TABLE OF CONTENTS

Executive Summary

The University of Canterbury's Geography 309 research course required students to complete a geographic research project in partnership with a community-based organisation. The authors of this report were partnered with Steve Bush of Trees for Canterbury (TFC), a non-profit organisation committed to native tree planting, environmental education and social opportunity provision (Trees For Canterbury [TFC], 2019). Project research aims proposed by TFC were to quantify carbon (C) stocks and ultimately carbon dioxide (CO_2) levels sequestered by their tree plantings. Therefore, the research question of "*how many tonnes of carbon have been sequestered*

1. Introduction

International concerns over anthropogenically induced climate change have made CO_2 sequestration a global focus. New Zealand is one of several nations worldwide that has made commitments to international climate treaties such as The Paris Agreement and The Kyoto Protocol to move towards C neutrality (Ministry for Primary Industries [MPI], 2015). Offsetting CO_2 emissions with reforestation and afforestation initiatives such as the "One Billion Trees Program" is the New Zealand Government's primary strategy in reaching greenhouse gas reduction goals (MPI, 2015; Te Uru Rakau, 2018). As demand for trees in New Zealand is increasing, tree nurseries are providing vital services on a national scale (Te Uru Rakau, 2018). To assess the impact trees are having on offsetting emissions, it is becoming increasingly important to be able to quantify the CO_2 sequestration capacity of trees.

Trees for Canterbury (TFC) is an eco-conscious and charitable native plant nursery founded in Christchurch in 1990 (TFC, 2019). TFC supplies trees to the One Billion Trees Program and to date, estimate their total number of plants either sold, donated and/or directly planted, has exceeded one million (S. Bush, personal communication, July 25, 2019).

The community partners operating on behalf of TFC are Steve Bush and Richard Earl, who proposed a research project for Geography 309 students at the University of Canterbury. They requested a geospatial record of their total planted area throughout Canterbury be generated, complete with a tree attribute database containing tree species variety, diameter and height. Quantitative tree attribute data was to be collected to ultimately estimate how many t of CO_2 TFC plantings had sequestered.

From these requests, a group research question of "how many tonnes of carbon have been sequestered at select Trees for Canterbury planting sites?" was developed; this underlined the to calculate tree height using an in-built trigonometric function. Quantifying forest biomass is fundamental in determining tree C stock and CO_2 sequestration levels (Gil, Blanco, Carballo, & Calvo, 2010). Accurately estimating tree carbon content (TCC) and CO_2 sequestration levels typically involves analysis of both above ground biomass (AGB) and below ground biomass (BGB) (Makinde, Womiloiu, & Ogundeko, 2017; Schwendenmann & Mitchell, 2014; Wulder et al., 2008). However, with tree DBH and height measurements from sample plots, an allometric

A handheld digital GPS device, model Garmin GPSMap 60CSX

3.1 Field Methods

Pre-recorded GPS coordinates from the simple random sampling grid were used to locate sample areas, however, once onsite at Otukaikino Reserve, accessibility issues to randomly selected sample areas became apparent. This led to the adoption of accessibility sampling which is a form of convenience sampling (Rice, 2010). Similar issues also required accessibility sampling to be applied at Styx Mill Reserve. Forestry sample plots are commonly 20m x 20m (Makinde et al., 2017), however, due to time and resource constraints 10m x 10m sample plots were established at each sample site. A measuring tape was used to establish the 10m x 10m plots with a white ribbon positioned at each corner of the plot. A Garmin GPS device was then used to georeference each of the plot corners. Employing the methods of Schwendenmann, & Mitchell (2014), any tree with 50% or more of their stem within the plot boundaries were measured for key parameters of DBH and height. In New Zealand, breast height (BH) is standardized at 1.4m up from the base of the tree stem (Beets et al., 2012). For each DBH measurement, a 1.4m long measuring stick was used to determine BH. A diameter tape was then used to output the DBH of each tree. According to Perez-Quezada et al. (2015), a base minimum DBH must be established so as not to skew results. Perez-Quezada et al.'s (2015) base minimum of 3cm DBH was applied, excluding any trees with a DBH of <3cm from the data collected. Trees with a DBH >3cm were measured for height using a Haglöf Vertex Hypsometer. The transponder was attached to each tree at BH and the handheld digital device was held by a user positioned a minimum distance of the tree's height away. A signal was then sent from the Haglöf Vertex Hypsometer to the transponder. A signal was then recorded of the top of the tree and trigonometric relationships were detected to digitally output tree height. The variety of tree species within each plot was also recorded using the help of native tree identification books "Knowing Your New Zealand Trees" by Lawrie Metcalf and "Native Trees of New Zealand 2" by J.T. Salmon. These steps were repeated at each stand at each sample site.

3.2 GIS Methods

Following field data collection, two GIS software programs were used to visualise the numerical data. GPS coordinates of each of the 10m x 10m sample plots were loaded onto a New Zealand Imagery Basemap in ArcMap. These were formatted as geographic coordinates in degrees, minutes

***Figure 1**. GIS rendered map of 200m x 90m polygon grid, overlaid on the Styx Mill Road planting area. 66m x 30m subgrids are labelled accordingly from 1-9 for random plot area selection*

***Figure 2.** GIS rendered map of systematic grids overlaid in Charlesworth Reserve, with grids 3 and 5 being randomly selecting for sampling.*

Figure 3. *Polygons in Charlesworth Reserve (in red) were created in ArcMap from GPS coordinates collected in-field. Each polygon represents the exact locations of the 10m x 10m sample plots.*

Figure 4*. 3D polygons and outlines of sites 1-3 in Charlesworth Reserve. The red outlines are snapped above ground level for visibility, with the green interior highlighting the entire planting area. The 10m x 10m sample plots are symbolised by the 3D red blocks, set at the height of the average tree height of each location.*

Table 1. *The range in tree measurements taken from Styx Mill Reserve (SMR)*

Table 4. *C and* CO_2 *sequestration at Styx Mill Reserve (SMR)*

Site	**SMR One**	**SMR Three**	**SMR Four**	**Total**
Planting area (ha)	1.98	0.48	3.32	4.78
Sample plot C (t)	0.23	0.23	0.01	0.47
Total planted area C (t)	39.34	35.77	8.22	83.33
Total Planted area CO_2 (t)	144.37	131.29	30.16	305.82

Table 5 shows the estimated C and CO_2 sequestration from Charlesworth Reserve.

Table 5. *C and* CO_2 *sequestration at Charlesworth Reserve (ChR)*

Site	**ChR One**	**ChR Two**	**ChR Three**	**ChR Four**	**Total**
Planting area (ha)	0.19	0.33	0.31	0.74	1.57
Sample plot C (t)	0.08	0.18	0.05	0.03	0.34
Total planted area C (t)	1.53	5.13	1.55	2.45	10.67
Total Planted area CO_2 (t)	5.60	18.84	5.69	9.01	39.14

Table 6 shows the estimated C and CO_2 sequestration from Travis Wetland Reserve.

Table 6. *C and* CO_2 *sequestration at Travis Wetland Reserve (TWR)*

Site	**TWR One**	**TWR Two**	**TWR Three**	**TWR Four**	**T78 13**

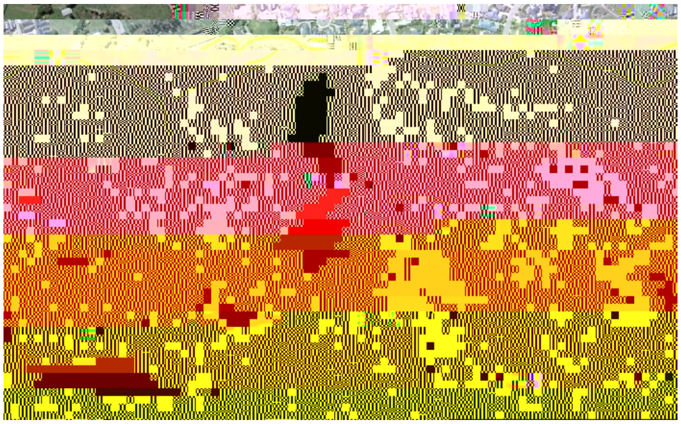

Figure 5. *Choropleth map distinguishing the average height of trees across TFC several planting areas in Styx Mill Conservation Reserve.*

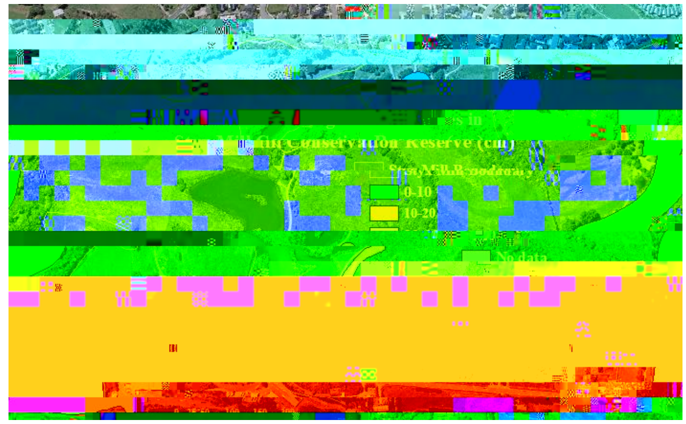

Figure 6. *Choropleth map distinguishing the average DBH of trees across several TFC planting areas in Styx Mill Conservation Reserve.*

Figure 7. *Choropleth map distinguishing the average height of trees across several TFC planting areas in Travis Wetland.*

Figure 8. *Choropleth map distinguishing the average DBH of trees across several TFC planting areas in Travis Wetland.*

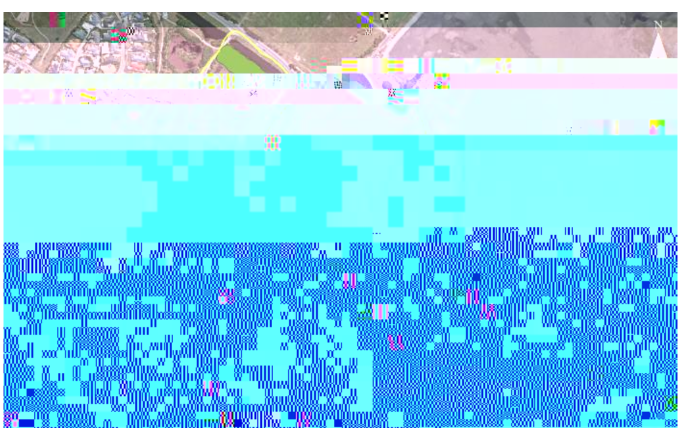

Figure 9. *Choropleth map distinguishing the average height of trees across several TFC planting areas in Charlesworth Reserve.*

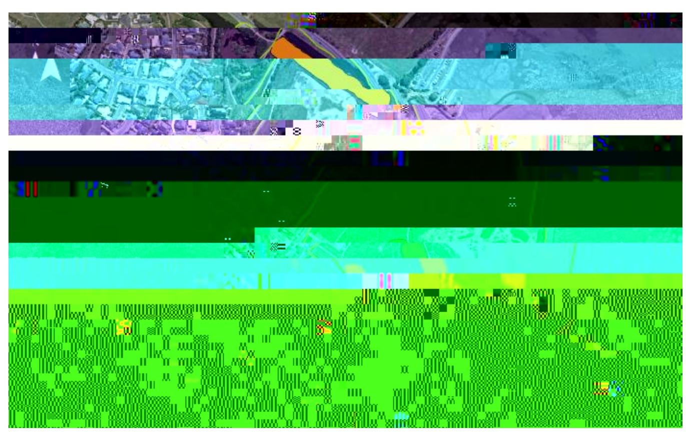

Figure 10. *Choropleth map distinguishing the average DBH of trees across several TFC planting areas in Charlesworth Reserve.*

5. Discussion

The results showed considerable variation in C sequestration across three separate TFC planted sites. Travis Wetland sequestered the most C at 176.73 t compared to Styx Mill which sequestered 83.33 t and Charlesworth which sequestered 39.14 t. GIS area estimations showed Travis Wetland had 11.84 ha of TFC plantings compared to Styx Mill with 4.78 ha and Charlesworth with 1.57 ha. Due to the range TFC of planting areas, variation in C sequestration levels can be expected. Tree age and stocking density would also be major components of C content variations, however they were not addressed within the scope of this report.

The combined total C content of Travis Wetland, Styx Mill and Charlesworth was estimated to be 270.60 t which equates to 993.56 t of CO_2. The total TFC planting area across the three sites was estimated to be 18.19 ha. These results suggest that 14.88 t of C and 54.60 t of CO_2 are sequestered per ha of TFC plantings. For context, research completed on native trees within an Auckland park showed 45.9 t of C stored in the AGB and BGB (Schwendenmann & Mitchell, 2014). The results of this report were lower than those of Schwendenmann and Mitchell (2014) which can be attributed to several factors including inabilities to: fell trees, measure BGB, process entire tree mass to study chemical composition, assess stocking density, measure all nine TFC planted sites and so on.

Calculating BGB C stocks requires extracting tree roots and studying tree litter and soil minerals (Bequires **e**100000912 0fnd

In maintaining estimations of CO_2 sequestration levels, the geospatial database generated from this

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