Landcare Research
Manaaki Whenua
POLICY BRIEF

Effectiveness of protecting urban vegetation: assessing vegetation cover changes with urban expansion and intensification

Technical Document for Protecting the Urban Forest

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CONTENTS

Subdivisions that have retained some native remnant vegetation and planted new native vegetation along streams and coastal margins, Schnapper Rock Road area, North Shore.

Native urban remnants are under intense pressure

Due to the high value of land and dynamic nature of the urban environment. The essence of these problems for small remnants of indigenous lava forest in Auckland City is summarized by Smale and Gardiner (1999):

'[An] ill-fated location [central Auckland]… leading directly to rapid destruction for more pressing uses than nature conservation, indirectly to slow demise by weed incursion from surrounding suburbia… perhaps a measure of 'familiarity breeding contempt' has been responsible; preservation of nature at the back door tends to be neglected in favour of more remote, more romantic and supposedly more valuable areas'

EXECUTIVE SUMMARY

As our cities expand and densify, vegetative cover is removed or damaged, diminishing the benefits these areas originally provided. This is also happening in Auckland. What we do not know is the extent to which our legislative and policy frameworks are able to protect those remaining areas of vegetation through the urbanisation process. To start addressing this question we investigated the impact of vegetation protection provisions on the North Shore City (NSC) area of Auckland. Within this concentration of people and built infrastructure lie many remnant examples of endemic forest ecosystems with high ecological significance. Protecting these ecosystems and other woody vegetation helps protect our air and water quality (including the harbours), increases the resilience of the built environment against climate extremes, and is essential for our well-being (Blaschke 2013).

This study reviews the effectiveness of vegetation protection rules and vegetation changes under urbanisation between 2001 and 2009 within NSC. The NSC had strong, clear vegetation protection rules from before 2001 until 2011; rules that could be clearly delineated on maps. The most highly protected vegetation (3% of the area) was along coastal cliffs/mean high water springs, along streams/riparian areas, and within native remnants with high naturalness and structural diversity. About 21% of the city's vegetation (in residential and rural 2A zones) had moderate protection, while the majority of land in business and some residential zones (64% of the area) had very little protection during the study period.

We used overlays of NZ Land Cover Database (LCDB) derived from 2000/01 and 2008/9 images to quantify changes in land cover in five vegetation protection zones at a relatively coarse scale, as LCDB uses a Minimum Mapping Unit of about 1 ha. Data showed the NSC rules influenced vegetation outcomes. Over the period an additional 590 ha (~7%) of new urban ('built') land was developed. This urbanisation removed 890 ha of pasture and non-native vegetation, including about 140 ha of exotic forest in high vegetation protection zones. Such areas tended to be then established in native vegetation, either by natural regeneration or by planting. This contributed to a net 333-ha increase in native plant cover over the following 8 years. However, native vegetation was also removed from all five protection zones. Losses of native vegetation were lowest in areas with the highest vegetation protection (Zones 4 and 5), indicating the protection rules influenced vegetation loss. The fact that much remnant native vegetation is on steeper slopes and flood plains is likely a contributing factor, as such sites are less suitable for urbanisation and less impacted by fire (Esler 2011). High protection, however, did not stop vegetation removal. From 2001 to 2009, 45 ha of new impervious cover (buildings and roads) were built in areas with the highest level of vegetation protection. The vegetation cover displaced by new impervious surfaces in high protection zones included 6 ha of woody vegetation (including native shrubland and forest); the remainder was grassland. Impervious surface cover is correlated with vegetation protection, being highest (37%) in business areas (zone 2), reducing to 27% and 21% in residential zones (vegetation protection zones 3 and 4 respectively), and to 2.9% in areas with highest protection (Zone 5).

Closer analysis of 1999 and 2010 aerial photographs revealed patterns of urbanisation at a much finer scale than possible using LCDB. We analysed 102 LCDB polygons (covering 661 ha) that changed classification between 2001 and 2009. Over 80% of the changed classifications were driven by residential, industrial or school construction. The analysis revealed substantial losses of woody vegetation within pasture-dominated polygons, especially in the largest polygons (>10 ha) and in industrial developments. Although this woody vegetation included both non-native and native species, it has the structure (and potentially soil horizons) to support indigenous insects and bird populations that are absent in pasture. We investigated each case where native forest loss or gain was identified by LCDB3 (i.e. >1 ha). While the vast majority of losses were due to residential or industrial subdivisions, it must be acknowledged that some were largely unavoidable due to infrastructure projects such as motorways. Such vegetation losses mirror the national pattern: impacts are greatest in the most 'productive' areas, i.e. the lowest altitude, flattest areas, including those along ridges, with easiest access.

The transition from native forest remnant to 'built' land appears to be 'sharpening' due to smaller section sizes and a higher proportion of impermeable, built, and earth-worked surfaces within each section. This means the potential for plants in private sections to buffer adjacent native remnants is much reduced – the space for plants is smaller compared with older residential areas. Impacts are exacerbated when new edges are created by clearing into native remnants, rather than by planting buffers out from remnant edges.

In established urban areas connectivity of vegetation is decreasing, and fragmentation is increasing, as new houses and upgraded roads are constructed. Remnants in older urbanised areas are generally characterised by broader buffers, but these are being degraded as intensification continues – this 'death by a thousand cuts' can only be detected by LCDB once enough 'forest' is removed to trigger reclassification of the polygon as 'built'.[1] Connectivity between remnants is increasing in those urban areas developed from pasture when accompanied by new riparian planting. NSC achieved extensive riparian plantings as part of storm water management. However, where riparian areas are earth-worked, plantings are more homogeneous, less resilient, and much less diverse (pers. obs.). Intact soils and hydrology, especially soils with a cover of woody vegetation (native or non-native), have particular biodiversity values that appear to be undervalued.

RECOMMENDATIONS

Monitoring of urban vegetation losses needs to use higher resolution approaches such as impervious surface and LIDAR. LCDB overlays are useful to identify relatively large (> 1 ha), homogenous areas where vegetation cover has changed. In the study such areas were clustered on urban fringes. The LCDB approach also gave a good approximation of the total change in land use. The analysis should be repeated using the LCDB4.1 polygons.[2] However, higher resolution is needed to detect small losses or increases in woody vegetation both within polygons and in areas <1 ha, given these can have large cumulative effects. LCDB is not suited for identification or protection of individual ecosystem types or values associated with sub-canopy or sub-dominant plants or intact soils.

Identify and protect ecological buffers and corridors before urbanisation. Urbanisation offers a one-off opportunity to conserve space for ecological buffers around remnants and to re-establish connections between remnants. It is also a one-off opportunity to increase the resilience of native remnants by optimising their shape (e.g. to create more 'core' habitat), size, and range of ecosystems or landforms – actions that help safeguard their future values. Once an area is divided into small sections, the opportunity to enhance buffers or connectivity is usually extinguished in perpetuity. Large public spaces created as part of urbanisation offer restoration opportunities along storm water reserves, mean high water springs zones, parks, and maybe roads and cycle ways.

Beware non-equivalency of vegetation mitigation planting. Native planting and succession should be prioritised and promoted in areas that can achieve high value ecosystems. Such areas are non-native forests (e.g. plantations) with intact soils, hydrology and woody cover, 'wet' pasture, and, particularly, areas that link and buffer existing native vegetation. Native planting into earth-worked areas and narrow strips should be discounted or negatively weighted by, for example, requiring a high ratio of planted to cleared area, rather than the 1:1 ratio observed in this research.

Identify high value ecosystems. The very low percentage cover of native vegetation in areas with low statutory protection for urban forest (i.e. Zones 2–3 in this study), and the ongoing clearance of native vegetation within these zones, emphasises the importance of specifically identifying and protecting actual and potential high value ecosystems (e.g. non-native forest with intact soils, hydrology and woody cover) and locations (corridors).

[1] Note however, that the LCDB4.1 released July 2015 identified over 12 500 new polygons (>1 ha) of woody vegetation in grassland and over 27 000 polygons affected.

[2] Note however, in July 2015 **Version 4.1 of the Land Cover Database** was released. In this version Unmapped woody vegetation patches in grassland polygons were detected by spectral methods verified with radar (ALOS PALSAR) analysis, and incorporated in a semi-automated process. As a result, over 12 500 new polygons (>1 ha) of woody vegetation in grassland were identified and over 27 000 polygons are either new, have changed class or have been significantly re-mapped (> 20% of their area changed) to improve boundaries (David Pairman, 17 July 2015, pers. comm.). This greatly enhances LCDB ability compared with LCDB2 and 3, to detect woody vegetation in pasture areas.

BACKGROUND

This research note reports work with Auckland Council that investigated the effectiveness of vegetation protection provisions on the North Shore of the Auckland metropolitan area (i.e. legacy North Shore City, NSC). Urban vegetation provides many 'ecosystem services' that are extinguished when replaced by buildings and roads (Dymond 2014). Ecosystem services are the benefits nature provides to humans (MA 2005). These services include regulating services such as water purification (capture and filtering of storm water), air quality regulation (reduction of air-pollution), noise, and local climate regulation (temperature extremes, wind, radiation (UV)). Urban forests, green spaces, and plantings contribute to cultural services, particularly to those related to urban liveability. Urban liveability is regarded as an important competitive advantage for many New Zealand cities.

Enhancing urban liveability is a priority of the Auckland Plan (Auckland Council 2012a), which articulates Auckland's vision to become the world's most liveable city. Many of the leading cities in various international ranking studies, e.g. Monocle's "Most Liveable Cities Index", Economist Intelligence Unit's "Liveability Ranking and Overview", and "Mercer Quality of Living Survey", have policies based on protecting and enhancing urban vegetation to enhance liveability and resilience (e.g. Melbourne 2012 Urban Forest Strategy[3], Seattle Green Factor[4]). A common target in these cities is 40% urban tree cover. A recent study reports Auckland Isthmus has 6% urban forest (vegetation over 8 m height) (Wyse et al. 2015[5]).

Role of vegetation in urban centres

Vegetation, particularly remnant native vegetation on undisturbed soils, is where most of Auckland's native terrestrial biodiversity resides. Many of Auckland's urban forest remnants are typical of lowland New Zealand ecosystems, being highly diverse due to their benign climate and location at the productive junction of streams and estuaries. However, lowland ecosystems are grossly under-represented and under-protected nationally (Walker et al. 2012). In Tāmaki Ecological District (ED), the district that encompasses most of Auckland including the original North Shore City, indigenous vegetation remnants cover is less than 7% (Lindsay et al 2009). NSC also contains a relatively large proportion of this remaining native forest and scrub. Remnants, including local parks, are mostly in gullies along streams or the coastline escarpments. On the North Shore, the values of reserves such as Le Roy Bush for protecting Auckland's 'remarkable number of native plant species' (Esler 1991) were identified as early as 1871 by Thomas Kirk. Although Auckland's natural heritage is severely depleted in some contexts, there is still much to protect. North Shore kauri forests are not yet impacted by kauri dieback. Vegetation and tree protection rules/zoning influence the protection of these resources (Auckland Council 2012b Indigenous Biodiversity Strategy[6]). Vegetation protection rules in expanding and intensifying urban areas were designed to avoid, mitigate or minimise impacts of new development on our residual natural heritage.

Study Area – North Shore City

NSC was selected because it had specific and hierarchical vegetation protection rules that could be accurately depicted spatially. North Shore District Schemes (Appendix 4) had provisions to protect trees and vegetation before 2011 amendments to the Resource Management Act 1991. These provisions included rules on Schedules of Protected Trees,[7] which covered stands of trees, as well as broad-scale zoning to protect trees and other vegetation; such zoning was extremely important for vegetation protection and maintenance of indigenous biodiversity. These protection rules were challenged by developers in the late 1990s during a period of intense development pressure in which NSC urban vegetation management was investigated by the Parliamentary Commissioner for the Environment (PCE[8]). The PCE identified 'a general lack of appreciation of the great value and values of urban vegetation' (by the public and parts of NSC), and recommended the development of an urban vegetation plan to integrate policies across all programmes of NSC Parks,

[3] www.melbourne.vic.gov.au/Sustainability/UrbanForest/Pages/About.aspx
[4] www.seattle.gov/dpd/cityplanning/completeprojectslist/greenfactor/whatwhy/
[5] Landscape and Urban Planning 141:112-122. Discussion at: www.radionz.co.nz/national/programmes/ninetonoon/audio/201757488/stocktake-of-auckland-trees-finds-low-numbers-and-poor-protection
[6] www.aucklandcouncil.govt.nz/EN/planspoliciesprojects/plansstrategies/Councilstrategies/Documents/indigenousbiodiversitystrategy.pdf
[7] Such trees are also referred to as Listed or Notable. 2011 Amendments to the RMA 1991 affected what could be protected, as noted on Auckland Council website www.aucklandcouncil.govt.nz/EN/ratesbuildingproperty/consents/landtrees/Pages/trees.aspx
[8] www.pce.parliament.nz/assets/Uploads/Reports/pdf/urban_vegetation.pdf

Road and Planning departments. These new NSC vegetation and tree rules, which were successfully upheld in 2002 in the Environment Court, are expected to have had a relatively consistent influence on vegetation cover in NSC between 2000/01 and 2008/09.

This assessment investigates vegetation changes within the legacy NSC boundary from 2000/01 to 2008/9, when vegetation protection rules that provided a range of different protection levels for remnant native ecosystems were in place. Our research discusses patterns of land cover change and the links between land cover change and the underlying statutory vegetation protection levels. The findings are intended for use by regional and district authorities to help understand and inform vegetation protection rules and policies in planning documents (e.g. Auckland Plan).

Our approach

Using land cover data from the New Zealand Land Cover Data Base (LCDB) we identified polygons within the legacy NSC boundaries where cover changed between LCDB2 (2000/01 images) and LCDB3 (2008/9 images, released in 2012). We overlaid these with post-2010 impervious surface and building footprints from Auckland Council, 1999 and 2010 aerial photographs, and a vegetation protection typology (Appendix 1). All analysis was done using ArcGIS (ESRI 2013). The vegetation protection typology is based on our analysis of the rules and ranged from 1 (zero to very low protection) to 5 (very high protection). The areas with the highest protection were primarily riparian and coastal protection strips

The LCBD vegetation cover classes[9] were also amalgamated into built-up area (artificial surfaces by combining 'built-up area', 'Dump', 'urban parkland open space' and 'transport Infrastructure'), indigenous ecosystems (combining 'broadleaf indigenous hardwood',' indigenous forest', 'kānuka/mānuka', 'herbaceous saline vegetation' and 'mangrove') or exotic vegetation (combining 'deciduous hardwoods', 'gorse and broom', 'pine forest', 'forest harvested', 'mixed exotic shrubland', orchard', 'cropland' and 'exotic grassland') to reduce potential errors due to differences in the classification of individual types of vegetation between LCDB versions which may have led to incorrect classifications of change.

To verify the LCDB analysis was identifying actual change, and to look more closely at changes within polygons, we examined in detail 101 Land Cover Change (LCC) polygons covering 662 ha. These polygons represented 74% of the 137 possible polygons where land cover had changed between LCDB2 and LCDB3. We prioritised large polygons and clusters of smaller polygons.[10] We overlaid LCC polygon boundaries with 1999 ortho-photos and high resolution 2010 colour aerial photos. Based on the 2010 land use, the development pressure in LCC polygons was categorised as residential, industrial, car park, school, motorway or park. We then estimated the area of woody cover in 1999 and 2010 in each individual polygon (combining native and exotic woody vegetation). We differentiated areas that were new planting in 2010, i.e. new woody cover that was not visible in the 1999 ortho-photos. We also noted whether this new woody cover buffered remnant vegetation, a riparian area or pond or a motorway. Finally, roof density within LCC polygons was counted and converted to low (>1200 m^2 section per roof), conventional (800–1200 m^2), medium (350–800 m^2) or high (<350 m^2) density development.

Box 1. New Zealand's Land Cover Data Base (LCDB)

New Zealand's land cover has been mapped using remote sensing techniques applied to satellite images for 4 time periods – summer 2000/01, 2008/09, 2008/09 and 2012/13. This produced the New Zealand LCDB, which is widely used by central and local government for monitoring, planning, and reporting. The objective of the LCDB is to maintain a consistent land cover classification of known accuracy at the national level. The classification has 7 first order classes at the higher level, based on land cover physiognomy (built up areas, bare surfaces, water bodies, cropland, grassland, shrubland, forest). The dominant cover determines the class. LCDB2 has a 15-m spatial resolution and minimum map unit of 1 ha. www.lcdb.scinfo.org.nz

[9] https://lris.scinfo.org.nz/document/134-illustrated-guide-to-lcdb2-target-classes-part1/)

[10] Lower priority polygons were small and isolated. About half these polygons were in established (older) areas of city and half in rural areas. In urban areas these polygons typically changed from grassed areas classified as 'park/urban open space' to 'built'. Often this was due to car park, path or road upgrades or construction, for example school buildings on playing fields or house building on grassed lots. About half were in rural areas, and were associated with new farm houses or removal of shelter belts that was enough to 'trigger' change in LCDB classification.

OUR FINDINGS

The big picture

Between 2001 and 2009 137 polygons changed land cover (Chart 1, Fig. 1). LCDB classifies over 60% of North Shore City is as built up area[11], and 18% (2008) as indigenous vegetation (Chart 1). Between 2001 and 2009, 590 ha were urbanised. These areas were largely in polygons dominated by pasture and other non-native vegetation. Over the 8 years, 403 ha of exotic forest-dominated polygons and 487 ha of pasture-dominated polygons were removed for the expanding city – on average over 100 ha per year (Chart 3). Most of this was converted to residential subdivision. Over 140 ha classified as 'exotic forest' was removed in areas with the highest vegetation protection (zone 5). Our more detailed case studies indicate these areas tended to be replanted in native vegetation.

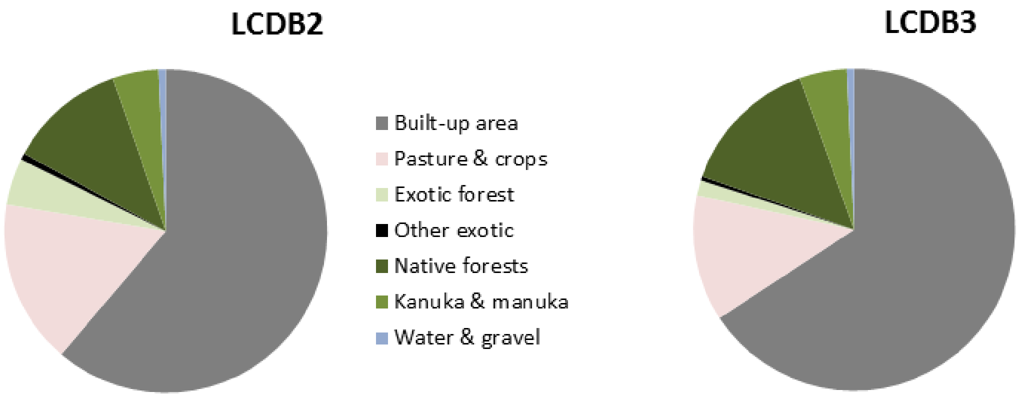

Chart 1. Percentage of North Shore City in each major cover class in 2000/01 (LCDB2) and 2008/09 (LCDB3). Exotic trees and pasture-dominated polygons are combined as 'exotic vegetation'.[12]

Areas with more valued vegetation and less development were more likely to be afforded vegetation protection in the NSC District Plan; however, vegetation protection rules may influence land cover – impervious surface area and building footprint as a % of total area decreases as protection increases, from Zone 2 to 5. For example, impervious surface drops from 37% for business zones (vegetation protection Zone 2) to 27% and 21% in residential zones with vegetation protection zones 3 and 4 respectively. The percentage of impervious footprint is lowest in Zone 5 (2.9%), reflecting the high priority placed on retaining vegetation and avoiding construction on coastal cliffs and riparian zones.

[11] 'Urbanised' in this context means converted to 'built' classifications under LCDB that include 'Built-up Area' + Urban Parkland /open space (typically playing fields, mown grass with scattered or no trees) + Transport Infrastructure where features are discernable and exceed 1ha MMU such as motorways (see https://lris.scinfo.org.nz/document/134-illustrated-guide-to-lcdb2-target-classes-part1/)

[12] 'Exotic vegetation' included LCDB polygons classified as Deciduous Hardwoods, Harvested Forest, Gorse and Broom, High (and Low) Producing Exotic Grassland, Mixed Exotic Shrubland and Forest, Orchard, Pine Forest and Short-rotation cropland (see https://lris.scinfo.org.nz/document/134-illustrated-guide-to-lcdb2-target-classes-part1/)

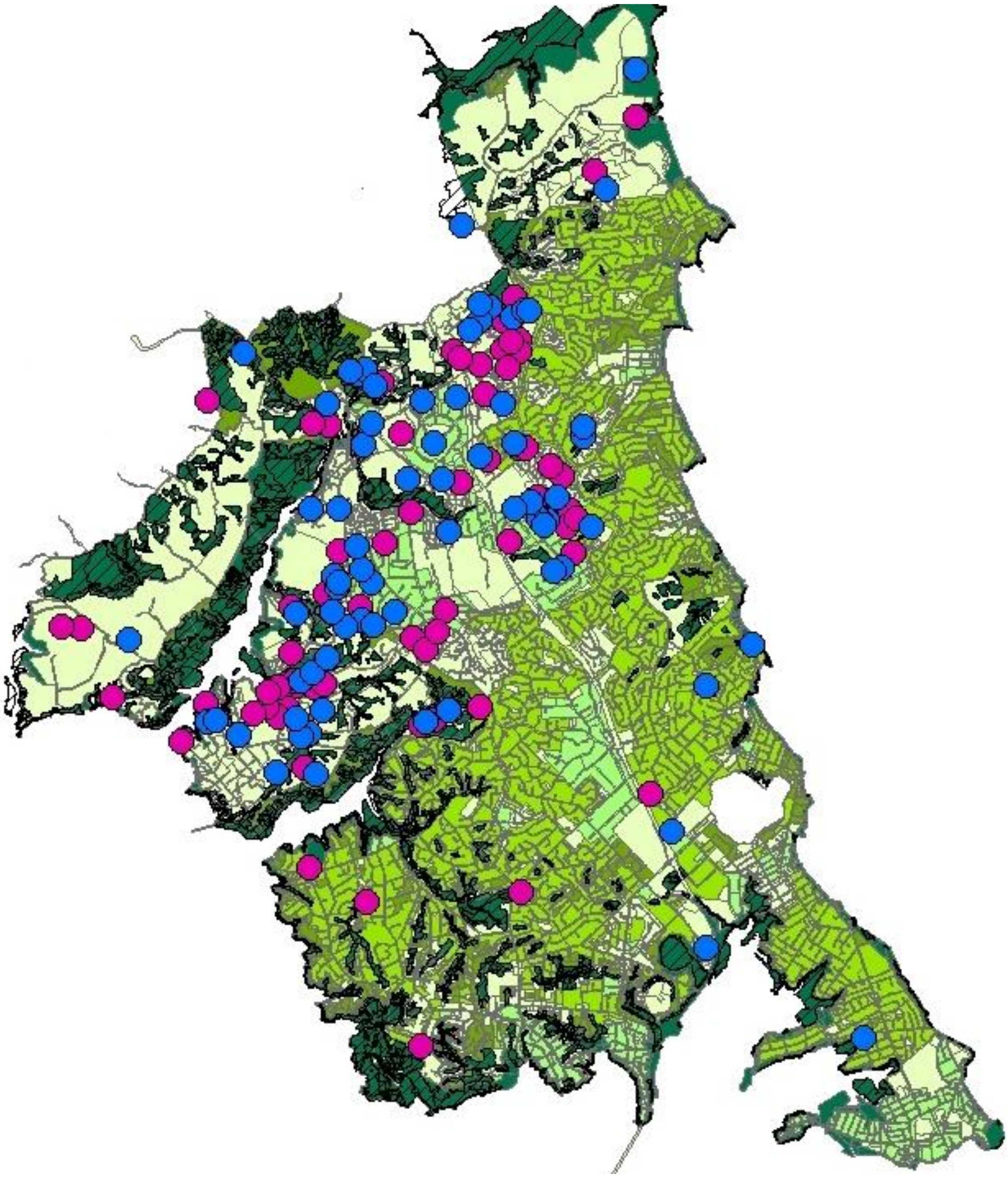

Figure 1. Individual polygons where land cover classification changed between LCDB1 and LCDB2 (pink circles), and between LCDB2 and 3 (blue circles) on the vegetation protection overlay for North Shore City. Dark green areas have the highest protection; light green areas the lowest protection. The map highlights the location of smaller, more isolated polygons within the more built-up areas of North Shore City, and do not represent the size of a polygon (see Appendix X).

The LCDB analysis identified an average of over 40 ha of new native vegetation each year, a total of 333 ha over the eight years between LCDB2 and 3 measures. The majority of this new vegetation was in areas with the highest level of vegetation protection, i.e. Zone 5 (235 ha). Most of the Zone 5 vegetation was coded 'indigenous forest' (Chart 2). Indigenous vegetation decreased in zones with low vegetation protection (Zones 2 and 3). For example, in 2001/2 only 14 ha of indigenous vegetation remained in Zone 2, and about one quarter (4 ha) of this was removed by 2009.[13]
Conversion of non-built-up land cover to buildings occurred in all vegetation protection zones. Most of these areas became residential developments (559 ha), with small areas of new transport infrastructure (16 ha, motorways) and urban

[13] The NZLRI may not accurately code the vegetation type; however, both native and non-native woody vegetation are usually associated with much higher ecosystem service and native terrestrial biodiversity values than occur in grassed areas. This indicates it is important that high value ecosystems and corridors are specifically identified in industrial areas due to expectations of unimpeded use and large, contiguous impervious footprints of industrial developments.

parkland or open space (22 ha). In many cases parkland and open space were temporary. This temporary nature is reflected in the overall loss of 44 ha of open space in vegetation protection Zones 2 and 3, and an increase of 75 ha in vegetation protection Zone 1. An increase of 45 ha of built area was recorded in areas with the highest vegetation protection (Zone 5). The majority of this built area was linked with residential subdivisions and a small proportion linked with construction of new motorway. Tree and shrub removal for construction of motorways was under-detected by LCDB. For example, changes in the Greenhithe Road area between LCDB2 and 3 were not detected. It appears this may be due to an over-riding classification of the polygons where the motorway was designated as 'Transport Infrastructure' in LCDB1, 2 and 3, even though the land was dominated by tree/shrub cover in 1999. This SH16/18 road corridor had been identified for transport infrastructure for many years. The highway construction required mitigation plantings by court consent order.

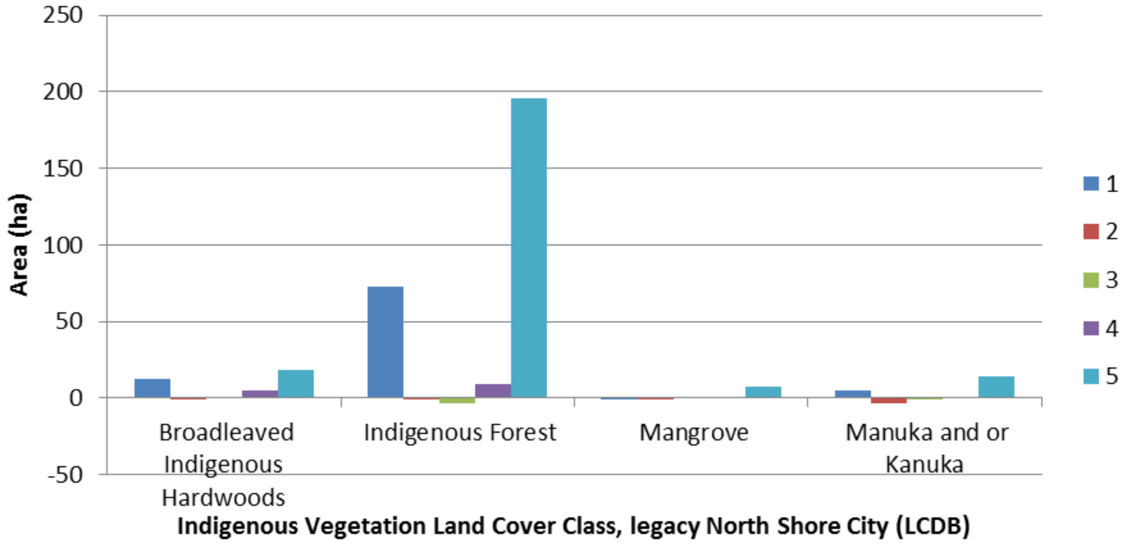

Chart 2. Change in area (ha) coded as indigenous vegetation by vegetation protection zone (1-low protection to 5-high protection) between LCDB2 and LCDB3 in legacy North Shore City.

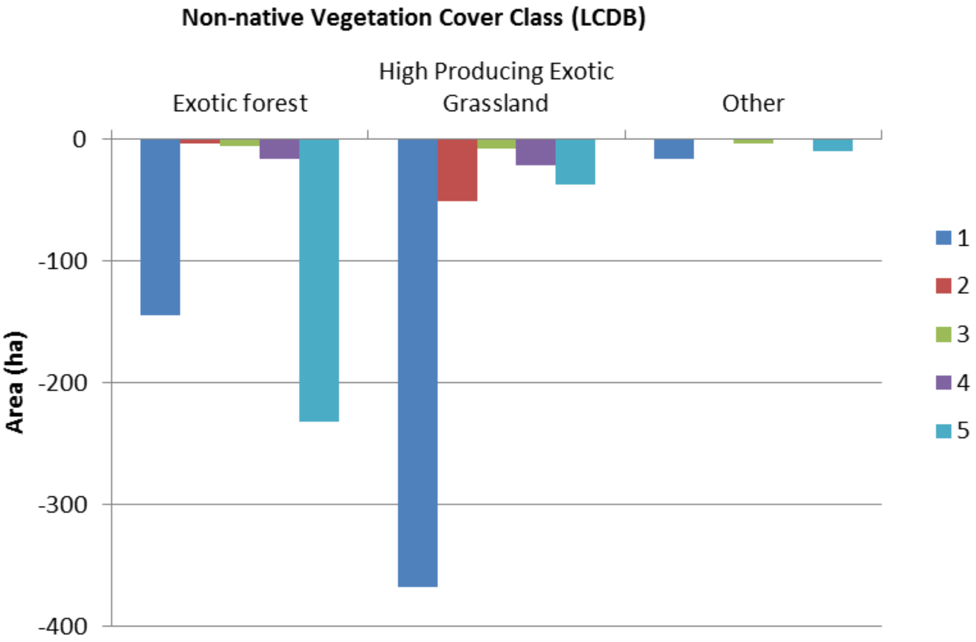

Chart 3. Change in area coded as non-native vegetation by vegetation protection zone (1-low protection, 5-high protection) between LCDB2 and LCDB3 (ha) in legacy North Shore City.

LCDB2 and 3 identified new woody vegetation in areas over about 1 ha (MMU) that are blocky in shape and contrast with the adjacent land cover. For example, in a 2010 photograph of Long Bay Regional Park (Fig. 2) the two green areas are LCDB2 polygons; the shaded area outlined in black is a new LCDB3 polygon identifying contiguous areas planted from 1997 to 2006. Two coastal blocks planted with native scrub species in 1994 (identified with white arrows) are 0.35 and 0.40 ha respectively, and too small to be identified as separate polygons in any LCDB (1–3). The large area to the south of the black line that was planted in 2007, the coastal strip, and narrow riparian fingers along the streams are too thin and small to be detected; they remain part of the larger polygon classified High Producing Exotic Pasture in LCDB3.

Figure 2. 2010 photograph of Long Bay Regional Park with LCDB2 and LCDB3 polygons marked in green and white shading respectively.

AT A FINE SCALE

Drivers of tree/shrub cover change

The fine-scale analysis of 101 polygons where LCDB classification changed between LCDB2 and 3 using aerial photographs showed the overall driver for clearance of tree/shrub vegetation was urbanisation, i.e. houses, industrial areas, roads and schools. Each of the four bars in Chart 4 shows the total area of woody vegetation lost or gained for a single land cover classification: 'cleared', 'grassland', 'Low density housing' and 'woody vegetation' in 1999 measured within the 101 individual polygons. All the 42 ha of woody vegetation cleared on land classified as 'grassland' in 2001 was converted to 'built' (the blue part of 'grassland' bar), and 6 ha became new woody vegetation (the orange part of the 'grassland' bar). Of land classified as woody vegetation in 1999, 28 ha was converted to buildings in 2010, 5 ha was bare (cleared for building), and 4 ha converted to grassland by 2010.

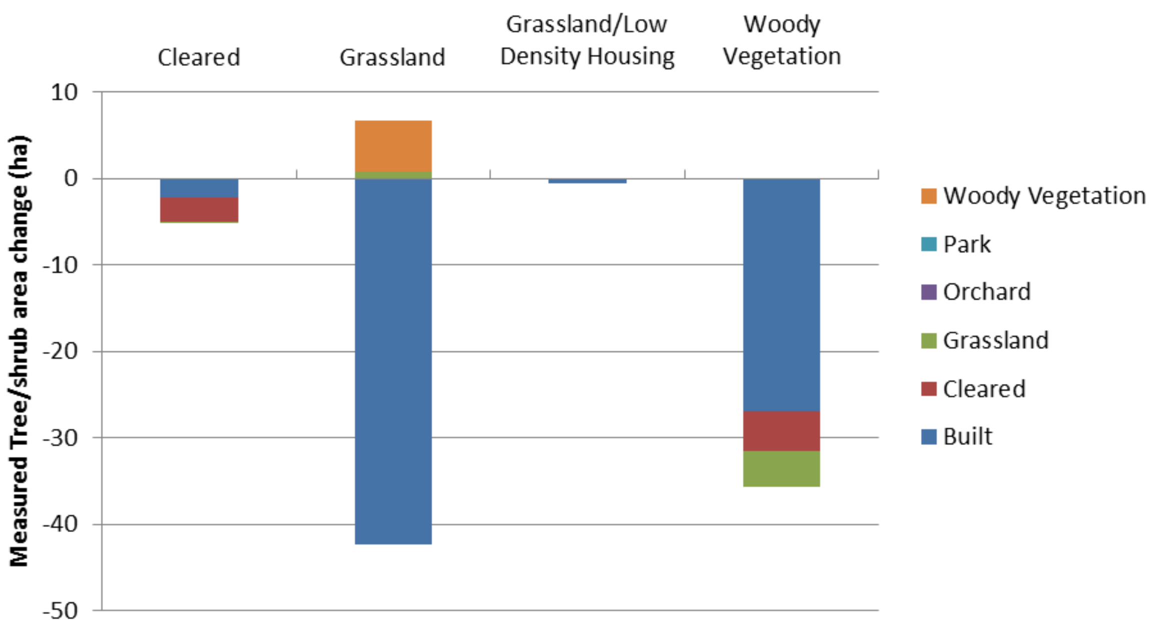

Chart 4. Area of woody vegetation lost or gained in different LCDB cover classes in North Shore between 1999 and 2010.

How and where vegetation change due to urban expansion is expressed

Change in vegetation cover was also investigated at a finer scale in LCC polygons. Table 2 shows the area of manually measured ('actual') tree/shrub cover within LCC polygons that were dominantly 'forest/shrub, 'grass or urban parkland' and 'cleared/built' in 1999, and in the same polygons in 2010 (i.e. after land use change). Only blocks of shrub/trees were included; scattered individual trees were excluded. The analysis showed more vegetation was retained in polygons that started with higher tree/shrub cover. On average, woody vegetation covered 74% of LCC polygons classified as 'tree/shrub'; this dropped to 28% after development. Woody vegetation in grassland polygons dropped from 17% to 11% in grassland polygons and from 14% to 6% in 'built' polygons on average.

Table 2: Shrub/tree vegetation in Land Use Transitions LCDB 2 to LCDB 3. Aerial interpretation vs LCDB

LCDB2 cover classification	LCDB2 by polygon (ha)	Actual woody cover in 1999 (ha)	Actual woody cover 2010 (ha)	Actual new woody cover 2010 (ha)	Total woody cover 2010 (ha)
Forest/shrub	46	34	13	2	15
Grass/Urban Parkland	254	43	23	5	28
Cleared/Built	361	51	14	6	20
Total Area	**662**	**128**	**51**	**14**	**65**

Overall, more woody vegetation was cleared from polygons that were grasslands in 1999 (43 ha) than in all polygons initially classified as woody vegetation (34 ha). Analysis of aerial photograph images showed that removed tree and shrub vegetation tended to have one of four features: poorly protected;[14] scattered within pasture or urban areas; a narrow form (especially if a 'peninsula'); or a large area associated with continuous forest. Each is examined below.

[14] Unfortunately we cannot assign a number to each of these cases to get an idea of their relative importance

- **Poorly protected woody vegetation.** Tree/shrub vegetation in areas with low or no vegetation protection, i.e. protection zone 1, 2 or 3. This woody vegetation included mixed exotic shrub land, gorse and harvested forest.

- **Scattered woody vegetation.** Scattered trees and shrubs within dominant pasture polygon or small individual patches of tree/shrub land within a larger and dominant pasture or urban matrix. Tree and shrub land were particularly vulnerable to removal where they were in areas zoned 'industrial' and in larger subdivisions. A reason is the common practice of large-scale earth-working to create terraced, level sections. Vegetation was more likely to be retained along the edges of a development and beside streams in steeper land, but not streams in gently sloping land, as these were vulnerable to removal, culverting or shifting.

  Photographs of the Apollo Drive area in 1990 and 2010 illustrate these features (Fig. 3). This largely industrial area is dissected by a stream and lake, and includes vegetation protection Zones 1 and 5. Development included extensive new riparian plantings in the northern area, outside the cleared polygons. However, a net loss of woody vegetation occurred because much of the (new) planted area originally had woody vegetation (which was cleared during site earthworks). In addition, shrubland that formed a potential north-south connection between stream and pond (the curved arrow in Fig. 3) was also cleared. Across three Zone 5 (high-protection) polygons, 1.5 of 4.8 ha of tree/shrub vegetation was removed. This form of forest/shrub land loss is not captured in LCDB and can be significant when rural areas are urbanised. For example, in the Schnapper Rock Rd/Albany Highway area a 40-ha 'pasture' polygon contained 8 ha of coastal fringe, riparian, shelter belts, and other woody vegetation in 1999. By 2010, 4.7 ha of this vegetation had been removed as part of urbanisation.

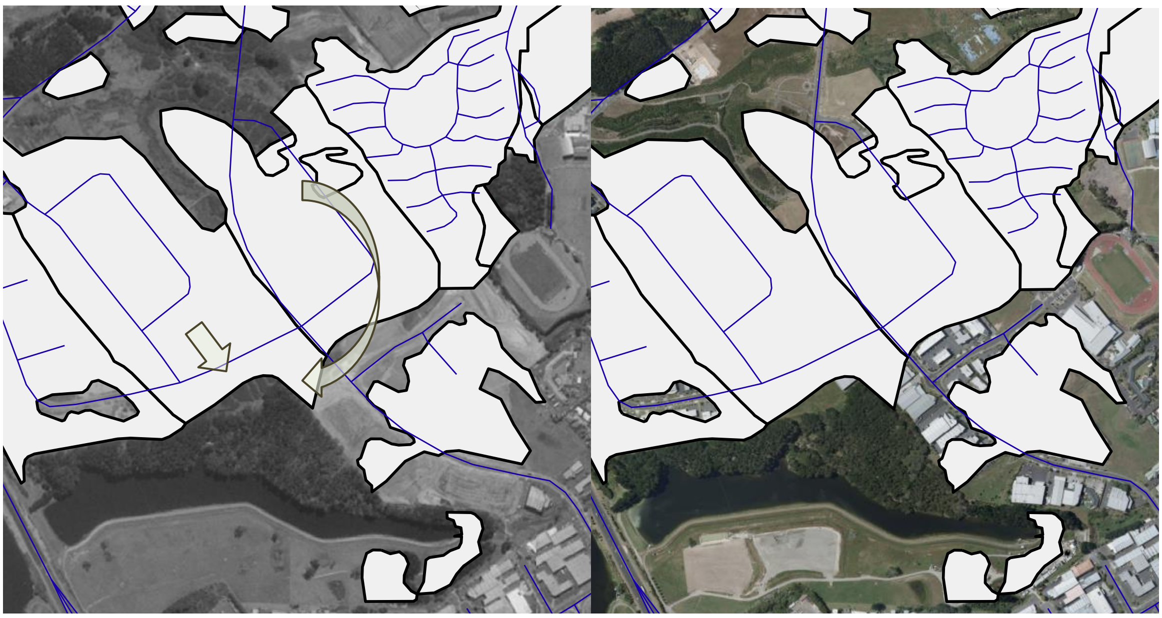

Figure 3. Apollo Drive Industrial area in 1990 (Left) and 2010 (right) overlaid with LCDB polygons (black lines) and roads (purple). Note the removal of scattered tree/shrub vegetation through the grass-dominated areas marked with the arrows.

- **Woody vegetation in peninsulas and margins.** 'Peninsulas' or narrow strips of native tree/shrub land are vulnerable, especially where they lie on ridgelines or shallow gullies. Such vegetation is likely to constrain earth works and/or decrease section yields. Forest/shrub land with irregular edges is also vulnerable to loss as during urbanisation woody vegetation is typically cleared to create smooth or straight edges. Larger losses are associated with rectangular playing fields, car parks, or industrial areas. Removing such edges exposes and degrades the interior of shrub land/forest. Both types of tree/shrub land removal are shown in Figure 3 by the two arrows. These small, incremental losses were not usually recorded as changes in LCDB3. However, boundaries of many polygons have been realigned in LCDB4.1.

- **Larger patches of woody vegetation within large forested areas.** The removal of relatively large (1–2 ha) areas of forest/shrubland within, or adjacent to, a larger area of continuous forest is usually, but not always, detected by LCDB. In NSC these continuous forest/shrub land areas generally included part of an ecological reserve or Significant Natural Area. The changes were driven either by complete removal of forest/shrub land, or by a decrease in overall density throughout the polygon (with woody vegetation still present), triggering a one-off reclassification.

  Complete removal of larger areas occurred in some new subdivisions. For example, along Glendhu Road a cluster of four small (1–2.1 ha) polygons were cleared within an extensive forest/shrub land (Fig. 4). Three of these were classified as indigenous forest in LCDB2. All four polygons were classified as 'built' (medium density housing) in 2010. LCDB comparisons identified five other areas in NSC where substantial areas of woody vegetation were cleared within forested polygons; this included areas with the highest vegetation protection (Zone 5) converted to industrial, residential and motorways.

Figure 4. Aerial photographs illustrating two types of urban development. In the top photo houses have been built along Glendhu Road, removing and fragmenting native vegetation that includes a significant ecological area; in the bottom photo former farmland has been cleared, and new riparian areas with in-stream ponds planted with native vegetation.

A decrease in overall canopy density was typically seen in established low-density housing adjacent to reserves. In such cases, low-density housing with established tree cover may be characterised by LCDB as indigenous forest (Fig. 8). Gradual fragmentation and reduction of tree canopy cover by in-fill housing eventually triggers a change in classification to 'built'. This change signals degradation of an adjacent as edge effects are increased, the effective size of the remnant reduces (larger remnants tend to have higher plant and native invertebrate diversity), and weed pressure from dumped or escaped garden plants increases.

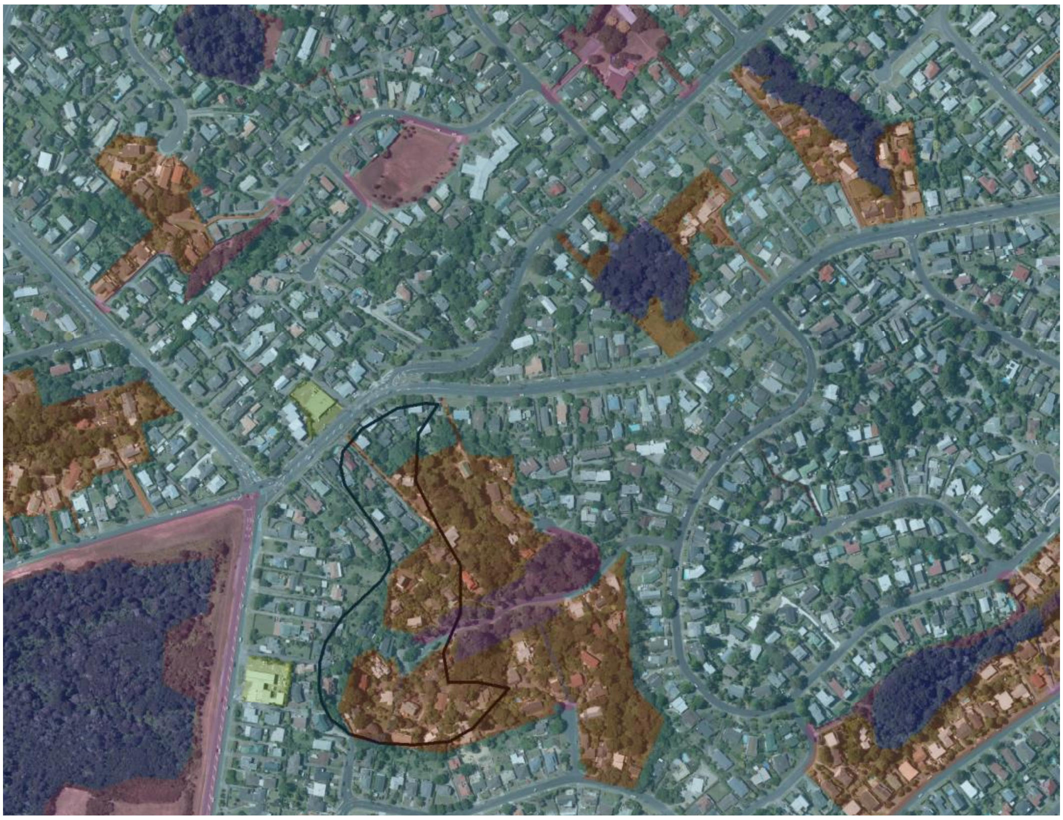

Figure 5. The black line shows the boundary of the LCDB polygon coded 'Indigenous Forest' in 1996 and 'Built Up' from 2001 subsequently; dark colours have highest vegetation protection; grey areas have lowest vegetation protection.

Low-density, rural residential areas can reverse this trend of deforestation. These areas, typically at the city periphery, have space to create valuable woody vegetation (Fig. 6). Such buffers are often along property boundaries and/or along riparian/wetland zones where they may be integrated with storm water retention or effluent treatment. Such significant areas of new planting are discussed in the next section of this report.

Figure 6. Extensive shrub land planting in a rural-residential block in Greenhithe covering the eastern half of the photographs (arrowed). In the centre, 1.3 ha of shrub land within a larger forested strip is entirely removed (arrowed). Both changes are undetected by LCDB 1, 2 and 3.

Native vegetation is being re-established in some areas

The 101 polygons with changed dominant cover between LCDB2 and 3 included large blocks of new tree/shrub vegetation. These were generally on public land, specifically Long Bay Regional Park (Fig. 2), along motorways and riparian zones (Fig. 4). Regional Parks stand out as places with potential for large-scale revegetation. North Shore City also undertook extensive planting of riparian areas as part of its storm water management. LCDB overlays did not identify areas where native tree/shrub cover was 'created' by reversion from gorse/non-native to native. This contrasts with the Waitakere Ranges Heritage study, where native regeneration through gorse was evident. No areas were identified where land cover changed from 'built' to 'shrub land/forest'. However, there was evidence that low-density urban areas can be coded 'shrub land/forest' under LCDB if canopy cover is high enough, particularly where adjacent to a larger reserve.

An LCDB analysis is likely to under-report the area of new tree/shrub land established for two reasons. First, new native tree/shrub land on private urbanised land is typically narrow, being along edges of riparian zones (protecting streams and as part of storm water infrastructure) and adjacent to remnant vegetation (typically along streams). Such relatively thin slivers are unlikely to be large enough to trigger a new polygon. However, LCDB4.1 does redefine some polygon boundaries. Second, where native planting replaces cleared woody vegetation, the overall classification remains tree/shrub land.

Substantial new planting is evident at the margins of some cleared polygons, for example, the Apollo Drive Industrial area (Fig. 3 above) and the Upper Harbour Motorway. Motorway plantings approximately balance the area removed for construction of the motorway; planting was required by Court order. In other places there is no evidence of such mitigation, e.g. an Apollo Drive residential subdivision was built on 2.9 ha of 3.3 ha forest/shrub land present in 1999. Near Oratau Reserve, 1.4 ha (coded exotic forest, but not visibly different to the adjacent native forest polygon) was cleared between LCDB2 and 3, and this extended into the adjacent forested polygon. A similar pattern was observed at Glendhu Road, where several ha was cleared (with no observed mitigation planting) and near Oteha Valley Road. The decision-making process behind the clearance of such sites would be useful to investigate.

The potential for native tree/shrub planting within urban areas, but outside defined remnants and riparian areas, tends to be severely restricted for two reasons. First, new developments have small sections with high impervious surface and little space for large trees. Most of the developments measured had section sizes less than 800 m^2 (Fig. 5). Second, many residential and all industrial areas are extensively earth-worked. Extant soils are removed and the soils with which they are replaced are nearly always of lower value for plant growth and without (at least in the medium term) the diverse invertebrate, fungi and soil fauna. Streets with sufficiently wide verges and car parks are two places where substantial tree cover can be established if adequate root zone quality and volume for trees are created.

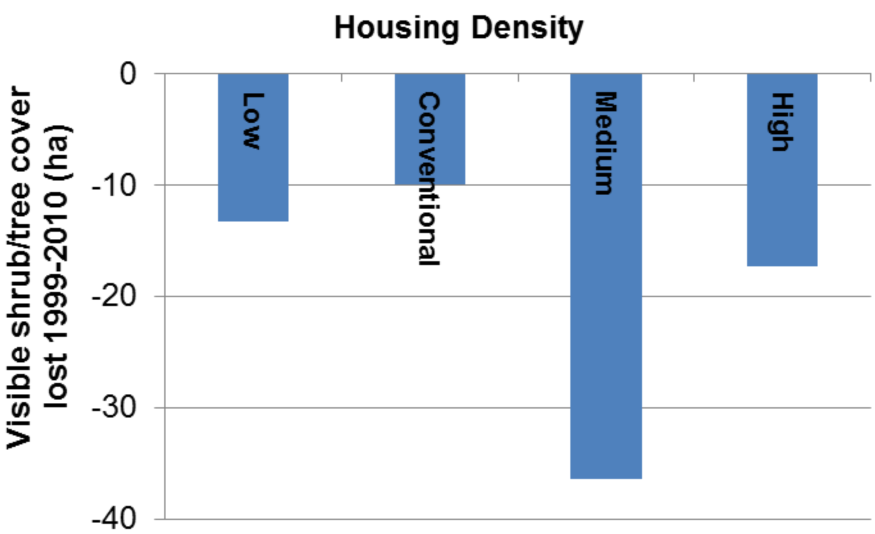

Figure 10. Cover of shrub land/ trees removed between 1999 and 2010 by density of housing in 2010, for polygons that changed LCDB classification between LCDB 1 and LCDB3. *Low density = >1200 m^2 sections including open space (parks), conventional = 800–1200 m^2 sections and schools, medium density = 350–800 m^2 sections and high density was industrial development and <350 m^2 sections. Coverage is based on number of roofs in 5000 m^2 areas.*

CONCLUSIONS

- Our 'big picture' analysis showed North Shore 'Built' area polygons increased by about 100 ha annually from 2001 to 2008, and this was driven by residential subdivision. Overall, tree/shrub land vegetation cover increased at the whole polygon-scale (but possibly not at a finer scale), with a large contribution by native planting in areas with high vegetation protection typology (4 and 5) that were originally low-stature or non-native woody vegetation.
- Shrub and tree losses during urbanisation are probably larger than indicated by the big-picture, LCDB analysis because LCDB2 and LCDB3 polygons do not record a) loss of sub-dominant vegetation or b) canopy loss within polygons insufficient to trigger a classification change. Also LCDB 1, 2, and 3 included some large 'pasture' polygons with significant scattered woody vegetation. Shrub land /forest covered an average 74% of shrubland/forest polygons and c. 15% of 'pasture' polygons before development. New 'built' polygons had 6% shrubland/forest on average. *S*ubstantial real changes in indigenous cover or protection extent may not change a category when an environment is originally far from a threshold (as noted by Cieraad et al. 2015).
- Analysing polygons where LCDB category had changed was a useful way to identify sites for more detailed analysis using aerial photographs and ground-based surveys. The latter can better identify the age and value of woody vegetation, and confirm if sites have been earth worked. The former shows connectivity and buffering.
- Urbanisation fragments and disconnects native vegetation. Edge effects in both new and existing (intensifying) urbanising areas are increased. Major threats to native vegetation and ecosystems are: cumulative impacts of vegetation removal from individual and small-lot subdivision bordering remnants in existing urban areas; extinguishment of potential buffering and connectivity in areas with narrow buffers; and earth-working of reserve areas before planting.
- In North Shore City, blocks of conventionally planted woody vegetation more than ~0.8 ha take 3–8 years to be sufficiently differentiated from grass to trigger classification change.
- Impervious surface data could be used to quantify changes in buffers around urban remnants and ecologically important areas (e.g. riparian areas). However, classification of grassland, impervious surface, and any woody (i.e. including non-native) vegetation would also enable comparison of many ecosystem services between different built-up areas. A combination of LIDAR (detecting vegetation height) and infra-red (to identify vegetation) has been effective. Contribution to biodiversity requires ground- surveys to identify species composition.
- Urbanisation offers a one-off opportunity to retain, conserve and connect space for relatively intact native ecosystems and the ecological services they contribute. Once an area is divided into small sections, the opportunity to enhance buffers or connectivity in the future is largely extinguished. These opportunities are greatest in large-lot, rural-residential areas, regional parks, and motorways. It can be achieved by planting grassed open space or removing woody weeds.
- A comparison of new polygon boundaries of LCDB4, released in June 2014, and old polygon boundaries (LCDB2 and 3) could reveal areas where tree canopy has increased. This analysis might be useful as a measure of reserve integrity, as a measure of buffering combined with use of impervious surface coverage.

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APPENDIX 1 - DESCRIPTION OF LCDB2 AND LCDB3 CLASSES USED, NORTH SHORE

(from https://lris.scinfo.org.nz/document/134-illustrated-guide-to-lcdb2-target-classes-part1/)

Artificial Surfaces

- Built-up Area – CBD, urban, commercial and industrial areas, dominated by structures and sealed surfaces, roads, car parks. Includes low density residential areas.
- Urban Parkland/Open Space – open, typically mown grasses amenity areas within or associated with built-up areas: parks with scattered trees, airports, golf courses, cemeteries, playing fields
- Transport Infrastructure – roads, railways and airport runways where features are discernable and exceed 1ha MMU

Grassland

- High Producing Exotic Grassland [40] can include areas where low productive grasses are dominant

  Low producing grassland [41] was not recorded in NSC

Bare or lightly vegetated surfaces (no significant areas in NSC): sand, rock or gravel

Water bodies (Rivers, lakes, Harbour)

Cropland, Vineyards and Orchards (no significant areas in NSC):

Scrub and Shrubland

- Gorse or Broom (51), Mānuka or Kanuka (52), Broadleaved Indigenous hardwoods (54), Mixed Exotic Shrubland (56)

Forest

- Forest – harvested (64), Deciduous Hardwoods (68), Indigenous Forest (69), Mangrove (70)

APPENDIX 2 - STANDARD VEGETATION PROTECTION ZONING CLASSIFICATION AND RAW RESULTS

This typology was based on Auckland Council District Plans base zoning interpreted by Marie Brown.

Level of Protection		North Shore City Council Zone
1	Zero to very low	Legacy NSC SNA Layer
2	Low protection	Legacy NSC Business Zones
3	Medium protection	Legacy NSC Residential 4A
		Legacy NSC Residential 4B
4	Medium - High protection	Legacy NSC Residential 2B
		Legacy NSC Rural 2
5	Very high protection	Legacy NSC Scheduled 'clouds' [NOTE 1]
		= Legacy NSC riparian zones (5 m in urban; 20 m in rural) and
		Legacy NSC Foreshore Yard

[NOTE 1] The scheduled 'clouds' were created as they were not legacy zones as such, but defined by distance to a stream or distance to a coast (cliff or Mean High Water Springs).

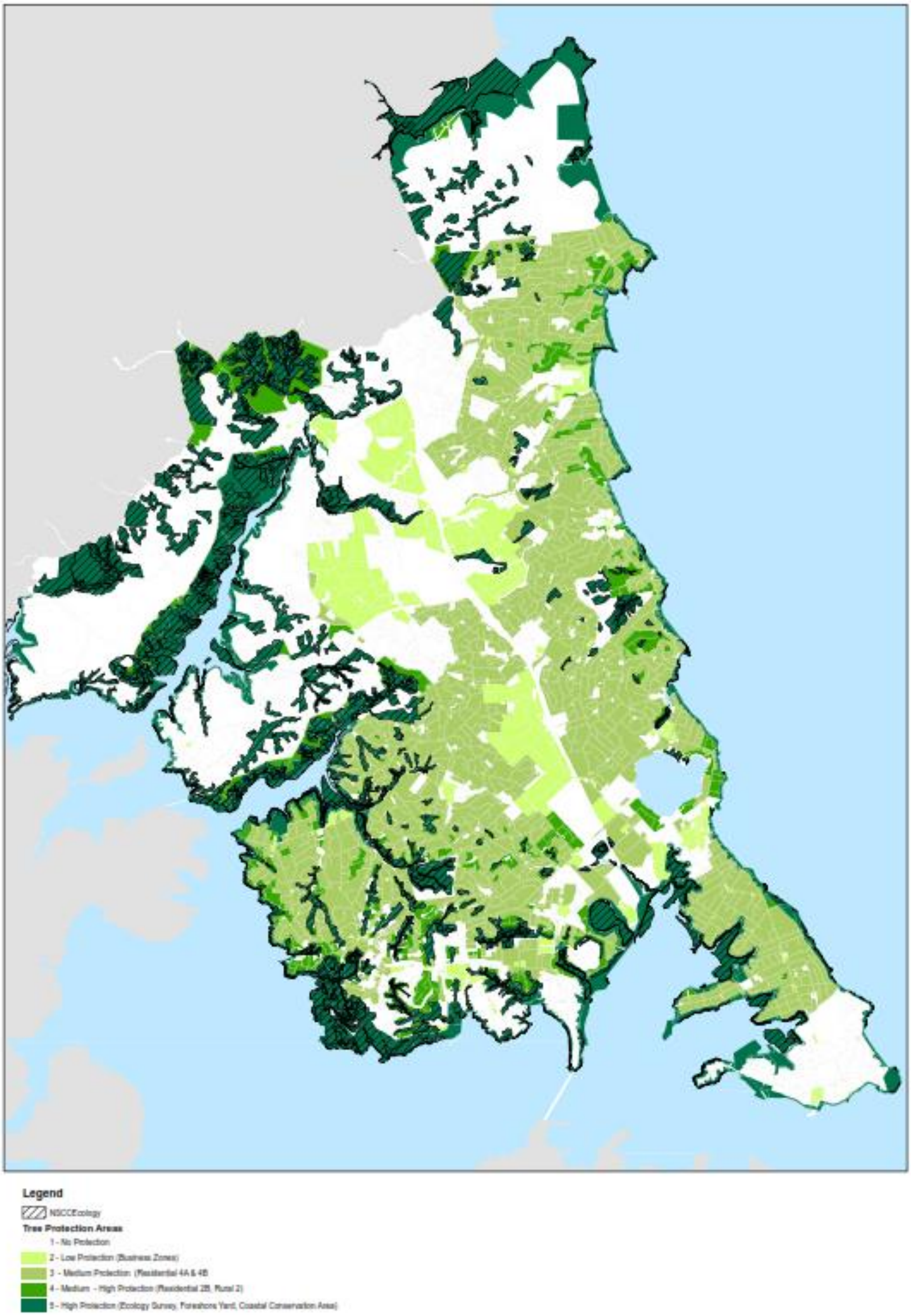
An issue with creating the zones was the need to extend the zone to the middle of the road, which was fiddly because there was no automated way to process this. Reserves were excluded from this analysis (pers. comm. Auckland Council Geospatial Unit, January 2014).

LCDB2 (ha)

Row Labels	1	2	3	4	5	Grand Total
Built-up area	2181	1016	3651	490	594	7931
Exotic vegetation	1943	87	36	132	617	2815
Indigenous ecosystems	313	14	80	149	1568	2124
Open ground	0.1	0.0	0.0	0.0	11	11
Open water	50	1.2	0.6	1.1	30	83
Grand Total	4487	1118	3768	771	2821	12964

LCDB3 (ha)

Row Labels	1	2	3	4	5	Grand Total
Built-up area	2622	1075	3672	513	639	8520
Exotic vegetation	1413	32	18	94	338	1894
Indigenous ecosystems	402	10	77	164	1804	2457
Open ground	0.0	0.0	0.0	0.0	10	11
Open water	50	1.2	0.6	1.0	31	84
Grand Total	4487	1118	3768	771	2822	12965



North Shore City Vegetation Protection Overlay. Protection increases as green shading increases. White areas have no vegetation protection. Deep green areas have the highest level of vegetation protection.

APPENDIX 3 - METHOD FOR FINE-SCALE ASSESSMENT OF LCDB POLYGONS

For each polygon where a land cover classification changed between LCDB2 and 3, the following features were manually quantified:

- Polygon identifier & area descriptor (e.g. Apollo Drive north, Glendhu road)
- Development Type: residential, industrial, N/A, vegetation growth (4), car park (X), school (3), motorway (3), park (2)
- Polygon Area (ha)
- Category recorded by LCDB1, LCDB2 (1999), LCDB3 (2010):

  The categories were amalgamated to reduce error between years, and to match the focus of this report, the change in shrub/tree cover (linking to ecosystem services) compared with (any) grassed area. Our analysis did not therefore differentiate between exotic and native tree/shrub vegetation. 'Cleared areas' are of interest. They appear pale to white and are usually transition between grassland or treed vegetation and urban or industrial development. In an impervious mapping (Landcare Research 2009) of Auckland region such areas are considered impervious if they occur in urban areas. This was identified as a reason no change, or slight reduction, in overall impervious area between 2000 and 2007 in NSC
- Actual category LCDB1 verified from 1999 Ortho photo: 'Grassland. Cleared. Vegetation (shrub land or forest), Built (Housing)
- Actual category LCDB2 verified from 2010 Aerial photo: as for 1999 and with additional categories not present in 1999 aerial: Park, Built (Industrial), Built (School), Built (car park), Motorway

The following characteristics were also recorded for each polygon

- Where indigenous vegetation has been affected by the land use change and this is recognised by the LCDB or, where Indigenous vegetation has been affected by the land use change and this has not been recognised by the LCDB
- Dominant and subdominant Vegetation protection Zone (1 to 5, very high). Larger subdivisions typically had a combination of zones 1 & 5 adjacent
- If the area included a legacy NSC 'Ecology' Zone (from significant natural areas map (insert reference)
- Presence of extensive indigenous vegetation in an adjacent polygon
- Roof/house density in 1999 and 2010. This was based on the number of roofs /5000 m^2
- Area of established (tree) vegetation in 1999 and 2010 (ha)
- Area of new (planted) shrub or tree vegetation in 2010 (ha) and if the new vegetation was associated with streams or storm water treatment (e.g. a new pond), or remnant forest/shrub land (contributing to buffering), or a motorway planting
- From these, the difference in area between established and new vegetation (contiguous shrub or trees) for individual polygons was calculated as a raw area and percentage of original shrub/tree vegetation.

APPENDIX 4 - NORTH SHORE CITY PLANS

North Shore City Council 2002 District Plan

http://www.aucklandcity.govt.nz/council/documents/districtplannorthshore/text/section8-natural-environment.pdf
Sections 8.3.1 & 2, 8.4.2

http://www.northshorecity.govt.nz/our_environment/draft_ecological_plan/Summary.htm

The Ecological Enhancement Plan (draft 2008) identifies how NSC planned to maintain and enhance remnant and regenerating indigenous vegetation within the city's parks and reserves networks. In 2008 (based on 2005 mapping) indigenous vegetation occupied about 17% of its former extent. The North Shore City Ecological Survey (2005) mapped 2,157 hectares of significant terrestrial and estuarine indigenous vegetation within North Shore City, using the national Protected Natural Areas Programme survey methodology. Eighty-nine Sites of Ecological Significance and 28 'ecological linkage' areas were identified.

Key objectives were:

- Provide suitable habitat for indigenous flora and fauna, thereby increasing indigenous biodiversity;
- Enhance existing ecological corridors within North Shore City;
- Add value to current and future capital and volunteer works programmes and projects within NSC parks and reserves;
- Help realise the intrinsic, amenity, cultural, recreational and educational values and potential of NSC parks and reserves.