FORUM ARTICLE

Re-examination of recent loss of indigenous cover in New Zealand and the relative contributions of different land uses

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Abstract: Loss of indigenous habitat is a key factor in the decline of New Zealand's biodiversity. A recent contribution by Walker et al. (2006, New Zealand Journal of Ecology 30: 169–177) described losses of indigenous vegetation between 1996/97 and 2001/02 (some 17 000 ha) based on an analysis of changes in the Land Cover Database, LCDB1 and LCDB2, respectively. We agree that the general approach of using these and other spatial datasets appears to be appropriate to investigate changes in land cover and the types of land uses that are responsible, but we would like to offer some comments to aid with the interpretation of this and other studies that use LCDB comparisons and similar techniques. Using aerial photography, satellite imagery, site visits, and other methods, we evaluated a stratified sample of 67 of the 449 polygons that were indicated to have changed from the most affected indigenous classes ('Tall Tussock Grassland', 'Manuka and/or Kanuka', and 'Broadleaved Indigenous Hardwoods') to the exotic forest classes 'Afforestation (not imaged)' and 'Afforestation (imaged, post LCDB1)'. Our assessment of the entire area of each of these polygons covered 56.6% of the total area that was identified to have changed, and this revealed an error rate of c. 70% for this particular comparison of LCDB1 and LCDB2 data. This indicates the accuracy of such analyses may be too low to be meaningful and requires verification of the data that are primarily based on remote sensing, even when the overall aggregate accuracy is very high. In addition, we comment on the relative merits of different land uses in relation to the conservation of indigenous biodiversity, particularly the contributions of low-producing exotic grassland and exotic plantation forests. This is important because much indigenous biodiversity remains in exotic forests and embedded indigenous remnants, and the current clearing of potentially over 100 000 ha of such land for exotic pasture will cause significant losses of indigenous biodiversity.

Keywords: agriculture; land cover; loss of indigenous habitat; plantation forestry; remote sensing.

Introduction

The loss and degradation of indigenous vegetation are undoubtedly major factors in the ongoing decline of New Zealand's unique indigenous biodiversity (DOC/MfE 2000). Historically, New Zealand was predominantly covered in forest (McGlone 1989; McGlone et al. 2004), but about two-thirds of this area has been cleared, mostly for agriculture and other development. There were also substantial losses of other indigenous habitats such as wetlands. Such changes in indigenous cover and other vegetation can now potentially be tracked at various scales due to the development of spatial databases on land cover, based on satellite imagery, aerial photography, and other sources. The Land Cover Database (Terralink 2004) is an immensely valuable and indispensable tool for biodiversity and landscape ecology research in New Zealand. Walker et al. (2006) described changes in indigenous cover between 1996/97 (according to the Land Cover Database, LCDB1) and 2001/02 (according to LCDB2). We agree that the general approach used by Walker et al. (2006) appears to be appropriate, but we would like to offer some constructive

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comments to aid with the interpretation of this and other studies that use LCDB comparisons and similar methods (e.g. Ewers et al. 2006).

The analysis presented by Walker et al. (2006) (their table 5) suggests that from 1996/97 (LCDB1) to 2001/02 (LCDB2) a total area of 17 646 ha across New Zealand changed from indigenous to non-indigenous land cover and that most (over 65%) of this change was attributable to afforestation with pines or other exotic trees. Although the 1990s were a period of much exotic afforestation (and preceded the initiation of Forest Stewardship Council certification in New Zealand around 2000), the extent of replacement of indigenous vegetation is nevertheless surprising. Historically, agricultural development caused far more loss of indigenous habitats than did exotic afforestation (MfE 1997), and trends towards further agricultural development and intensification continue. Furthermore, the New Zealand Forest Accord (August 1991), requires that forest owners who are signatories do not clear indigenous forest and other indigenous vegetation that is recommended for protection (http://www.nzfoa.org.nz/file_libraries_resources/agreements_accords). In our experience, forestry companies generally respect this accord, particularly those that have become Forest Stewardship Council (FSC)-certified (Goulding 2006), as FSC's Principle 10 specifically prohibits the clearance of indigenous vegetation (www.fsc.org). Nevertheless, we are aware of several cases where indigenous vegetation has been cleared for exotic afforestation, within the last 5 years, in both the North and South islands, although not by FSC-certified forest managers. However, we question the scale of the relative contributions to indigenous vegetation clearance for exotic afforestation vs agricultural development, as presented by Walker et al. (2006). While the authors comment on the limitations of the LCDB, namely in relation to changes in grassland types, we are aware of substantial errors in some of the other classes, particularly the exotic afforestation classes. For example, research conducted to assess carbon stocks in the Nelson–Marlborough area revealed that three out of four plots shown as 'Afforestation not imaged' (class 62) were not actually afforested (Moore et al. 2005, unpubl. report to MAF). This prompted us to verify the areas (polygons) shown by LCDB to have changed from an indigenous cover to one of the afforestation classes. Although the overall accuracy of the individual LCDBs appears to be reasonable, particularly at a larger scale, we advise caution about the reliability of analyses such as that done by Walker et al. (2006) because our detailed examination of a large sample of the change polygons demonstrates that there are much higher inaccuracies when combining LCDB1 and LCDB2 data.

Here we present the results of a per-class accuracy assessment of these changes, based on verification of 67 out of the total of 449 polygons that changed from the most affected indigenous cover classes to one of the afforestation classes, using stratified random sampling methodology. Our sample covered 5554 ha (over 56%) of the total area that was identified to have changed between these cover types. We also comment on the relative merits of different land cover in relation to the conservation of indigenous biodiversity, particularly the contributions of exotic plantation forests and low-producing, exotic grassland. Because many native species occur in, or even depend on, habitats outside the natural estate and protected areas (e.g. DOC/MfE 2000; Brockerhoff et al. 2005), these considerations are important for the protection of New Zealand's biodiversity. This is an issue of urgency as much indigenous biodiversity remains in exotic forests and embedded indigenous remnants, and the current clearing of potentially over 100 000 ha of such land for exotic pasture will cause significant losses of indigenous biodiversity unless adequate conservation measures are taken.

Methods

For our verification of land cover change that occurred between 1996/97 and 2001/02 we used the same spatial datasets, LCDB1 and LCDB2 (Terralink 2004), as Walker et al. (2006). We obtained identical results as Walker et al. (2006) from the comparison of LCDB1 and LCDB2, which confirmed that we used the same datasets and classes within them. Most of the changes from indigenous vegetation to the various exotic forest classes occurred between the indigenous classes 'Tall Tussock Grassland' (class 43), 'Manuka and/or Kanuka' (class 52), and 'Broadleaved Indigenous Hardwoods' (class 54) and the exotic forest classes 'Afforestation (not imaged)' (class 62), 'Afforestation (imaged, post LCDB1)' (class 63) and 'Other Exotic Forest' (class 67). We then extracted all the individual polygons of indigenous vegetation from these (LCDB1 classes 43, 52, and 54) that were shown to have been afforested (LCDB2 classes 62 and 63). Several of these polygons were split by district (political) boundaries, and we combined these because for the present study district-specific information is not relevant.

These polygons were ranked by area, and each was assigned to one of five strata (< 3 ha, 3–10 ha, 10–50 ha, 50–87.5 ha, and > 87.5 ha – i.e. the 20 largest polygons). We then evaluated samples of about 10% of the smaller polygons, about 25% of those between 50 ha and 87.5 ha, and all the largest polygons (Appendix 1), to determine whether LCDB1 and/or LCDB2 cover types were accurate. To do this we used relevant aerial photography (LINZ), topographical maps (NZMS 260, as well as NZMS 1 to assess earlier situations), satellite imagery (Digital Globe's QuickBird imagery on Google Earth), personal communications with forest managers and Department of Conservation staff, and site visits. Note that we verified the entire area of each change polygon that we assessed, unlike methods used for standard accuracy assessment where samples of points or pixels are assessed to determine per-class classification errors (e.g. Dymond & Shepherd 2004). We examined c. 5554 ha, about 56.6% of the total area that changed from the selected indigenous vegetation to afforestation. The area of each polygon that was found to have changed from indigenous cover in 1996/97 to one of the afforestation classes in 2001/02 was assigned as 'correct', while the area that was either incorrect for 1996/97, for 2001/02, or at both times was assigned as 'not correct' (Table 1, Appendix 1). For about 0.8% of the polygons we assessed it was not possible to determine whether or not this particular change in land cover occurred; these areas were assigned as 'uncertain'. Note that many polygons were not homogenous but actually contained several types of land cover larger than the 1-ha minimum mapping unit of the LCDBs. If this affected the land cover change we consider here, then we determined the actual 'correct' and 'not correct' area within a polygon, or, when this was not possible, we provide a conservative estimate of the area changed.

For statistical analysis, the area percentage in each category (i.e. correctly identified, incorrectly identified, uncertain) was estimated using standard stratified sampling methodology (e.g. Cochran 1977). Mean percentages were weighted by polygon areas. The standard errors of the weighted mean percentages in each stratum were estimated using the SAS PROC MEANS procedure, adjusted using the finite population correction. Formulas used in the analysis are given below.

The following symbols and equations apply to each stratum:

N total number of units in the stratum

n number of units sampled in the stratum

a area of each sampling unit

p percentage area (e.g. correct) in the unit

$A = \sum_{i=1}^{N} a$ total area in the stratum

$f = 1 - \sum_{i=1}^{n} a \Big/ \sum_{i=1}^{N} a$ finite population correction

$\bar{p} = \sum ap \Big/ \sum a$ sample mean percentage weighted by area

$se(\bar{p}) = \sqrt{\dfrac{f \sum a(p - \bar{p})^2}{(n-1)\sum a}}$ standard error of weighted mean

The estimate of the population mean percentage across all strata is:

$$\bar{p}_{st} = \sum A\bar{p} \Big/ \sum A$$

with standard error:

$$se(\bar{p}_{st}) = \sqrt{\sum A^2 se(\bar{p})^2 \Big/ \left(\sum A\right)^2}$$

Standard errors multiplied by t values were used to calculate confidence intervals for mean percentages.

Results and discussion

Based on our evaluation, the classification of the areas that apparently changed between 1996/97 and 2001/02 from an indigenous land cover to one of the exotic classes was incorrect for 70.1 ± 7.3% (95% confidence interval) and correct for 29.1 ± 7.3% of the total area examined (Table 2). Areas were found to be incorrect either because the cover was not indigenous when the LCDB1 assessment occurred or because the land was not afforested at the time of the LCDB2 assessment (see below and Appendix 1). From the mean percentages and their standard errors given in Table 2, estimates and 95% confidence intervals for the total areas incorrectly and correctly identified as having changed from indigenous vegetation to exotic forest are 6873 ± 717 ha and 2856 ± 714 ha , respectively. Only 81 ± 102 ha could not be identified as either correctly or

Table 1. Matrix of possible states of land cover comparison between LCDB1 and LCDB2. Note: Only one out of four possible cases correctly identifies a change that requires both databases to be correct.

	LCDB1 (1996/97) Native vegetation classification **correct**	**LCDB1** (1996/97) Native vegetation classification **NOT correct**
LCDB2 (2001/02) Exotic forest classification **correct**	Native vegetation loss due to afforestation **correct**	Native vegetation loss due to afforestation **NOT correct**
LCDB2 (2001/02) Exotic forest classification **NOT correct**	Native vegetation loss due to afforestation **NOT correct**	Native vegetation loss due to afforestation **NOT correct**

incorrectly classified using our methodology. Although the error rate appeared to be somewhat lower for the stratum of smallest polygons (< 3 ha), there was no significant difference in the percentage correctly classified between strata (i.e. error rates were similar regardless of polygon size). Note the above calculations were made on the basis of detailed examinations of actual areas correctly and incorrectly classified in each polygon.

For the 5554 ha we examined, the accuracy of polygons was greater when LCDB1 and LCDB2 were assessed independently. For these polygons, over half of the areas were correctly identified (about 54% and 57%, respectively); whereas for the comparison between the two, less than 30% of the area was correct (Table 3). This shows how the errors of the two databases are compounded in cases where both land cover classifications are relevant, such as the analyses presented by Walker et al. (2006) (see Table 1 for an illustration of this).

Examination of the causes of the errors (i.e. misclassifications) in LCDB1 showed that the most common type of error (in about a third of the cases) was that the selected indigenous vegetation classes were actually pasture. At times there were 'modifiers' present such as scattered trees or low density scrub, but the dominant land cover was found to be pasture. Another error that occurred in about a fifth of the cases was that the area was already afforested before the LCDB1 assessment took place. Another common cause of error was that mature exotic trees and exotic scrub were misclassified as indigenous forest or scrub.

The most common errors in LCDB2 that affected this analysis (in almost half of the cases) were that areas were either not afforested at all or that non-afforestation areas between afforestation areas were added to the latter (i.e. commission error). For example, in a 300-ha polygon of Department of Conservation administered land near Hokitika (LCDB polygon 55178), there was no afforestation. Here, the error seems to have occurred because the signature in the image used for LCDB2 is the same for 'Afforestation (imaged, post LCDB1)' and 'Broadleaved Indigenous Hardwoods' (Ingrid Gruener, DOC, Hokitika, pers. comm., September 2006). Commission errors also occurred over large areas, e.g. near Blenheim (LCDB polygon 15013) over 100 ha of indigenous scrub were considered part of an adjacent area of afforestation.

The error rate we detected is surprising, given the results of other studies that examined the accuracy of land cover assessments using satellite imagery. For example, Dymond and Shepherd (2004) state that a land cover map

Table 2. Percentage of area identified as changed from indigenous vegetation in 1996/97 to exotic plantation forest in 2001/02 that was identified correctly, identified incorrectly, or that could not be classified.

Stratum	Units		Area (ha)		% correct		% not correct		% uncertain	
	Total	Sampled	Total	Sampled	Mean	SE	Mean	SE	Mean	SE
largest 20 (> 87.5 ha)	20	20	4921	4921	28.8	0.0	71.2	0.0	0.0	0.0
50–87.5 ha	19	5	1264	309	29.0	16.7	71.0	16.7	0.0	0.0
10–50 ha	119	13	2643	231	29.1	10.4	70.9	10.4	0.0	0.0
3–10 ha	131	13	718	68	27.8	11.5	66.5	12.2	5.6	6.3
< 3 ha	160	16	264	26	39.0	12.0	45.6	12.2	15.4	8.9
Total	449	67	9811	5554	29.1	3.6	70.1	3.7	0.8	0.5

Table 3. Percentage of area of polygons identified as changed from indigenous vegetation in 1996/97 to exotic plantation forest in 2001/02 that were identified correctly or incorrectly as indigenous vegetation in LCDB1, exotic forest (afforestation) in LCDB2, and in both LCDB1 and LCDB2.

	Overall percentage correct	Overall percentage NOT correct
LCDB1 = indigenous vegetation	53.5 ± 4.1%	46.5 ± 4.1%
LCDB2 = exotic forest	57.0 ± 3.5%	42.2 ± 3.5%
LCDB1 = indigenous vegetation *and* LCDB2 = exotic forest	29.1 ± 3.6%	70.1 ± 3.7%

of the Wellington region based on Landsat ETM+ images provided an accuracy of approximately 95%. However, the analysis by Dymond and Shepherd (2004) was not based on actual LCDB data and used only eight broader vegetation classes, compared with the 43 detailed classes of the LCDB2, and their analysis of per-class classification errors was based on samples of points whereas we verified the entire area of each change polygon that we assessed. Even if the methods of Dymond and Shepherd (2004) delivered such high accuracy, this was obviously not the case for the data underlying the study by Walker et al. (2006). However, we would like to stress that the low accuracy of LCDB data we determined applies only to this specific case of a particular per-class change classification and not to the entire LCDB, which we did not examine as a whole. Overall, the accuracy of the LCDB2 is likely to be considerably higher.

Another conceptual problem with the assessment by Walker et al. (2006) is that it is not at all clear whether all exotic afforestation of regenerating shrubland constitutes evidence of 'continuing clearance of indigenous cover'. It should be noted that hardly any exotic afforestation replaced indigenous forest. By far the majority of indigenous vegetation actually lost to afforestation was regenerating shrubland. Our survey found that most of the affected areas of indigenous shrubland are on land formerly cleared for conversion to pasture that has since been abandoned and is now gradually returning to successional shrubland. Such land is now often dominated by indigenous species or a combination of indigenous and exotic species. A comparison of the topomap series NZMS 1 and NZMS 260, for example, in the Marlborough Sounds region, also indicates that, over the last few decades, there has probably been a net increase in such indigenous cover, rather than a loss, because only some of this land has subsequently been returned into a predominantly exotic land cover. It would be highly desirable to determine these earlier land cover changes more accurately, but to our knowledge no comprehensive data exist that allow this.

With the error rate we determined, the accuracy of the analysis by Walker et al. (2006) is too low to be meaningful. Moreover, indigenous vegetation losses due to conversion of tall tussock to pasture are probably highly under-represented (Walker et al. 2006). On the other hand, there are most probably areas that were covered in indigenous vegetation in 1996/97 that changed to exotic forest but were not detected by the LCDB1/LCDB2 comparison (i.e. no-change error), and, hence, were not covered by our analysis. Interestingly, several colleagues that are familiar with such issues about land cover change stated in discussions that this reverse error 'would probably cancel out the incorrectly identified losses due to afforestation'. While we cannot say what the inverse error rate is, due to a lack of available data, we would consider such assertions that are not based on any valid evidence surprising and unscientific. Furthermore, a preliminary assessment of the accuracy of LCDB2 using broad land cover classes (pasture, planted forest, and indigenous forest and scrub) based on data from Paul & Brownlie (2007) (similar to an earlier assessment of LCDB1 by Dunningham et al. (2000) for the Ministry for the Environment) showed that errors of commission (i.e. LCDB2 added an area of a particular land cover incorrectly to another class) and errors of omission (i.e. LCDB2 omitted an area from its correct land cover class) are not symmetrical and differ between the different class comparisons (anywhere from c. 3% to 16%). In other words, it is clearly not acceptable to assume that such errors cancel each other out. We suggest that there is an urgent need for further, and more accurate, analysis of indigenous vegetation loss. The role of different land cover types (or land uses) in this loss clearly requires further investigation. National datasets are indispensable tools for this, but their use should ideally be accompanied by adequate quality and accuracy assessments, including classification of change error and no-change error levels and delineation accuracies.

Regardless of the errors in the analysis by Walker et al. (2006), the statement 'despite biodiversity certification processes adopted by the sectors of the forestry industry […] plantation forestry remained one of the major causes of indigenous cover loss in New Zealand' is untenable. Apart from the uncertainties about the actual contribution of plantation forestry to indigenous vegetation loss during this period, certification (presumably the authors mean FSC certification) only began in New Zealand around 2000, basically after the period considered by Walker et al. (2006). We would also like to comment on the assessment by Walker et al. (2006) that exotic afforestation of low-producing (primarily exotic) grassland results in 'significant loss of indigenous biodiversity'. This statement may be directed primarily towards grazed tussock grasslands as these, although modified, nevertheless retain a significant indigenous element (and many areas of degraded tussock grasslands also have very significant landscape values). However, most pasture is almost devoid of indigenous plants (e.g. Ecroyd & Brockerhoff 2005), and is inhabited by comparatively few indigenous invertebrates (Pawson et al. 2008) and birds (Brockerhoff et al. unpubl. data). By contrast, there is clear evidence that many of New Zealand's exotic forests also provide habitat for a wide range of indigenous forest species (e.g. Allen et al. 1995; Ogden et al. 1997; Brockerhoff et al. 2003; Pawson & Brockerhoff 2005), including some threatened species (e.g. Kleinpaste 1990; Brockerhoff et al. 2005), as well as aquatic biodiversity (Quinn et al. 1997, 2004). Moreover, it is widely recognised that '*Pinus radiata* provides a fast-growing nurse crop for the establishment of native species' and that 'there are examples in many parts of New Zealand of areas of native vegetation that have established under radiata pine' (Porteous 1993). The extent to which this happens depends largely on the amount of rainfall and the availability of propagules of indigenous species for colonisation. In some of the drier environments in eastern parts of New Zealand, there is limited colonisation by native plants, particularly when indigenous seed sources are lacking. In other environments, exotic afforestation of pasture (excluding tussock grasslands) can be expected to lead to significant gains of indigenous biodiversity. Despite such benefits, major problems with wilding pines need to be addressed (e.g. Buckley et al. 2005); a significant issue in the North and South islands, particularly concerning the invasion of tussock grasslands, some indigenous shrublands, and, in the case of Douglas-fir, some indigenous forest communities.

Finally, there is another, more recent development that is highly relevant to the debate of land cover change that affects indigenous biodiversity: the current conversion of potentially over 100 000 ha of plantation forest to pasture (Manley 2006, unpubl. report for MAF) and effects of the associated intensification of land use (PCE 2004). These conversions will lead to substantial losses of indigenous biodiversity (Maunder et al. 2005). Such conversions are under way in several parts of New Zealand, mainly in the central North Island, where plantation forests contain much indigenous biodiversity, both within planted stands and in the substantial pockets of indigenous vegetation that are embedded in these plantations (Wildland Consultants, unpubl. data from numerous field surveys throughout New Zealand). Even the ongoing conversion of plantation forests in Canterbury is a significant concern. It is not widely known that Eyrewell Forest actually contains a much greater area of kānuka remnants, as an understorey, than all the other kānuka remnants on the Canterbury Plains taken together (Ecroyd & Brockerhoff 2005). In addition, Eyrewell Forest is the only remaining habitat of a critically endangered ground beetle that is endemic to this part of Canterbury (Brockerhoff et al. 2005). On the whole, indigenous biodiversity in plantation forests is now typically better protected and better managed than in the past, and it is recognised that sympathetic farmers also actively protect many natural areas. With increasing uptake of Forest Stewardship Council certification of plantation forest management since 2000 (Hock & Hay 2003), which occurred mostly post-LCDB2, forest managers have made substantial contributions to the protection of indigenous biodiversity on private land. Many plantation forest managers have conducted surveys of indigenous biodiversity in both indigenous remnants and planted areas, and often actively control pests and invasive weeds (including wilding pines). Compared with pasture, plantation forests have many other environmental benefits, including reduced soil erosion (e.g. Knowles 2006), lower nutrient outputs (e.g. Davis 2005), improved water quality, and they are carbon sinks, all of which also benefit indigenous biodiversity, both terrestrial (above) and in streams (Quinn et al. 1997, 2004).

The current scale and rate of exotic deforestation will exacerbate environmental concerns about pastoral agriculture (PCE 2004). The main period of exotic forest conversion to pasture has been in the last 3–4 years, post-LCDB2, and this is likely to continue for another 5 years or more. This highlights the critical importance of monitoring land cover and land use in New Zealand, and relevant central government agencies need to give this a high priority.

In conclusion, we agree with Walker et al. (2006) that any further loss of indigenous vegetation should be prevented, particularly in those parts of New Zealand that have experienced the most significant losses. To this end, there is indeed a 'need for more sophisticated assessment of biodiversity status and loss', and much could be learned from the use of land cover data and other spatial databases. However, such analyses will always benefit from a thorough examination of the accuracy of the data and verification of the results. Private land, including that used for forestry and agriculture, plays an important role in the protection of indigenous biodiversity, especially in those environments where indigenous vegetation has become rare. Sound and up-to-date information on land cover and land use is very important, to guide evolving land-use policy and decision making and to ensure that opportunities for indigenous biodiversity protection on private land are used to best effect.

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Appendix 1. Results of verification of land cover change of areas indicated to have changed from indigenous vegetation (LCDB1) to afforestation (LCDB2).

NI/SI NZMG ID	Area (ha)	Location	LCDB1 (1996/97)	Actual in 1996/97	LCDB2 (2001/02)	Actual in 2001/02	Native vegetation loss due to afforestation NOT correct (ha)	Native vegetation loss due to afforestation IS correct (ha)	Native vegetation loss uncertain (ha)
North Island									
6498	73.23	Far North District	Manuka/ Kanuka	10 ha plantation; remainder scrub	Afforestation	Afforested in most parts, however 2 polygons indigenous shrub/forest (3 & 4 ha) and 2 polygons (17 & 4.4 ha) grassland/wetland type not afforested	38.40	34.83	
10208	10.96	Far North District	Manuka/ Kanuka	Probably pasture; some scrub possible	Afforestation (imaged, post LCDB 1)	Pasture	10.96		
16314	1.31	Whangarei District	Manuka/ Kanuka	Probably mānuka/ kānuka	Afforestation (not imaged)	(Afforestation unknown)			1.31
17734	1.70	Whangarei District	Broadleaved Indigenous Hardwoods	Probably broadleaved indigenous hardwoods	Afforestation (imaged, post LCDB 1)	(Afforestation unknown)			1.70
37964	2.27	Rodney District	Broadleaved Indigenous Hardwoods	Harvested or open-canopy pine forest likely	Afforestation (imaged, post LCDB 1)	Open-canopy pine forest	2.27		
50510	5.48	Thames–Coromandel District	Manuka/ Kanuka	Probably mānuka/ kānuka	Afforestation (not imaged)	Afforested		5.48	
59748 and 59772	6.27 and 0.00 (6.27)	Western BOP and Hauraki District	Broadleaved Indigenous Hardwoods	Old pine plantation (probably fairly open) with understorey of native and exotic scrub	Afforestation (not imaged)	Afforested	6.27		
60865	2.64	Western Bay of Plenty District	Broadleaved Indigenous Hardwoods	Pasture	Afforestation (not imaged)	Afforested	2.64		
84519	170.01	Opotiki District	Manuka/ Kanuka	Afforested	Afforestation (imaged, post LCDB 1)	Open-canopy pine forest and mānuka/kānuka	170.01		
84990	6.91	Gisborne District	Manuka/ Kanuka	Pasture and mānuka/kānuka	Afforestation (imaged, post LCDB 1)	Afforested (except remnants)	3.46	3.46	
90731	6.21	Gisborne District	Manuka/ Kanuka	Pasture and mānuka/kānuka	Afforestation (not imaged)	Pasture and some mānuka/kānuka	6.21		
92755	2.84	Rotorua District	Broadleaved Indigenous Hardwoods	Probably broadleaved indigenous hardwoods	Afforestation (not imaged)	Afforested		2.84	
107367 107343 108089 108144 107414 107428 107437	359.73 and 1.40, 0.06, 0.43, 0.00, 0.00, 0.32,	Mainly Ruapehu District with multiple edge polygons in Waitomo District	Broadleaved Indigenous Hardwoods	Mostly pasture with some broadleaved indigenous hardwoods	Afforestation (imaged, post LCDB 1)	Afforested with some remaining broadleaved indigenous hardwoods along edges	239.52	122.54	

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107524 107533 107540 107562 107572	0.00, 0.00, 0.02, 0.00, 0.10 (362.06)								
112741	0.95	Taupo District	Broadleaved Indigenous Hardwoods	Broadleaved indigenous hardwoods	Afforestation (imaged, post LCDB 1)	Afforested		0.95	
125945	2.15	New Plymouth District	Broadleaved Indigenous Hardwoods	Broadleaved indigenous hardwoods	Afforestation (imaged, post LCDB 1)	Afforested		2.15	
126551	54.90	Wairoa District	Broadleaved Indigenous Hardwoods	Indigenous scrub	Afforestation	Afforested		54.90	
128199	0.88	New Plymouth District	Manuka/ Kanuka	Probably broadleaved indigenous hardwoods mixed with maānuka/ kānuka	Afforestation (imaged, post LCDB 1)	Probably broadleaved indigenous hardwoods mixed with mānuka/ kānuka	0.88		
146694	56.26	Ruapehu District	Manuka/ Kanuka	Plantation	Afforestation	Looks like a harvested area; image is coarse	56.26		
147016	31.24	South Taranaki District	Broadleaved Indigenous Hardwoods	Closed-canopy forest, scrub, pasture	Afforestation (imaged, post LCDB 1)	Closed-canopy forest, scrub, possibly pasture. No afforestation	31.24		
150486	99.60	Hastings District	Manuka/ Kanuka	13.7 ha = high-producing pasture; 20.6 ha = mānuka/ kānuka; 65.3 ha = low-producing pasture	Afforestation (imaged, post LCDB 1)	3.7 ha remains high-producing pasture; 20.6 ha remains mānuka/kānuka; 65.3 ha = afforested	99.60		
154007	14.39	Hastings District	Manuka/ Kanuka	10.7 ha probably mānuka/kānuka; 3.69 ha = garden and shelterbelts for a small paddock by the farm homestead	Afforestation (imaged, post LCDB 1)	10.7 ha afforested; area by homestead (3.69 ha) not afforested	3.69	10.70	
154217	464.24	South Taranaki District	Broadleaved Indigenous Hardwoods	Probably broadleaved indigenous hardwoods	Afforestation (imaged, post LCDB 1)	Probably broadleaved indigenous hardwoods (no afforestation in 304 ha within DOC estate; no known afforestation in remaining area)	464.24		
156923	5.09	Hastings District	Broadleaved Indigenous Hardwoods	Probably afforested	Afforestation (imaged, post LCDB 1)	Pine forest – closed canopy	5.09		
160006	73.19	Wanganui District	Manuka/ Kanuka	Pasture and scattered trees	Afforestation	Afforested	73.19		
161988	3.81	South Taranaki District	Broadleaved Indigenous Hardwoods	Probably pasture	Afforestation (imaged, post LCDB 1)	(Afforestation unknown)			3.81
164361	0.70	Rangitikei District	Broadleaved Indigenous Hardwoods	Probably pasture	Afforestation (imaged, post LCDB 1)	Pine forest – closed canopy	0.70		

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167767	13.56	Wanganui District	Broadleaved Indigenous Hardwoods	Afforested	Afforestation (imaged, post LCDB 1)	Pine forest – open canopy	13.56		
191089	0.92	Palmerston North City	Broadleaved Indigenous Hardwoods	Probably broadleaved indigenous hardwoods	Afforestation (imaged, post LCDB 1)	(Afforestation unknown)			0.92
195563	12.43	Tararua District	Broadleaved Indigenous Hardwoods	Broadleaved indigenous hardwoods	Afforestation (imaged, post LCDB 1)	Other exotic and broadleaved indigenous hardwoods	12.43		
198860	210.10	Kapiti Coast District	Broadleaved Indigenous Hardwoods	Likely to have been regenerating indigenous scrub	Afforestation (imaged, post LCDB 1)	Afforested; also closed-canopy, broadleaved indigenous	23.40	186.70	
204011	94.86	Porirua City	Manuka/ Kanuka	Mānuka/kānuka and plantation closed canopy or harvested	Afforestation (imaged, post LCDB 1)	Afforested, open-canopy and mānuka/ kānuka	47.43	47.43	
206263	51.40	Wellington City	Broadleaved Indigenous Hardwoods	Pasture	Afforestation	Afforested in most parts, however 3.7 ha grassland under pylons, 2 polygons shrubland (2 ha & 1.2 ha)	51.40		
206348 and 206426	31.18 and 0.12 (31.30)	Upper Hutt City and Lower Hutt City	Broadleaved Indigenous Hardwoods	Broadleaved indigenous hardwoods	Afforestation (imaged, post LCDB 1)	Approx. half afforested, half broadleaved indigenous	16.22	15.08	
210819	87.70	South Wairarapa District	Manuka/ Kanuka	Cleared pre-1996/97	Afforestation (imaged, post LCDB 1)	Afforested	87.70		
64164 and 64302	95.68 and 0.12 (95.80)	Gisborne District and Opotiki District	Manuka/ Kanuka	Probably mānuka/ kānuka	Afforestation (not imaged)	Afforested (except remnants and riparian areas)		95.80	
71102	2.90	Waikato District	Manuka/ Kanuka	Indigenous scrub	Afforestation (imaged, post LCDB 1)	Afforested		2.90	
South Island									
704	14.88	Tasman District	Manuka/ Kanuka	Mānuka/ kānuka	Afforestation (not imaged)	Afforested		14.88	
1749	0.53	Tasman District	Manuka/ Kanuka	Other exotic forest	Afforestation (imaged, post LCDB 1)	Other exotic forest	0.53		
6294	191.61	Marlborough District	Broadleaved Indigenous Hardwoods	Broadleaved indigenous hardwoods, and 94 ha pasture	Afforestation (imaged, post LCDB 1)	Afforested but not 13.1 ha broadleaved indigenous hardwoods	107.10	84.51	
8789	6.21	Tasman District	Broadleaved Indigenous Hardwoods	Probably broadleaved indigenous hardwoods	Afforestation (imaged, post LCDB 1)	Afforested		6.21	
10332	1.13	Nelson City	Broadleaved Indigenous Hardwoods	Broadleaved indigenous hardwoods	Afforestation (imaged, post LCDB 1)	Afforested		1.13	

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12166	14.28	Marlborough District	Broadleaved Indigenous Hardwoods	Broadleaved indigenous hardwoods	Afforestation (imaged, post LCDB 1)	Afforested		14.28	
12258	516.12	Marlborough District	Manuka/ Kanuka	Mānuka/kānuka and broadleaved indigenous hardwood, except 15.4 ha of open-canopy pines	Afforestation (imaged, post LCDB 1)	Afforested, other exotic, indigenous forest, low-producing pasture	465.02	51.10	
13356	191.90	Marlborough District	Manuka/ Kanuka	Pasture and mānuka/kānuka	Afforestation (not imaged)	Pasture and mānuka/kānuka	191.90		
13983	137.71	Marlborough District	Broadleaved Indigenous Hardwoods	Broadleaved indigenous hardwoods	Afforestation (not imaged)	Partly afforested (c. 50%) between 2000 and 2003, other parts pasture reverting into scrub, other parts remain mānuka/kānuka and broadleaved indigenous hardwoods	68.86	68.86	
15035	228.83	Marlborough District	Broadleaved Indigenous Hardwoods	Pasture, some broadleaved indigenous hardwoods possible, e.g. the riparian areas not afforested	Afforestation (not imaged)	Afforested, some broadleaved indigenous hardwoods remain in riparian areas	217.39	11.44	
15247	192.59	Marlborough District	Broadleaved Indigenous Hardwoods	Mostly pasture, parts in low scrub (Spanish heath, gorse, blackberry and some mānuka)	Afforestation (not imaged)	Afforested	173.33	19.26	
15326	11.79	Tasman District	Broadleaved Indigenous Hardwoods	Afforested	Afforestation (imaged, post LCDB 1)	Open-canopy forest	11.79		
15362	218.58	Marlborough District	Broadleaved Indigenous Hardwoods	Pasture and indigenous shrubland (30%)	Afforestation (not imaged)	Afforested in parts (60%), big areas are still in shrub (e.g. gullies) and still cabbage trees and shrubs scattered between	109.29	109.29	
15463	450.06	Marlborough District	Broadleaved Indigenous Hardwoods	Broadleaved indigenous hardwoods and exotic scrub	Afforestation (not imaged)	66% afforested, 33% not afforested, 1% closed-canopy pine – from aerial photo	300.04	150.02	
16222	18.43	Marlborough District	Broadleaved Indigenous Hardwoods	Low scrub (indigenous?)	Afforestation (not imaged)	Afforested and some broadleaved indigenous	6.14	12.29	
19264	1.09	Marlborough District	Broadleaved Indigenous Hardwoods	Probably as per adjacent other exotic	Afforestation (not imaged)	Other exotic forest	1.09		
21466	5.13	Marlborough District	Broadleaved Indigenous Hardwoods	Probably already afforested	Afforestation (not imaged)	Open-canopy forest	5.13		
29764	13.80	Tasman District	Manuka/ Kanuka	Pasture and bracken	Afforestation (imaged, post LCDB 1)	Afforested	13.80		

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57337	300.20	Westland District	Broadleaved Indigenous Hardwoods	Broadleaved indigenous hardwoods and afforested	Afforestation (imaged, post LCDB 1)	Broadleaved indigenous hardwoods, some open-canopy	300.20		
102910	1.69	Banks Peninsula District	Broadleaved Indigenous Hardwoods	Mostly mānuka/ kānuka	Afforestation (imaged, post LCDB 1)	Mostly mānuka/ kānuka and gorse	1.69		
187332	4.99	Dunedin City	Broadleaved Indigenous Hardwoods	Probably indigenous	Afforestation (not imaged)	Life-style block, broadleaf unmodified and woodlot (approx 10% of size of polygon)	4.99		
191258	4.15	Dunedin City	Broadleaved Indigenous Hardwoods	Broadleaved indigenous hardwoods and other exotic forest	Afforestation (imaged, post LCDB 1)	Broadleaved indigenous hardwoods and other exotic forest	4.15		
192569	3.65	Clutha District	Broadleaved Indigenous Hardwoods	Broadleaved indigenous hardwoods	Afforestation (imaged, post LCDB 1)	Afforested		3.65	
194732	19.74	Southland District	Tall Tussock Grassland	Afforested (Douglas-fir) in 1994	Afforestation (imaged, post LCDB 1)	Other exotic forest	19.74		
194950	24.31	Southland District	Tall Tussock Grassland	Afforested (Douglas-fir) in 1994	Afforestation (imaged, post LCDB 1)	Other exotic forest	24.31		
195852	4.66	Southland District	Tall Tussock Grassland	Tall tussock grassland and mānuka/ kānuka	Afforestation (imaged, post LCDB 1)	Tall tussock grassland and mānuka/ kānuka	4.66		
195939	1.84	Southland District	Manuka/ Kanuka	Mature trees but not conifer species, could be indigenous forest or broadleaved indigenous hardwoods	Afforestation (imaged, post LCDB 1)	Mature trees but not conifer species, could be indigenous forest or broadleaved indigenous hardwoods	1.84		
197822	4.97	Southland District	Manuka/ Kanuka	Probably mānuka/ kānuka	Afforestation (imaged, post LCDB 1)	Pasture	4.97		
205608	117.67	Clutha District	Tall Tussock Grassland	Tall tussock grassland, indigenous scrub, closed-canopy pine forest	Afforestation (imaged, post LCDB 1)	Afforested and closed -canopy pine forest	43.09	74.58	
207630	694.88	Clutha District	Tall Tussock Grassland	Low-producing grassland, tall tussock, afforested	Afforestation (imaged, post LCDB 1)	Afforested and open -canopy pine forest	347.44	347.44	
197506	96.75	Southland District	Tall Tussock Grassland	Tall tussock grassland, exotic and indigenous scrub	Afforestation (imaged, post LCDB 1)	Afforested except gullies	48.38	48.38	
Totals							3943.64	1603.06	7.74