Chapter 6

Land-Use Change and Forestry (LUCF)

6.1 Introduction

The LUCF sector represented the removal of approximately 33% of all greenhouse gas emissions in 2001 and there was an increase in net removals of 0.7% from 2000. Net removals in 2001 were almost 10% above net removals in 1990.

New Zealand has a substantial estate of planted forests, mainly comprising *Pinus radiata*, and has well established data on its extent and characteristics. These forests have removed and stored substantially more carbon over the period 1990 to 2001 than has been emitted through forest harvesting of both planted and natural forests together.

Some land-use change has been occurring, mostly in the form of new forest planting. Rates of new planting were high between 1992 and 1998. During this period new planting averaged 69,000ha per year. Since 1998 the planting rate has declined but is still occurring at an average annual rate of between 30,000ha and 40,000ha. However, a current lack of data on other forms of land-use change and changes in soil carbon has limited reporting in this sector. A substantial project has been funded since 1996 to remedy these gaps in New Zealand's inventory. This project is discussed at the end of this chapter.

6.2 Country-specific approaches different from the IPCC methodology

The worksheets for this section of the inventory are in a format that is consistent with the 1996 revised IPCC guidelines. However, these worksheets have been designed to match New Zealand's national methodology for estimating emissions and carbon uptake by planted forests. For transparency, these worksheets have been designed to be as equivalent as possible to the IPCC worksheets. As a modified form of the IPCC worksheets has been used, Tables 5(a)-(d) of the CRF have not been completed.

The worksheets with carbon/CO_2 emissions from "land conversion" have not been included in the "uptake from forests" in the reporting tables. LUCF therefore shows data in both the CO_2 emission and the CO_2 removals columns. This has been done to make the calculation more transparent. For completion of Table 5 and the summary tables of the CRF, the net CO_2 emissions/removals figure has been reported (as per the reporting instructions accompanying the tables).

The worksheets discussed below are included at the end of the chapter and cover emissions/removals for 1990 to 2001.

Worksheet 5.1 equivalent

Uptake has only been estimated for planted forests, as this is the major anthropogenic sink. Surveys and forest models have been used to estimate emissions and removals. Estimates include above- and below-ground biomass components (including the forest floor). The models account for both the removal of stemwood carbon through harvesting and the release of non-stemwood carbon on-site over a longer period following harvesting. The release of carbon through harvesting natural forests is also accounted for. This methodology gives significantly more accurate results than could have been achieved using the IPCC methodology. It is assumed that stemwood removed at harvest for both natural and planted forest is oxidised in the year of harvest.

Worksheet NZ 5a-d

Data on forest and grassland conversion is currently limited. Emissions from clearing land for new forest planting are reported (including carbon emissions as the carbon uptake in the subsequent planting is already accounted for in Worksheet 5.1). Non-CO_2 emissions are reported for scrub and forest wildfires (as per the IPCC default method the carbon is assumed to be absorbed during re-growth) and for land clearing.

Abandonment of managed lands

Abandonment of managed lands is not reported due to a lack of data. However, some pasture does revert to scrub in marginal farming areas.

Soil carbon

Changes in soil carbon are also not reported due to a current lack of data.

6.3 Methodological approach

The estimates derived from modelling March years are converted to calendar years, before applying a three-year average as per the IPCC approach.

The following calculations were made to estimate emissions and the uptake of carbon/non-CO_2 in the LUCF sector:

Changes in forests and other woody biomass stocks

1. Uptake of carbon by planted forests.
2. Emissions from planted forests through harvesting.
3. Emissions from natural forests from unsustainable harvesting.

Forest and grassland conversion

1. Emissions from clearing land in preparation for new forest planting.
2. Non-CO_2 emissions from scrub and forest wildfires and land clearing.

Planted forests

The total biomass in New Zealand's planted forests is relatively simple to estimate as planted forest stands are almost exclusively of a single species and single age. Annual surveys are used in conjunction with the models (C-change and FOLPI) to estimate forest biomass and carbon at one point in time. The models "time-shift" the estate forwards to represent future forest growth and forest management, including harvesting. The models then time-shift backwards to improve historical estimates.

This time-shifting of the estate is necessary to minimise errors. Changes in carbon stocks are typically very small relative to the stocks themselves, and even small inconsistencies in the stocks will lead to large errors in the stock change. As the estimation of carbon stocks is continuously being improved, it is necessary to recalculate both past and future years in each run of the model.

The process begins with the National Exotic Forest Description (NEFD) survey, which provides estimates of the forest area and merchantable stemwood volume (via yield tables). The NEFD subdivides the forest estate by crop-type and age class. A crop-type is an aggregate of forest stands that are similar in respect to species, site quality, management regime and location. Each crop-type has a yield table that provides estimated volumes of stemwood per hectare by age.

To simplify the subsequent modelling, all crop-types are then aggregated to form a single, national area-weighted crop-type (still broken down by age class) and associated area-weighted national yield table.

Both models used in this part of the inventory are managed and run by the New Zealand Forest Research Institute (Forest Research). The first is the **C-change model** (previously known as the CARBON/DRYMAT model). This estimates carbon stock per hectare, by component and age-class, from stemwood volume data. The modelling steps are as follows:

1. Stemwood volume is first converted to an oven-dry biomass weight.
2. The dry weight of non-stemwood components (bark, branches, foliage, cones, stumps, roots, floor litter and understorey) is from stemwood volume using allometric equations. Various equations built into the model take account of age, spacing and site fertility.

3. Total forest biomass is lastly converted to carbon weight. Carbon is taken as being 50% of biomass.

The forestry models

Several simplifications have been made in the C-change model. Firstly, the wood density factors for the different age classes assume that all trees grow in a medium-density region of New Zealand. Secondly, the model takes the weighted national crop-type as being wholly *Pinus radiata*, when in fact around 10% of the estate is made up of Douglas fir *(Pseudotsuga menziesii* – 5%) and other species.

The C-change model assumes four tending and thinning regimes. These scenarios are then aggregated to show the stock of biomass and carbon for the total planted forest estate at one time.

Biomass and carbon totals take into account the biomass left in the forest after harvesting. Harvesting is defined in the models as the removal only of the stemwood from the forest. Non-stemwood biomass is modelled to decay on-site over approximately 12 years.

The biomass and carbon stocks at one point in time are available for time-shifting to give carbon stocks for each modelled year and changes in carbon stocks between those years. This is done in the **FOLPI** (Forest Oriented Linear Programming Integrator) forest estate model, the second of the two models run by Forest Research. FOLPI is a linear programming model that optimises the management of the forest estate across time while maximising the discounted harvest volume. The model simulates actual rates of planting and harvesting where historic data exists.

Among the outputs of the FOLPI model are the LUCF inventory results for 1990 to 2001. These results include:

1. Stemwood volume harvested from the planted estate and, hence, carbon "emitted" in that harvest.
2. *Total stock of estate carbon* after harvesting in each year (accounting also for the decay of non-stemwood carbon left after harvesting).

From the *total stock* values we calculate the *uptake of carbon (net of harvest)*. The *gross uptake of carbon* is then calculated by adding the harvested stemwood carbon back into the net carbon uptake figures. This gives the change in carbon stock between last year's harvested forests and this year's unharvested forests.

This approach, in conformity with IPCC methodology, assumes that all carbon held in harvested stemwood is emitted at the time of harvest (the decay of non-stemwood biomass is accounted for in the models and hence in the net carbon uptake results). The difficulty with this approach is that some carbon remains stored in long-life wood products and a substantial proportion of harvested wood is exported and therefore removed from New Zealand. The emissions from harvest figures therefore refer to potential, rather than actual, emissions.

For more information regarding the NEFD surveys, the most recent publication by the Ministry of Agriculture and Forestry (2001) was used. Information regarding the modelling methodology is provided in Wakelin and Te Morenga (1995), although greater detail on certain aspects of the work can be found in Hollinger et al. (1993) and Garcia (1984). The model results used here are given in Te Morenga and Wakelin (2003) and replace those previously reported in Marshall and Wakelin (2002).

Natural forests

Estimates of the stemwood volumes removed from natural forests were provided by the Ministry of Agriculture and Forestry. These figures show a significant decrease in natural forest harvesting following the passing of new legislation in 1993 and its implementation in 1995. The Forest Act 1993 has made logging in natural forests illegal, but for several limited-life exemptions. Natural forest harvest data for 1995 onwards therefore show only logging from these exempted forests. Such logging is assumed to cease by 2005, although government policy announcements mean that unsustainable harvesting in some areas will end (and has ended) sooner than this.

Stemwood volumes are converted to oven-dry weight using a factor of 0.5 (accounting for wood moisture) and then expanded to include non-stemwood biomass using a factor of 2.04. As for harvesting in planted forests, emissions from harvesting natural forests are potential rather than actual.

Land clearance for new forest planting

Data is available from the Ministry of Agriculture and Forestry including the proportion of new forest planting that occurs on scrubland. There is data from 1993 to the present and we assume this proportion to have been around 20% prior to that time. It is assumed, for calculation purposes, that 25% of the scrub biomass is burnt on-site and that the remainder is left to decay.

Wildfire burning

Emissions from wildfires are based on fire reports collected by the National Rural Fire Authority. These reports show the areas of forest and scrub burnt. It is assumed that all forest burning occurs in natural forests. As reported in the national inventory reports submitted in 2001 and 2002, carbon released from scrub and forest burnt in wildfires is no longer reported since it is mostly re-absorbed during re-growth on the burnt land. Hence, only non-CO_2 emissions are reported here (consistent with the IPCC default method). For planted forests, fires occur relatively infrequently and fire-damaged standing trees are usually salvaged and thus appear in harvest statistics. Some areas in the Fire Authority statistics involve land clearing, however the Fire Authority does not specify whether this is for agricultural or forestry purposes. This may imply some double-counting between these figures and those allowed for in the land clearing for new forest planting calculations discussed above.

As reported previously, the quantity of on-site biomass for both scrub and forest, used in the land conversion calculations (Worksheets 5a-d), is now based on the (provisional) results of research into indigenous forest and scrub (adapted from Hall et al., 1998). The values reported (136t dm/ha for scrub and 364t dm/ha for forest) are based on a national area weighted average for biomass per hectare for a range of the principal forest and scrub vegetation classes.

The non-CO_2 emissions estimated for burning of both forest and scrub biomass are likely to be overestimated as not all biomass is typically consumed in a fire event. For forests, the typical fuel load combusted may only be 10-40% of on-site biomass. For scrub, the upper value could be somewhat higher (depending on seasonal and other factors), although combustion is again unlikely to be complete for wildfire events (Fire Researchers, pers comm.). The current assumptions reflect a lack of data on the percentage of fuel load combusted.

6.4 Changes since the last inventory submission

The incorporation of new input data has not resulted in significant overall changes to the inventory but has meant revisions to all years in the time series.

New data incorporated since the last inventory included the following:

1. The results of the latest NEFD survey as at 1 April 2001 have been incorporated in the planted forest models. This brings in new data for new planting, restocking and harvesting and also improves data for earlier years in the time series. The total forest estate area after harvest for the year ending March 2001 is based on (a) the latest area estimates provided by the 2001 NEFD; (b) an estimate of the area to be planted during the year; and (c) an estimate of the area harvested during the year, which is derived from the estimate of clearfell volume production. The total estate area for the years before 2001 has been estimated through back-calculations using this latest NEFD area data combined with historic new planting and harvesting information.
2. New proportions of area by NEFD regime have been used to weight the carbon yield. Area data and carbon yields underlying the models in this report are similar to those used previously. The difference in net "managed forest" CO_2 removals between this and the previous inventory is generally of the order of less than 2%. Further work will be undertaken to investigate whether alternative inventory and modelling approaches could be used for inventory estimates, to avoid recalculation of historic estimates either as a result of changes in future intentions or as a product of the forwards and backwards forecasting required by the current model.
3. The area of new land planting is based on Ministry of Agriculture and Forestry statistics. These estimates are revised annually (including for the previous years, as provisional estimates are replaced by confirmed actual areas).

Estimates of CO_2 emissions from the liming of agricultural soils were included in the CRF for 2000. This submission provides data on these emissions for all years from 1990 in a table at the end of this chapter and via the recalculation tables in the CRF.

The recalculation tables also show that, although the last National Inventory Report submission included tables (like the ones at the end of this chapter) showing the CO_2 released from burning on land cleared for new forest planting, due to an oversight these emissions were not included in the total CO_2 emissions from this source. This has been corrected in this submission and included in the recalculations reported for the whole of the time series.

6.5 Uncertainty

Attempts have been made to quantify the uncertainties in the carbon sequestration estimates for planted forests. However, it is difficult to quantify the overall error due to the assumptions implicit in the models. Some uncertainties within the CARBON/DRYMAT model are well characterised (Hollinger et al., 1993). These include ±3% for wood density, ±15% for carbon allocation and ±5% for carbon content. Taking the root mean squares of the uncertainties indicates that the proportional error in the carbon sequestration estimates is likely to be at least ±16%.

However, the overall level of uncertainty could be higher, depending on the errors in the NEFD area and commercial yield data. The total national planted area is thought to be accurate to within ±5% (Ministry of Agriculture and Forestry, 2001) and the yield tables are assumed to be accurate to within ±5%.

Sensitivity analysis was conducted using the above accuracy ranges for total planted area and commercial yield and a proportional uncertainty error of ±16%. The CARBON/DRYMAT model runs indicate that the precision of the carbon sequestration estimates could be of the order of ±25%.

No uncertainty estimates are currently available for emissions from unsustainable harvesting of natural forests or from forest and grassland conversion.

6.6 Future work

Both forest models held by Forest Research are regularly revised and re-run on the basis of the latest year's NEFD survey. NEFD data improves each year because more planted area is included and boundaries are defined more precisely. This will lead to future revisions and improvements in the inventory data, including revisions to historical years as a result of back calculations or new data[4].

Major new work in this sector includes research on the carbon held in soils, scrub and natural forests. This research was initiated by the Ministry for the Environment in 1996 and is being carried out jointly by Landcare Research New Zealand and Forest Research.

[4] New data in this context includes the case where the NEFD survey may detect previously unrecorded stands of trees at particular ages. In such cases, NEFD data for the previous seven years must be adjusted to account for the revised area in each age class. A similar situation arises with harvesting data and the need to adjust historical data to match the latest information on harvest by age class. Changes in the historical time series data of estate area by age class can thus affect both uptake and harvest estimates.

This research will make it possible to fill the major gaps in the current inventory, including land-use changes other than new forest planting, the abandonment of managed lands, and changes in soil carbon. The project is a five-year programme with the following objectives:

1. The estimation of carbon storage in soils, scrub and natural forests in 1990.
2. The development of a national system for monitoring changes in carbon storage.
3. The development of an effective information system to manage the above information.

The soil carbon work focuses on the major factors influencing carbon storage (the soil and vegetation research components have been separated for the purposes of this project). Data on soil type, land use and climate is currently being improved and is being used to stratify New Zealand into compartments with similar characteristics, thus revising estimates of soil carbon across the country and enabling estimates of the changes in carbon stock that accompany changes in land use and land management. Changing carbon storage will be monitored over time to establish the time profile over which it occurs.

The research on scrub and natural forest vegetation is synthesising several existing sources of information on vegetation area and composition, updating and completing this data as necessary. Other research is aimed at improving data on vegetation biomass and the carbon held in the various vegetation components. It is hoped that dead material and below-ground material will be able to be included in the resulting carbon estimates.

Provisional results are available from the work under objective 1 above. Hall et al. (1998) have estimated that in 1990 carbon stored in natural forests was 933Mt C, while 527Mt C were stored in scrub and other woody mixed-vegetation. Forest floor litter carbon is estimated separately, based on Tate et al. (1997), as containing 570Mt C for all natural vegetation (i.e. both forest and scrub areas). These estimates are highly sensitive to both the accuracy of mapped areas and heterogeneity within mapped classes. Current (very provisional) estimates for soil carbon at soil depth intervals of 0-0.1, 0.1-0.3, and 0.3-1m are 1,208Mt C, 1,532Mt C, and 1944Mt C respectively. Some soil cells are still poorly represented in the database and additional field work is being undertaken.

Further information on this project and initial estimates of carbon stocks at 1990 are stated by Lawton and Barton (2002), Lawton and Calman (1999), and Hall et al. (1998).

In 1999, the carbon monitoring systems developed during the first three years of the project were reviewed by an international panel of forestry and soil experts. The panel's report concluded that the systems being developed for forests were consistent with current forest inventory practices in other countries. Furthermore, the soils that the system represented were measured in a significantly advanced methodology as compared with the IPCC default method (Theron et al., 1999). The international review of the system was held in time for the key recommendations of the review to be undertaken before the development phase was concluded.

The statistical design of the carbon monitoring system provides for the establishment of 1,400 permanent field plots on an 8x8km grid across indigenous forest and shrub across territorial New Zealand. This includes the North and South Islands, Stewart Island, the Chatham Islands and other offshore islands. A range of standard tree and other botanical measurements and site characteristics is recorded for each 20x20m plot. Soil samples to a depth of 0.3m are taken for one in three plots and are analysed for carbon content.

The carbon monitoring system is currently moving from its design phase to its implementation phase. The first year's field work for the operational carbon monitoring system commenced in January 2002 and was completed early in 2003. The second year's field work began in March 2003. Field work over three more years will be required to install the complete network of field plots. Following this, another five-year round of sampling will be required to validate the implementation and begin monitoring of any changes. The current intention is then to repeat these measurements every ten years.

In conjunction with the above field work, 40 paired soil plots will eventually be established to monitor key changes in soil carbon when land-use changes (i.e. scrub to pasture and pasture to plantation forest and vice versa). The first four paired plots are planned to be established in the second quarter of 2003.

A remote-sensing based Land Cover Database (LCDB), significantly improving the accuracy of the mapped land use and land cover, became available in 2000. The LCDB has provided a tool for improved information on the extent of all forest types (planted and natural forest, and scrub) and land conversion and abandonment. Work is underway to commission LCDB 2, which is intended to increase the number of major classes and improve the thematic depth for forest classes. It is expected that LCDB 2 will be completed in 2004. LCDB 2 is also likely to draw on ancillary land-use data from annual landowner surveys such as those involving AgriBase.

Further enhancements to the above described system are planned, including the incorporation of IPCC Good Practice once it has been agreed and adopted by the Conference of the Parties.

6.7 References

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Appendix to Chapter 6:
Land-use change and forestry calculation tables 1990 to 2001
Agricultural lime calculation table 1990 to 2001

Land Use Change and Forestry calculation tables 1990 -2001

SCENARIO Medium New Planting

FOREST RESOURCES All Forests

Module Land-use change and forestry (New Zealand)
Submodule Changes in forest and other woody biomass stocks
Worksheet Equivalent to 5.1 (2 of 3)
Sheet Carbon release from harvesting in *Pinus radiata* plantations (temperate) and native forests

	Stem volume in plantation forest harvest[1] (merch. m^3)	Biomass conversion ratio[2] ($t\ dm/m^3$)	Dry matter in stem[1,3] t C/t dm = 0.5 (t dm)	Carbon in plantation forest harvest[1] (t C)	Stem volume in native forest harvest (merch. m3)	Biomass conversion ratio ($t\ dm/m^3$)	Biomass expansion ratio ($t\ dm/m^3$)	Dry matter in total native forest harvest (t dm)	Carbon in native forest harvest (t C) t C/t dm = 0.5	Carbon release from total forest harvest (t C)
1990	10,813,787	0.497	5,371,388	2,685,694	365,000	0.50	2.04	372,300	186,150	2,871,844
1991	11,797,488	0.482	5,691,506	2,845,753	307,667	0.50	2.04	313,820	156,910	3,002,663
1992	12,500,584	0.482	6,024,758	3,012,379	257,333	0.50	2.04	262,480	131,240	3,143,619
1993	13,232,522	0.481	6,368,363	3,184,182	205,000	0.50	2.04	209,100	104,550	3,288,732
1994	13,987,203	0.479	6,693,260	3,346,630	158,000	0.50	2.04	161,160	80,580	3,427,210
1995	14,700,793	0.471	6,927,101	3,463,550	107,333	0.50	2.04	109,480	54,740	3,518,290
1996	15,214,390	0.455	6,921,513	3,460,757	50,000	0.50	2.04	51,000	25,500	3,486,257
1997	15,202,118	0.472	7,169,323	3,584,662	56,667	0.50	2.04	57,800	28,900	3,613,562
1998	15,746,397	0.482	7,590,993	3,795,497	57,667	0.50	2.04	58,820	29,410	3,824,907
1999	16,672,535	0.499	8,321,132	4,160,566	57,000	0.50	2.04	58,140	29,070	4,189,636
2000	18,226,875	0.492	8,961,734	4,480,867	38,333	0.50	2.04	39,100	19,550	4,500,417
2001	19,576,074	0.493	9,659,696	4,829,848	23,667	0.50	2.04	24,140	12,070	4,841,918

All data are three-year straight averages.
[1] Estimated using Forest Research models.
[2] Derived from the model results contained in columns 1 and 3.
[3] No adjustment from stem volume to total biomass volume is made here as on-site decay is accounted for in the carbon uptake data.

Module Land-use change and forestry (New Zealand)
Submodule Changes in forest and other woody biomass stocks
Worksheet Equivalent to 5.1 (1 of 3)
Sheet Carbon uptake in *Pinus radiata* plantations (temperate)

	Total forest estate area (net of harvest) (ha)	Total Forest estate carbon (net of harvest) (t C)	Forest estate carbon uptake (net of harvest) (t C)	Carbon in plantation forest harvest (t C)	Total forest carbon uptake (before harvest) (t C)
1990	1,243,837	118,886,179	6,454,675	2,685,694	9,140,368
1991	1,272,913	125,052,116	6,165,937	2,845,753	9,011,691
1992	1,313,737	130,742,461	5,690,344	3,012,379	8,702,723
1993	1,376,816	135,983,896	5,241,435	3,184,182	8,425,616
1994	1,452,659	141,075,779	5,091,883	3,346,630	8,438,513
1995	1,536,124	146,109,439	5,033,660	3,463,550	8,497,211
1996	1,613,397	151,250,246	5,140,807	3,460,757	8,601,563
1997	1,683,459	156,774,789	5,524,543	3,584,662	9,109,205
1998	1,740,442	162,806,387	6,031,598	3,795,497	9,827,094
1999	1,786,237	169,406,056	6,599,669	4,160,566	10,760,235
2000	1,824,130	176,470,501	7,064,445	4,480,867	11,545,311
2001	1,855,741	183,614,247	7,143,746	4,829,848	11,973,594

All data are three year straight averages.
Data were estimated using Forest Research Institute models.

Module Land-use change and forestry (New Zealand)
Submodule Changes in forest and other woody biomass stocks
Worksheet Equivalent of 5.1 (3 of 3)
Sheet Net Carbon uptake in forest

	Total forest carbon uptake (before harvest) (Gg C)	Carbon release from total forest harvest (Gg C)	Net carbon uptake in forests (Gg C)	Net CO2 uptake in forests (Gg CO2)
1990	9,140	2,872	6,269	22,985
1991	9,012	3,003	6,009	22,033
1992	8,703	3,144	5,559	20,383
1993	8,426	3,289	5,137	18,835
1994	8,439	3,427	5,011	18,375
1995	8,497	3,518	4,979	18,256
1996	8,602	3,486	5,115	18,756
1997	9,109	3,614	5,496	20,151
1998	9,827	3,825	6,002	22,008
1999	10,760	4,190	6,571	24,092
2000	11,545	4,500	7,045	25,831
2001	11,974	4,842	7,132	26,149

All data are three year straight averages.
Data were estimated using Forest Research Institute models.

Module Land-use change and forestry (New Zealand)
Submodule Forest and Grassland conversion
Worksheet NZ 5a
Sheet Carbon release from scrubland cleared for new forest planting

	Scrub land cleared for forest planting[1] (ha)	Clearance where scrub is burned[2] (25% of total) (t dm)	Quantity of biomass burned (t dm/ha = 136) (t dm)	Oxidised biomass (90% of total) (t dm)	C release from burning scrub (t C/t dm = 0.5) (t C)	CO2 release from burning for new planting (t CO2)	Clearance where scrub decays[2] (75% of total) (ha)	Quantity of biomass decay[3] (t dm/ha =136) (t dm)	C release from decay (t C/t dm = 0.5) (t C)	CO2 release from decay for new planting (t CO2)
1990	3,579	895	121,679	109,511	54,756	200,771	2,684	365,038	182,519	669,236
1991	5,427	1,357	184,507	166,056	83,028	304,436	4,070	553,520	276,760	1,014,787
1992	8,480	2,120	288,320	259,488	129,744	475,728	6,360	864,960	432,480	1,585,760
1993	11,200	2,800	380,800	342,720	171,360	628,320	8,400	1,142,400	571,200	2,094,400
1994	12,464	3,116	423,776	381,398	190,699	699,230	9,348	1,271,328	635,664	2,330,768
1995	9,376	2,344	318,773	286,895	143,448	525,975	7,032	956,318	478,159	1,753,250
1996	10,323	2,581	350,971	315,874	157,937	579,102	7,742	1,052,912	526,456	1,930,339
1997	9,263	2,316	314,953	283,458	141,729	519,673	6,948	944,860	472,430	1,732,243
1998	4,662	1,166	158,508	142,657	71,329	261,538	3,497	475,524	237,762	871,794
1999	5,847	1,462	198,809	178,928	89,464	328,035	4,386	596,428	298,214	1,093,451
2000	5,905	1,476	200,759	180,683	90,341	331,252	4,429	602,276	301,138	1,104,173
2001	6,373	1,593	216,671	195,004	97,502	357,507	4,780	650,012	325,006	1,191,689

All data are three year straight averages
[1] Ministry of Agriculture and Forestry
[2] Percentage assumed for calculation purposes.
[3] Biomass on the land cleared is assumed to decay over five years.

Module Land-use change and forestry (New Zealand)
Submodule Forest and Grassland conversion
Worksheet NZ 5b
Sheet Carbon release from wildfires

	Area of scrub burned in wildfires[1] (ha)	Quantity of biomass burned (t dm/ha = 136) (t dm)	Oxidised biomass (90% of total) (t dm)	C release from scrub wildfires (t C\t dm = 0.5) (t C)	Area of Forest burned in wildfires[1] (ha)	Quantity of biomass burned (t dm/ha = 364) (t dm)	Oxidised biomass (90 % of total) (t dm)	C release from forest wildfires (t C/t dm = 0.5) (t C)
1990	2,564	348,738	313,864	156,932	323	117,663	105,897	52,948
1991	2,064	280,659	252,593	126,296	207	75,318	67,786	33,893
1992	1,954	265,744	239,170	119,585	165	60,151	54,136	27,068
1993	2,330	316,812	285,131	142,565	239	86,814	78,133	39,066
1994	2,529	343,978	309,580	154,790	314	114,266	102,839	51,420
1995	2,645	359,765	323,789	161,894	472	171,929	154,736	77,368
1996	2,532	344,318	309,886	154,943	727	264,598	238,138	119,069
1997	3,320	451,565	406,409	203,204	762	277,520	249,768	124,884
1998	3,268	444,391	399,952	199,976	692	251,949	226,754	113,377
1999	3,049	414,709	373,238	186,619	403	146,571	131,914	65,957
2000	2,119	288,184	259,366	129,683	334	121,576	109,418	54,709
2001	1,893	257,493	231,744	115,872	282	102,527	92,274	46,137

Module Land-use change and forestry (New Zealand)
Submodule Forest and Grassland conversion
Worksheet NZ 5c (adaptation of 5.3)
Sheet Non-CO2 emissions from the on-site burning of scrub

	Carbon release by on-site burning (t C)	Nitrogen released (t N/t c = 0.01) (t C)	Carbon in CH_4 emissions (ratio = 0.012) (t C)	Nitrogen in N_2O emissions (ratio = 0.007) (t N)	Nitrogen in NO_x emissions (ratio = 0.121) (t N)	Carbon in CO emissions (ratio = 0.06) (t C)	CH_4 emissions from burning (ratio = 1.333) Gg CH	N_2O emissions from burning (ratio = 1.571) (Gg N2O)	NO_x emissions from burning (ratio = 3.286) (Gg CO)	CO emissions from burning (ratio = 2.333) (Gg CO)
1990	211,688	2,117	2,540	15	256	12,701	3.386	0.023	0.842	29.632
1991	209,324	2,093	2,512	15	253	12,559	3.348	0.023	0.832	29.301
1992	249,329	2,493	2,992	17	302	14,960	3.988	0.027	0.991	34.901
1993	313,925	3,139	3,767	22	380	18,836	5.022	0.035	1.248	43.943
1994	345,489	3,455	4,146	24	418	20,729	5.526	0.038	1.374	48.362
1995	305,342	3,053	3,664	21	369	18,321	4.884	0.034	1.214	42.742
1996	312,880	3,129	3,755	22	379	18,773	5.005	0.034	1.244	43.797
1997	344,933	3,449	4,139	24	417	20,696	5.518	0.038	1.371	48.284
1998	271,305	2,713	3,256	19	328	16,278	4.340	0.030	1.079	37.977
1999	276,083	2,761	3,313	19	334	16,565	4.416	0.030	1.098	38.646
2000	220,024	2,200	2,640	15	266	13,201	3.520	0.024	0.875	30.799
2001	213,374	2,134	2,560	15	258	12,802	3.413	0.023	0.848	29.868

Module Land-use change and forestry (New Zealand)
Submodule Forest and Grassland conversion
Worksheet NZ 5d (adaptation of 5.3)
Sheet Non-CO2 emissions from the on-site burning of forests

	Carbon release by on-site burning (t C)	Nitrogen released (t N/t c = 0.01) (t C)	Carbon in CH_4 emissions (ratio = 0.012) (t C)	Nitrogen in N_2O emissions (ratio = 0.007) (t N)	Nitrogen in NO_x emissions (ratio = 0.121) (t N)	Carbon in CO emissions (ratio = 0.06) (t C)	CH_4 emissions from burning (ratio = 1.333) Gg CH	N_2O emissions from burning (ratio = 1.571) (Gg N2O)	NO_x emissions from burning (ratio = 3.286) (Gg CO)	CO emissions from burning (ratio = 2.333) (Gg CO)
1990	52,948	529	635	4	64	3,177	0.847	0.006	0.211	7.412
1991	33,893	339	407	2	41	2,034	0.542	0.004	0.135	4.744
1992	27,068	271	325	2	33	1,624	0.433	0.003	0.108	3.789
1993	39,066	391	469	3	47	2,344	0.625	0.004	0.155	5.469
1994	51,420	514	617	4	62	3,085	0.823	0.006	0.204	7.198
1995	77,368	774	928	5	94	4,642	1.238	0.009	0.308	10.830
1996	119,069	1,191	1,429	8	144	7,144	1.905	0.013	0.473	16.667
1997	124,884	1,249	1,499	9	151	7,493	1.998	0.014	0.497	17.481
1998	113,377	1,134	1,361	8	137	6,803	1.814	0.012	0.451	15.870
1999	65,957	660	791	5	80	3,957	1.055	0.007	0.262	9.233
2000	54,709	547	657	4	66	3,283	0.875	0.006	0.218	7.658
2001	46,137	461	554	3	56	2,768	0.738	0.005	0.183	6.458

Module Land-use change and forestry (New Zealand)
Submodule Abandonment of managed lands

Not estimated due to lack of data

Module Land-use change and forestry (New Zealand)
Submodule Change in soil carbon

Not estimated due to lack of data

Module 2001 Land use change and forestry (New Zealand)
Submodule Carbon emissions from liming of agricultural soils
Worksheet 5.5
Sheet 3 of 4 (adapted)

	Total annual amount of limestone[1] (Mg)	Total annual amount of limestone (3yr average) (Mg)	Carbon conversion factor[2]	Carbon emissions from liming (MgC)	Emissions of CO_2 (Gg)
1989	662,753				
1990	817,127	787,329	0.12	94,479	346
1991	882,107	882,107	0.12	105,853	388
1992	947,087	951,619	0.12	114,194	419
1993	1,025,662	1,033,210	0.12	123,985	455
1994	1,126,880	1,126,880	0.12	135,226	496
1995	1,228,097	1,152,047	0.12	138,246	507
1996	1,101,163	1,182,354	0.12	141,883	520
1997	1,217,803	1,217,803	0.12	146,136	536
1998	1,334,442	1,334,442	0.12	160,133	587
1999	1,451,082	1,451,082	0.12	174,130	638
2000	1,567,721	1,567,721	0.12	188,127	690
2001	1,684,361	1,684,361	0.12	202,123	741
2002	1,801,000				

1. Statistics New Zealand June year data for 1989, 1990, 1992, 1993, 1995, and 1996. 2002 is a MAF estimate based on provisional data from Statistics New Zealand
1991 estimate is average of 1990 and 1992
1994 estimate is average of 1993 and 1995
1997 to 2001 is interpolated between 1996 and 2002

2 IPCC default value