DEVELOPING METHODOLOGY FOR RESOURCE ASSESSMENT OF NATURALLY REGENERATING TOTARA IN THE WHANGAROA COMMUNITY AREA, NORTHLAND, NEW ZEALAND

Report for; Tane's Tree Trust,
on behalf of
The Northland Totara Working Group

Chris Kennedy

ISBN 987-0-473-13051-0

Funding for this study has been provided by the ASB Community Trust;

ASB Community Trust
Te Kaitiaki Putea o Tamaki o Tai Tokerau
supported by ASB

Additional support for this study has been provided by the following organisations;

NORTHLAND REGIONAL COUNCIL

NZ Landcare Trust
landcare action on the ground

CSIRO
SCION
THE JOINT FORCES OF CSIRO & SCION

Sustainable Farming Fund
Ministry of Agriculture and Forestry
Te Manatū Ahuwhenua, Ngāherehere

Far North District Council

DEVELOPING A METHODOLOGY FOR RESOURCE ASSESSMENT OF NATURALLY REGENERATING TOTARA IN THE WHANGAROA COMMUNITY AREA, NORTHLAND, NEW ZEALAND

Report for; Tane's Tree Trust, on behalf of
The Northland Totara Working Group

Chris William Kennedy

December 2007

This report has been prepared by Geoinfo Ltd for the client; Tane's Tree Trust, on behalf of The Northland Totara Working Group, with funding from; ASB Community Trust. The opinions and information have been presented in good faith for the client's specific requirements. Consequently any other use of this report is at the readers own risk. Geoinfo Ltd or persons acting on behalf of Geoinfo Ltd accept no responsibly or liability for the opinions and information provided in this report.

ISBN 987-0-473-13051-0

ABSTRACT

In Northland totara (*Podocapus totara*) is clearly abundant on much of the hill country pastures, riparian margins and in regenerating indigenous scrub and forest areas. Is this potentially a significant timber resource? Prior to this study there was no estimate available of the totara resource in Northland. A project to develop a method for estimating the resource of totara is part of several initiatives underway by the Northland Totara Working Group set up to determine the potential of naturally regenerating totara on farmland as a long term sustainable timber resource.

A sampling methodology has been developed using a combination of digital mapping technology and forestry inventory methods within a selected study area in Northland. The results of this study provide an estimate of the quantity and quality of the existing totara resource. Estimates are based on the data collected within the study area. As part of the methodology development these estimates are extrapolated with less precision out from the study area to the local districts and the entire northland region.

Prior to commencing the study expectations were that this naturally regenerating resource would be highly variable. The results of sample tree measurements show this resource is indeed highly variable, with stems per hectare (SPH) ranging from 0 to 4737 and tree sizes ranging from small seedlings with a diameter (DBH) of less than 1 cm to large trees with a trunk DBH of 130 cm. Total tree volumes recorded ranged from 0 to 249 m^3/ha.

The results show the quantity of regenerating totara is relatively large although highly variable in spatial distribution. A large proportion of trees are small to medium in size. The average quality or tree form is significantly higher in stands either in totara dominant stands or within mixture with other species in shrubland and forest areas, compared to scattered individual trees in open ‘paddock’ situations, the latter on which the resource is often judged.

The characteristics of the resource surveyed in this study suggest that scope exists to improve tree quality through silvicultural operations - potentially leading to significantly improved quality of recoverable timber. However, implications for silvicultural management require further detailed analysis and are part of further work being undertaken by the Northland Totara Working Group.

The results indicate that it is possible to assess naturally regeneration totara resources in various land cover types, using high resolution aerial photography and the methods described in this report.

The tentative regional estimation, points to a significant total regional volume that could potentially become a sustainable source of timber in the not to distant future.

KEYWORDS: *Podocarpus totara*, Northland, sustainability, resource, management, GIS, survey, indigenous, aerial photography, mapping, remote sensing

INTRODUCTION

Totara is a light demanding pioneer species that compared with other native podocarps grows relatively quickly and produces seed from a young age. It germinates and establishes successfully in grazed environments and consequently, the extensive conversion of forest to pastoral farming in the past has probably assisted in its current proliferation particularly on hill country landscapes and along riparian areas (Bergin 2003).

As with a number of other regions in New Zealand, Northland has extensive areas of totara regenerating on farmland and amongst second-growth shrubland and forest. The Northland Totara Working Group (NTWG) was formed in late 2005 as a result of land owner interest in exploring the productive potential of naturally regenerating totara on private land in the region. Potential for sustainable management of this resource was highlighted by research undertaken by Bergin (2001). The NTWG has initiated research into several aspects relating to the sustainable management of naturally developing totara on farmland including silviculture requirements and developing an inventory method for determining the resource of regenerating totara in Northland. Many small stands of totara on private land may cumulatively sum to a significant resource at a regional scale. However, the actual extent and quality of this resource in Northland had not been assessed.

This study to develop an inventory method for assessing the naturally regenerating totara resource has been commissioned by Tane's Tree Trust on behalf of the NTWG. Funding has been provided by the ASB Community Trust.

OBJECTIVE

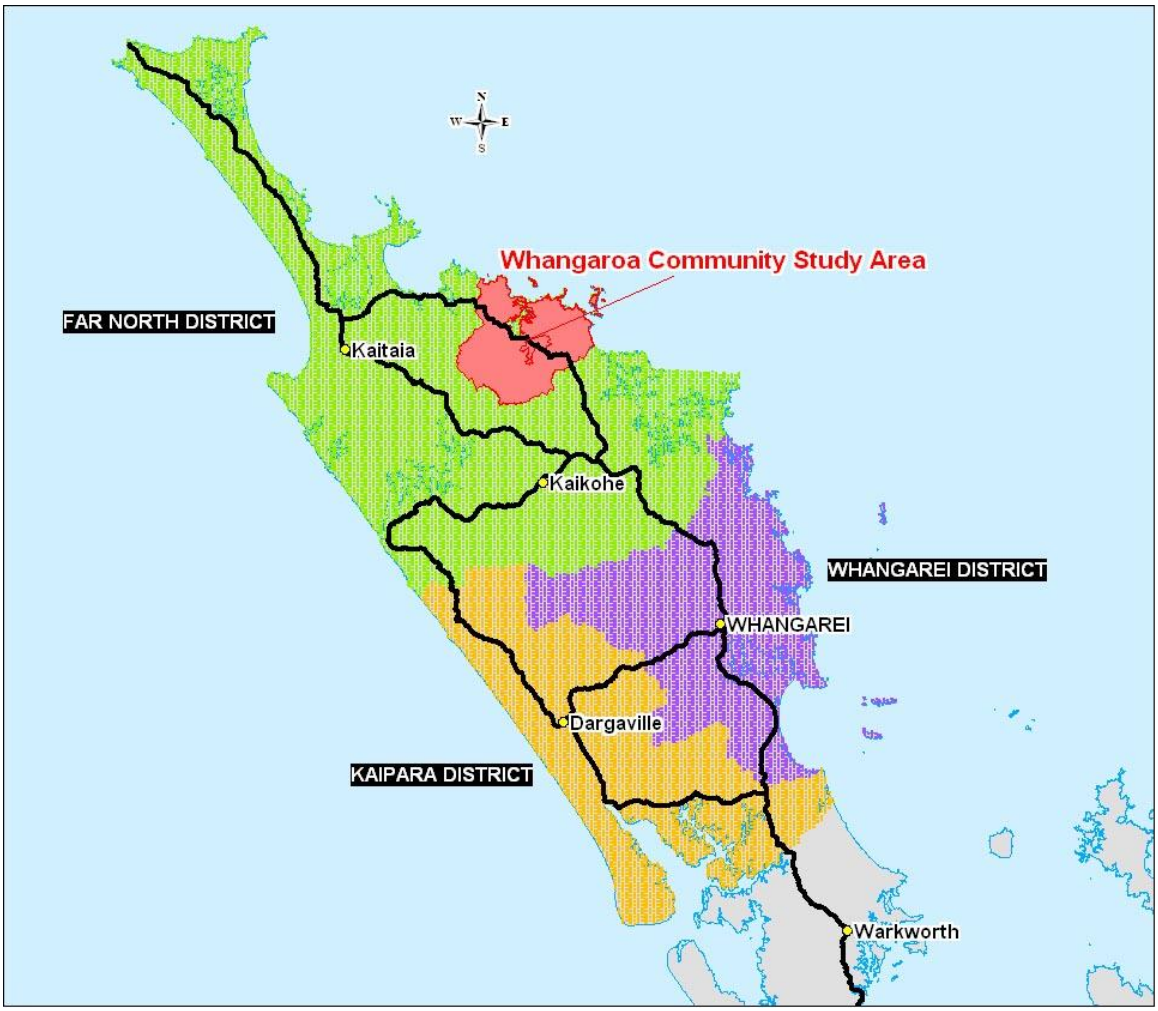
The aim is to develop a practical method for assessing the current resource of naturally regenerating totara on farmland and previously cleared land under private tenure. At least one district within the Northland region with regenerating totara was to be surveyed using advanced remote sensing methods (digital mapping based on aerial photography) followed by ground-based stand assessments.

METHODOLOGY

Study site

The resource assessment was undertaken in one district within the Far North District Council (FNDC) in Northland identified for the purposes of this study as the "Whangaroa Community Study Area" (Fig. 1). This 63,675 hectare (ha) study area was defined using Statistics NZ ward boundaries of the Mangapa-Matauri Bay and Kaeo areas. The area was reduced to 47,579.3 ha when irrelevant landuse or insignificant land-cover classes were excluded. Excluded areas comprised reserves/QE II, mangrove, coastal-sands and other insignificant LCDB2 areas. (refer to Area excluded in Appendix 1).

Figure 1: Location of the Whangaroa Community Study Area, Far North District Council, Northland, selected for developing a methodology for determining the resource of naturally-regenerating totara on farmland.



As with many other regions in Northland, the Whangaroa Community Study Area has typically significant areas of previously-cleared land reverting to shrubland which includes totara. The area also includes two farm properties near Kaeo owned by Paul Quinlan and Doug Lane where the characteristics of the vegetation cover were known from previous work on totara and where there was good local knowledge of the vegetation cover and landuse.

The vegetation cover mapping and photography

Geographic Information System (GIS) and Remote Sensing (RS) were used to correlate a sample of high resolution photography with the comprehensive Land Cover Database (LCDB2). Standard plantation forestry inventory methods were used to estimate volumes and also provided ground truth verification of GIS/RS mapping classifications.

Two databases have been developed; a GIS enabling mapping and spatial analysis in conjunction with a series of spreadsheets used to calculate volumes from the inventory data.

The three main levels of data were used in order of resolution. These were from lowest to highest resolution:

1. Ministry of the Environment , Land Cover Data Base Version 2 (**LCDB2**)
2. Mapping/classification of totara identified on randomly selected high resolution **aerial photography**.
3. Randomly selected totara **inventory plots** (located using GPS)

Land Cover Data Base

The Land Cover Database (LCDB2) from the Ministry of the Environment (MfE 2001) was selected as the base map population layer. This is a national GIS dataset derived from remote sensing classification of satellite imagery. *"The revised database uses Landsat satellite images to identify land cover change. A set of images for the country was acquired over the summer of 2001/02" (www.mfe.govt.nz).*

Research indicted this was the most current and comprehensive land cover description available. The broad generic classes and resolution of this dataset are insufficient to accurately identify quantities of any individual tree species such as totara. The LCDB2 does however provide a comprehensive base layer to correlate with higher resolution samples.

Regarding the accuracy of the LCDB 2, 'In 2000 the Ministry for the Environment commissioned Forest Research to carry out an accuracy assessment of the classification classes used in LCDB1. Land cover was evaluated at 17,000 points across the country. Overall map accuracy was estimated at 93.9% using the simple accuracy percentage statistic. However classification error in LCDB1 is being corrected as part of the LCDB2 process and the overall accuracy of LCDB1 is expected to improve accordingly." (MfE 2001).

Aerial Photography

A total set of 302 high resolution vertical digital photographs were taken during three flights in October 2006, January 2007 and May 2007. From this total set, a sub-set of 58 were selected representing the; "photo sample coverage" and "mapping sample area". The photography was taken during flight runs generally selected to provide an even spread of the sample coverage across the Whangaroa community study area (refer to; 'Mapping sample area" in, Appendix 1).

Two photography flight runs were selected specifically to provide photography covering two particular properties, Quinlan's and Lane's within the mapping sample area. This involved manually selecting six photographs to provide coverage of these properties. In general, most of the flight runs were selected to give a higher representation of "scrub" type LCDB2 classes; (refer Appendix 1 LCDB classes shaded grey). The bias toward scrub was to ensure sufficient coverage of these classes, which were expected to contain the most significant totara resource.

In Phase I (pilot study) another 28 photographs were randomly selected from the October 2006 and January 2007 flights and added to the initial 6 selected giving a total of 34 photographs in the pilot study photo sample. In the final Phase II of the study another 24 images were randomly selected from the May 2007 runs. All 58 digital images in the total photo sample were digitally rectified in order to calibrate with the NZTM map grid. This rectification process was controlled using the Far North District Council's ortho photography (March 2000).

Land cover types and mapping classes
The Kaeo Study Site was initially stratified into mapping classes and individual paddock trees, with the objective of gaining a better understanding of the resource variability and consequently improving the total extrapolated resource estimates for the study area. Major land cover types were determined and mapping classes based on size of predominant tree size of totara present and stand density were developed.

GIS analysis
GIS analysis was carried out to relate the mapping sample to the LCDB2 base map**.** In essence the GIS analysis process creates a union (join) between two layers:

1. Mapping sample layer
2. LCDB2 layer

A new "Mapping Sample/LCDB2" layer is generated from the two original layers. The original polygons in the mapping sample have effectively been split by the polygons in the LCDB2 creating a new layer. The new polygons are a subset of polygons from the original layers. These new polygons are classified by both the mapping class and the LCDB class and the area in hectares is calculated. These new polygon areas are then summarised to produce a "LCDB2 class/Mapping Class Area" matrix for the Mapping sample area and then extrapolated to the Whangaroa Community Study Area.

Stand and tree assessment
Standard forestry inventory plots were used within totara stands to provide an estimate of volume, stem quality and ground-truth verification of the mapping sample classification process. This involved the establishment of circular temporary plots from 0.01-0.04 ha in size. Small plots were used in densely stocked stands and larger plots used in lower density stands. Plot dimensions were adjusted for slope where required.

In the initial pilot study, 15 inventory plots were measured. In the final phase of the study a further 39 plots were measured. Plot locations were randomly selected from within areas classified as totara stands during the mapping sample process. All plots were randomly selected using a grid overlay method, except for plots x1 and x2 which were manually selected to ensure inclusion in the sample of the mapping classes in which these plots are located. (refer Appendix 1 for plot locations).

Plot locations uploaded as waypoints into a Garmin 76CSx GPS (new receiver, with improved under canopy reception) were used to locate plot centres in the field. The inventory plot variables recorded in the field are listed and described in (**Error! Reference source not found.**).

Table 1 Plot Variables (Shaded green indicates varibles recorded for individual trees except when tree has multiple stems from its base)

Variable code	Description
Date	Measurement date
Slope (deg)	Slope (used to determine corrected plot radius)
Size (ha)	Most 0.1 or 0.04 ha (exceptions refer to appendix 4.)
Plot reference	From GPS waypoint
Tree number	Order tree was measured
DBH (cm)	Tree diameter at 1.4 m above ground
Height (m)	Maximum of 4 predominant heights per plot
Form (class)	Subjective assessment of potential log quality (refer tree form)
Comment	Any general observation
Count Saplings	A tally of saplings with DBH > 2cm and < 5 cm
Count Seedlings	A tally of seedlings with DBH <= 2cm

In "non-totara stands" within the mapping sample area a random sample of paddock trees was measured for the following variables: DBH (cm), Height (m), Form (class), Photo reference, Comment (refer Appendix 5).

For most of the paddock trees sampled a digital photograph was taken.

Tree Form

During the inventory, tree form was recorded as a subjective assessment of tree shape related to apical dominance, stem straightness and proportional lower branch size. The form class, was assessed from a wood products perspective relative log quality. Tree form was recorded for almost all trees measured for DBH in both paddock and stand trees sampled. A detailed description of the tree form was developed for each form class.

Other comments

Any other factor affecting tree growth, pattern or health was recorded during field work.

Tree Volume Function
Currently there is no volume equation available specific to totara, consequently the tree volume function for Pole Rimu (Westland) Ellis (1979) was used.

Pole Rimu (Westland)
$V = 0.034275\ D^2\ (H^2 / H\text{-}1.4) + 5.945143$

For trees with multiple stems at the base, each stem volume was calculated individually and then the volume of all stems was combined to produce the tree volume.

Using the data collected during the field work (inventory) volumes were calculated for each tree with dbh recorded (> 5 cm), these individual tree volumes were then combined to give; total tree volume plot volumes and per hectare volumes.

DBH height equations

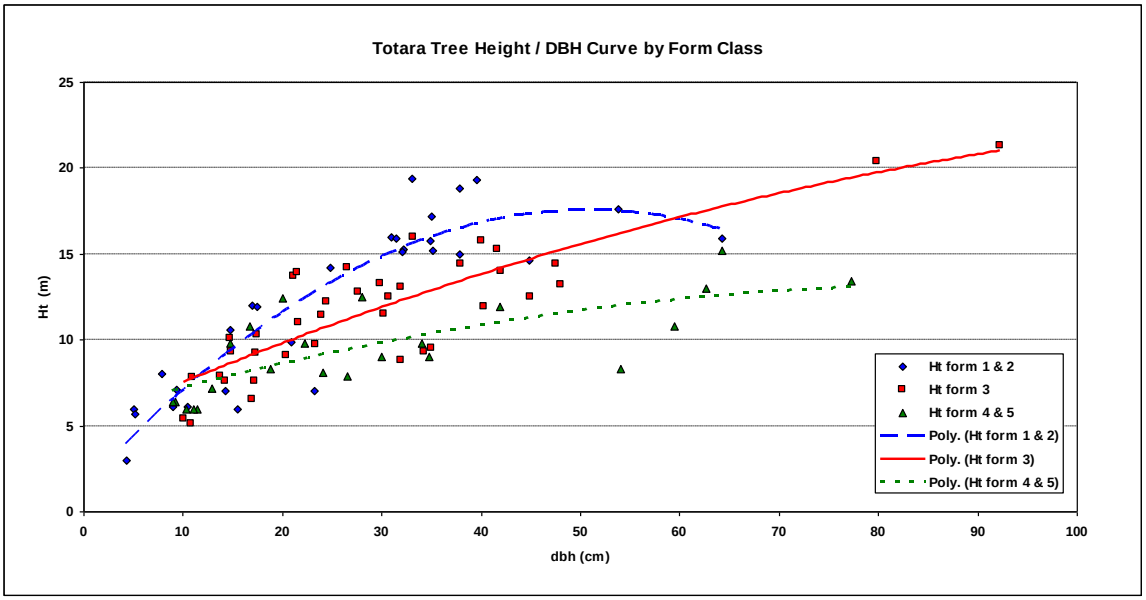
DBH/ Tree height regression analysis was carried out to estimate height for trees with height not measured. Tree heights were combined into 3 form class groups (refer **Error! Reference source not found.**)

Table 2 Stand trees 2nd order polynomial regression and linear regression for paddock trees

Group	Formula	R^2 Value
Form 1 & 2	$H = -0.0063\ D^2 + 0.6406\ D + 1.2806$	$R^2 = 0.8334$
Form 3	$H = -0.0009\ D^2 + 0.2532\ D + 5.0707$	$R^2 = 0.7098$
Form 3 & 4	$H = -0.0009\ D^2 + 0.1676\ D + 5.6278$	$R^2 = 0.5466$
All Paddock trees	$H = 0.0351\ D + 9.851$	$R^2 = 0.2061$

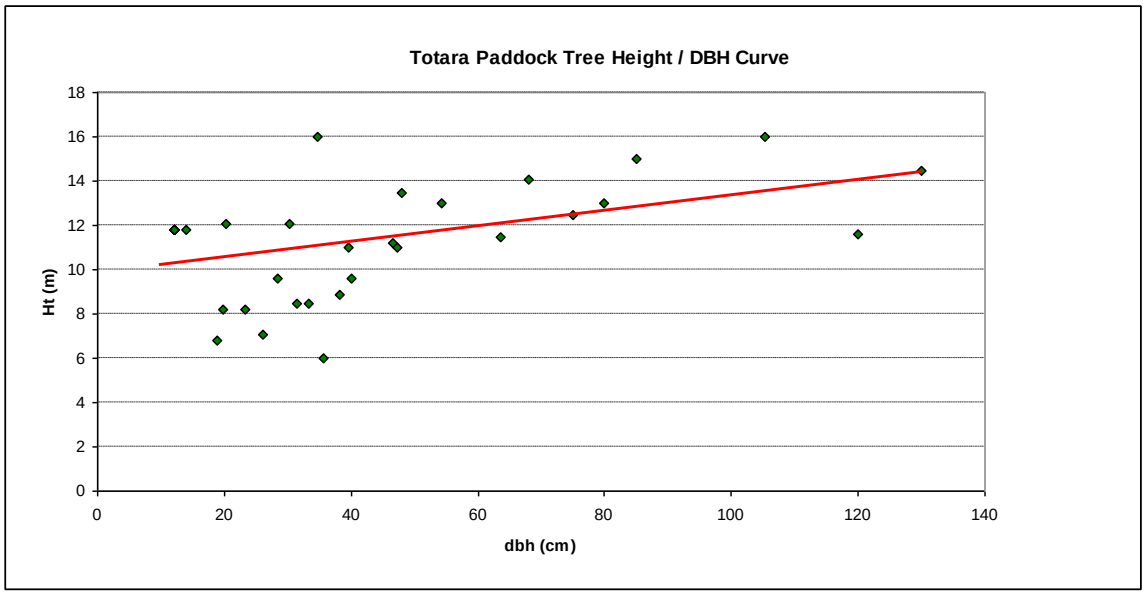
The regression types and formula were selected to minimize the R^2, and used to estimate the unmeasured heights. These estimates will tend to be unreliable if extrapolated outside the sample data range.

Figure 2 Totara Tree Height /DBH curve by form class group



The inventory plot measurements of heights and dbh show there is a relationship between height and form, with predicted heights at 30 cm, being; 9.8 m, 11.9 m, and 14.8 m for groups, form 4 & 5, form 3 and form 1 & 2 respectively.

Figure 3 Totara Paddock Tree Height /DBH curve



Paddock tree heights had significant variability, particular with diameters less than 45 cm, consequently the R^2 value is low. This is associated with the very poor form of some of these paddock trees (refer, **Error! Reference source not found.**).

The data from the 64 inventory plots was entered into a spreadsheet database. An estimate of total tree volume m^3 was then calculated for each tree measured in the inventory plots and individual paddock trees. These results are summarised with other variables. (refer appendices 5 and 6).
This per hectare plot summary data was then again summarised by mapping class to produce the "Summary Inventory Plot Data" presented in Appendix 2.
Additional summary variables of interest are also presented in Appendix 2 including;

Mean SPH all (includes saplings and seedling) – This include the tally of seedling <2 cm and saplings <= 5 cm which were recorded as part of the inventory.

Mean SPH trees (Dbh > 5cm) the stocking of trees with dbh measured, and volume calculated. The summary stocking values appear to correlate with the stocking value assigned during the mapping classification.

Mean plot Dbh (cm) (Dbh > 5 cm) the mean of plot mean Dbh. This diameter or tree size also appears to correlate with the size value assigned during the mapping classification.

Mean plot BA (m2/ha) Basal area is a function of both Dbh and SPH. Consequently these results also appear to correlate with the mapping classification.

Form %, is calculated from the sum of tree volumes which form was recorded (94% of trees with measured Dbh) The results of this show a spread of form across all mapping classes.

It is anticipated that this data will be useful for any subsequent resource utilisation and analysis studies.

In Appendix 2 the "Mean plot total tree volume" was multiplied with the "Total Area (ha)" estimates from the GIS Analysis of the study area to calculate the estimate of "Total Volumes (m^3)" by mapping sample class for the study area.

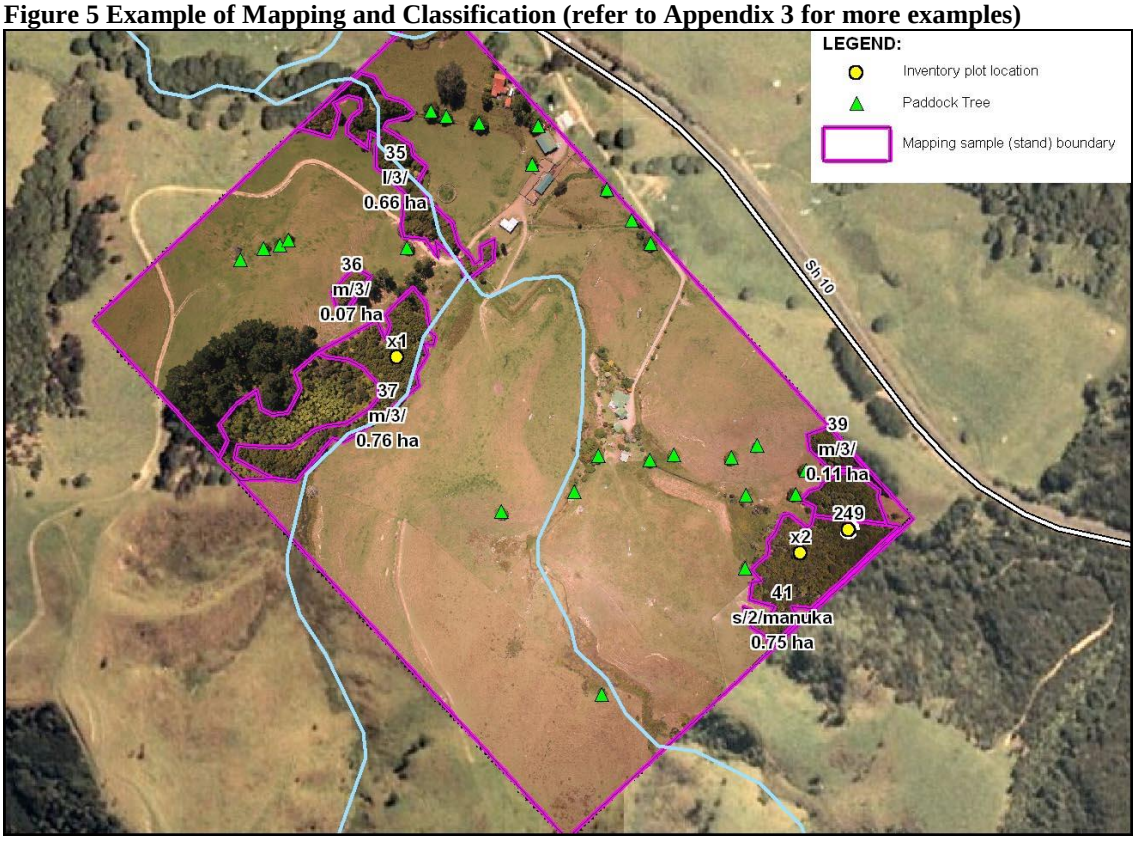
RESULTS

Digital mapping and classification

The areas covered by the photo sample (shown in Figure 2) were digital mapping and classified to create the mapping sample (shown in Figure 3).

Figure 4: High resolution aerial photograph (image 1320), overlaid on FNDC ortho-photography.

Figure 5 Example of Mapping and Classification (refer to Appendix 3 for more examples)



The mapping sample was stratified into mapping classes with the objective of gaining a better understanding of the resource variability and consequently improving the total extrapolated resource estimates for the study area. The mapping sample was divided into three main types;

1. Totara Stands (areas of trees with a totara stand mapping class)
2. Non-Totara Stands (areas without a totara stand mapping class)
3. Paddock Tree Points (individual tree locations within the Non-Totara Stand areas)

Mapping classes were developed based on an initial assessment of a subset of the photo sample. Totara stands were classified into 11 totara classes (Table 1), based on the following two variables;

1. apparent totara tree size – large, medium, small, 0 = not visible but likely
2. apparent totara tree stocking – ranging from 0 = very low to 3 = high

Table 3 Totara stand mapping classes

Mapping Code	Class Description (size, stocking)
00	no totara visible, but likely to be present
l2	large size, medium stocking
l3	large size, high stocking
m0	medium size, very low stocking
m1	medium size, low stocking
m2	medium size medium stocking
m3	medium size high stocking
s0	small size, very low stocking
s1	small size, low stocking
s2	small size medium stocking
s3	small size high stocking

(Refer to Appendix 3, for examples of stand mapping and classification)

The areas which could not be assigned a stand class code became the default “Non totara stands” areas and include pasture, plantation forestry and remnant indigenous forest. Forest areas of large indigenous trees (remnants of old-growth forest) were generally considered not to be the targeted regenerating resource and were excluded from the stands and consequently included in the “No totara stand” default class.

Paddock trees were defined as individual trees with too low a stocking to be classified as a stand. These were mapped as points in the GIS and given a reference number (

)

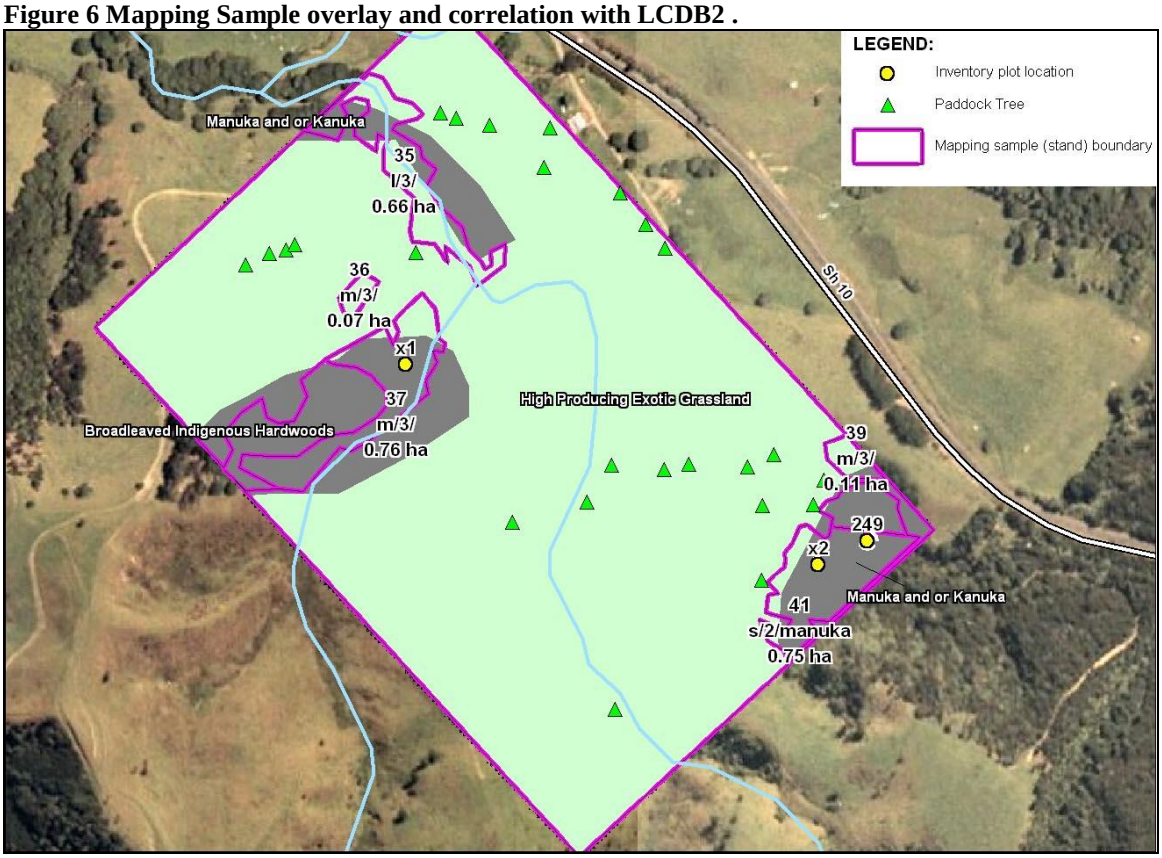
Digital mapping of the photo sample was undertaken at a scale of approximately 1:1000.
Stand mapping classes were defined using a subjective visual assessment mapping technique based on the defined mapping classes (Table 3).Areas which appeared to have similar visual characteristics relative to the prevalence of totara and the defined classes were grouped into stands and assigned a mapping code. The other main species of vegetation visible, was also recorded when stand class was assessed.

Some areas on Lane’s farm were mapped without high resolution aerial photography and outside the photo sample area. The reason for this was to meet one of the project objectives; “the total assessment of an individual farm”. In this case the photo sample was substituted with the FNDC 2000 ortho-photography to define stand boundaries and stand classes were assigned during an additional ground survey. These areas were included in the mapping sample.

Mapping class and LCDB2
GIS overlay analysis was used to merge the mapping sample polygon layer and the LCDB2 polygon layer. This process created a new polygon layer shown in Figure 4. The areas of these new polygons were calculated and summarised to produce the "LCDB2 class/Mapping Class Area" matrix (Error! Reference source not found.).

The area proportions in this matrix are extrapolated to the Whangaroa Study Area to produce the population "LCDB2 class/Mapping Class Area" matrix for the study area, these areas are presented in Appendix 2.

Figure 6 Mapping Sample overlay and correlation with LCDB2 .



Mapped area of totara
In total 1226 hectares (ha) were mapped in the mapping sample, within this total, 444.6 hectares were mapped as totara stands and assigned a sample mapping class code. The total "totara stand" portion of the mapping sample is comprised of 253 stands with a average area of 1.76 ha. Subtracting this portion from the total mapping sample gives 781.4 ha remaining of "non-totara stand".

The largest totara stand mapping classes by area were; 00, s1 and m1 with a total area of 287.6 ha or 65% of the total 444.6 ha. (refer to **Error! Reference source not found.** for detail).

Using GIS analysis, the mapping sample layer was correlated with the LCDB2 layer to produce the "mapping sample/LCDB2" layer. This process effectively splits the initial 253 stands into 429 new sub-stands with unique LCDB2 classes. The area of these new sub-stands is calculated and summarised to produce the "mapping sample/LCDB2" area matrix for the mapping sample area (refer Appendix 2).

Table 4 Matrix of Sample Mapping Correlation with LCDB2 for the mapping sample area.

	Sample Mapping Classes												
LCDB2 Class Name	**Non totara stand**	**00**	**l2**	**l3**	**m0**	**m1**	**m2**	**m3**	**s0**	**s1**	**s2**	**s3**	**Total (ha)**
Afforestation (imaged, post LCDB 1)	23.3	2.4											25.7
Broadleaved Indigenous Hardwoods	15.4	11.3			1.3	10.4	0.6	1.5	0.8	29.6	10.8		81.7
Deciduous Hardwoods	0.1												0.1
Forest Harvested	13.5												13.5
Gorse and Broom	9.6	0.5								2.5			12.6
Grey Scrub	0.3									0.6			0.8
High Producing Exotic Grassland	474.6	7.0	0.2	0.7	2.5	3.8	5.4	1.3	2.7	7.3	4.7	0.1	510.2
Indigenous Forest	58.8	29.4		1.1	15.2	15.6	19.8	1.0	0.7	10.4	2.8	8.3	163.0
Low Producing Grassland	25.5	2.6				0.4	0.8			0.0	0.9	0.2	30.5
Manuka and or Kanuka	60.7	53.3		0.2	2.8	32.3	19.3	0.3	26.8	52.7	7.3	0.3	256.1
Pine Forest - Closed Canopy	89.3	0.3	0.2		1.3	11.3	9.2	1.2	0.9	0.5	0.0		114.2
Pine Forest - Open Canopy	1.3					2.2	0.8			0.1	3.2		7.6
Surface Mine	9.1	1.0											10.0
Total (ha)	**781.4**	**107.8**	**0.4**	**2.0**	**23.0**	**76.1**	**55.9**	**5.2**	**31.9**	**103.7**	**29.8**	**8.9**	**1226.0**

This “mapping sample/LCDB2” table is then used to extrapolate the sample mapping class proportions to the study area, providing an estimate of the hectares of study area in each sample mapping class.The result of the GIS analysis and extrapolation is presented in Appendix 2 in the section “GIS Analysis, LCDB2 class/Mapping class (ha)”.

The total mapping sample represents 2.6% of the total 47,579.7 ha study area. **Error! Reference source not found.** shows the mapping sample proportion of LCDB2 class areas relative to the proportion of the LCDB2 class areas for the study area or population. The column “Difference in % of Total” shows how well the sample represents the population.

Table 5 Representation LCDB2 classes, Sample vs Study Area (Population)

	Mapping Sample		Study Area		
LCDB2 Class	**Total (ha)**	**Class % of Total**	**Total (ha)**	**Class % of Total**	**Difference in % of Total**
Afforestation (imaged, post LCDB 1)	25.7	2.1%	104.9	0.2%	1.9%
Broadleaved Indigenous Hardwoods	81.7	6.7%	1787.9	3.8%	2.9%
Deciduous Hardwoods	0.1	0.0%	4.7	0.0%	0.0%
Forest Harvested	13.5	1.1%	549.7	1.2%	-0.1%
Gorse and Broom	12.6	1.0%	263.6	0.6%	0.5%
Grey Scrub	0.8	0.1%	14.7	0.0%	0.0%
High Producing Exotic Grassland	510.2	41.6%	23507.2	49.4%	-7.8%
Indigenous Forest	163.0	13.3%	8433.8	17.7%	-4.4%
Low Producing Grassland	30.5	2.5%	1145.0	2.4%	0.1%
Manuka and or Kanuka	256.1	20.9%	8455.6	17.8%	3.1%
Pine Forest - Closed Canopy	114.2	9.3%	1885.7	4.0%	5.4%
Pine Forest - Open Canopy	7.6	0.6%	1346.1	2.8%	-2.2%
Surface Mine	10.0	0.8%	80.8	0.2%	0.6%
Grand Total	**1226.0**	**100%**	**47579.7**	**100%**	

It can be seen in **Error! Reference source not found.** that the LCDB2 classes; “High Producing Exotic Grassland” and “Indigenous Forest” are under-represented and “Pine Forest - Closed Canopy”, “Manuka and or Kanuka” are over-represented. This is likely to be associated with the deliberate bias in favouring the “scrub” type classes (shaded grey)introduced during the planning and implementation of the photography flight runs. This outcome was anticipated. The bias was deliberate, as with limited resources it was considered that more value would be gained from a higher representation of the LCDB2 classes which were more likely to contain significant resources of totara. Overall the sample appears to represent to population reasonably well.

Some issues with mapping

In hindsight the number of mapping classes could be condensed. Size could be reduced to just medium and small. This is due to difficulty with interpretation of size “large”, individual trees are often not apparent, as the forest canopy is usually quite tight and large trees appear as one mass. Consequently in the current sample, large tree will be often grouped in with medium. Other mapping classes with a low occurrence; m0, s0 could be combined with 0,0. The s3 class could also be combined with mapping class s2. Combining these classes would reduce the overall number of mapping classes from 11 to 6 giving a more practical group for subjective classification.

During the ground truthing exercise occasionally some mapping class interpretation errors were noted. In the areas where totara was identified and mapped/classified from the photography but the ‘ground truthing’ indicated that a mis-identification may have occurred as no totara was found on the ground. The species that have a similar appearance to totara in the photography and are likely to have created confusion in these instances were;

1. Possibly either a natural hybridisation between *Lophomyrtus obcordata* (Rohutu) and *Lophomyrtus bullata* (Ramarama), or alternatively, *Coprosma crassifolia*
2. *Caldcluvia rosaefolia* (Makamaka), or alternatively young and vigorous *Weinmannia silvicola* (Towai)

This issue could be reduced by: increasing the time spent during classifing at the totara identification and class interpretation stage (from the photographs). Another solution could be to re-classify the entire sample after the ground truthing.

Miscellaneous Tree Health

While undertaking the field work some concerning observations regarding poor totara tree health were also noted. In some isolated areas, particularly in the gorge area of the Waiare river and south of Upokorau Farm, die-back of totara trees was noticeable. This was often associated with heavy lichen cover on branches and particularly trees in a bush environment and relatively tall canopy. Halls totara were also noticeably more common in this area. No obvious cause was apparent.

Tree Form

Totara were placed into one of five tree form classes:

1. Excellent
2. Good
3. Fair
4. Poor
5. Non merchantable

A detailed description of the five classes of tree form are given in Table 3.

Table 6 Tree form class description

Form Class Description and Characteristics/ defects	Photography example
Class Code:1 **Rating:** Excellent **Log lengths:** 6+ m **Description:** Single straight trunk, clear bole or only a few small branches or knots, no other apparent defects. **Photo #:**2490 **Tree #:** n/a	
Class Code:2 **Rating:** Good **Log lengths:** 5-6+ m **Description:** Single straight lower trunk, but may have some small-medium branches or knots, and may have heavy branches or fork above lower log length.. **Photo #:** 1602 **Tree #:** 35	
Class Code: 3 **Rating:** fair **Log lengths:** 2.7 - 5+ m **Description:** Short logs, or multiple logs, down-graded by defects such as moderate-heavy branching/ knots slight sweep, twist or wobble. **Photo #:** 1605 **Tree #:** 38	

Class Code: 4 **Rating:** Poor **Log lengths:** 1.5 -2.7 m **Description:** Short recoverable butt log length, may have confused grain and some knots.. **Photo #:** 1583 **Tree #:** 598	
Class Code: 5 **Rating:** Non-merchantable **Log lengths:** <1.5 m **Description:** No merchantable trunk length. May have multiple stems/ heavy branches and or forks. N.B. some branches may have considerable size. **Photo #:** 2502 **Tree #:** 645	

Estimated totara volumes

The total tree volume estimated for stands in the study area was 453,860 m^3 (refer Appendix 2) and 27,340 m3 for paddock trees. The combined estimate of total study volume of totara trees is **481,257 m^3**. The stand volume is the major proportion of the toata totara resource with approximately 94% of the total and paddock trees comprise just 6% as shown in Figure 7.

The paddock tree volume was estimated using the measurements of random sample of paddock trees. Of the 56 trees measured 9 (16 %) were incorrectly identified from the photography as totara but were another species of tree. This error included 7 kahikatea, 1 rimu and 1 sequoia. A total sample of 658 paddock trees were mapped within the mapping sample. A total volume of 27,340 m^3 is estimate for paddock trees within the study area. (refer to Table 7 and Appendix 5).

Table 7 Estimation of Total Tree Volume (m^3) of Paddock Trees within study area

Number of paddock trees mapped	658
Estimated actual totara (less 16% mapping class error)	552
Area (ha) mapped with no totara stands	781.4
Paddock trees per non-stand (ha)	0.71
Mean tree volume (m3)	1.25
Total non stand area (ha)	30,843
Total tree volume (m3) =	**27,340**

(refer to appendix 5 for detail)

Figure 7 Proportion of total volume m3

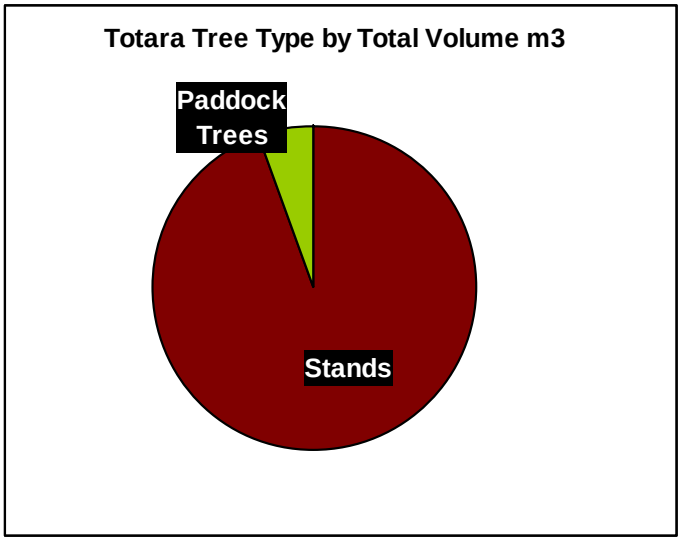


Figure 8 Total Stand Trees m3 by Form

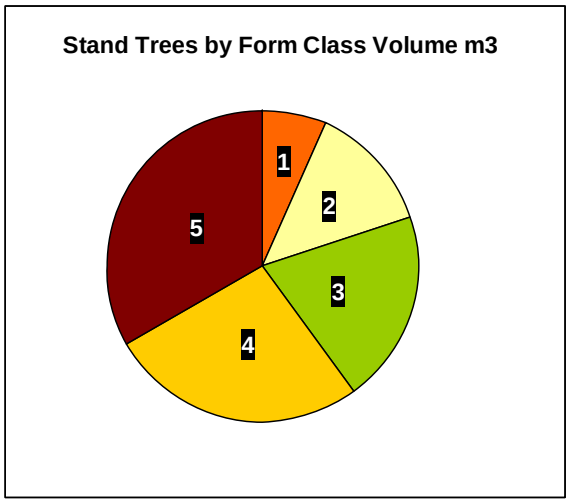
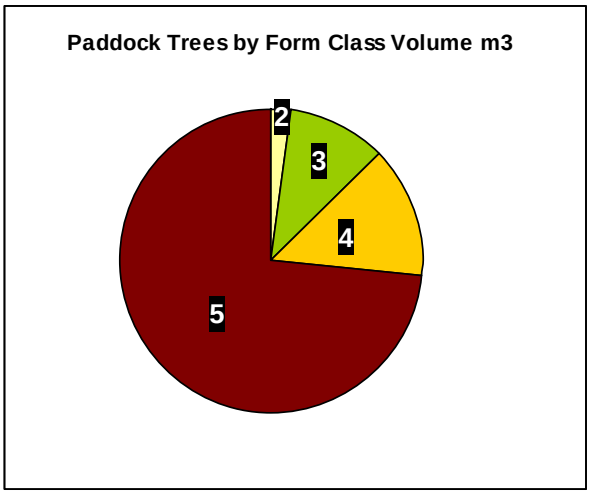


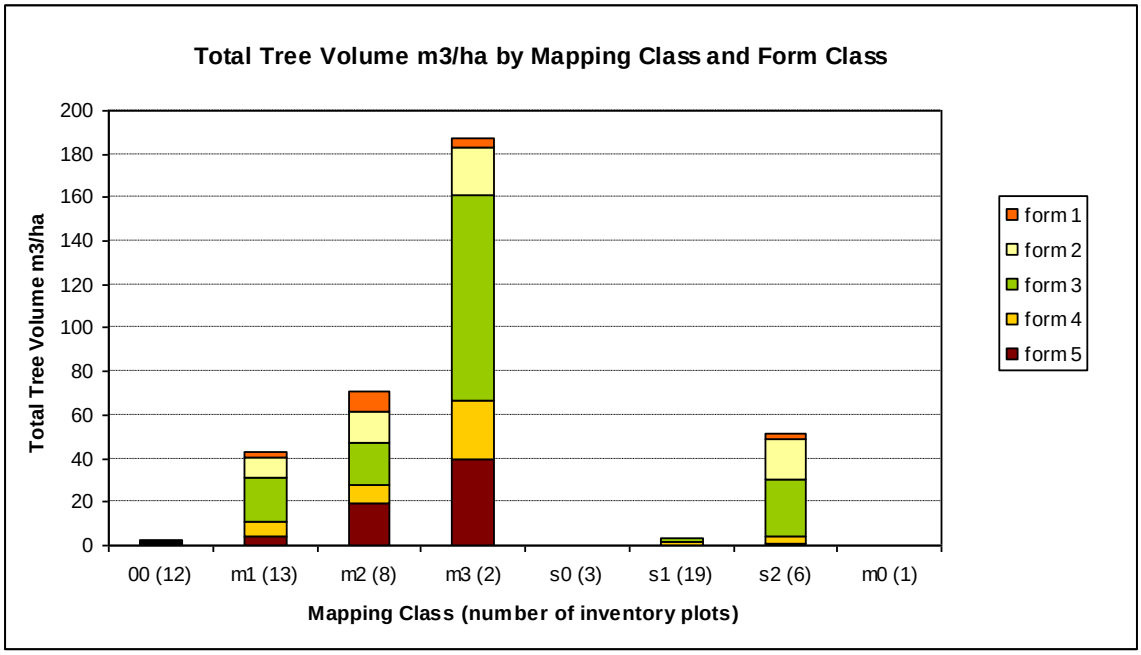
Figure 9 Paddock Trees m3 by Form



Figures 8 and 9 show the proportion volume in each form class for each totara tree type. As expected, the total paddock trees volume has a significantly higher proportion of un-merchantable form class 5. In contrast a large proportion of the stand volume is comprised of trees with reasonable form classes ranging from 3-1. (refer Appendix 2 for detail of stand form % by m^3/ha)

A large proportion 79% the total stand tree volume is accounted for by three stand mapping classes; m2, m1 and s2. The actual volumes (m^3/ha) of these three mapping classes are not particularly high; however they represent a significant area of the resource, and consequently a large proportion of the total volume estimate.

Figure 10 Stand Mapping Class Volumes m3 by Tree Form



In contrast the mapping class "m3" has a relatively high volume (m^3/ha) but represents a relatively small proportion of the total resource area. (refer Figure 10). This "m3" class is potentially the most immediate source of significant harvestable volumes.

Figure 11 Number of stems and form by Dbh class

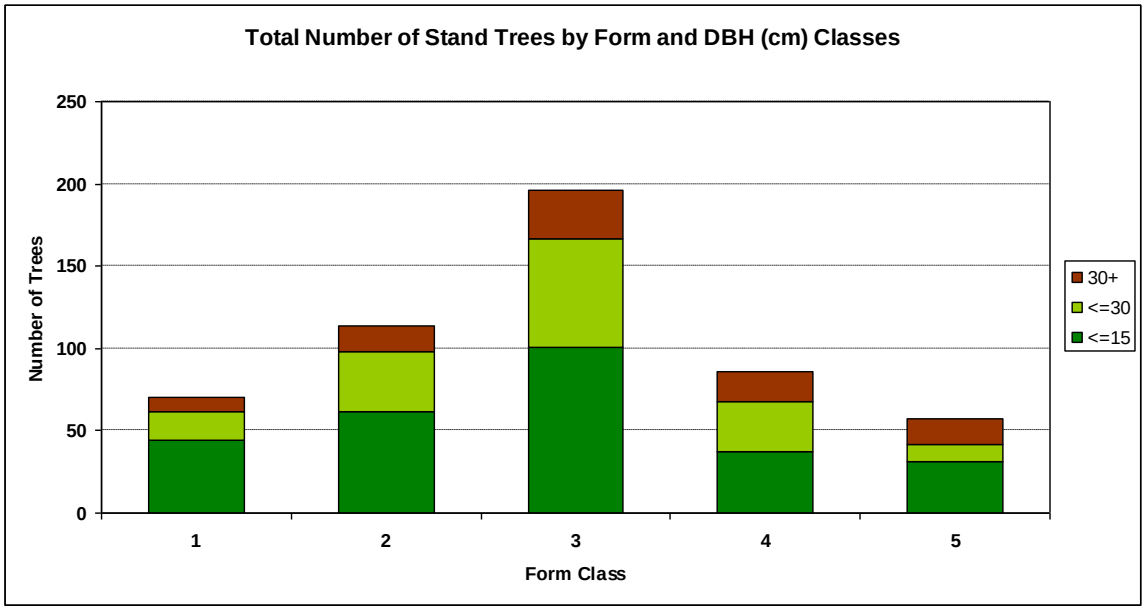


Figure 11 shows a breakdown of the number of stems in each form class by Dbh class, for all trees measured in the inventory plots. This chart shows the size of most trees is small, with a large proportion less than 30 cm, indicating this is currently generally an immature resource from a wood products perspective. It also shows a large number of stems with Dbh <= 30 with average to poor form indicating there is currently significant potential to improve the quality of this resource through silvicultural operations.

Regional extrapolation of the resource estimate

The study area represents approximately 10% of the total Far North District (FNDC). Using the comprehensive LCDB2 coverage the results from the study area can be extrapolated out to cover the districts and region (Fig. 12). These district and regional estimates given in Table 8 will be less reliable than the estimate from within the study, due to lack of ground truthing verification and inventory.

Figure 12 Northland Districts LCDB2 private ownership (refer Appendix 1 for legend)

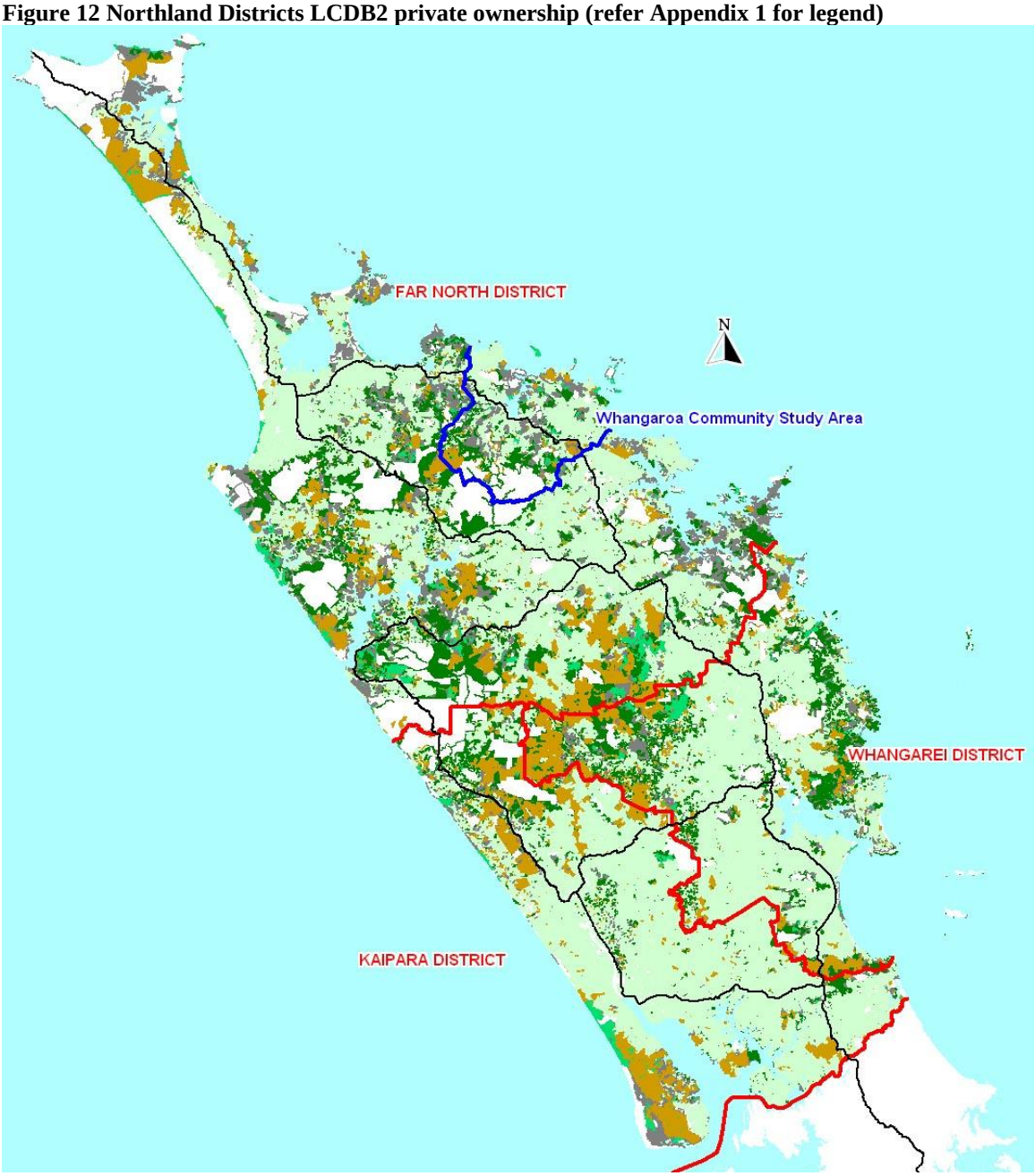


Table 8 Extrapolation of estimated areas and volumes by LCDB2 class from the Whanagaroa Study Area to the Northand region. Detailed estimates are given in Appendix 6.

	Northland Region			
LCDB2 Class	Total (ha)	No Totara Stands (ha)	Totara Stands (ha)	Totara Stands Tree Volume (m3)
Afforestation (imaged, post LCDB 1)	8237	7459	778	1875
Broadleaved Indigenous Hardwoods	15081	2849	12232	268392
Deciduous Hardwoods	1425	1425	0	0
Forest Harvested	8729	8729	0	0
Gorse and Broom	6098	4642	1456	4592
Grey Scrub	189	63	125	413
High Producing Exotic Grassland	580481	539974	40506	1391274
Indigenous Forest	144853	52238	92615	2801208
Low Producing Grassland	22776	19081	3695	103986
Manuka and or Kanuka	84327	19998	64330	1172867
Pine Forest - Closed Canopy	82878	64809	18069	1006464
Pine Forest - Open Canopy	37525	6404	31120	1577995
Surface Mine	620	560	60	144
Total Stand (m3)	**993218**	**728233**	**264986**	**8329209**
Total Paddock Trees (m3)		**821513**		

Of the total number of privately owned (excluding reserves,QEII) hectares in Northland (993, 218 ha) covered by the LCDB, 264,986 ha is estimated through extrapolation from the study area to have at least some totara present (Table 8). This amounts to approximately 8 million m3 of totara in the region (Table 8).

DISCUSSION

A practical method that provides a reasonable estimate of the totara resource in a district has been developed using remote sensing and mapping classes. The method is based on the use of aerial photographs at high resolution that are overlayed with the MfE land cover database (LCDB2) that covers the country (reference to the MfE source).

Based on the Whangaroa Community Study Area, 35 % of privately owned land is estimated to have at least some totara. Of this only approximately a quarter 4,419ha (9% of the total) is totara with reasonable stocking greater than 300 SPH. These higher stocked classes have 71% of total tree volume (approximately 220,000m3) from trees with fair form or better making up approximately half the total volume in the study area.. This shows there is a significant proportion of area (26%) with low densities of totara making up approximately half the volume of the study area. The average diameter are also small relative to merchantable standards with most stems DBH less than 30 cm (refer Appendix 2 for detail).

Using the methodology of matrixing map classes with the LCDB2, and extrapolating from the Whangaroa Study Area, it is estimated that in the Northland region there is approximately 26% of the land cover (265,000 ha) where at least some totara is present. Based on the results of the study area, approximately 70,000 ha (7%) of this

regional total will be totara that has reasonable tree form and stocking greater than 300 SPH. This indicates that the present potential total tree volume on a regional basis from these reasonably stocked areas is in the order of 3.5 million m3. A large proportion of this volume will have small DBH and is unlikely to be immediately merchantable.
The major proportion of the estimated totara resource, is classified in the small to medium size class and low stocking class that are likely to respond significantly to silvicultural intervention. Thinning and pruning is likely to improve growth rates and form and therefore considerably improve the overall volume and quality of totara that can be sustainably managed.

The survey method developed here can be applied to any district in Northland or indeed other regions in the country. The methods developed should provide an estimate of landcover with totara, some estimate of the stocking and tree form of the totara resource, and using volume functions, an estimate of the total volume in various cover and tree form categories.

CONCLUSION

Although not as yet subjected to rigorous statistical testing, the results demonstrate that it is possible to assess naturally regenerating totara resources, using high resolution aerial photography and the methods described in this report.

Reviewing the issues encountered in the practical execution of this study suggests some minor refinements to this methodology could be made to improve the efficiency of similar studies on this type of resource in the future. Nevertheless, the data captured in this study now provides a valuable body of information to which more can be added

The results show the totara resource is relatively large and variable, with a large proportion of small to medium sized trees and highly variable form. This suggests opportunities may exist for silvicultural intervention and management to have significant effect on the potentially recoverable timber quality of any future harvests. The Northland Totara Working Group are currently establishing thinning and pruning plots covering a range of totara stands with small to medium size trees (Bergin 2007).

The extrapolated (less reliable) regional estimation, points to a significant total regional resource that could potentially become a source of sustainably managed timber in the not to distant future.

ACKNOWLEDGEMENTS

The NTWG for support and commissioning this study. The ASB Community Trust for providing funding. Appreciation to; Paul Quinlan for support and many metres in the field, David Bergin and Peter Berg for advice. Terry Conaghan (DOC) and Judy at the FNDC for data they freely provided. All the landowners who allowed access onto their land.

REFERENCES

Bergin, D.O. 2001: Growth and management of planted and regenerating stands of *Podocarpus totara* D.Don. PhD thesis, Univeristy of Waikato. 316p.

Bergin, D.O.2003: Totara; Establishment, growth and management. New Zealand Forest Research Institute, Rotorua. New Zealand Indigenous Tree Bulletin No. 1. 40p.

Bergin, D.O.2007: Establishment of silvicultural trials in naturally-regenerating stands of totara on farmland, Northland, New Zealand. Progress report for the Northland Totara Working Group. Ensis, 10p.

Ellis, J.C. 1979: Tree volume equations for the major indigenous species in New Zealand. New Zealand Forest Service, *Forest Research Institute Technical Paper No. 67*: 64p.

Ellis, J.C. 1995: Measuring logs, *New Zealand Institute of Foresrty Forestry Handbook, Section 5.1.2*. Christchurch. 107-108.

Ellis, J.C.; Hayes, J.D. 1997: Field guide for sample plots in New Zealand forests. New Zealand Forest Research Institute, Rotorua. *FRI Bulletin No. 186*. 84p.

Goulding, C.J.; Lawrence, M.E. 1992: Inventory practice for managed forests. New Zealand Forest Research Institute, Rotorua. *FRI Bulletin No. 171*. 51p.

MfE 2001: http://www.mfe.govt.nz/issues/land/land-cover-dbase/classes.html

LIST OF APPENDICES:

Appendix 1 Study overview map

Appendix 2 Summarised Results of; Inventory, Mapping and GIS Analysis for Totara Stands within Study Area

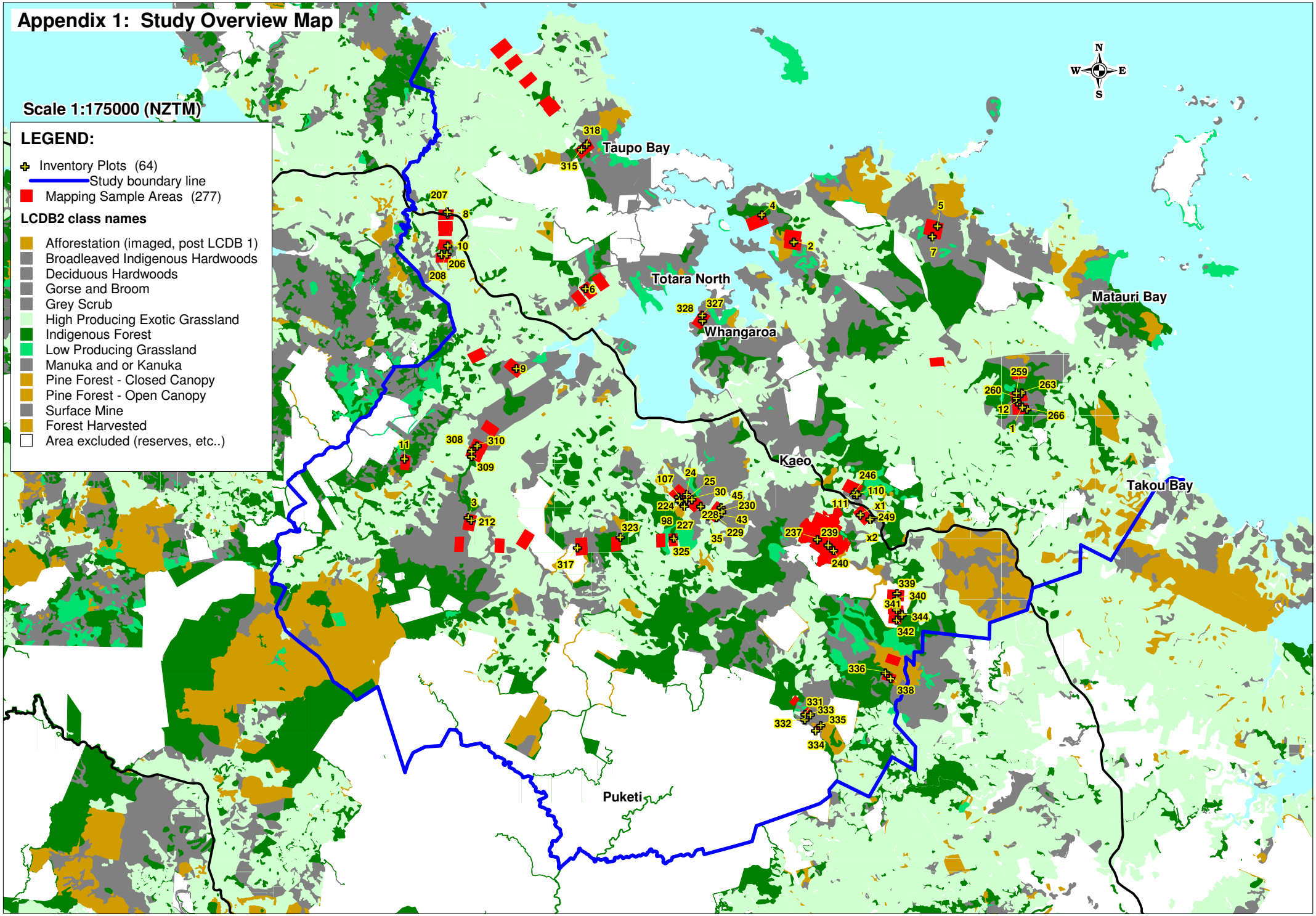
Appendix 3 Example aerial photography and mapping sample (stand) areas

Appendix 4 Inventory Plot Summary

Appendix 5 Paddock Tree Data

Appendix 6 Extrapolation of District and Regional, Areas and Volume.

Appendix 1: Study Overview Map



Appendix 2: Summarised Results of; Inventory, Mapping and GIS Analysis for Totara Stands within Study Area

note: table colouring corresponds approximately to map legend in Appendix 1

note: values shaded this colour are estimated using similar class

	Mapping sample classes														
Summary Inventory Plot Data	**00**	**I2**	**I3**	**m0**	**m1**	**m2**	**m3**	**s0**	**s1**	**s2**	**s3**	**Total Plots**			
Number of plots	**12**	**0**	**0**	**1**	**13**	**8**	**2**	**3**	**19**	**6**	**0**	**64.0**			
Mean SPH all (includes saplings & seedlings)	93.3			0.0	272.7	749.5	1587.5	93.3	356.3	1088.5					
Mean SPH trees (Dbh > 5 cm)	26.3			0.0	113.1	328.2	1075.0	3.3	41.8	457.8					
Mean plot Dbh (cm) (Dbh > 5 cm)	14.0				21.8	19.6	17.6	5.1	14.8	12.4					
Mean plot BA (ha)	0.4			0.0	6.6	11.1	31.7	0.0	0.8	9.2					
Mean plot total tree volume (m^3/ha)	**2.4**	**71.2**	**187.5**	**0.0**	**43.3**	**71.2**	**187.5**	**0.04**	**3.3**	**51.8**	**51.8**				
Form 1 (% of total tree volume m^3/ha)	2%				7%	13%	3%		0%	6%					
Form 2 (% of total tree volume m^3/ha)	23%				20%	20%	12%		5%	35%					
Form 3 (% of total tree volume m^3/ha)	57%				48%	28%	50%		44%	50%					
Form 4 (% of total tree volume m^3/ha)	17%				15%	12%	14%		43%	7%					
Form 5 (% of total tree volume m^3/ha)	1%				9%	27%	21%		7%	2%					
	00	**I2**	**I3**	**m0**	**m1**	**m2**	**m3**	**s0**	**s1**	**s2**	**s3**	**Total (ha)**	**No Totara Stands (ha)**	**Totara Stands (ha)**	
Mapping Sample Areas (ha)	**107.8**	**0.4**	**2.0**	**23.0**	**76.1**	**55.9**	**5.2**	**31.9**	**103.7**	**29.8**	**8.9**	**1226.0**	**781.4**	**444.6**	
GIS Analysis LCDB2 Class /Mapping Class (ha)	**00**	**I2**	**I3**	**m0**	**m1**	**m2**	**m3**	**s0**	**s1**	**s2**	**s3**	**Total (ha)**	**No Totara Stands (ha)**	**Totara Stands (ha)**	**Totara Stands Tree Volume (m^3)**
Afforestation (imaged, post LCDB 1)	9.9											104.9	95.0	9.9	23.9
Broadleaved Indigenous Hardwoods	246.3			28.3	228.1	13.3	31.9	16.9	648.0	237.3		1787.9	337.8	1450.2	31818.4
Deciduous Hardwoods												4.7	4.7	0.0	0.0
Forest Harvested												549.7	549.7	0.0	0.0
Gorse and Broom	10.5								52.4			263.6	200.7	62.9	198.5
Grey Scrub									9.8			14.7	5.0	9.8	32.3
High Producing Exotic Grassland	321.1	7.5	30.7	113.9	175.3	248.2	60.4	124.2	335.6	218.7	4.9	23507.2	21866.9	1640.4	56341.3
Indigenous Forest	1518.9		55.4	786.2	806.0	1023.9	51.9	36.8	538.9	143.5	430.8	8433.8	3041.5	5392.3	163095.9
Low Producing Grassland	98.7				14.4	31.2				33.0	8.5	1144.9	959.2	185.7	5227.1
Manuka and or Kanuka	1761.6		7.6	91.5	1067.6	636.7	9.0	885.5	1741.3	241.1	8.4	8455.6	2005.2	6450.4	117604.3
Pine Forest - Closed Canopy	5.7	3.9		21.1	186.9	151.6	19.7	14.2	8.0			1885.4	1474.3	411.0	22895.8
Pine Forest - Open Canopy					393.2	143.5			12.9	566.7		1346.1	229.7	1116.3	56604.4
Surface Mine	7.8											80.8	73.0	7.8	18.8
Total Area (ha)	**3980.6**	**11.4**	**93.7**	**1041.0**	**2871.4**	**2248.5**	**173.0**	**1077.5**	**3346.8**	**1440.3**	**452.6**	**47579.3**	**30842.6**	**16736.7**	
Total Volume (m^3)	**9593**	**814**	**17573**	**0**	**124200**	**160187**	**32436**	**42**	**11056**	**74541**	**23422**				**453860**

Appendix 3: Example aerial photography and mapping sample (stand) areas

Image 1- Mapping class 00 (stand 141) with approximate GPS location of plot 212

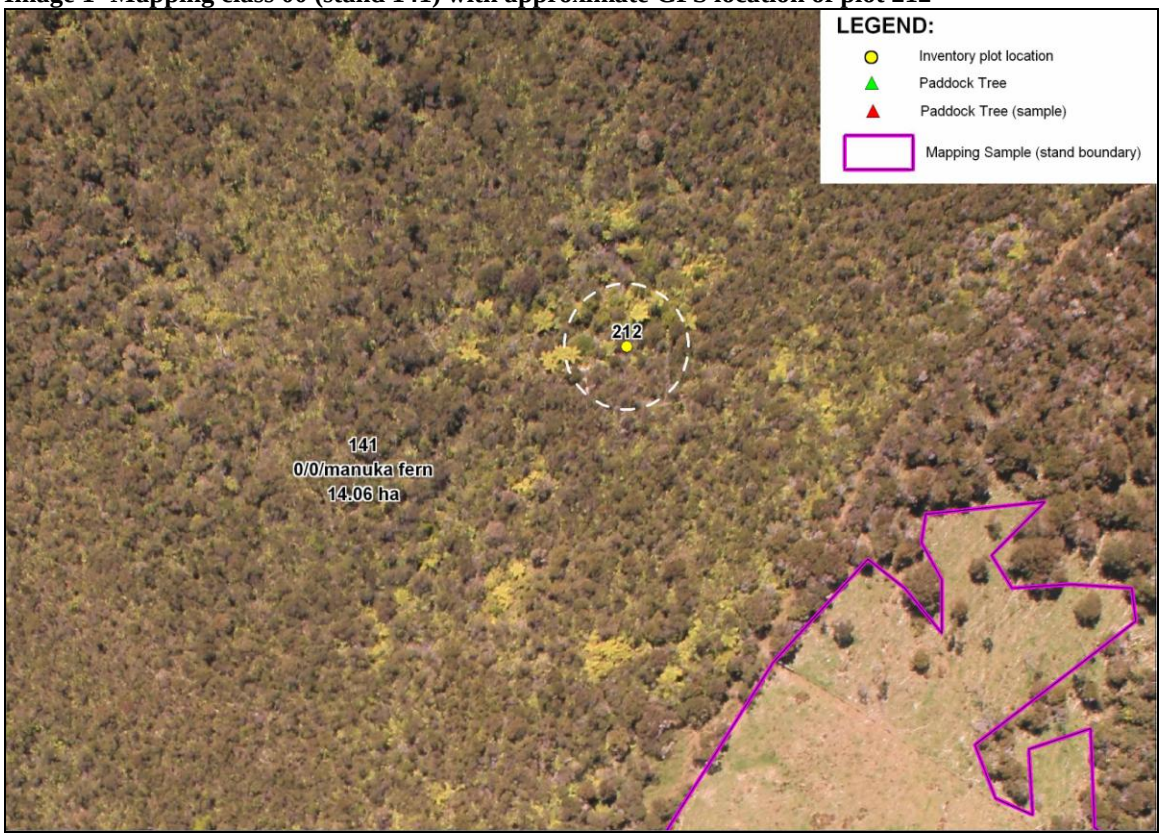


Image 2 - Mapping class m1 (stand 69) with approximate GPS location of plot 25

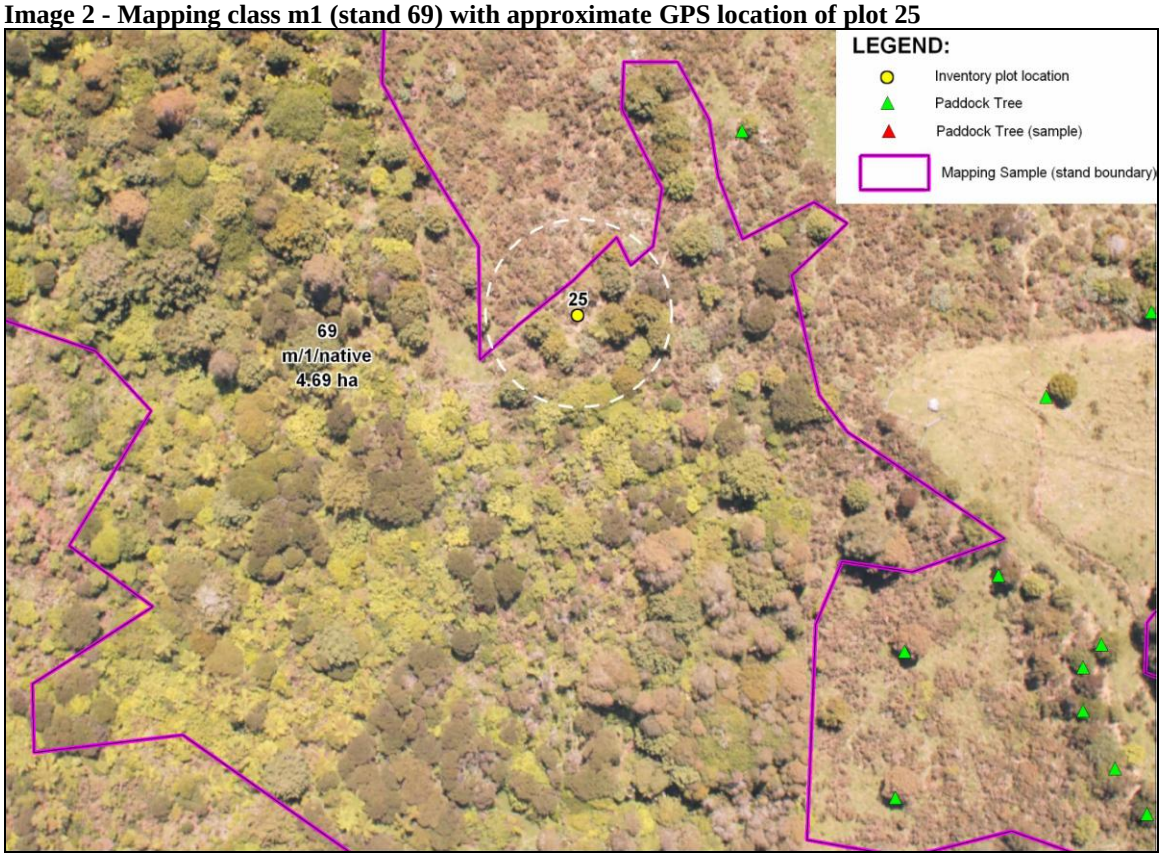


Image 3 - Mapping class m2 (stand 247) with approximate GPS location of plot 323

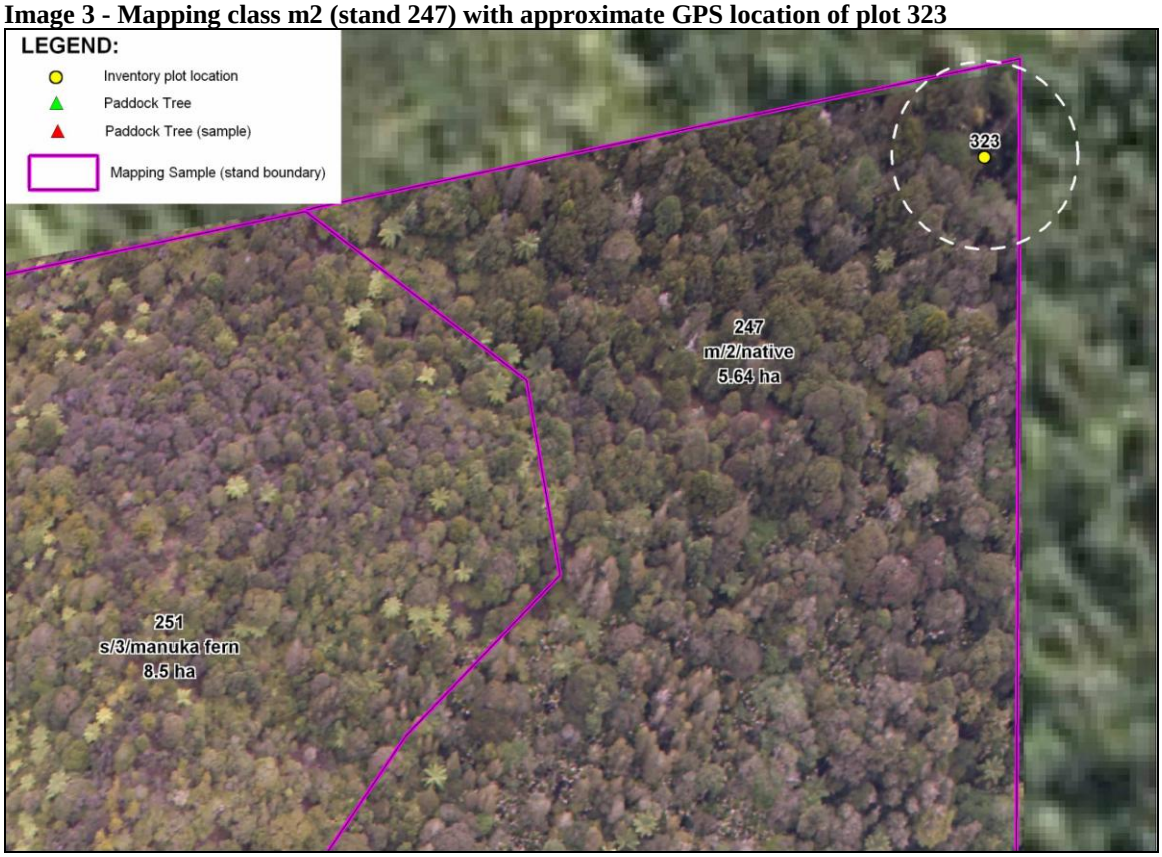


Image 4 - Mapping class m3 (stand 234) with approximate GPS location of plot 325

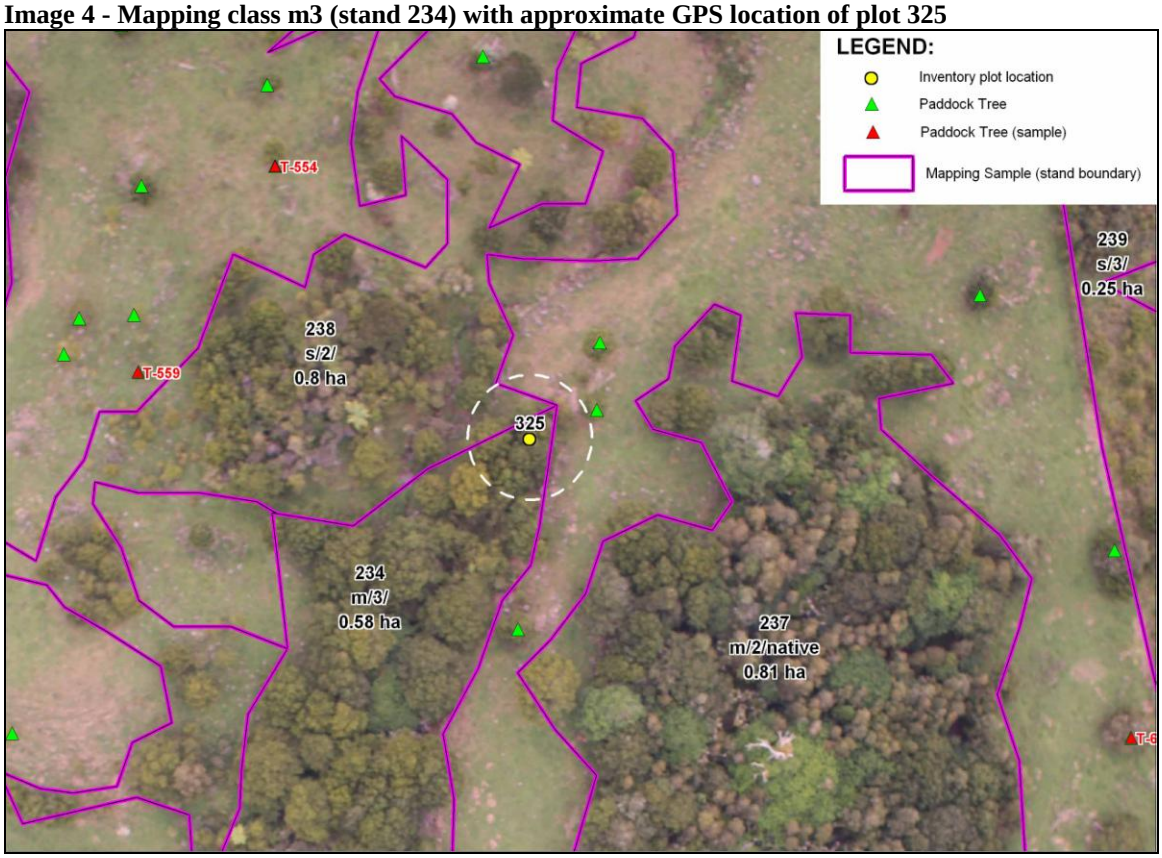


Image 5 - Mapping class s1 (stand 61) with approximate GPS location of plot 35

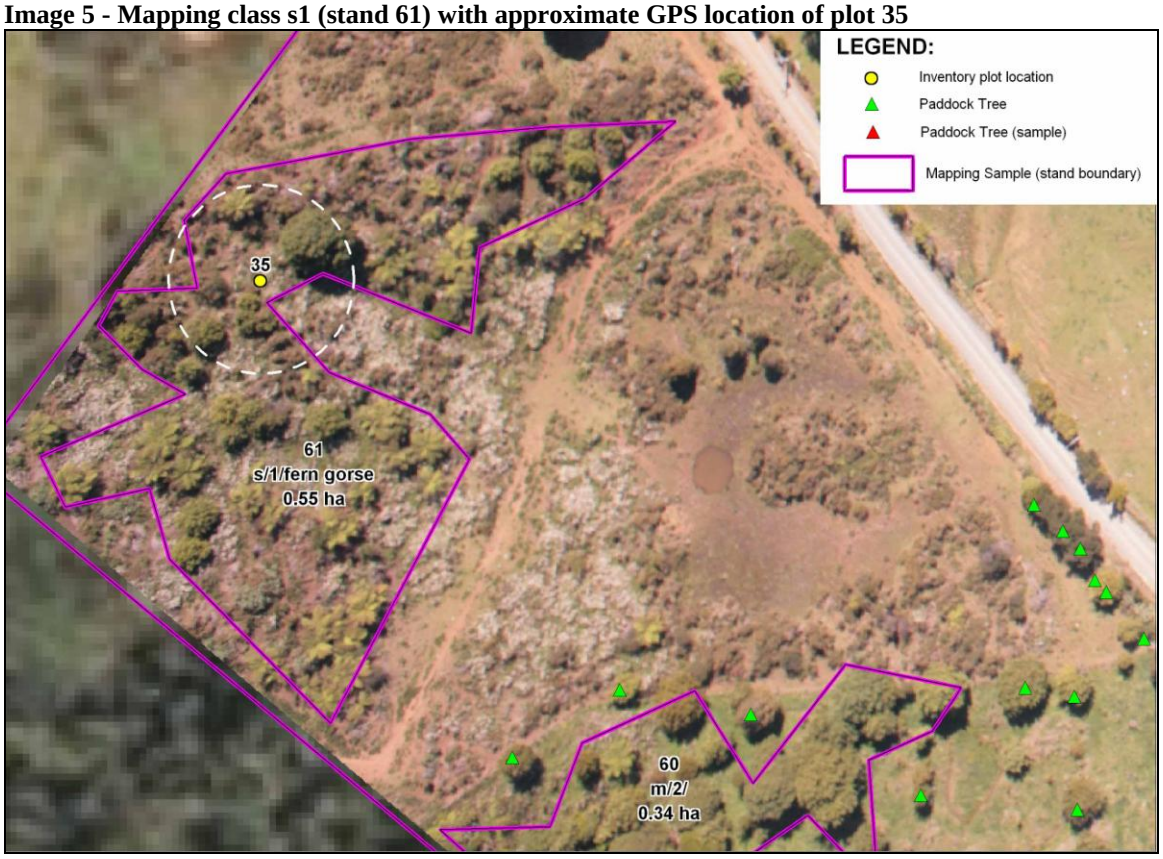
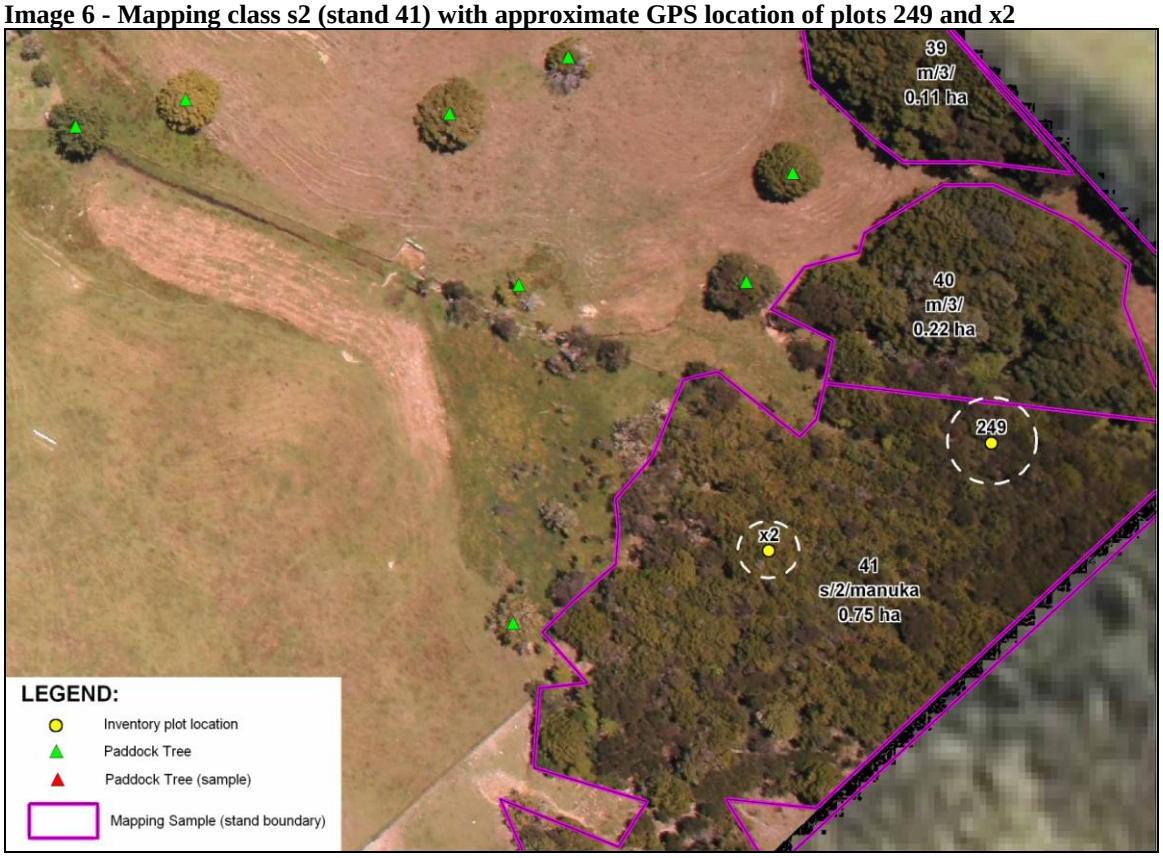


Image 6 - Mapping class s2 (stand 41) with approximate GPS location of plots 249 and x2



Appendix 4: Inventory Plot Summary

Plot ref	Plot Area (ha)	Stems per plot	SPH all	SPH trees > 5cm dbh	Total tree volume m^3/ha	m3/ha form 1	m3/ha form 2	m3/ha form 3	m3/ha form 4	m3/ha form 5	BA (m^2/ha)	Mean dbh (cm)	GIS Stand ref	GIS Area (ha)	GIS Species other	GIS Class
1	0.040												44	18.2	manuka fern	**s1**
2	0.040												87	1.0	manuka	**00**
3	0.040												141	14.1	manuka fern	**00**
4	0.040												82	6.8	manuka	**00**
5	0.040												80	30.6	manuka	**00**
6	0.100	56	560	40	12.0			3.7	8.4		2.1	21.7	104	4.8	gorse/fern/native	**s1**
7	0.040												80	30.6	manuka	**00**
8	0.040												116	3.3	manuka	**s1**
9	0.100	23	230	10	0.1							5.1	135	13.9	manuka	**s0**
10	0.040	60	1500	175	4.6	2.0					0.9	8.0	124	3.8	native	**m2**
11	0.100	15	150	160	10.9	0.3	0.7	3.6	2.7	3.7	2.3	12.2	140	14.0	manuka fern	**s2**
12	0.040	1	25										47	16.9	manuka gorse	**00**
24	0.100	61	610	480	38.8		1.6	14.3	17.9	3.6	7.6	11.7	70	2.2	manuka	**s1**
25	0.100	12	120	120	43.8	0.1	1.7	9.8	20.2	9.4	8.6	28.9	69	4.7	native	**m1**
30	0.172	38	221	221	65.8		2.9	8.2	25.3	29.4	12.4	23.7	68	0.8		**m2**
35	0.100	8	80	80	3.6		0.7	1.5	0.4	1.0	0.8	10.7	61	0.6	fern gorse	**s1**
43	0.100	4	40	40	5.6	0.6		3.1		1.9	1.1	16.6	59	5.8	native	**m1**
45	0.100	63	630	150	51.8	0.4	0.3	33.0	17.7	0.4	8.7	23.1	58	2.2	manuka	**m1**
98	0.100	2	20	20	1.1		0.7	0.4			0.2	12.4	72	4.4	native	**s2**
107	0.100	5	50	60	2.1	0.9	0.8				0.4	8.5	74	14.2	native manuka	**m1**
110	0.040												42	0.8	manuka	**s1**
111	0.100	34	340	150	5.2	0.3	0.1	2.9	1.3	0.2	0.9	7.3	43	18.9	manuka Pine	**00**
206	0.100	32	320	70	8.4		0.7	7.6			1.8	16.2	130	3.2	manuka	**s1**
207	0.040	1	25										116	3.3	manuka	**s1**
208	0.040	30	750										130	3.2	manuka	**s1**
212	0.040	2	50										141	14.1	manuka fern	**00**
224	0.157	2	13	13	0.2				0.2			5.9	72	4.4	native	**s2**
227	0.173	15	87	87	22.0	4.3	16.0	1.4	0.3		3.1	15.2	72	4.4	native	**s2**
228	0.100	35	350	110	95.6	0.5	0.6	6.5		88.0	15.6	31.4	65	3.1	manuka fern	**m2**
229	0.100	5	50	20	3.6	0.6	3.0				0.6	18.3	59	5.8	native	**m1**
230	0.100	33	330	110	8.5	2.6	1.2	4.5		0.1	1.6	12.9	59	5.8	native	**m1**
237	0.100	86	860	300	131.2	3.8	8.1	87.7	29.8	1.8	17.5	19.5	6	1.1	native	**m2**
239	0.100	73	730	410	100.7	40.6	39.8	19.2	1.2		14.1	17.9	15	2.8	QE2 manuka	**m2**
240	0.020	40	2000	1200	71.0	0.8	3.4	22.7	9.5	34.6	14.5	11.2	157	1.0	manuka	**m2**
246	0.040	23	575	125	7.3	0.3	0.4	3.1	3.6		1.5	10.6	43	18.9	manuka Pine	**00**
249	0.040	61	1525	625	66.8	0.9	12.2	51.2	2.5		11.9	14.0	41	0.8	manuka	**s2**
259	0.100	13	130	40	16.4		6.1	10.3			2.5	24.1	47	16.9	manuka gorse	**00**
260	0.040												47	16.9	manuka gorse	**00**
263	0.040												47	16.9	manuka gorse	**00**
266	0.040	1	25										44	18.2	manuka fern	**s1**
308	0.100	28	280	150	66.2	0.7	6.2	58.3	0.9		8.0	18.3	263	3.8	manuka	**m1**
309	0.100	16	160	140	85.6	4.7	13.8	1.5	46.9	18.6	13.2	29.4	264	2.6	manuka	**m1**
310	0.040	1	25										267	7.3	manuka fern	**m2**
315	0.040												306	14.1	native	**m0**
317	0.040	82	2050	125							2.9	13.6	252	5.3	manuka	**s1**
318	0.040	1	25										307	7.5	manuka	**s0**
323	0.100	31	310	210	101.0	26.1	59.3	15.6			13.6	25.4	247	5.6	native	**m2**
325	0.040	50	1250	675	248.8	8.4	26.9	108.5	17.1	76.8	39.5	22.0	234	0.6		**m3**
327	0.040												311	15.6	manuka pines	**s1**
328	0.040												311	15.6	manuka pines	**s1**
331	0.040												224	4.2	native	**s1**
332	0.040	8	200										225	0.7	native	**s1**
333	0.040	6	150										224	4.2	native	**s1**
334	0.040												219	0.7	manuka	**s1**
335	0.040	1	25										216	0.2	fern	**s0**
336	0.040	31	775										213	10.4	native	**s1**
338	0.040	49	1225										213	10.4	native	**s1**
339	0.040	23	575	525	254.8	30.0	82.4	142.4			37.1	28.0	201	2.4	native	**m1**
340	0.100	6	60	30	5.3		1.5	3.8			1.0	20.0	201	2.4	native	**m1**
341	0.040	3	75										205	6.6	native	**m1**
342	0.040	11	275	25	21.5					21.5	3.8	44.0	208	7.9	native	**m1**
344	0.040	36	900	100	13.6			12.7		0.8	2.3	13.5	205	6.6	native	**m1**
X1	0.040	77	1925	1475	126.2	0.8	14.9	74.5	34.9	1.0	24.0	13.2	37	0.8		**m3**
X2	0.019	90	4737	1842	209.5	12.0	80.3	99.2	17.0	1.1	37.5	14.7	41	0.8	manuka	**s2**

Appendix 5: Paddock Tree Data

Tree reference	Dbh (cm)	Ht (m)	Form (class)	Photo reference	Comment	Derived Ht (m)	Volume m^3
205	28.4	9.6	5	1499	Multi		0.3
205	40	9.6	5	1499	Multi		0.6
210	30.2	12.1	5	1502	Multi		0.4
210	20.3	12.1	5	1502	Multi		0.2
219	13.9	11.8	5	1503	Multi		0.1
219	12	11.8	5	1503	Multi		0.1
219	12	11.8	5	1503	Multi		0.1
219	12	11.8	5	1503	Multi		0.1
219	12	11.8	5	1503	Multi		0.1
219	12	11.8	5	1503	Multi		0.1
219	12	11.8	5	1503	Multi		0.1
219	12	11.8	5	1503	Multi		0.1
188					Kahikatea		
224					Kahikatea		
171	35.8		5	1511		11.1	0.6
122	120	11.6	5	1515	Multi		6.5
131	38.3	8.9	4	1518			0.5
15	85	15	5	1581	multi		4.1
67	63.5	11.5	4	1582	shortbole		1.8
17					sequoia		
16	79.8	13	4	1588	shortbole heavy branch		3.2
76	54.3	13	3	1594	heavy multi branch		1.5
33	105.2	16	5	1600	shortbole		6.7
34	35.6	6	4	1601			0.3
35	48	13.5	2	1602			1.2
38	75	12.5	3	1605			2.7
40					Rimu		
59	34.8	16	3	1608	epicormics		0.7
428	46.7		3	1617		11.5	1.0
706	47.3	11	5		Multi		1.0
706	39.5	11	5		Multi		0.7
582	26		5		Multi	10.8	0.3
582	24		5		Multi	10.7	0.2
594	48.2		5	2479		11.5	1.1
593	12.9		4	2480	Multi	10.3	0.1
593	14.9		4	2480	Multi	10.4	0.1
613	9.9		5	2481		10.2	0.0
604					Kahikatea		
598	33.2	8.5	4	2483			0.4
599	23.4	8.2	3	2484	Multi		0.2
599	19.9	8.2	4	2484	Multi		0.1
623					Kahikatea		
554	31.5	8.5	4	2486			0.4
559	24.2		4	2488		10.7	0.3
663	47.3		5	2492		11.5	1.0
635	53		5	2494		11.7	1.3
639	80.6		5	2496		12.7	3.2
640	50.2		5			11.6	1.1
628	40		3	2497		11.3	0.7
643	61.5		5	2500		12.0	1.8
645	130	14.5	5	2502			9.3
656	46.5	11.2	5	2503			1.0
655	68.1	14.1	4	2505			2.5
660					Kahikatea		
659	18.3		5	2506		10.5	0.1
668	79.1		5	2507		12.6	3.1
685	80		5	2508		12.7	3.1
681	27.7		5	2509		10.8	0.3
679	26.5			2510		10.8	0.3
691	23.9		3	2511		10.7	0.2
690	18.5		4	2512		10.5	0.1
728	71.3		5			12.4	2.4
537	17.4		5	2316		10.5	0.1
539	22.5		3	2317		10.6	0.2
538					Kahikatea		
540					Kahikatea		
543	11.1		2	2523		10.2	0.1
514	18.9	6.8	3	2543			0.1
521	26	7.1	2				0.2
Mean	**39.74**	**11.31**	**4.35**			**11.16**	**1.2**

Appendix 6: Extrapolation of District and Regional, Areas and Volume

	FNDC				WDC				KDC				Northland Region			
LCDB2 Class	**Total (ha)**	**No Totara Stands (ha)**	**Totara Stands (ha)**	**Totara Stands Tree Volume (m3)**	**Total (ha)**	**No Totara Stands (ha)**	**Totara Stands (ha)**	**Totara Stands Tree Volume (m3)**	**Total (ha)**	**No Totara Stands (ha)**	**Totara Stands (ha)**	**Totara Stands Tree Volume (m3)**	**Total (ha)**	**No Totara Stands (ha)**	**Totara Stands (ha)**	**Totara Stands Tree Volume (m3)**
Afforestation (imaged, post LCDB 1)	4689	4246	443	1067	2400	2173	227	546	1148	1040	108	261	8237	7459	778	1875
Broadleaved Indigenous Hardwoods	8372	1581	6790	148983	2783	526	2257	49525	3927	742	3185	69884	15081	2849	12232	268392
Deciduous Hardwoods	597	597	0	0	328	328	0	0	500	500	0	0	1425	1425	0	0
Forest Harvested	5251	5251	0	0	1072	1072	0	0	2406	2406	0	0	8729	8729	0	0
Gorse and Broom	4085	3109	975	3076	1176	896	281	886	837	637	200	630	6098	4642	1456	4592
Grey Scrub	54	18	36	119	24	8	16	53	110	37	73	241	189	63	125	413
High Producing Exotic Grassland	246089	228917	17172	589817	141124	131276	9848	338240	193268	179781	13486	463216	580481	539974	40506	1391274
Indigenous Forest	81861	29521	52340	1583053	42754	15418	27336	826798	20237	7298	12939	391356	144853	52238	92615	2801208
Low Producing Grassland	14786	12387	2399	67506	3896	3264	632	17790	4094	3430	664	18690	22776	19081	3695	103986
Manuka and or Kanuka	64045	15188	48857	890765	12131	2877	9255	168730	8151	1933	6218	113372	84327	19998	64330	1172867
Pine Forest - Closed Canopy	42574	33292	9282	517021	18088	14145	3944	219660	22216	17372	4843	269784	82878	64809	18069	1006464
Pine Forest - Open Canopy	19237	3283	15954	808962	6139	1048	5091	258145	12149	2073	10075	510887	37525	6404	31120	1577995
Surface Mine	235	212	23	54	317	287	31	74	68	62	7	16	620	560	60	144
Total Stand (m3)	**491874**	**337604**	**154270**	**4610424**	**232234**	**173318**	**58916**	**1880447**	**269110**	**217311**	**51800**	**1838338**	**993218**	**728233**	**264986**	**8329209**
Total Paddock Trees (m3)		**380848**				**195519**				**245146**				**821513**		