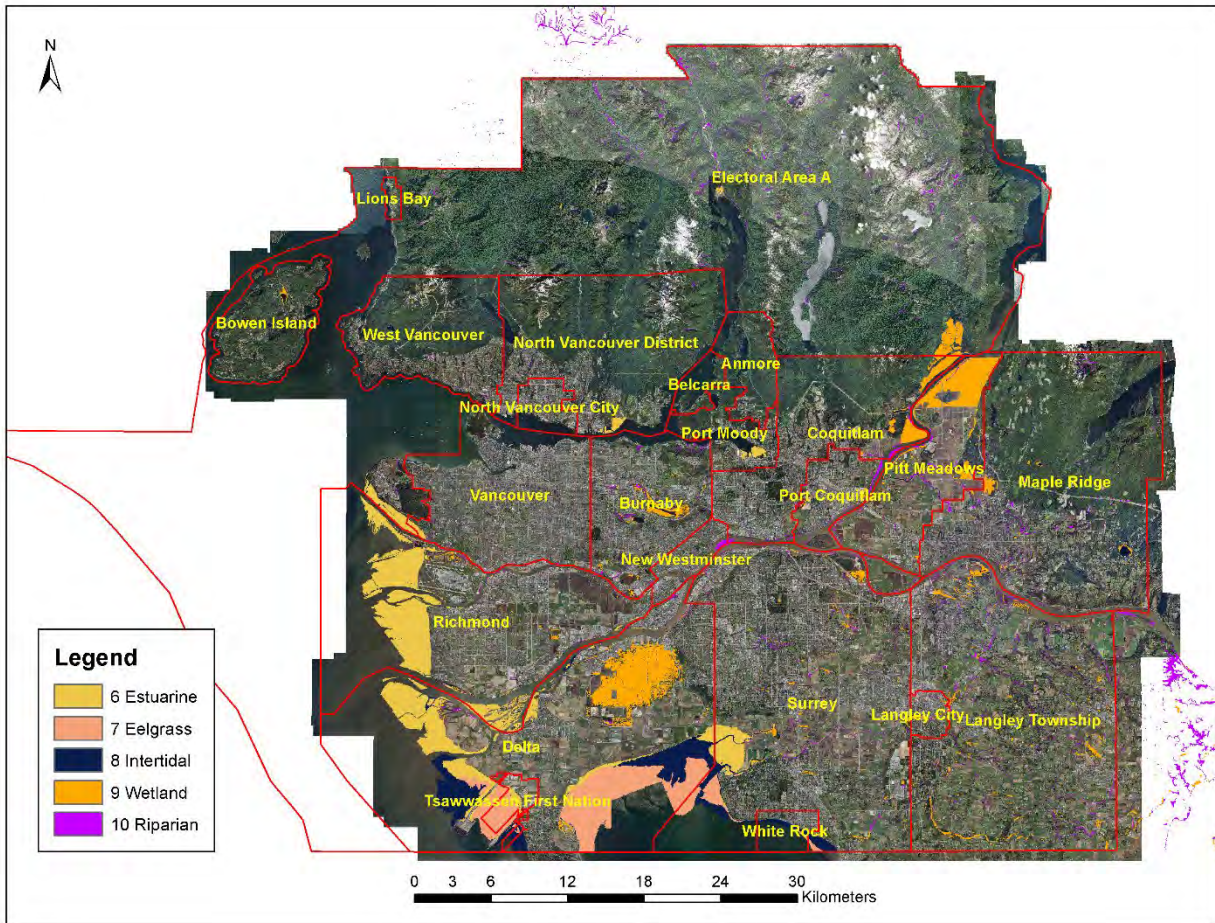


Figure 11. Spatial distribution of ecotype codes assigned to SEI ecosystem types.

2.4.4 Delta Agriculture Soil Database Preparation

Carbon density calculations

The agricultural soil organic concentration data described in Section 2.3.5 was used to calculate soil carbon density for the municipality of Delta. The data were provided as a 30m raster image containing soil organic carbon percent concentration in each cell. The percent concentration was converted to carbon density by utilizing a general bulky density estimate of 1.2g/cm³ at 30cm soil depth.

The following calculation was done for each cell.

Bulk Density = 1.2g/cm³

Soil Sample Depth = 30cm

Unit conversion factor (g/cm² to tonnes/ha) = 100

Carbon density (tC/ha) = ((Soil Organic carbon Concentration(SOC%) / 100) * Bulk Density * Soil Sample Depth) * Unit conversion factor

The spatial distribution of the agricultural soil carbon density data for the municipality of Delta is shown in Figure 18. All agriculture soil C cells were assigned to ecotype code 11.

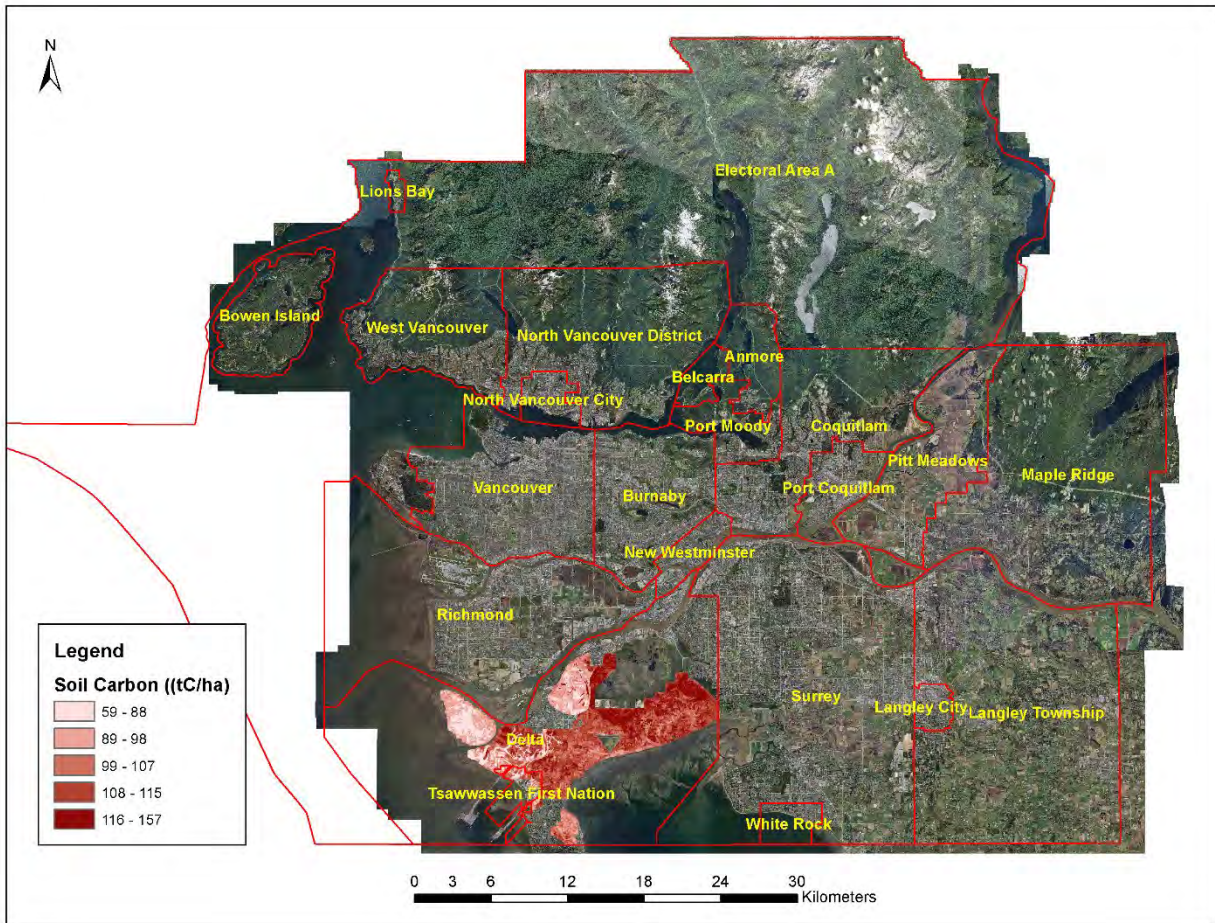


Figure 12. Agricultural soil carbon density calculated from soil organic carbon concentration for Delta.

2.4.5 Preparation of Metro Vancouver Parcel Data

The original parcel data file contained many lots that were split into multiple parcels which created a larger database that was slower to query. Thus, to streamline the database, the original parcel layer was simplified by using the 'dissolve' function in ArcGIS (by the GlobalID, FirstAddress and Municipality fields). As a result, single-part polygon parcels were transformed into multi-part parcel features which allows for simplified queries and reporting. An example of the effect of this operation is shown in Figure 19. The parcels were subsequently converted to raster format. This step was taken to allow for a more spatially accurate summary of carbon statistics when overlaying the carbon rasters on the parcels layer (using the raster statistics function in ArcGIS). Since the GlobalIDs were not numeric, a numeric surrogate field called CParcelID was created to represent the GlobalIDs, so that it could be used as the ID value in the rasterized parcels.

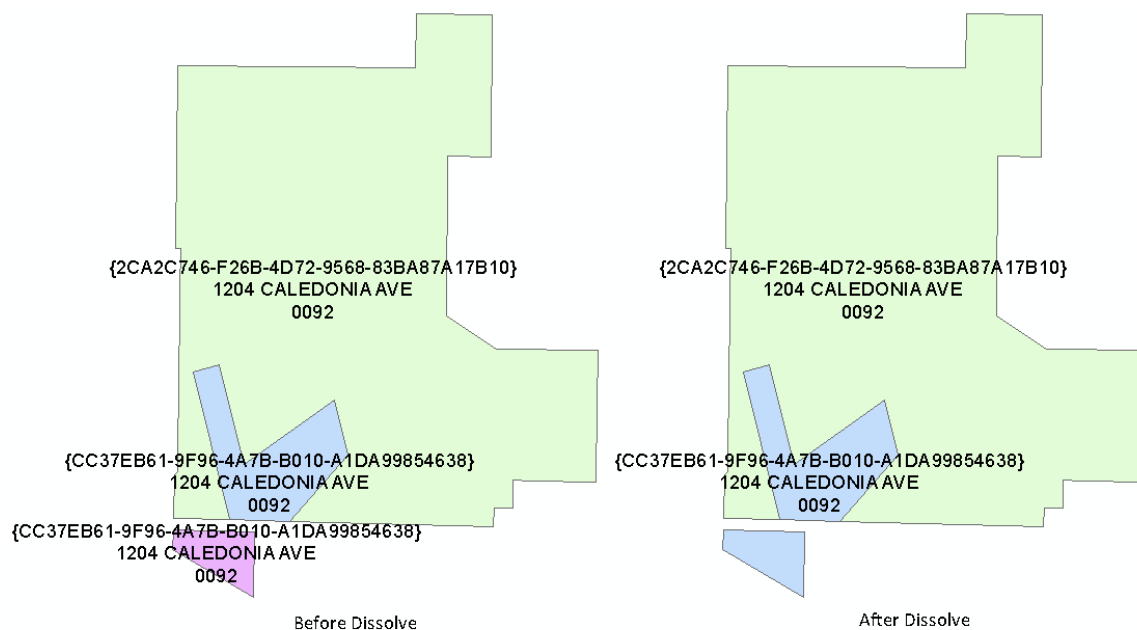


Figure 13. Two parcel polygons with the same GlobalID (CC3...) are merged into a multi-part feature after dissolving. Note, parcels with the same address can contain different parcel Global IDs.

2.4.6 Joining Data Layers to Create the C database

Combining biomass carbon rasters

The data layers containing tree biomass (VRI and LCC) were combined into a single raster for biomass carbon density. Since, there were overlapping areas between the datasets, the merging order of precedence was as follows:

1. VRI - considered the best estimate of carbon and took precedence over all other sources
2. LCC – second best source of carbon

Note, water areas were removed from the datasets prior to combining. The resulting biomass carbon density data layer (2m) is shown in Figure 20.

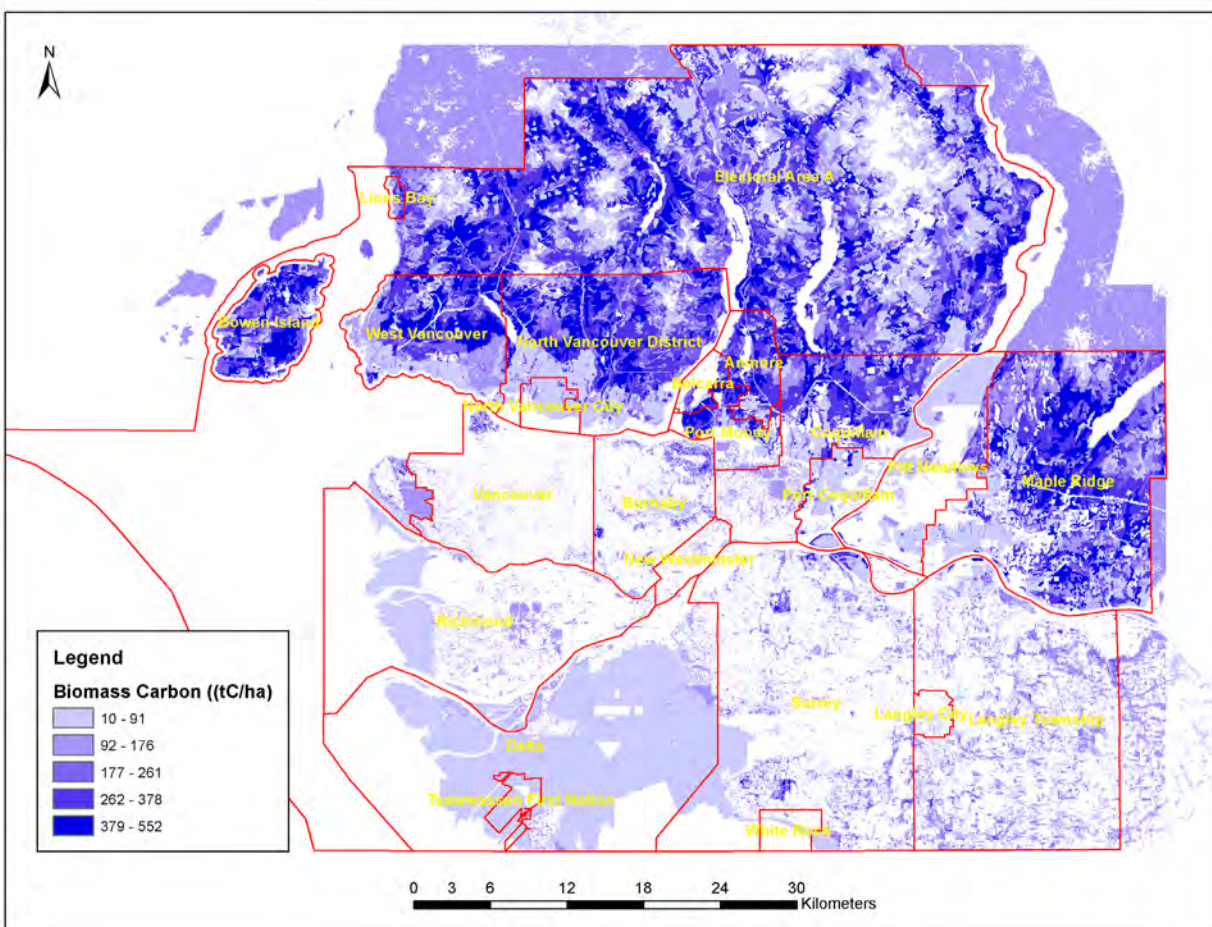


Figure 14. Combined biomass carbon density raster using VRI and LCC.

Combining soil carbon rasters

Soil carbon density data from VRI, LCC, SEI and Delta agricultural soil layers were combined into a single raster (2m). Since there were overlapping areas between the datasets, the merging order of precedence was as follows:

1. VRI - considered the best estimate of carbon and took precedence over all other sources
2. LCC – second best source of carbon
3. SEI – third best source of carbon
4. Delta agricultural soils – lowest precedence

Note, water was filtered from the datasets prior to combining.

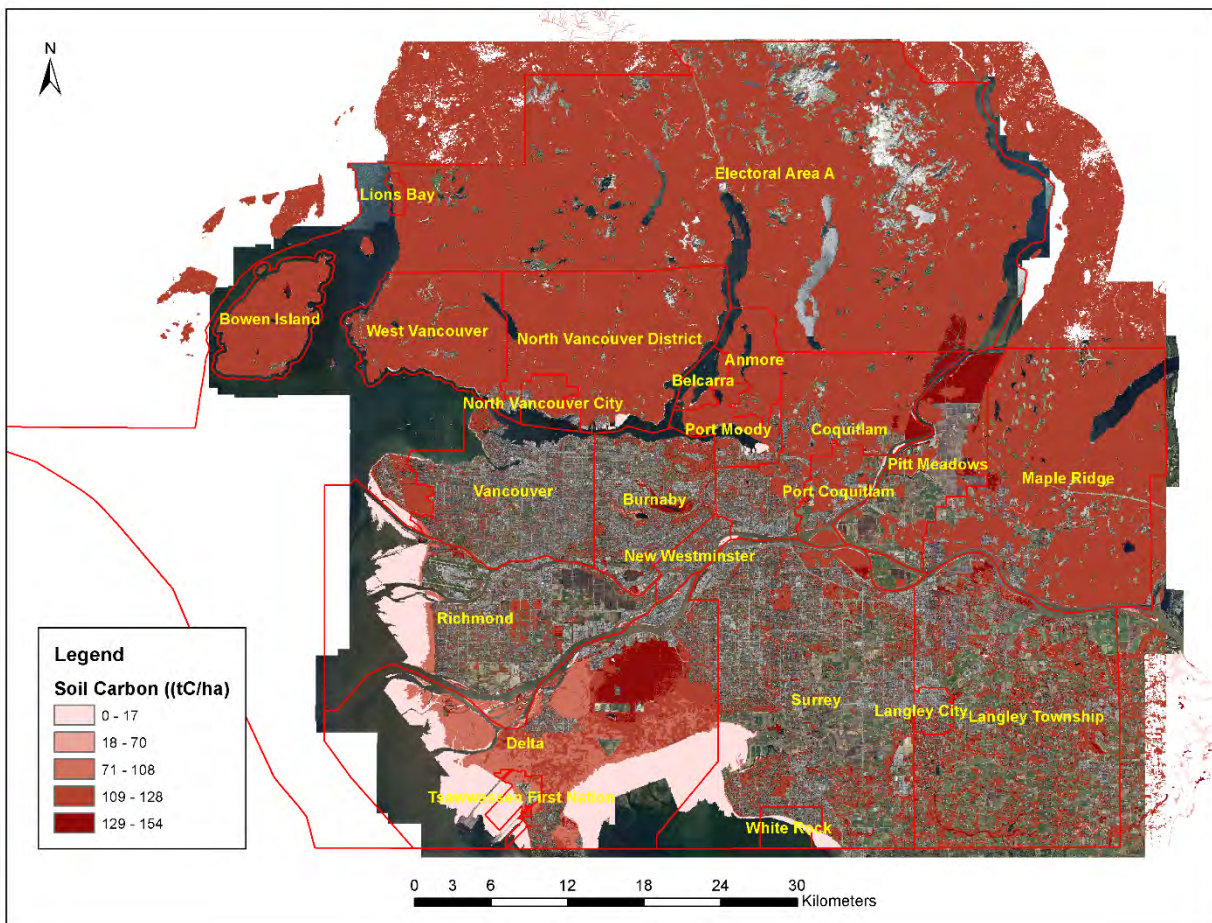


Figure 15. Combined soil carbon raster using VRI, LCC, SEI, AGR order of precedence.

Combining ecotype raster

Ecotype layers generated as part of the updating process for VRI, LCC, SEI and Delta agricultural soil C were combined into a single raster data set (2m). Since, there were overlapping areas between the datasets, the merging order of precedence was the same as that described for soil carbon density above. The resulting map is shown in Figure 22.

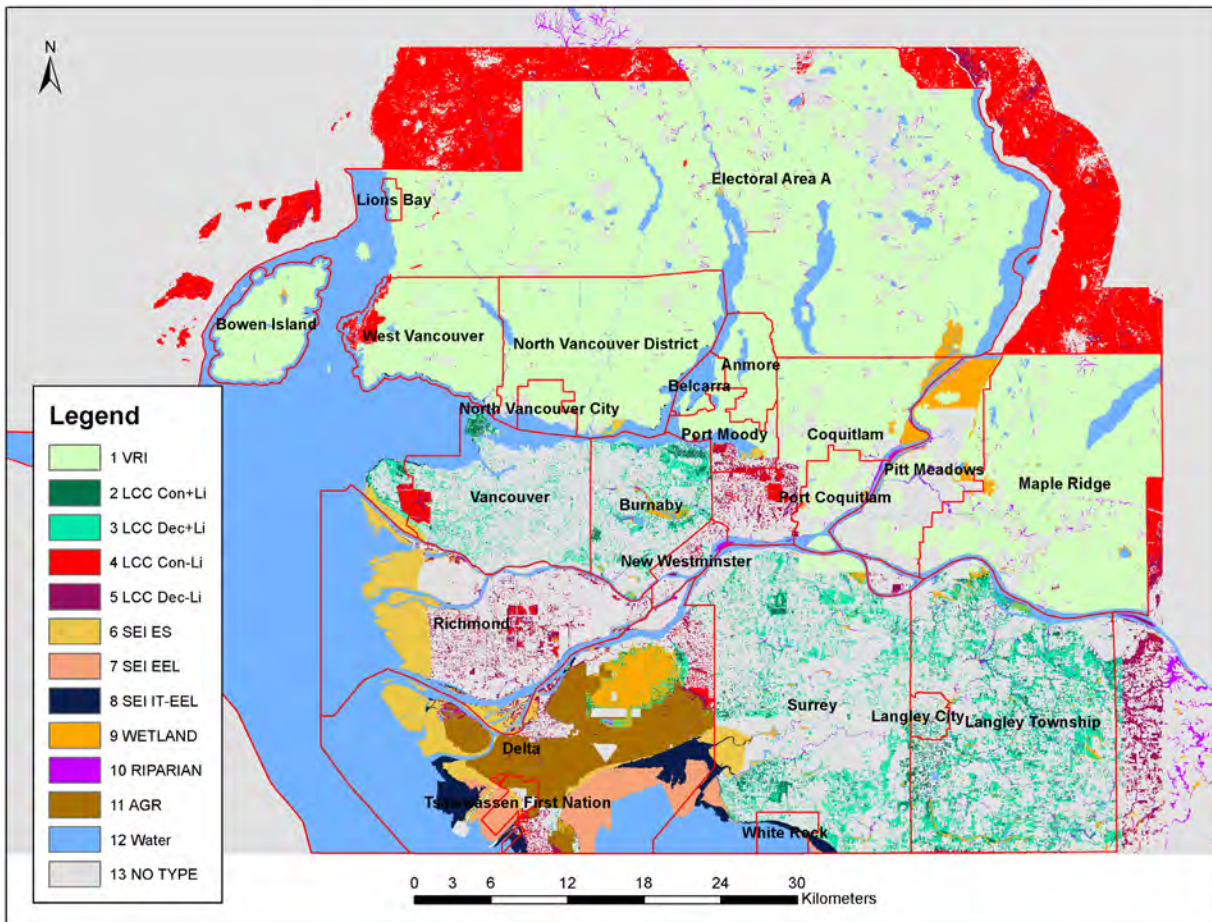


Figure 16. Combined ecotype raster using VRI, LCC, SEI, AGR order of precedence.

2.4.7 Creating a Parcel-based Database

A parcel-based, vector format database was created to provide a tool that could be easily used by planners to explore the potential carbon implications of different development options within a given municipality (see Section 5). The database is provided as a geodatabase feature class called parcelscarb. For each parcel the fields shown in Table 5 were calculated using the combined carbon density and ecotype rasters. The n_ fields (Table 5) can be used to characterize the nature of the carbon within a given parcel. For example, if a user wanted to know the percent of the area within a given parcel that was forested she could calculate it as:

$$\text{Percent area forested (\%)} = n_{\text{Forest}} * 4\text{m}^2 / (10000\text{m}^2/\text{ha}) / \text{ParcelHa} * 100$$

Table 5. A description of the fields included in the parcelscarb database.

Field	Description
ParcelHa	Area of the parcel polygon.
CCellCount	Total number of cells that contain carbon within the parcel.
CCellHa	Area of cells that contain carbon within the parcel.
TotSoilTC	Total amount of soil carbon (tC) for cells that contain soil carbon within the parcel.
TotBiomTC	Total biomass carbon (tC) for cells that contain biomass carbon within the parce
TotalTC	Total carbon (tC) within the parcel. The sum of SoilC + BiomC.
AvgSoilTCHa	SoilC / ParcelHa
AvgBiomTCHa	BiomC / ParcelHa
AvgTotTCHa	AvgSoilTCHa + AvgBiomTCHa
n_VRI	Number of VRI ecotype cells within the parcel.
n_LCC	Number of LCC ecotype cells within the parcel. This includes conifer and deciduous with LiDAR or without LiDAR.
n_SEI	Number of SEI ecotype cells within the parcel. This includes estuarine, eelgrass, intertidal, wetland and riparian.
n_AGR	Number of agriculture ecotype cells within the parcel.
n_CSrcs	Number of sources used to determine the carbon content. This includes VRI, LCC, SEI or Agriculture.
n_LCC_Li	Number of LCC cells with LiDAR within the parcel.
n_LCC_Dec	Number LCC deciduous cells within the parcel.

Field	Description
n_LCC_Con	Number of LCC conifer cells within the parcel.
n_Forest	Number of forested cells (n_VRI + n_LCC) within the parcel.
n_UrbSub	Number of untyped cells within the parcel with a GlobalID.
n_Agriculture	Number of agriculture cells within the parcel.
n_Estuarine	Number of SEI estuarine cells within the parcel.
n_Eelgrass	Number of SEI eelgrass cells within the parcel.
n_Intertidal	Number of SEI intertidal cells within the parcel.
n_Water	Number of water cells within the parcel.
n_Wetland	Number of SEI wetland cells with the parcel.
n_Riparian	Number of SEI riparian cells within the parcel.
n_Unknown	Number of unknown cells within the parcel without a GlobalID.

Demonstration of calculations for an example parcel

Figure 23 shows an example of carbon calculations and ecotype summarization for a parcel. The following results were generated from the example parcel as a demonstration of the field calculations and classifications that take place with respect to calculating and reporting the carbon statistics for that parcel. A full list of fields and sources used in the database is provided in Appendix 1.

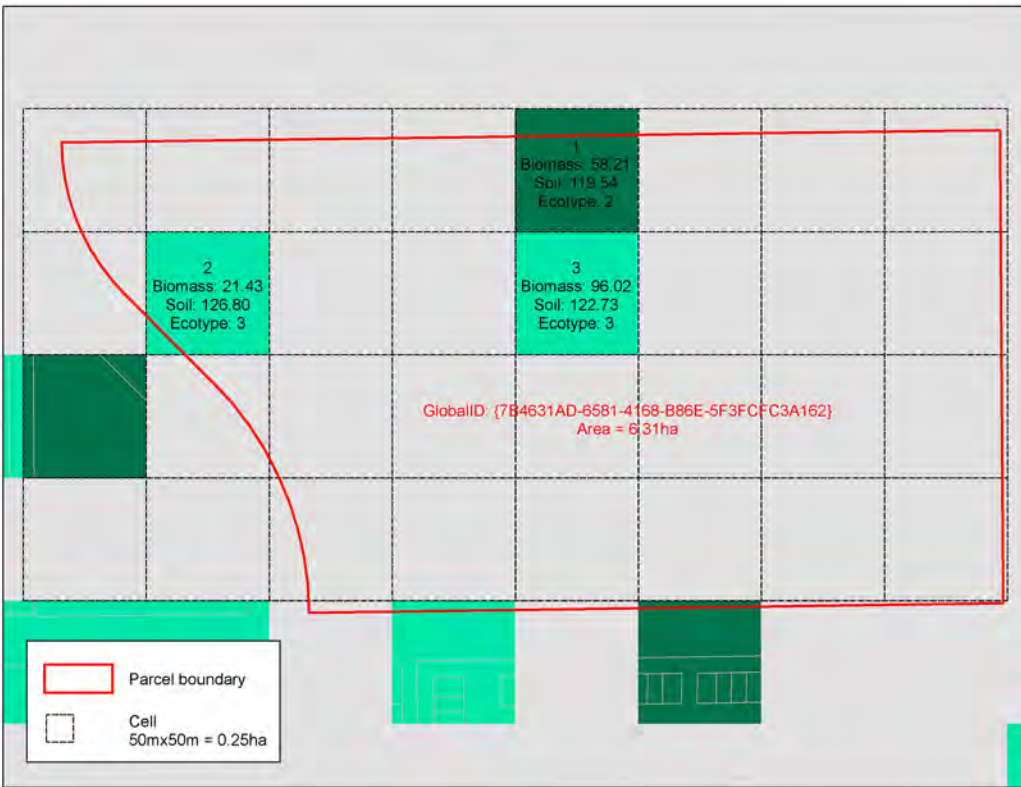


Figure 23. This example shown with the 50m raster resolution is for illustration purposes only and does not represent the final resolution. The final calculations for the parcelcarb database were done using the 2m rasters

Example calculations & classifications

GlobalID: {7B4631AD-6581-4168-B86E-5F3FCFC3A162}

ParcelHa: the area of the parcel polygon boundary. 6.31 ha

CCellCount: cell 1,2 and 3 have carbon and within the boundary, so the count is 3.

CCellHa: since there are 3 cells with carbon and the cell area is 0.25ha, the area is 0.75ha (3x0.25ha).

TotSoilTC: the 3 cells have soil carbon density values of 119.54, 126.8, and 122.73 tC/ha. The total soil C is $(119.54 + 126.8 + 122.73) * 0.25\text{ha} = 92.27 \text{ tC}$.

TotBiomTC: the 3 cells have biomass carbon density values of 58.21, 21.43, and 96.02 tC/ha. The total soil C is $(58.21 + 21.43 + 96.02) * 0.25\text{ha} = 43.91 \text{ tC}$.

TotalTC: the total of SoilC + BiomC. = 136.18 tC.

AvgSoilTCHa: average soil density is calculated by taking the soil carbon and dividing it by the parcel area. $\text{SoilC} / \text{ParcelHa} = 14.62 \text{ tC/ha}$.

AvgBiomTCHa: average soil density is calculated by taking the biomass carbon and dividing it by the parcel area. $\text{BiomC} / \text{ParcelHa} = 6.96 \text{ tC/ha}$.

AvgTotTCHa: the total of AvgSoilTCHa + AvgBiomTCHa = 21.58 tC/ha.

n_VRI: there are no VRI type cells within the parcel.

n_LCC – cell #1 is ecotype 2 and cell #2,#3 are ecotype 3, Both ecotypes are LCC types, so the count is 3.

n_SEI: there are no SEI type cells with the parcel.

n_AGR: there are no agriculture type cells within the parcel.

n_CSrcs: LCC type cells were the only sources of carbon, so the source count is 1.

n_LCC_Li : cell #1 is ecotype 2 and cell #2,#3 are ecotype 3, Both ecotypes are LCC types cells with LiDAR, so the cell count is 3.

n_LCC_Dec : cell #2,#3 are ecotype 3, which is LCC type deciduous, So the cell count is 2.

n_LCC_Con: cell #1 is ecotype 2, which is LCC type conifer, So the cell count is 1.

n_Forest: $n_VRI + n_LCC = 0 + 3 = 3$.

n_UrbSub: all of the grey cells are untyped and the parcel has a GlobalID. The count is 24.

n_Agriculture: there are no agriculture cells with the parcel.

n_Estuarine: there are no SEI estuarine cells within the parcel.

n_Eelgrass: there are no SEI eelgrass cells within the parcel.

n_Intertidal: there are no SEI intertidal cells within the parcel.

n_Water: there are no water cells within the parcel.

n_Wetland: there are no SEI wetland cells with the parcel.

n_Riparian: there are no SEI riparian cells within the parcel.

n_Unknown: all of the grey cells are untyped, but the parcel GlobalID is not null, so the count is 0.

3 Comments on accuracy of the dataset

The objective is to create a dataset that can provide accurate estimates of carbon stored with a minimum scale of ~50 ha in order to support accurate land use decision-making.

3.1 A general comment on accuracy

Two versions of the raster database have been created, at cell spatial resolutions of 2m and 50m, respectively. The higher-scale dataset is smaller and thus easier to handle, with faster processing speeds. It is appropriate for broader level analyses. At this scale, uncertainty can be introduced because the attributes (and associated carbon estimates) assigned to a given raster cell are represented by the 'dominant' ecotype. The smaller-scale dataset resolves this issue because it includes much smaller cells and therefore allows for a more refined analysis.

3.2 Uncertainty in Class and Subclass assignments

Only the forest ecotype derived from the VRI data was updated to document changes in cover and which, in most cases, was a consequence of a land-use change. For all other ecotypes, class and subclasses were assigned in the database from prior classification; this represents one potential source of error. Obtaining uncertainty estimates in ecosystem classification requires field surveys (see, for example, Meidinger et al. 2014). In terms of the SEI, Meidinger et al (2014) conducted an independent quality assurance analysis using a randomly selected array of polygons, and determined that class was mapped correctly 91% of the time and subclass 86% of the time. SEI database assignment might thus be subject to relatively low uncertainty. Ruan et al. (2017) achieved accuracies in land cover classification of 88% using the fine spatial resolution of LiDAR and the spectral detail of RapidEye imagery.

At the scale employed in this work, there are significant barriers associated with undertaking an accuracy assessment over an area the size of Metro Vancouver (Meidinger et al. 2014; see also Coombes 2010). One issue is the cost that will be required to install a comprehensive plot network. Another issue is that many ecotypes are situated on private land and obtaining access will require considerable outreach. Options to mitigate these issues include incremental (ongoing) investment to incrementally build out the plot network, and the use of 'citizen science' networks of NGOs to aid in classification and plot installation.

3.3 Uncertainty in Carbon Estimates by Ecotype

With the exception of the FOREST ecotype, most of the other ecotypes have few direct estimates of carbon density. Rather, carbon estimates in these non-forest ecotypes have been generated from mapping exercises each with varying degrees of error. The following section contains a description of the uncertainty associated with the specific carbon ecotypes used in the database.

FOREST

Carbon estimates in the forest ecotypes are derived from the VRI dataset. VRI is a photo-based, two-phased vegetation inventory design consisting of Photo Interpretation and Ground sampling. Typically funded by government, VRI has a generally high reliability though there is no specified re-inventory cycle.

AGRICULTURE

There are two significant sources of error associated with the agriculture ecotype. One issue is that this ecotype was not specifically identified in any municipality other than Delta. Other municipalities contain agricultural areas but they have not been mapped. These areas are included as urban/suburban areas (n_UrbSub) in the parcel database and have no carbon value associated with them. Accurate classification of the various forms of agricultural land for inclusion in future versions of the database is required. At present, agriculture and its associated carbon stock is underrepresented within the database. A second, related consideration is that, following land conversion, crop production has generally resulted in a decline in soil organic matter levels (Jarecki and Lal 2003). Depletion rates can be variable, depending on soil type, previous land use, and cropping practices. Conversely, abandonment and restoration practices (see Jarecki and Lai 2003, for examples) can act to restore soil organic carbon (SOC). In most cultivated soils, however, these changes in SOC are slow and significant improvements may require many decades (Lal et al., 1998). Improvements in SOC then can likely be ignored within the carbon database, at least over the medium term.

INTERTIDAL (EELGRASS)

The distribution of eelgrass beds within the Metro Vancouver region is poorly understood and this is an important source of error within the database. Accurate mapping of eelgrass beds should therefore be a priority, given that eelgrass is sensitive to both physical disturbance and rising sea levels. Work is underway within Metro Vancouver that may be useful in terms of developing more precise estimates of carbon density in intertidal areas. The distribution of native eelgrass (*Zostera marina*) is being mapped and monitored in Boundary Bay, for example.³ If associated vegetative and soil carbon densities were also to be collected, this would contribute to estimating carbon storage in these ecosystems.

WETLAND (freshwater)

³ Matt Christensen, Conservation Programs Specialist, Ducks Unlimited (Canada), for a project by the [Friends of Semiahmoo Bay Society](#).

With agricultural expansion and flood prevention, the prevalence of freshwater wetlands (and riparian areas) within Metro Vancouver is likely much reduced over what existed in the pre-settlement period (BC Ministry of Water Land and Air Protection, 2006; Fraser River Action Plan, 1999). Wetlands are also likely subject to ongoing loss and degradation. To remain 'healthy', these ecosystems require fluctuating water levels. Historically, many wetlands were likely recharged principally from floodwaters of the Fraser River during the spring freshet and, possibly, runoff and seepage from local mountains, though bogs can be sustained from precipitation alone. Dyking of the Fraser has eliminated regular, extensive flooding, while drainage installed to facilitate development (both for agriculture and the built environment) is likely to have lowered the water table and minimized overland water flows. Many remaining wetlands systems might therefore be converting to wet meadow and upland ecosystems. Change detection via high-resolution orthophoto sequences are likely the most practical means of documenting wetland status over broad areas. Potential metrics include open-water area, and woody vegetation encroachment. Assessing wetland carbon stock is problematic because few of these ecosystems within Metro Vancouver have any direct measures.

The carbon balance in wetland ecosystems (i.e., whether they are functioning as sources or sinks) depends on the competing processes of soil organic matter oxidation versus the carbon sequestered as vegetation becomes established. There are two principal approaches to determine the soil C balance of wetlands, process and inventory studies (Simola et al. 2012). Process studies report gas exchange from soil or the entire ecosystem while inventory studies examine the long-term changes in C stocks (Krüger et al. 2016). Each approach has its merits and limitations. Process studies are time consuming and expensive. Furthermore, results are relevant only for several years (because conditions change), and are very much a function of climatic conditions prior to and during the measuring period. Inventory studies examine the long-term C balance of wetlands. Hence, any management and drainage history have to be well documented. Changes in soil C balance are documented in either of two ways: (i) resampling a site over decades to compare C-stocks between present and historical measures (Simola et al., 2012) or (ii) profiles of paired undrained and drained parts of a wetland are compared (Minkinen et al., 1999; Pitkänen et al., 2013) in a space-for-time substitution approach.

RIPARIAN

A characteristic of riparian zones is their high capacity for carbon storage (Rallings 2016), in both living biomass and soil (Dybala et al. 2018). Variation in carbon density can be considerable, depending on age (in the case of forested areas), species composition, and management history (Dybala et al. 2018). Change detection via high-resolution orthophoto sequences are likely the most practical means of documenting changes in riparian status and could also be used to better define species composition. Age could be estimated from LiDAR, in conjunction with assumptions

regarding stand productivity. Field estimates are generally lacking and would provide an important means of ground-truthing.

4 Future Updates to Dataset

The nature of datasets such as the carbon database described here is that their accuracy declines over time as the landscape changes due to human activities and natural processes. Thus, it is important to have a system in place to update the regional carbon storage dataset over time. Since the carbon database is derived in-part from other primary mapping datasets maintained by Metro Vancouver (Sensitive Ecosystem Inventory, Land Cover Classification), it makes sense to update the databases together. For example, if the Metro Vancouver were to update the LCC database, it would be relatively straight forward to update the carbon database utilizing the methodology and following the steps described in Section 2. Similarly, the province provides updates to the VRI dataset on an annual basis. While annual updates are not necessary for the carbon database, it would make sense to consider updating the VRI component on a five-year time period. It would also require the use of updated orthophotos to identify areas missed by the VRI updating process (see Section 2.4.1). Another data layer that would be subject to relatively frequent changes is the parcel database. Lots are commonly redrawn due to changes in ownership and development, etc. It would be relatively easy to update the parcelcarb database to a revised lot database without making any changes to the underlying carbon density raster data layers.

Clearly, periodic and consistent updating of these datasets should be a priority. For those ecotypes for which remote sensing data is of only limited (or no) utility, field plots will be required to provide better carbon density estimates than are currently available. In terms of deriving field estimates, priority should be given to sampling ecotypes by ranking their relative C stocks (= area x C density). This provides an index of how significant is a given ecotype to the overall carbon stock. In the case of wetlands, Meidinger et al (2014) provide a useful classification of wetland classes and subclasses with the MetroVancouver region. This could be used to stratify a series of field plots to measure soil carbon densities and obtain a better resolution by ecosystem type (as reflected in the subclasses). Challenges with this approach are discussed in the footnotes to Table 3. Carbon datasets have been collected for the Richmond Northeast bog forest and the Burns Bog Conservation Area but these data are not yet generally available⁴.

⁴ Richmond bog forest: Levi Higgs, Corporate Energy Manager, City of Richmond, Richmond, BC; Burns bog: Conor Reynolds, Sr. Project Engineer, Air Quality and Management Division, Metropolitan Planning, Environment and Parks, Metro Vancouver, Vancouver, BC.

5 Potential applications of the carbon storage database

In addition to serving as a repository of current carbon stocks, the database could be developed and applied as:

1. The basis to predict other ecosystem services,
2. A tool for change detection, and
3. A management tool to guide decision-making.

5.1 Using the database as the basis for predicting other ecosystem services

In a previous report (3GreenTree 2017), a range of indices were developed that could represent both a foundation for a regional carbon management plan and as the basis for a consideration of ecosystem services. The concept of an ecosystem service (ES) is founded on a principle of natural capital, the environmental stock or resources that provide the goods and ecological processes upon which society depends. The list of ESs that may be relevant to Metro Vancouver is considerable, and include: biodiversity, local climate control, moderation of extreme events, water purification, erosion control, nutrient cycling, habitat, pollination, food, raw materials, freshwater, recreation, tourism, aesthetics, and spirituality (Runting et al. 2017; see 3GreenTree 2017, Table 8).

The academic literature is replete with efforts at linking relationships among ES and various indices and metrics. These include efforts to increase ESs from agricultural activities while mitigating environmental degradation (Foley et al., 2011), the effects of vegetation buffers and plantations on ES provision (Ferrarini et al. 2017, and Blanco-Canqui 2016, respectively), spatiotemporal development of annual biomass production in river floodplains (Koopman et al. 2018), tree species diversity (Gamfeldt et al. 2012), and trade-offs and synergies among ESs at different spatial and temporal scales (Qiao et al. 2018).

While carbon sequestration is itself an ES, it can also be used as a predictor of additional services. This concept is illustrated in Figure 24. Using carbon as a proxy for other ESs has two benefits. First, carbon sequestration and loss are linked directly to greenhouse gas balances within Metro Vancouver. More importantly, carbon is more practical to measure and monitor than many other ESs. If necessary, carbon can be easily converted to biomass since many ESs are linked directly with the latter metric. Agricultural projects are often expressed as mass-specific yields, whereas m^3/ha is a common metric of forest productivity. Species-specific conversion factors for the latter are widely available.

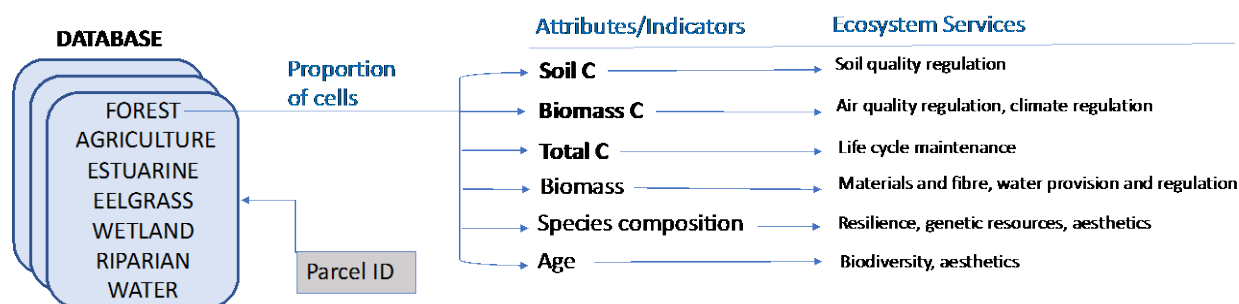


Figure 24. Application of the carbon database as a tool to predict ecosystem services.

5.2 Using the database for change detection

Once the predictive elements associated with the database have been established (as per Fig.24), the resulting summary of core ecosystem attributes and their ecological services provides the baseline against which subsequent assessments can be compared. This then constitutes an exercise in change detection, whereby the impact of subsequent land use decisions can be compared and contrasted over time (Fig. 25).

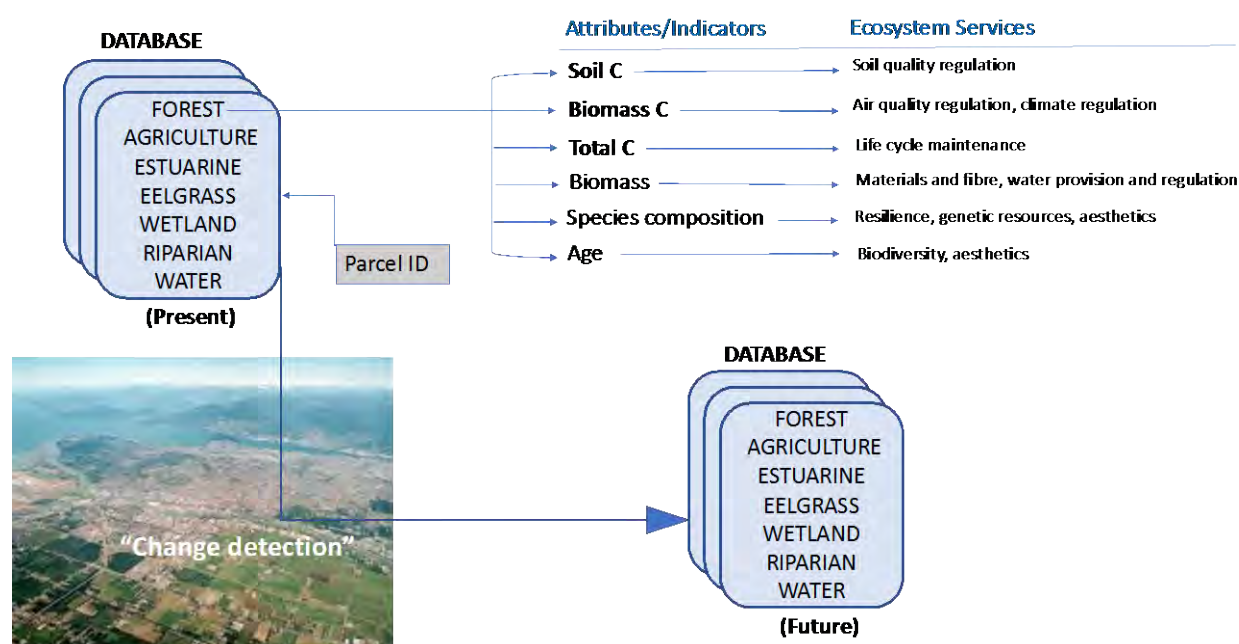


Figure 25. Application of the carbon database to account for change detection.

The principles and practices necessary to update the dataset are precisely those employed to generate the current database, as described above.

5.3 Using the database as a management tool to guide decision-making

The two uses of the database discussed thus far can be considered as largely ‘passive’ applications, in that the tool is employed to simply assess the status of the natural assets within Metro Vancouver subsequent to development. The database also has utility, however, in addressing questions regarding proposed and potential development activities. Comparing and contrasting development options and their impact on ESs allows for identification of trade-offs and synergies (Fig. 26). This will facilitate a more informed discussion on development choices, particularly when the analysis includes an explicit consideration of the spatial relationships among the ecotypes within the database.

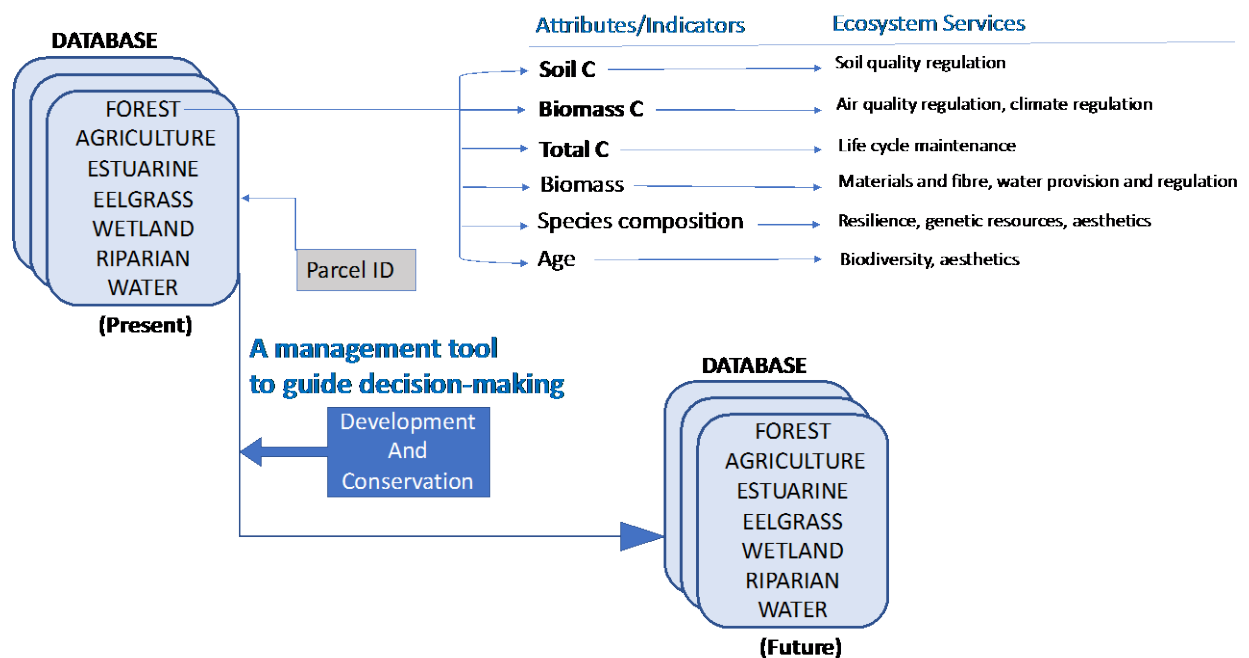


Figure 26. Application of the carbon database as a tool for decision-making.

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7 Appendix 1.

Table A1. Field dictionary for the carbon database.

Field	Description	Units	Source
OBJECTID	Object ID	n/a	n/a
Municipality	Parcel Municipality Code	n/a	Parcel
FirstAddresses	Street Address	n/a	Parcel
GlobalID	Lot Global ID	n/a	Parcel
CParcelID	Parcel ID (surrogate of Global ID)	n/a	internal ID
ParcelHa	area of lot polygon (ha)	(ha)	Parcel
CCellCount	count of C cells in lot polygon	count	BiomaTCHa+SoilTCHa
CCellHa	area of C cells in lot polygon	(ha)	BiomaTCHa+SoilTCHa
TotSoilTC	Soil carbon content	(tC)	SoilTCHa
TotBiomTC	Biomass carbon content	(tC)	BiomTCHa
TotalTC	Total carbon content	(tC)	BiomaTCHa+SoilTCHa
AvgSoilTCHa	Soil carbon density	(tC/ha)	SoilTCHa
AvgBiomTCHa	Biomass carbon density	(tC/ha)	BiomTCHa
AvgTotTCHa	Total carbon density	(tC/ha)	BiomaTCHa+SoilTCHa
n_VRI	count of C cells from VRI layer	count	1
n_LCC	count of C cells from LCC layer	count	2,3,4,5
n_SEI	count of C cells from SEI layer	count	6,7,8,9,10
n_AGR	count of C cells from AGR layer	count	11
n_CSrcs	Count of total C sources used to determine C content	count	n/a
n_LCC_Li	Count of LCC cells with LiDAR data	count	2,3
n_LCC_Dec	count of LCC Dec cells	count	3,5
n_LCC_Con	count of LCC Con cells	count	2,4
n_Forest	count of LCC Class 6&7 & VRI cells	count	1,2,3,4,5
n_UrbSub	count of cells with Lot Global Id but no other ecotype	count	13
n_Agriculture	count of cells from Agricultural designation and no other ecotypes	count	11
n_Estuarine	count of SEI Estuarine cells regardless of carbon content	count	6
n_Eelgrass	count of Eelgrass subclass cells within SEI intertidal	count	7
n_Intertidal	count of non-Eelgrass subclass cells within SEI intertidal	count	8

n_Water	count of waterbody cells	count	12
n_Wetland	count of SEI Wetland cells regardless of carbon content	count	9
n_Riparian	count of SEI Riparian cells regardless of carbon content	count	10
n_Unknown	Count of unknown cells with no lot Global ID	count	13
MunNum	Administration boundary municipality code	n/a	n/a
MunName	Municipality name	n/a	n/a

Source column values explanation:

Fields sources labelled with Parcel indicates that the values in these fields originated from the original parcel polygon dataset.

Field sources labelled with BiomTCHa indicates that the values in these fields were derived from the combined biomass density source raster called biomtcha.

Field sources labelled with SoilTCHa indicates that the values in these fields were derived from the combined soil carbon density source raster called soiltcha.

Field sources labelled with BiomTCHa and SoilTCHa indicates that the values in these fields were derived from the combined biomass and soil carbon density source rasters called biomtcha and soiltcha.

Fields labelled with the numeric values indicates that the values in these fields were derived from the combined ecotype source raster called ecotype. See Appendix Ecotype codes.

Table A2. Description of ecotype codes used within the database.

Ecotype	Description	Code
VRI	VRI	1
LCC Con+Li	LCC conifer with LiDAR	2
LCC Dec+Li	LCC deciduous with LiDAR	3
LCC Con-Li	LCC conifer with no LiDAR	4
LCC Dec-Li	LCC deciduous with no LiDAR	5
SEI ES	SEI estuarine	6
SEI EEL	SEI eelgrass	7
SEI IT-EEL	SEI intertidal, but no eelgrass	8
WETLAND	SEI wetland	9
RIPARIAN	SEI riparian	10
AGR	Agriculture	11
WATER	water	12
NOTYPE	no type	13

Table A3. Height over age curves used to estimate age from top height (m) for deciduous and coniferous types.

Adjusted top ht conifer	Est. Age (y)		Adjusted top ht deciduous	Est Age (y)
0.2	1		1.4	1
0.4	2		2.8	2
0.6	3		4.3	3
1.0	4		5.6	4
1.6	5		7.0	5
2.2	6		8.2	6
2.8	7		9.5	7
3.5	8		10.7	8
4.2	9		11.8	9
4.9	10		12.9	10
5.7	11		13.9	11
6.5	12		14.9	12
7.3	13		15.8	13
8.1	14		16.6	14
8.9	15		17.3	15
9.7	16		18.0	16
10.5	17		18.7	17
11.3	18		19.4	18
12.1	19		20.0	19
13.0	20		20.6	20
13.8	21		21.2	21
14.7	22		21.8	22
15.5	23		22.4	23
16.3	24		22.9	24
17.1	25		23.4	25
17.9	26		23.9	26
18.7	27		24.3	27
19.5	28		24.7	28

20.2	29		25.1	29
21.0	30		25.5	30
21.7	31		25.9	31
22.4	32		26.2	32
23.1	33		26.5	33
23.8	34		26.8	34
24.5	35		27.1	35
25.1	36		27.3	36
25.8	37		27.6	37
26.4	38		27.8	38
27.0	39		28.1	39
27.7	40		28.3	40
28.3	41		28.5	41
28.9	42		28.7	42
29.4	43		28.9	43
30.0	44		29.1	44
30.6	45		29.3	45
31.1	46		29.5	46
31.7	47		29.6	47
32.2	48		29.8	48
32.7	49		30.0	49
33.3	50		30.1	50
33.8	51		30.2	51
34.2	52		30.4	52
34.7	53		30.5	53
35.2	54		30.6	54
35.6	55		30.8	55
36.1	56		30.9	56
36.5	57		31.0	57
36.9	58		31.1	58
37.3	59		31.2	59
37.6	60		31.3	60
38.0	61		31.3	61
38.4	62		31.4	62
38.7	63		31.5	63
39.1	64		31.6	64
39.4	65		31.7	65
39.7	66		31.7	66
40.1	67		31.8	67

40.4	68		31.9	68
40.7	69		31.9	69
41.0	70		32.0	70
41.3	71		32.0	71
41.6	72		32.1	72
41.9	73		32.1	73
42.2	74		32.2	74
42.5	75		32.2	75
42.8	76		32.3	76
43.1	77		32.3	77
43.3	78		32.3	78
43.6	79		32.3	79
43.9	80		32.3	80
44.2	81		32.3	81
44.4	82		32.3	82
44.7	83		32.3	83
45.0	84		32.4	84
45.2	85		32.4	85
45.5	86		32.4	86
45.7	87		32.4	87
46.0	88		32.4	88
46.2	89		32.4	89
46.5	90		32.4	90
46.7	91		32.4	91
47.0	92		32.4	92
47.2	93		32.4	93
47.5	94		32.4	94
47.7	95		32.4	95
48.0	96		32.4	96
48.2	97		32.4	97
48.5	98		32.4	98
48.7	99		32.4	99
48.9	100		32.5	100
49.2	101		32.5	101
49.4	102		32.5	102
49.7	103		32.5	103
49.9	104		32.5	104
50.1	105		32.5	105
50.3	106		32.5	106

50.5	107		32.5	107
50.8	108		32.5	108
51.0	109		32.5	109
51.2	110		32.5	110
51.4	111		32.5	111
51.6	112		32.5	112
51.8	113		32.5	113
52.0	114		32.5	114
52.1	115		32.5	115
52.3	116		32.5	116
52.5	117		32.5	117
52.7	118		32.5	118
52.8	119		32.5	119
53.0	120		32.5	120
53.2	121		32.5	121
53.3	122		32.5	122
53.5	123		32.5	123
53.7	124		32.5	124
53.8	125		32.5	125

Table A4. Carbon density lookup table based upon species and age (t C/ha).

Sp	Year	Tot Tree Mass C	Tot Deadwood C	Tot AG Litter C	Tot BG Litter C	Tot Soil C	Ecosystem C	Net Ecosystem C
Dec	1	1.90	5.50	0.00	0.00	131.30	138.70	7.40
Dec	2	3.80	5.10	0.10	0.10	130.50	139.60	9.00
Dec	3	5.40	4.80	0.30	0.20	129.70	140.40	10.40
Dec	4	7.60	4.50	0.50	0.40	128.90	141.90	12.50
Dec	5	10.20	4.20	0.80	0.60	128.10	143.90	15.00
Dec	6	13.50	4.00	1.20	0.90	127.30	146.90	18.40
Dec	7	17.40	3.90	1.70	1.20	126.60	150.80	22.50
Dec	8	21.80	3.90	2.40	1.70	126.00	155.80	27.40
Dec	9	26.20	4.10	3.10	2.30	125.30	161.00	32.60
Dec	10	30.60	4.30	4.00	2.90	124.80	166.60	37.80
Dec	11	35.20	4.70	4.90	3.60	124.30	172.70	43.50
Dec	12	39.90	5.10	5.70	4.30	123.80	178.80	49.30
Dec	13	44.70	5.50	6.40	5.10	123.50	185.20	55.30

Dec	14	49.30	5.90	7.00	5.90	123.20	191.30	61.10
Dec	15	54.00	6.20	7.40	6.70	122.90	197.20	66.90
Dec	16	58.80	6.50	7.80	7.50	122.80	203.40	72.80
Dec	17	64.00	6.80	8.10	8.30	122.70	209.90	79.10
Dec	18	69.20	7.10	8.30	9.10	122.60	216.30	85.40
Dec	19	74.60	7.50	8.50	9.90	122.60	223.10	92.00
Dec	20	80.10	7.90	8.60	10.70	122.60	229.90	98.70
Dec	21	85.50	8.30	8.70	11.40	122.70	236.60	105.20
Dec	22	90.90	8.90	8.80	12.10	122.90	243.60	111.90
Dec	23	96.10	9.50	8.90	12.70	123.00	250.20	118.30
Dec	24	101.20	10.10	8.90	13.30	123.30	256.80	124.60
Dec	25	106.20	10.70	8.90	13.80	123.50	263.10	130.70
Dec	26	110.90	11.40	8.90	14.30	123.80	269.30	136.60
Dec	27	115.40	12.10	9.00	14.70	124.00	275.20	142.20
Dec	28	119.50	12.70	9.00	15.00	124.20	280.40	147.20
Dec	29	123.20	13.20	9.10	15.30	124.40	285.20	151.70
Dec	30	126.30	13.60	9.20	15.50	124.50	289.10	155.40
Dec	31	129.00	13.80	9.20	15.60	124.70	292.30	158.40
Dec	32	131.50	14.00	9.20	15.70	125.00	295.40	161.20
Dec	33	134.00	14.20	9.30	15.80	125.20	298.50	164.00
Dec	34	136.40	14.40	9.40	15.90	125.40	301.50	166.70
Dec	35	138.70	14.60	9.40	15.90	125.70	304.30	169.20
Dec	36	141.00	14.80	9.40	16.00	126.10	307.30	171.80
Dec	37	143.40	14.90	9.40	16.00	126.50	310.20	174.30
Dec	38	145.70	15.10	9.50	16.00	126.70	313.00	176.80
Dec	39	148.10	15.20	9.60	16.00	127.00	315.90	179.30
Dec	40	146.20	18.20	9.60	16.00	127.20	317.20	180.40
Dec	41	148.70	18.90	10.20	16.50	127.50	321.80	184.10
Dec	42	151.20	18.90	10.10	16.50	127.70	324.40	186.60
Dec	43	153.60	18.90	10.00	16.40	128.00	326.90	188.90
Dec	44	156.10	19.00	9.90	16.30	128.20	329.50	191.40
Dec	45	158.50	18.90	9.80	16.20	128.50	331.90	193.60
Dec	46	160.80	19.00	9.80	16.10	128.70	334.40	195.90
Dec	47	163.10	18.90	9.70	16.00	128.90	336.60	198.00
Dec	48	165.40	18.80	9.60	15.90	129.20	338.90	200.10
Dec	49	167.80	18.60	9.50	15.80	129.40	341.10	202.20
Dec	50	170.10	18.40	9.40	15.70	129.60	343.20	204.20
Dec	51	172.20	18.30	9.30	15.50	129.80	345.10	206.00
Dec	52	174.40	18.10	9.20	15.40	130.00	347.10	207.90

Dec	53	176.30	17.90	9.10	15.30	130.20	348.80	209.50
Dec	54	178.10	17.80	9.00	15.20	130.30	350.40	211.10
Dec	55	175.10	20.90	9.00	15.10	130.50	350.60	211.10
Dec	56	176.90	21.30	9.40	15.60	130.60	353.80	213.80
Dec	57	178.40	21.00	9.20	15.40	130.80	354.80	214.80
Dec	58	179.90	20.50	9.10	15.30	130.90	355.70	215.70
Dec	59	181.30	20.10	8.90	15.10	131.00	356.40	216.50
Dec	60	182.70	19.80	8.80	14.90	131.00	357.20	217.40
Dec	61	184.10	19.50	8.70	14.80	131.10	358.20	218.40
Dec	62	185.60	19.30	8.60	14.70	131.10	359.30	219.60
Dec	63	187.00	19.20	8.60	14.50	131.20	360.50	220.70
Dec	64	188.50	19.30	8.50	14.50	131.20	362.00	222.30
Dec	65	190.00	19.40	8.50	14.40	131.20	363.50	223.80
Dec	66	191.10	19.90	8.50	14.40	131.20	365.10	225.40
Dec	67	192.60	20.20	8.50	14.30	131.20	366.80	227.10
Dec	68	193.90	20.70	8.50	14.30	131.20	368.60	228.90
Dec	69	195.20	21.40	8.50	14.30	131.10	370.50	230.90
Dec	70	191.30	26.00	8.60	14.30	131.10	371.30	231.60
Dec	71	191.80	28.20	9.20	15.10	131.10	375.40	235.10
Dec	72	192.40	29.80	9.20	15.20	131.10	377.70	237.40
Dec	73	192.70	31.80	9.30	15.40	131.00	380.20	239.90
Dec	74	192.80	34.00	9.30	15.50	131.00	382.60	242.30
Dec	75	192.80	36.10	9.40	15.70	130.90	384.90	244.60
Dec	76	193.00	37.90	9.40	15.80	130.90	387.00	246.70
Dec	77	192.60	40.00	9.50	15.90	130.80	388.80	248.50
Dec	78	192.50	41.50	9.40	16.00	130.70	390.10	250.00
Dec	79	192.60	42.60	9.30	15.90	130.60	391.00	251.10
Dec	80	192.90	43.30	9.20	15.80	130.50	391.70	252.00
Dec	81	193.20	43.60	9.00	15.60	130.50	391.90	252.40
Dec	82	193.40	44.00	8.90	15.50	130.40	392.20	252.90
Dec	83	193.70	44.20	8.70	15.40	130.30	392.30	253.30
Dec	84	194.00	44.50	8.60	15.20	130.20	392.50	253.70
Dec	85	190.10	47.70	8.50	15.10	130.20	391.60	252.90
Dec	86	189.90	48.90	8.80	15.60	130.20	393.40	254.40
Dec	87	190.60	48.60	8.60	15.40	130.10	393.30	254.60
Dec	88	191.40	48.10	8.40	15.10	130.00	393.00	254.60
Dec	89	192.30	47.70	8.20	14.90	129.90	393.00	254.90
Dec	90	193.30	47.10	8.00	14.70	129.80	392.90	255.10
Dec	91	194.20	46.50	7.90	14.50	129.60	392.70	255.20

Dec	92	195.20	45.80	7.70	14.30	129.50	392.50	255.30
Dec	93	195.20	46.00	7.70	14.30	129.40	392.60	255.50
Dec	94	196.10	45.30	7.60	14.10	129.30	392.40	255.50
Dec	95	197.30	44.40	7.50	13.80	129.10	392.10	255.50
Dec	96	198.30	43.50	7.40	13.60	129.00	391.80	255.40
Dec	97	199.30	42.70	7.30	13.50	128.90	391.70	255.50
Dec	98	200.30	41.90	7.20	13.30	128.90	391.60	255.50
Dec	99	201.50	40.90	7.20	13.10	128.80	391.50	255.50
Dec	100	197.70	43.60	7.20	13.10	128.70	390.30	254.40
Dec	101	198.90	43.00	7.50	13.40	128.70	391.50	255.30
Dec	102	200.10	41.80	7.40	13.20	128.70	391.20	255.10
Dec	103	201.50	40.60	7.30	12.90	128.60	390.90	255.00
Dec	104	202.80	39.30	7.10	12.70	128.60	390.50	254.80
Dec	105	204.20	38.00	7.00	12.50	128.60	390.30	254.70
Dec	106	204.10	38.00	7.10	12.50	128.60	390.30	254.60
Dec	107	205.20	36.80	7.00	12.30	128.60	389.90	254.30
Dec	108	206.50	35.60	7.00	12.10	128.50	389.70	254.20
Dec	109	207.70	34.50	6.90	12.00	128.50	389.60	254.20
Dec	110	208.90	33.20	6.80	11.80	128.50	389.20	253.90
Dec	111	210.30	31.90	6.80	11.60	128.50	389.10	253.80
Dec	112	209.80	32.20	6.90	11.70	128.50	389.10	253.70
Dec	113	210.70	31.30	6.90	11.60	128.50	389.00	253.60
Dec	114	212.00	30.00	6.80	11.40	128.50	388.70	253.40
Dec	115	209.60	31.50	6.70	11.30	128.50	387.60	252.40
Dec	116	210.70	31.00	7.10	11.60	128.50	388.90	253.30
Dec	117	211.90	29.90	7.00	11.40	128.50	388.70	253.20
Dec	118	213.30	28.60	6.90	11.30	128.50	388.60	253.20
Dec	119	212.40	29.30	7.00	11.50	128.50	388.70	253.20
Dec	120	213.50	28.30	6.90	11.30	128.40	388.40	253.10
Dec	121	214.60	27.30	6.80	11.10	128.40	388.20	253.00
Dec	122	215.70	26.40	6.80	11.00	128.30	388.20	253.10
Dec	123	216.80	25.50	6.70	10.90	128.20	388.10	253.20
Dec	124	217.90	24.60	6.70	10.70	128.20	388.10	253.20
Dec	125	219.00	23.80	6.70	10.60	128.10	388.20	253.40
Con	1	0.20	5.50	0.00	0.00	131.30	137.00	5.70
Con	2	0.50	5.10	0.10	0.00	130.50	136.20	5.60
Con	3	0.90	4.80	0.10	0.00	129.70	135.50	5.70
Con	4	1.70	4.40	0.20	0.10	128.90	135.30	6.20
Con	5	2.90	4.20	0.40	0.10	128.10	135.70	7.20

Con	6	4.20	3.90	0.60	0.20	127.30	136.20	8.30
Con	7	5.60	3.70	0.80	0.20	126.60	136.90	9.50
Con	8	7.10	3.50	1.10	0.30	125.90	137.90	10.90
Con	9	8.70	3.40	1.50	0.40	125.20	139.20	12.50
Con	10	10.40	3.30	1.90	0.60	124.50	140.70	14.30
Con	11	12.30	3.20	2.30	0.70	123.90	142.40	16.20
Con	12	14.50	3.20	2.90	0.80	123.30	144.70	18.50
Con	13	17.00	3.10	3.40	1.00	122.70	147.20	21.10
Con	14	19.90	3.10	4.00	1.10	122.20	150.30	24.10
Con	15	23.10	3.10	4.50	1.30	121.70	153.70	27.50
Con	16	26.50	3.00	4.90	1.50	121.30	157.20	31.00
Con	17	30.20	2.90	5.20	1.70	120.90	160.90	34.80
Con	18	34.10	2.80	5.60	1.90	120.50	164.90	38.80
Con	19	38.40	2.70	5.80	2.10	120.20	169.20	43.20
Con	20	42.90	2.60	6.10	2.30	119.90	173.80	47.80
Con	21	47.70	2.50	6.20	2.50	119.70	178.60	52.70
Con	22	52.60	2.40	6.40	2.80	119.50	183.70	57.80
Con	23	57.60	2.30	6.50	3.00	119.30	188.70	62.90
Con	24	62.70	2.20	6.60	3.20	119.10	193.80	68.10
Con	25	67.90	2.10	6.70	3.40	118.90	199.00	73.40
Con	26	73.20	2.10	6.80	3.70	118.70	204.50	79.00
Con	27	78.60	2.10	6.80	3.90	118.50	209.90	84.60
Con	28	84.10	2.00	6.90	4.10	118.40	215.50	90.20
Con	29	89.70	2.00	6.90	4.30	118.30	221.20	96.00
Con	30	95.40	2.10	7.00	4.60	118.10	227.20	102.10
Con	31	101.30	2.10	7.10	4.80	118.00	233.30	108.20
Con	32	107.20	2.20	7.10	5.00	117.90	239.40	114.40
Con	33	113.30	2.20	7.20	5.30	117.80	245.80	120.80
Con	34	119.50	2.30	7.30	5.50	117.70	252.30	127.30
Con	35	120.60	5.50	7.30	5.70	117.60	256.70	131.80
Con	36	126.80	6.50	8.30	6.90	117.50	266.00	140.20
Con	37	133.30	6.60	8.20	7.00	117.40	272.50	146.90
Con	38	139.80	6.80	8.10	7.20	117.30	279.20	153.80
Con	39	146.40	6.90	8.10	7.40	117.30	286.10	160.70
Con	40	153.10	7.00	8.10	7.50	117.20	292.90	167.60
Con	41	159.80	7.10	8.20	7.70	117.20	300.00	174.60
Con	42	166.70	7.10	8.20	7.80	117.10	306.90	181.60
Con	43	173.70	7.30	8.20	8.00	117.10	314.30	189.00
Con	44	180.70	7.40	8.30	8.10	117.00	321.50	196.20

Con	45	186.50	8.30	8.30	8.30	117.00	328.40	203.10
Con	46	193.70	8.70	8.50	8.80	116.90	336.60	211.20
Con	47	201.20	8.70	8.50	8.90	116.90	344.20	218.80
Con	48	208.60	8.80	8.50	9.00	116.80	351.70	226.40
Con	49	216.10	8.90	8.60	9.20	116.80	359.60	234.20
Con	50	218.50	12.30	8.60	9.40	116.80	365.60	240.20
Con	51	226.10	13.30	9.40	10.50	116.80	376.10	249.90
Con	52	233.70	13.40	9.40	10.60	116.70	383.80	257.70
Con	53	241.40	13.40	9.30	10.70	116.70	391.50	265.50
Con	54	249.00	13.50	9.30	10.80	116.70	399.30	273.30
Con	55	255.50	14.10	9.20	11.00	116.80	406.60	280.60
Con	56	262.70	14.40	9.40	11.30	116.80	414.60	288.40
Con	57	269.90	14.40	9.30	11.40	116.90	421.90	295.70
Con	58	277.10	14.30	9.40	11.60	116.90	429.30	303.00
Con	59	284.10	14.30	9.40	11.70	116.90	436.40	310.10
Con	60	291.10	14.20	9.40	11.80	116.90	443.40	317.10
Con	61	297.90	14.20	9.50	11.90	117.00	450.50	324.00
Con	62	304.80	14.10	9.60	12.00	117.00	457.50	330.90
Con	63	311.60	14.10	9.80	12.20	117.10	464.80	337.90
Con	64	318.40	14.00	9.80	12.30	117.20	471.70	344.70
Con	65	317.70	18.80	9.90	12.40	117.30	476.10	348.90
Con	66	324.40	20.10	11.00	13.90	117.30	486.70	358.40
Con	67	331.10	20.10	10.90	14.00	117.40	493.50	365.20
Con	68	337.80	20.00	10.80	14.10	117.50	500.20	371.90
Con	69	344.40	19.90	10.80	14.10	117.50	506.70	378.40
Con	70	349.50	20.70	10.80	14.20	117.60	512.80	384.40
Con	71	355.70	21.30	11.00	14.60	117.70	520.30	391.60
Con	72	362.30	21.20	10.90	14.60	117.80	526.80	398.10
Con	73	368.90	21.10	10.90	14.60	117.90	533.40	404.60
Con	74	375.50	21.00	10.90	14.60	118.00	540.00	411.10
Con	75	381.70	21.30	11.00	14.70	118.10	546.80	417.70
Con	76	388.40	21.20	11.00	14.70	118.20	553.50	424.30
Con	77	395.30	21.10	11.00	14.70	118.40	560.50	431.10
Con	78	401.70	21.40	11.10	14.80	118.60	567.60	437.90
Con	79	408.70	21.30	11.00	14.80	118.70	574.50	444.80
Con	80	405.60	27.80	11.10	14.80	118.90	578.20	448.20
Con	81	412.30	29.60	12.40	16.60	119.00	589.90	458.50
Con	82	418.70	29.80	12.30	16.70	119.20	596.70	465.20
Con	83	425.50	29.70	12.20	16.60	119.30	603.30	471.80

Con	84	431.80	30.10	12.20	16.70	119.40	610.20	478.60
Con	85	436.90	31.10	12.10	16.60	119.50	616.20	484.60
Con	86	443.40	31.80	12.30	17.10	119.60	624.20	492.30
Con	87	450.30	31.80	12.20	17.00	119.70	631.00	499.10
Con	88	456.80	32.20	12.30	17.00	119.80	638.10	506.00
Con	89	463.40	32.60	12.30	17.00	119.90	645.20	513.00
Con	90	470.60	32.50	12.30	17.00	120.00	652.40	520.10
Con	91	477.30	33.00	12.40	17.00	120.20	659.90	527.30
Con	92	484.00	33.50	12.50	17.00	120.40	667.40	534.50
Con	93	491.40	33.30	12.50	16.90	120.50	674.60	541.60
Con	94	498.10	33.80	12.60	17.00	120.70	682.20	548.90
Con	95	493.10	42.00	12.70	17.00	120.90	685.70	552.10
Con	96	500.10	44.10	14.20	19.00	121.00	698.40	563.20
Con	97	506.60	44.50	14.10	18.90	121.20	705.30	570.00
Con	98	513.10	45.10	14.00	18.90	121.40	712.50	577.10
Con	99	519.40	45.60	13.90	18.90	121.50	719.30	583.90
Con	100	524.10	47.30	13.90	18.90	121.60	725.80	590.30
Con	101	530.40	48.30	14.10	19.30	121.80	733.90	598.00
Con	102	536.60	49.00	14.00	19.30	121.90	740.80	604.90
Con	103	543.00	49.50	14.00	19.20	122.00	747.70	611.70
Con	104	549.20	50.20	14.10	19.20	122.10	754.80	618.60
Con	105	555.20	50.90	14.10	19.20	122.20	761.60	625.30
Con	106	560.30	52.30	14.30	19.30	122.40	768.60	631.90
Con	107	566.40	52.90	14.30	19.20	122.50	775.30	638.50
Con	108	572.10	53.70	14.40	19.20	122.60	782.00	645.00
Con	109	578.00	54.30	14.40	19.10	122.80	788.60	651.40
Con	110	570.70	63.70	14.50	19.00	123.00	790.90	653.40
Con	111	576.10	66.80	16.10	21.20	123.20	803.40	664.10
Con	112	581.50	67.50	15.90	21.00	123.30	809.20	670.00
Con	113	586.70	68.30	15.70	20.90	123.50	815.10	675.90
Con	114	592.00	69.00	15.60	20.70	123.70	821.00	681.70
Con	115	596.10	70.30	15.20	20.30	123.80	825.70	686.70
Con	116	600.90	71.60	15.40	20.60	124.00	832.50	693.10
Con	117	605.70	72.40	15.40	20.40	124.10	838.00	698.50
Con	118	610.10	73.40	15.40	20.30	124.30	843.50	703.80
Con	119	615.80	73.20	15.30	19.90	124.40	848.60	708.90
Con	120	620.00	74.30	15.30	19.70	124.50	853.80	714.00
Con	121	625.50	74.10	15.30	19.30	124.70	858.90	718.90
Con	122	629.70	75.00	15.30	19.10	124.80	863.90	723.80

Con	123	635.00	75.10	15.30	18.80	124.90	869.10	728.90
Con	124	639.20	76.10	15.40	18.70	125.10	874.50	734.00
Con	125	628.90	86.70	15.20	18.30	125.30	874.40	733.90
Con	126	634.30	89.20	17.10	20.70	125.40	886.70	744.20
Con	127	639.50	89.30	16.80	20.30	125.60	891.50	749.10
Con	128	643.50	90.40	16.70	20.10	125.70	896.40	754.00
Con	129	648.80	90.20	16.50	19.70	125.80	901.00	758.70
Con	130	652.00	91.60	16.30	19.40	125.90	905.20	763.00
Con	131	655.90	93.20	16.60	19.70	125.90	911.30	768.80
Con	132	660.90	93.30	16.40	19.40	126.00	916.00	773.60
Con	133	666.20	93.20	16.30	19.10	126.10	920.90	778.50
Con	134	669.80	94.50	16.40	19.00	126.20	925.90	783.30
Con	135	674.70	94.60	16.40	18.70	126.30	930.70	788.00
Con	136	679.80	94.50	16.30	18.40	126.40	935.40	792.70
Con	137	684.80	94.40	16.30	18.00	126.60	940.10	797.20
Con	138	687.90	96.00	16.50	18.00	126.70	945.10	801.90
Con	139	692.80	95.90	16.40	17.80	126.90	949.80	806.50
Con	140	680.90	107.20	16.40	17.50	127.10	949.10	805.60
Con	141	685.50	110.00	18.40	20.00	127.30	961.20	815.50
Con	142	690.00	109.90	18.10	19.70	127.40	965.10	819.60
Con	143	694.30	110.10	17.90	19.40	127.50	969.20	823.80
Con	144	698.70	110.10	17.70	19.10	127.60	973.20	827.90
Con	145	700.80	111.50	17.50	18.80	127.70	976.30	831.10
Con	146	705.00	112.00	17.60	19.00	127.70	981.30	836.00
Con	147	708.90	112.20	17.50	18.80	127.90	985.30	839.90
Con	148	712.90	112.30	17.40	18.50	128.00	989.10	843.70
Con	149	716.50	112.50	17.40	18.30	128.00	992.70	847.30
Con	150	720.20	112.60	17.40	18.10	128.00	996.30	850.90
Con	151	723.90	112.60	17.40	17.80	128.10	999.80	854.30
Con	152	727.30	112.90	17.40	17.60	128.30	1003.50	857.80
Con	153	732.70	111.40	17.20	17.10	128.40	1006.80	861.20
Con	154	736.30	111.50	17.30	16.80	128.50	1010.40	864.60
Con	155	739.50	111.80	17.30	16.70	128.70	1014.00	868.00
Con	156	743.00	111.90	17.30	16.50	128.80	1017.50	871.40
Con	157	746.40	112.10	17.40	16.40	129.00	1021.30	874.90
Con	158	749.50	112.50	17.50	16.30	129.10	1024.90	878.30
Con	159	752.90	112.80	17.60	16.20	129.10	1028.60	881.90
Con	160	758.20	111.20	17.40	15.70	129.30	1031.80	885.10
Con	161	761.20	111.70	17.50	15.70	129.40	1035.50	888.60

Con	162	764.30	112.00	17.70	15.60	129.40	1039.00	891.90
Con	163	767.50	112.40	17.80	15.60	129.40	1042.70	895.50
Con	164	770.30	112.90	17.90	15.60	129.50	1046.20	898.80
Con	165	775.50	111.40	17.80	15.20	129.50	1049.40	902.10
Con	166	778.40	111.70	18.00	15.10	129.60	1052.80	905.20
Con	167	781.10	112.30	18.10	15.10	129.70	1056.30	908.50
Con	168	783.90	112.70	18.30	15.10	129.70	1059.70	911.70
Con	169	786.70	113.10	18.40	15.10	129.80	1063.10	914.90
Con	170	791.50	111.70	18.30	14.70	129.90	1066.10	917.90
Con	171	794.20	112.20	18.40	14.70	130.00	1069.50	921.10
Con	172	796.80	112.60	18.60	14.70	130.10	1072.80	924.10
Con	173	799.00	113.30	18.70	14.80	130.20	1076.00	927.10
Con	174	803.90	111.80	18.60	14.40	130.20	1078.90	930.10
Con	175	806.30	112.30	18.70	14.50	130.30	1082.10	933.10
Con	176	808.40	113.10	18.90	14.60	130.30	1085.30	936.10
Con	177	813.20	111.50	18.80	14.20	130.30	1088.00	938.90
Con	178	815.40	112.10	18.90	14.30	130.40	1091.10	941.80
Con	179	817.20	113.00	19.10	14.50	130.40	1094.20	944.70
Con	180	821.90	111.40	19.00	14.10	130.40	1096.80	947.40
Con	181	823.60	112.30	19.20	14.30	130.40	1099.80	950.20
Con	182	825.50	113.00	19.30	14.40	130.50	1102.70	952.90
Con	183	830.00	111.40	19.20	14.00	130.50	1105.10	955.40
Con	184	831.50	112.40	19.40	14.20	130.50	1108.00	958.10
Con	185	835.90	110.80	19.20	13.90	130.60	1110.40	960.60
Con	186	837.50	111.50	19.40	14.00	130.70	1113.10	963.00
Con	187	838.80	112.50	19.60	14.20	130.70	1115.80	965.50
Con	188	843.00	110.90	19.50	13.80	130.80	1118.00	967.70
Con	189	844.40	111.70	19.70	14.00	130.80	1120.60	970.10
Con	190	848.30	110.40	19.50	13.70	130.90	1122.80	972.40
Con	191	849.50	111.20	19.70	13.90	130.90	1125.20	974.60
Con	192	853.50	109.60	19.60	13.50	131.00	1127.20	976.60
Con	193	854.30	110.70	19.90	13.80	131.00	1129.70	978.80
Con	194	858.20	109.10	19.70	13.40	131.10	1131.50	980.70
Con	195	859.20	110.00	19.90	13.60	131.10	1133.80	982.80
Con	196	862.60	108.60	19.80	13.30	131.20	1135.50	984.50
Con	197	863.40	109.50	20.00	13.50	131.20	1137.60	986.40
Con	198	867.10	107.90	19.90	13.20	131.30	1139.40	988.20
Con	199	867.40	109.20	20.20	13.50	131.30	1141.60	990.10
Con	200	870.90	107.50	20.00	13.10	131.30	1142.80	991.50

