



Ministry for the  
**Environment**  
*Manatū Mo Te Taiao*



# Measuring carbon emissions from land-use change and forestry

THE NEW ZEALAND LAND-USE AND CARBON ANALYSIS SYSTEM



**LUCAS**<sup>PS</sup>



New Zealand Government

## New Zealand's profile

### Trends in New Zealand's emissions

New Zealand's total emissions trend is different to that of other developed countries. Instead of a predictable increase or decline in emissions, the trend for New Zealand is year-to-year fluctuations. These fluctuations are largely due to two factors. The first is the change in the proportion of non-renewable electricity generation, affecting CO<sub>2</sub> emissions. The second is the effect of droughts on agricultural productivity and livestock numbers, leading to changes in nitrous oxide and methane emissions.

### New Zealand's national greenhouse gas inventory

In New Zealand, the inventory is managed and produced by the Ministry for the

Environment. Emission and removal estimates are compiled using data from a number of government agencies, particularly the Ministry of Economic Development, the Ministry of Agriculture and Forestry and Statistics New Zealand. The inventory forms part of the Ministry for the Environment's wider 'state of the environment' reporting.

### Reporting systems

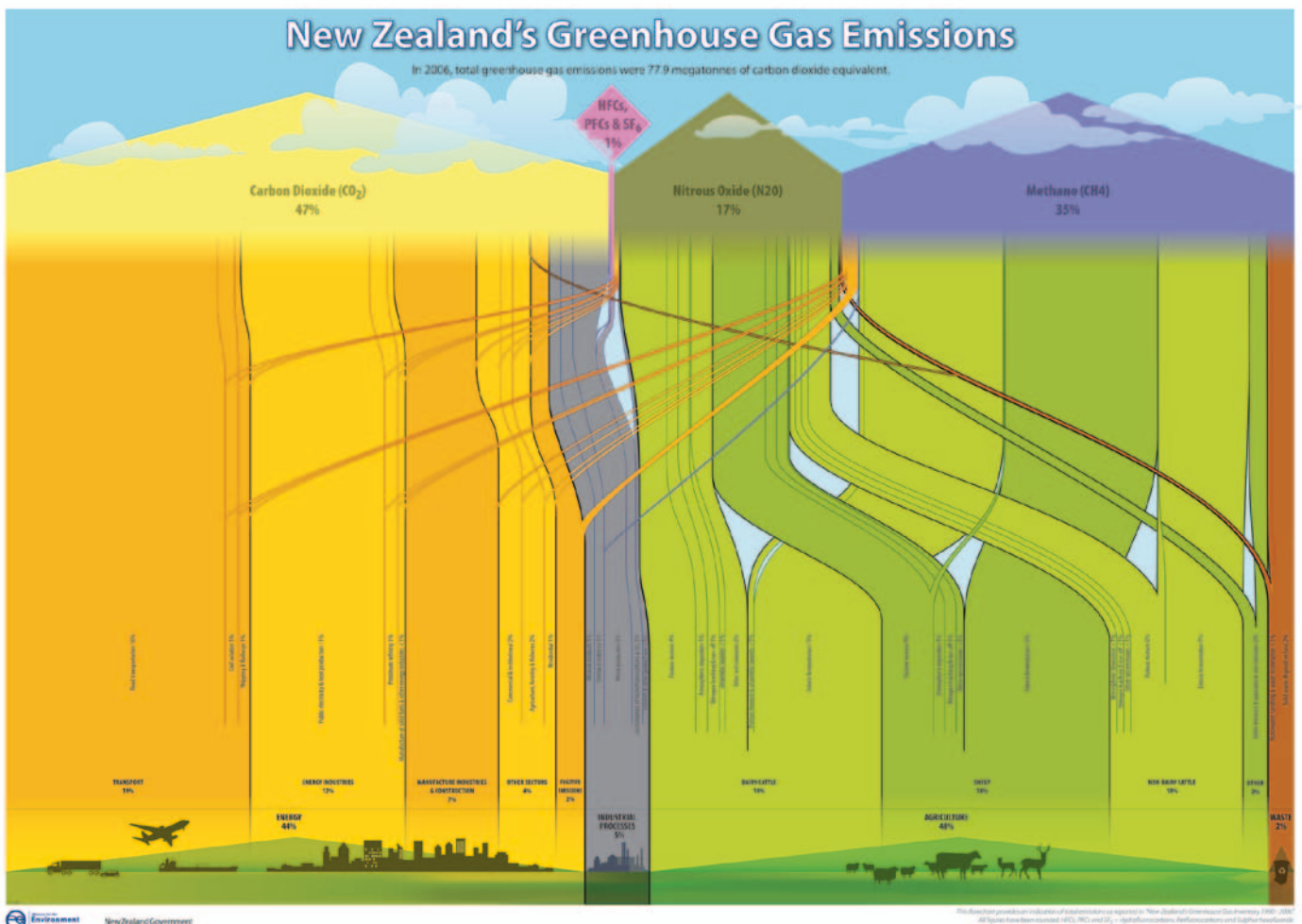
On signing up to the Kyoto Protocol in 2002, New Zealand did not have appropriate databases and reporting systems relevant for the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol reporting. The Land-use and Carbon Analysis System (LUCAS) was therefore established in 2005.

The programme started with development of the methodologies appropriate for New Zealand in accordance with the UNFCCC

and the Kyoto Protocol. LUCAS is now helping New Zealand meet its international reporting requirements. It tracks and quantifies changes in New Zealand land use, particularly since 1990.

The New Zealand Ministry for the Environment and the Ministry of Agriculture and Forestry compile the emissions and removals reported in the land use, land-use change and forestry (LULUCF) sector. Changes in planted forest stocks are assessed from national forest survey data and modelling of the planted forest estate. The IPCC default approach is used for the cropland, grassland, wetland, settlements and other land-use categories.

Results from LUCAS will improve the reporting for the LULUCF sector and provide consistency with reporting under the Kyoto Protocol.



### Key design considerations

#### Cross-government collaboration

– While the LUCAS Programme is led by the Ministry for the Environment, the New Zealand Government has encouraged all-of-government benefits realisation and capability building. For instance, the creation of shared systems and services between departments and making all datasets freely available is an important outcome.

#### Meet IPCC Good Practice Guidance

– Transparency, comparability, completeness, accuracy and consistency are key IPCC requirements. The system design, including the choice of technology and funding, focuses heavily on the ability to demonstrate and meet these requirements.

#### Partnerships and whole of New Zealand benefit –

New Zealand’s climate change response strategy provides several opportunities with significant social, environmental and economic benefits. As such, it is being implemented in partnership with the science (local and international) and business communities.

## LUCAS Data Management System

The LUCAS Data Management System stores, manages and retrieves data for international greenhouse gas reporting for the LULUCF sector. The system comprises three primary applications: the Geospatial System, the Gateway and the Calculation and Reporting Application. These systems are used for managing the land-use spatial databases and the plot and reference data, and for combining the two sets of data to calculate the numbers required for Climate Change Convention and Kyoto Protocol reporting.

The key objectives of these systems are to:

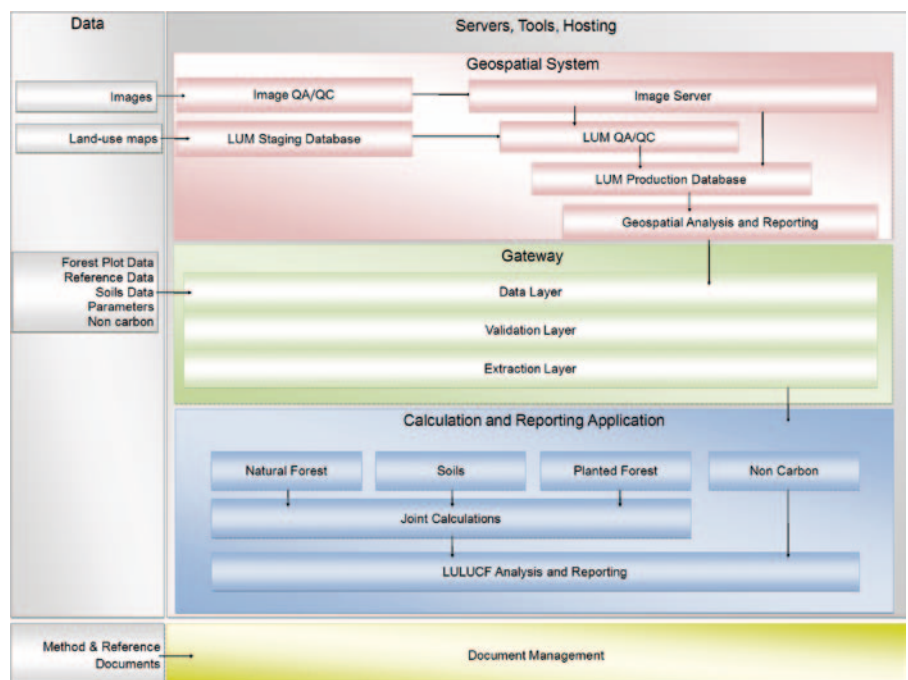
- provide a transparent system for data storage and carbon calculations
- provide a repository for the versioning and validation of plot measurements and land-use data
- calculate carbon stocks, emissions and removals per hectare for land uses and carbon pools based on the plot and spatial data collected
- calculate biomass burning and liming emissions by land use based on spatial and emission factors stored in the Gateway
- produce the outputs required for the LULUCF sector reporting under the Climate Change Convention and the Kyoto Protocol.

The data collected as part of LUCAS is stored and manipulated within three systems: the Geospatial System, the Gateway and the Calculation and Reporting Application (CRA).

The Geospatial System consists of hardware and specific applications designed to meet LULUCF reporting requirements. The hardware largely comprises servers for spatial database storage, management, versioning and running web mapping applications. The core components of the Geospatial System consist of:

- external images, feeding into an image server
- a land-use map (LUM) data supplier
- a LUM import/export application – Windows form and Arc object
- a LUM database (Arc SDE) and associated web-based QA/QC application
- a LUM attribute tool application
- a spatial Gateway database (Arc SDE) (Staging)
- versioning and validation
- a core geospatial database used to produce summary land-use tables, for use in the Calculations and Reporting Application (CRA).

These components can be accessed through a standard ArcGIS desktop.



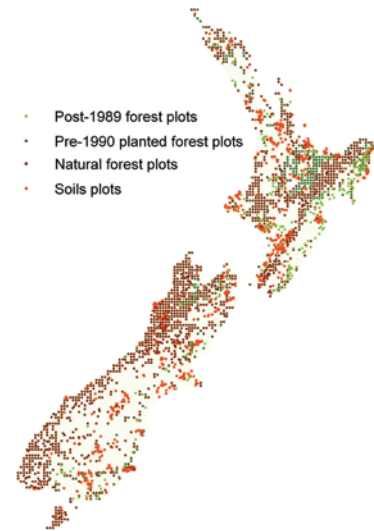
## New Zealand's National Inventory System

The method development for the carbon accounting system within LUCAS focuses principally on carbon inventory and modelling in natural forest, planted forest and soils. A first priority was to develop sound techniques for collecting land-use data, and then to work out how to calculate the carbon values for each of the five carbon pools (above ground biomass, below ground biomass, dead wood, litter, soil organic matter). The methodology needs to meet the IPCC's Good Practice Guidance.

The results of investigations and method development for each component are published in independent peer-reviewed journals. This provides transparency and ensures that New Zealand approaches are widely understood.

New Zealand's National Forest Inventory system uses permanent sample plots established systematically on a 4 or 8-km grid as follows:

- Natural Forest (8-km grid)
- Pre-1990 Planted Forest (8-km grid)
- Post-1989 Forest (4-km grid).



### Natural forest inventory

Natural, native or indigenous forest covers about 8.2 million hectares – 23 per cent of New Zealand's land area. This area has changed dramatically over the last century but has been relatively stable recently.

To estimate carbon stock in natural forest, New Zealand uses data collected from a network of 20 m x 20 m permanent plots which were established on a regular 8-km grid system ~1257 installed between 2002–07 total.

A natural forest plot network was installed to provide an unbiased estimate of carbon stocks, and to collect data suitable for determining whether New Zealand's natural forests are carbon neutral, or whether they are a carbon source or sink. Carbon stocks in live biomass and woody debris are estimated by collecting data related to the volumes of trees, shrubs and woody debris and converting them to carbon stocks per hectare using allometric functions and regression equations. Additional plot data have been collected to meet other national and international reporting requirements, such as biodiversity assessments.



### Exotic planted forest inventory

In order to determine carbon stocks at national level, site-specific data is gathered through permanent sample plots in the two categories of forest – first in post-1989 and subsequently in the pre-1990 forests. Post-1989 forest sites are located throughout New Zealand where a randomly allocated 4-km grid coincides with mapped post-1989 forest. In 2007/08, around 300 permanent post-1989 forest sample sites were measured by ground crews using standard forestry inventory methodology.



### Soil carbon monitoring

The Soil Carbon Monitoring System estimates the steady state soil carbon stocks for each land use (t/C/ha). For example, low-producing grassland has 117 t soil C / ha; whereas under planted forest the carbon stock is 104 tC/ha. By multiplying the differences in soil carbon stocks for each land-use change by the area of that land-use change, we get the soil carbon stock change over a period of 20 years. This is the time required for the soil C to reach equilibrium under a new land use.

1235 plots exist in New Zealand's Historic Soils dataset.

## Using LiDAR to improve carbon stock quantification in planted exotic forests

### LiDAR use in New Zealand

The term LiDAR is short for **L**ight **D**etection **A**nd **R**anging. The technique is also known as Laser Scanning. This determines the distance to an object or surface using concentrated light pulses. It is an 'airborne mounted technology', that is, it tends to be used from aircraft. LiDAR uses light waves rather than radio waves, but otherwise it is very similar to radar ('radio detection and ranging'). The range to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal.

Under the LUCAS programme, the use of LiDAR was as an alternative to exotic forest plot measurements. This avoids the problem of access to forestry land where owners are uncooperative, or where access is limited or restricted. Measured tree/forest characteristics using LiDAR can be correlated with concurrent field measurements.

The relationships between the data can then be applied to plots where only LiDAR measurements are available. LUCAS uses this to determine *carbon stock* in the above-ground biomass *carbon pool*.

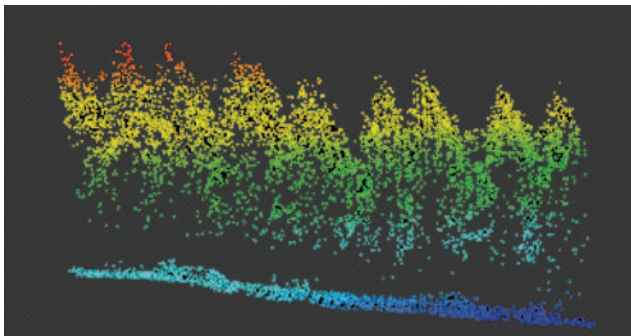
LiDAR measurements are well underway and, in combination with field measurements, are contributing to estimates of the total amount of carbon in forestry plots across New Zealand.

New Zealand has experienced rapid changes in land use since the 1840s. Currently, it comprises 23 per cent natural and 6 per cent planted forest. With no national forest inventory to provide data for carbon analysis in plantation forests, LiDAR became an obvious choice.

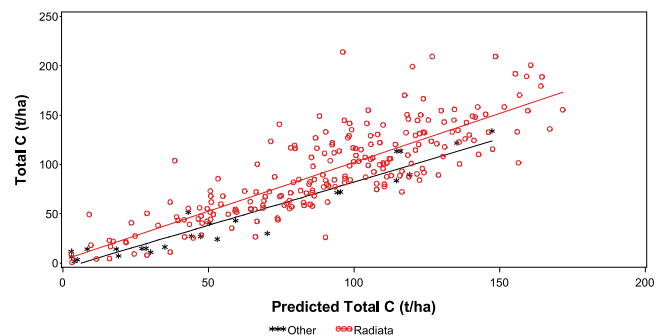
LiDAR has enabled New Zealand to improve the estimation of carbon stock in planted exotic forests by 6–10 per cent over other methods previously used.

Key facts about the benefits of using LiDAR include:

- ability to predict carbon stock where no ground measurements exist
- increased precision through use of consistent parameters
- LiDAR height measurements were found to be more precise than manual height measurements
- combined with a double sampling approach, LiDAR increases the precision of carbon estimates by between 6 and 10 per cent.



Part of a LiDAR image of a *Pinus radiata* forest near Rotorua. This extract is 10 m wide and clearly shows the profile of nine trees. The ground surface shows in blue and the tree foliage in light blue through green and yellow to red. Yellow and red denote the highest points above the ground surface. The absence of any lower branches indicates the forest has been pruned.



The graph shows ground measured carbon (total C, x-axis) versus carbon stock predicted by LiDAR metrics (predicted C, y-axis).

In this instance, LiDAR proved to be capable of predicting carbon stock to 74 per cent of the accuracy of ground measurements, ie,  $R^2 = 0.74$ ;  $RMSE = 22.7 \text{ t C ha}^{-1}$ .

Ground measurements involved measuring and recording numerous parameters in 0.06 hectare plots spread throughout New Zealand. Key parameters measured and recorded include: tree species diameter, height, management regime, tree health and soil nutrients. These parameters were then entered into the Forest Carbon Predictor giving carbon stocks and enabling projections of stock through the Kyoto First Commitment Period.

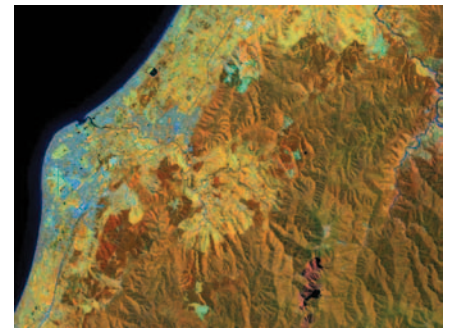
## Using remote sensing to map land use

### New Zealand offers unique challenges for mapping from space

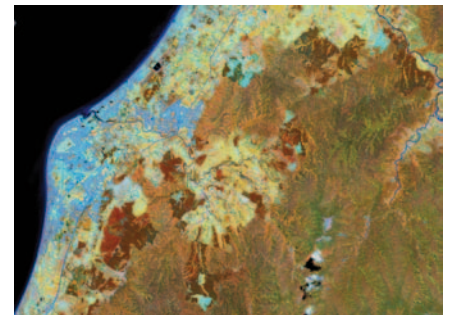
The starting point for land-use mapping across New Zealand is satellite imagery. Land-use mapping from satellite imagery over New Zealand is hampered by two factors. Firstly, it is difficult to get complete coverage of the country in one summer due to cloud cover, and secondly, steep slopes cause shadowing which makes automatic classification of the imagery difficult.

Landcare Research New Zealand Ltd has developed techniques to remove the effects of terrain from satellite imagery, which significantly improves the image classification and subsequent land-use mapping.

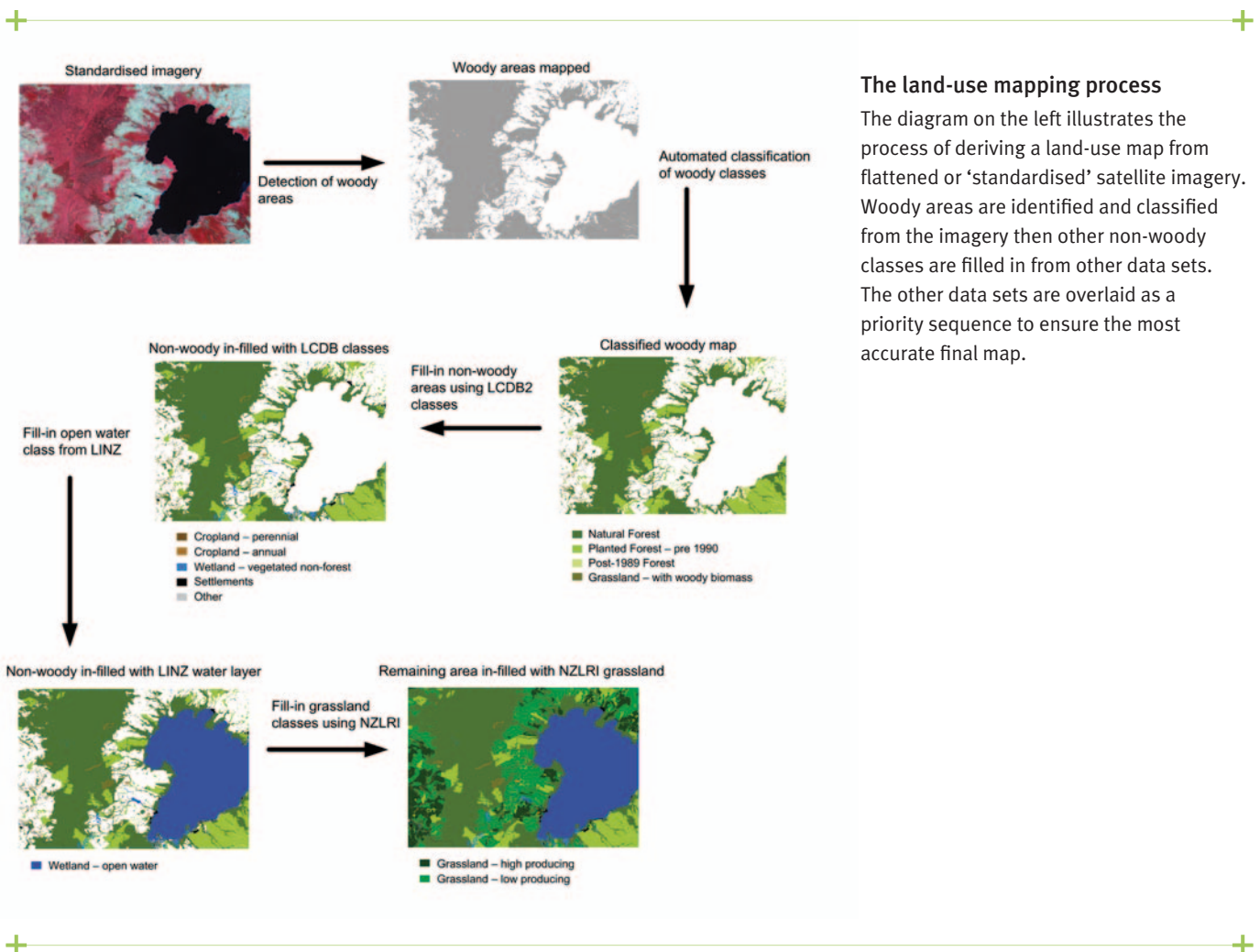
The top image on the right shows a SPOT 5 image (3,4,2 band combination) of an area just north of Wellington, New Zealand. It extends into the Tararua Ranges with peaks up to 800m in height. The bottom image shows the 'flattened' version of the same scene, where the effects of slope have been removed. This type of image is used for creating the land-use maps.



SPOT 5 ortho-rectified satellite image of the Kapiti Coast near Wellington, New Zealand.



Same area as above once topographic correction has been applied.



### The land-use mapping process

The diagram on the left illustrates the process of deriving a land-use map from flattened or 'standardised' satellite imagery. Woody areas are identified and classified from the imagery then other non-woody classes are filled in from other data sets. The other data sets are overlaid as a priority sequence to ensure the most accurate final map.

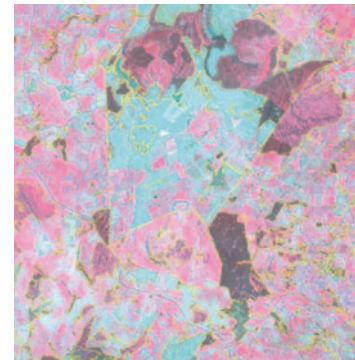
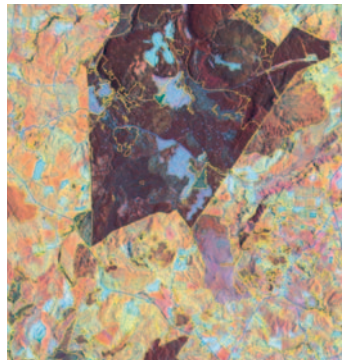
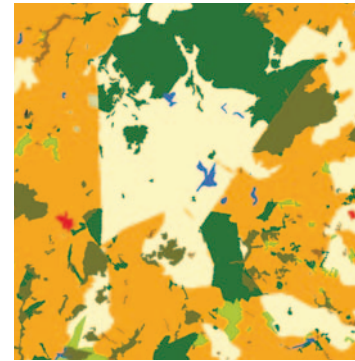
## Mapping land use, land-use change and forestry

### Detecting change

The 1990 land use is derived from classification of Landsat 5 satellite imagery acquired between summer 1989 and summer 1992.

The 2008 land use is derived from classification of SPOT 5 satellite imagery. There are 161 scenes that cover New Zealand. Eighteen per cent of the scenes were acquired during summer 2006/2007 and 82 per cent of the scenes were acquired during summer 2007/2008.

Once land-use maps are completed for 1990 and 2008, change can be identified. The images to the right show an area north of Taupo, New Zealand where deforestation has occurred. The pre-1990 planted forest area (dark green) has been converted to high-producing grassland (pale yellow). This is likely to be due to conversion to a dairy farming land use.



1990 Land use and Landsat 5 imagery

2008 Land use and SPOT 5 imagery

### Land use, land-use change and forestry (LULUCF)

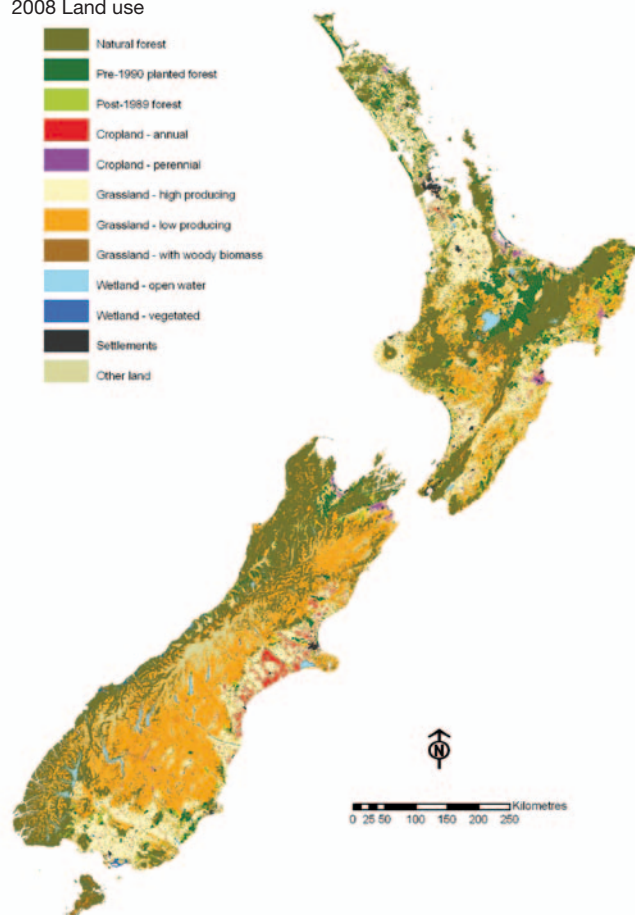
This is the only sector that acts as an overall carbon sink, absorbing more greenhouse gases from the atmosphere than it emits. Net removals from LULUCF can fluctuate greatly due to the planting, harvesting and deforestation of New Zealand's planted forests.

### Changes – 1990–2008

Between 1990 and 2008, net removals decreased by 4.9 Mt CO<sub>2</sub>-e (15.7 per cent). This decrease in net removals is largely due to the harvesting and replanting of plantation forests in the five years prior to 2008. These activities have lowered the average age and therefore CO<sub>2</sub> absorptive capacity of planted forests. Another factor in this decrease of net removals is an increase in emissions from the conversion of forestland to grassland, emitting greenhouse gases into the atmosphere.

2008 Land use

- Natural forest
- Pre-1990 planted forest
- Post-1990 forest
- Cropland - annual
- Cropland - perennial
- Grassland - high producing
- Grassland - low producing
- Grassland - with woody biomass
- Wetland - open water
- Wetland - vegetated
- Settlements
- Other land



## For more information

See the LUCAS website:

[www.mfe.govt.nz/issues/climate/lucas/](http://www.mfe.govt.nz/issues/climate/lucas/)

View the latest LUCAS newsletter:

[www.mfe.govt.nz/publications/climate/looking-at-lucas/index.html](http://www.mfe.govt.nz/publications/climate/looking-at-lucas/index.html)

See the latest New Zealand Greenhouse Gas Inventory report:

[www.mfe.govt.nz/publications/climate/greenhouse-gas-inventory-2010/index.html](http://www.mfe.govt.nz/publications/climate/greenhouse-gas-inventory-2010/index.html)

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