Factors and activity data to estimate nitrous oxide emissions from cropping systems, and stubble and tussock burning

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Factors and activity data to estimate nitrous oxide emissions from cropping systems, and stubble and tussock burning (restricted data excluded)

Thomas S, Hume E, Fraser T and Curtin D

June 2011

A report prepared for

Ministry of Agriculture and Forestry

Steve Thomas, Ellen Hume, Trish Fraser and Denis Curtin

Plant & Food Research, Lincoln

SPTS No. 5963

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Factors and activity data to estimate nitrous oxide emissions from cropping systems, and stubble and tussock burning

Thomas S, Hume E, Fraser T and Curtin D, June 2011, SPTS No. 5963

This report provides crop activity data and factors for use in estimating nitrous oxide emissions from cropping, and stubble and tussock burning in New Zealand. The key points and recommendations are listed below.

Recommendations

Crop activity data

Activity data (production area; 1990–09) for sweet corn and onions were obtained from Statistics NZ; for years in which no survey/census was conducted, estimates were made by interpolation of data for the years immediately before and after the missing year. Activity data for squash were based on a combination of Statistics NZ and Horticulture NZ data, with missing values estimated by interpolation. Activity data for production (tonnes) were estimated using the area data and mean yield values (supplied by local experts).

Activity data (area grown; 1990–09) for certified seed crops (herbage, pastoral legume (mostly clover) and brassicas) were obtained from AsureQuality. Activity data for non-certified seed are not available.

Statistics NZ have only very recently started (in the last 2 years) to collect information relating to forage brassica production. However, no information is collected for the area occupied by different types of forage brassicas (e.g. turnips, kale). Expert based estimates of the current brassica forage area, using certified seed sales data and conservative sowing rates, are 365,000 ha. These estimates are much larger than the Statistics NZ Agricultural Production Survey (APS) of approximately 236,000 ha. Seed companies are reluctant to share sales information due to the commercial sensitivity of their market share position. We recommend that Statistics NZ continue to collect information on forage brassicas in future years, but also expand the category to collect activity data for the different types of brassicas. We also recommend that the large discrepancy between the survey and expert opinion estimates is further investigated, and in particular whether APS survey questions are being misinterpreted and whether the respondents are under-reporting forage brassica areas.

No historical activity data could be found for vegetable seed crops, but in future years (starting 2011) the Foundation for Arable Research (FAR) intends to collect much more detailed information on all crops (areas and yields) grown by their farmers; hence such information may be available via FAR in future years.

Harvest index and residue N contents

Harvest index values, root to shoot ratios and N contents of above- and below-ground residues have recently been compiled from published and unpublished NZ data sources by scientists working on the OVERSEER nutrient budgeting model. We recommend that these values be used for estimation of nitrous oxide emissions (generally, the OVERSEER values are similar to those suggested in Thomas et al. 2008).

In the absence of measured root:shoot ratios, the OVERSEER approach is to use a default value of 0.1 for all crops. We recommend that this OVERSEER value be adopted until measured values for NZ-grown crops are available.

Emissions from stubble burning

Stubble from three cereal crops (wheat, barley and oats) is burned in NZ.

We recommend that modifications are made to the 1996 IPCC calculation for crop residue burning to take into account differences in the available activity data between 1990 and 2004, and 2005 to present. From 1990 to 2004, estimations of the amount of residue burned for each crop should be based upon total crop production and assumed fractions burned of each crop (which are influenced by factors such as market demand for baled straw). From 2005 to present, estimations of the amount of residue burned should be based upon the total cropping area burned according to the APS. To improve the accuracy of future estimates, more specific information is required on the area burned of each crop type and the amount of residue removed before burning.

We recommend that NZ crop-specific data (yields, harvest indices, residue N contents) are used for calculating emissions.

Emissions from tussock grassland burning

We recommend that APS data for annual areas of tussock grassland burned be used for estimation of emissions from 2005 onwards.

There is a large discrepancy between the APS tussock burning data and areas estimated based on consents issued by Regional Councils. The assumption that 20% of the consented area is burned annually (current approach for estimating emissions) appears to greatly underestimate burning. For the years before APS data became available (1990 to 2004), we recommend that the area of tussock burning be estimated as the entire consented area. Access to further information (e.g. compliance data) may improve accuracy of estimates of the areas burned prior to 2005.

Several factors used to calculate emissions (fraction burned, ratios of C to biomass loss and N to C loss upon burning) have been updated to be specific to the burning of tall tussock grasslands in NZ. Investigation is still needed into whether these factors are appropriate for other types of tussock grassland burned.

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1 Introduction

In 2008 Crop & Food Research (now The New Zealand Institute for Plant & Food Research Limited) completed a report for MAF on nitrous oxide (N_2O) emission factors and activity data for crops, and stubble and savannah (tussock) burning (Thomas et al. 2008). That report identified gaps in activity data that needed to be addressed to improve estimates of nitrous oxide emissions from cropping, and stubble and tussock burning.

The objectives of the present report are to:

1. Update crop activity data to include values for the 2008–10 period;

2. Provide activity data for squash, sweet corn, and onions (1990 to present);

3. Provide activity data for seed crops (clover, grass, vegetable) from 1990 to present;

4. Recommend harvest index values to be used to estimate inputs of residues for all key crops (barley, wheat, maize, oats, peas, lentils, potatoes, clover seed, lucerne, forage brassicas, squash, sweet corn, onions);

5. Recommend root:shoot ratio values for use in estimation of below-ground crop residue inputs;

6. Recommend residue (above- and below-ground) N concentration values for use in estimating residue-N inputs for all key crops;

7. Review and update the methodology for estimating emissions associated with stubble and tussock burning.

We have used a range of sources of published and unpublished data from New Zealand to examine the range of activity data and factors that are used in the current national inventory. The sources of all activity data are documented and assumptions underpinning the recommended factors are explained.

2 Crop activity data

2.1 Updated activity data (including new data since our 2008 report)

Activity data for cereals (barley, wheat, maize, and oats) have been updated by including production statistics from Statistics New Zealand Agricultural Production Survey (APS) for the 2008 to 2010 period (Table 1).

Table 2 presents updated production data from the Foundation for Arable Research (FAR) production database (FARPD). Recent changes in the levy system require farmers to annually sign a form stating that they have paid all levies as per their legal obligations. FAR believes that this formal change has slightly improved the accuracy of the data they now collect from levy payers. Note that from 2007 data for maize grain production have not been collected by FAR. This is because FAR’s data from 2007 are based on sales of “10,000 seed units”, which does not allow separation of maize grown for grain and silage.

A comparison of production data from Statistics NZ APS and FAR databases for barley, wheat, maize (grain) and oats is shown in Figure 1. For wheat, there is reasonably good agreement between the two data sets in recent years (except for 2009, when FAR was lower by ~68,000 tonnes). The FAR data for barley are always lower than the Statistics NZ values and the difference shows large year-to-year variability (in 2009 there was a particularly large difference of 175,000 tonnes). While FAR maize production data are consistently lower than the Statistics NZ values, the difference is relatively small (less than 25,000 tonnes) except for 1996, 2004 and 2005.

There was a strong trend for wheat production to increase between 1990 and 2010 – the average, annual increase estimated from Statistics NZ data was 9,500 tonnes. There was also a trend (albeit weaker) for maize grain production to increase between 1990 and 2010 (annual increase calculated from Statistics NZ data was 3,100 tonnes). There was no significant trend for barley between 1990 and 2010, while oat production showed a general decline from 1990.

Table 1: Annual production (tonnes) by crop to 30th June year, from Statistics New Zealand Agricultural Production Survey/Census. As: (1) no survey or census were conducted in 1997, 1998, 2000, or 2001 for these crops, (2) in 1999 a survey was conducted but data were not located, and (3) the Statistics NZ website does not provide information for all crops in all years; total production for these years was filled from New Zealand Inventory Spreadsheet and is shown in *italics*. Total production, as recorded in the New Zealand Inventory Spreadsheet, differs from survey/census data provided below for barley and wheat in 2003, 2005 and 2006; for maize and oats in 2004, 2005 and 2006; and for seed peas in 2004, 2005, and 2006.

Year	Barley	Wheat	Maize (grain)	Oats (grain)	Seed peas
1990	434,856	188,047	*161,651*	*65,892*	*57,378*
1991	382,043	180,690	*183,388*	*78,877*	*65,064*
1992	318,787	191,039	*163,842*	*57,187*	*75,290*
1993	389,523	219,414	*133,069*	*57,625*	*63,268*
1994	395,476	241,853	*142,768*	*56,793*	*59,898*
1995	302,804	245,173	*160,797*	*57,718*	*56,448*
1996	367,181	277,014	*209,710*	*38,735*	*50,337*
1997	*411,000*	*317,379*	*193,806*	*41,217*	*50,337*
1998	*340,000*	*302,100*	*176,148*	*49,065*	*66,200*
1999	*304,000*	*320,000*	*197,000*	*42,223*	*52,200*
2000	*302,000*	*326,000*	*181,000*	*41,702*	*64,000*
2001	*365,000*	*364,000*	*177,000*	*35,398*	*37,700*
2002	440,883	301,498	148,847	34,987	29,457
2003	371,837	318,916	*197,182*	*29,934*	*32,200*
2004	226,082	255,860	234,248	30,844	31,912
2005	302,739	318,947	210,253	28,714	29,068
2006	277,020	261,798	227,054	28,478	22,506
2007	335,627	344,434	185,627	27,531	22,053
2008[#]	408,700	343,400	205,600	25,500	*NA*
2009[#]	435,300	403,500	237,800	33,700	*NA*
2010[#]	314,200**P**	466,700**P**	202,600**P**	48,900**P**	*NA*
Average	353,574	294,655	187,114	43,382	48,073

= estimates were rounded by Statistics NZ to nearest 100 tonnes

P = provisional estimates

NA = not available

Table 2: Annual production (tonnes) by crop (for each calendar year), from the Foundation for Arable Research Production Database (FARPD).

Year	Barley	Wheat	Maize (grain)	Oats	Pulses	Other cereals	Borage/ linseed	Brassica/ Oil seed rape		Herbage (grass & legume seed)		Other crops
1995	198,034	203,941	-	-	50,046	-	-	-		-		-
1996	265,611	223,461	147,608	20,494	46,534	-	-	-		-		-
1997	307,956	232,021	169,840	18,256	41,749	-	300[#]	-		59,213		2,655
1998	227,452	312,837	153,802	21,817	69,074	3,401	2,732[#]	-		53,684		3,619
1999	203,337	268,545	173,111	18,424	50,405	5,088	1,580	299		68,201		-
2000	216,276	302,509	162,427	17,713	62,780	6,835	1,890	1,130		47,799		909
2001	285,756	359,940	162,186	15,796	37,261	5,621	1,831	2,496		47,059		4,175
2002	296,163	248,333	150,257	15,302	23,727	4,002	1,617	1,498		25,930		2,331
2003	303,837	250,897	188,424	14,558	31,477	4,860	1,612	3,404		64,583		8,539
2004	217,493	329,776	192,128	16,131	26,997	959	1,113	2,839		64,146		2,823
2005	200,265	275,723	159,350	13,331	29,640	9,961	1,243	1,524		75,378		2,017
2006	230,148	285,163	209,136	16,772	20,121	11,613	2,996	2,459		83,862		4,492
2007[A]	284,800	359,841	*NA*	19,152	27,095	11,344	1,982	3,773		35,728		3,333
2008	339,180	340,829	*NA*	18,763	*NA*	11,857	1,314	5,206		36,973		4,718
								Brassica	OSR	Grass	Legumes	
2009	260,005	335,183	*(482,411)*	18,598	26,436	12,408	1,292	4,701	1,162	35,031	3,389	3,182
2010**	305,189	445,522	*(641,998)*	21,125	40,367	13,524	1,049	4,568	4,326	30,223	3,653	1,048

= may include some oil seed rape

[A] = tonnes of maize no longer collected from 2007; instead data collected based on sales of 10,000 seed units of maize.

** = a slightly different method of data collection was introduced in February 2010 which may account for some number fluctuations.

NA = not available

Note that values in red correspond to number of 10,000 seed units sold in that year, not tonnes.

OSR = Oil Seed Rape

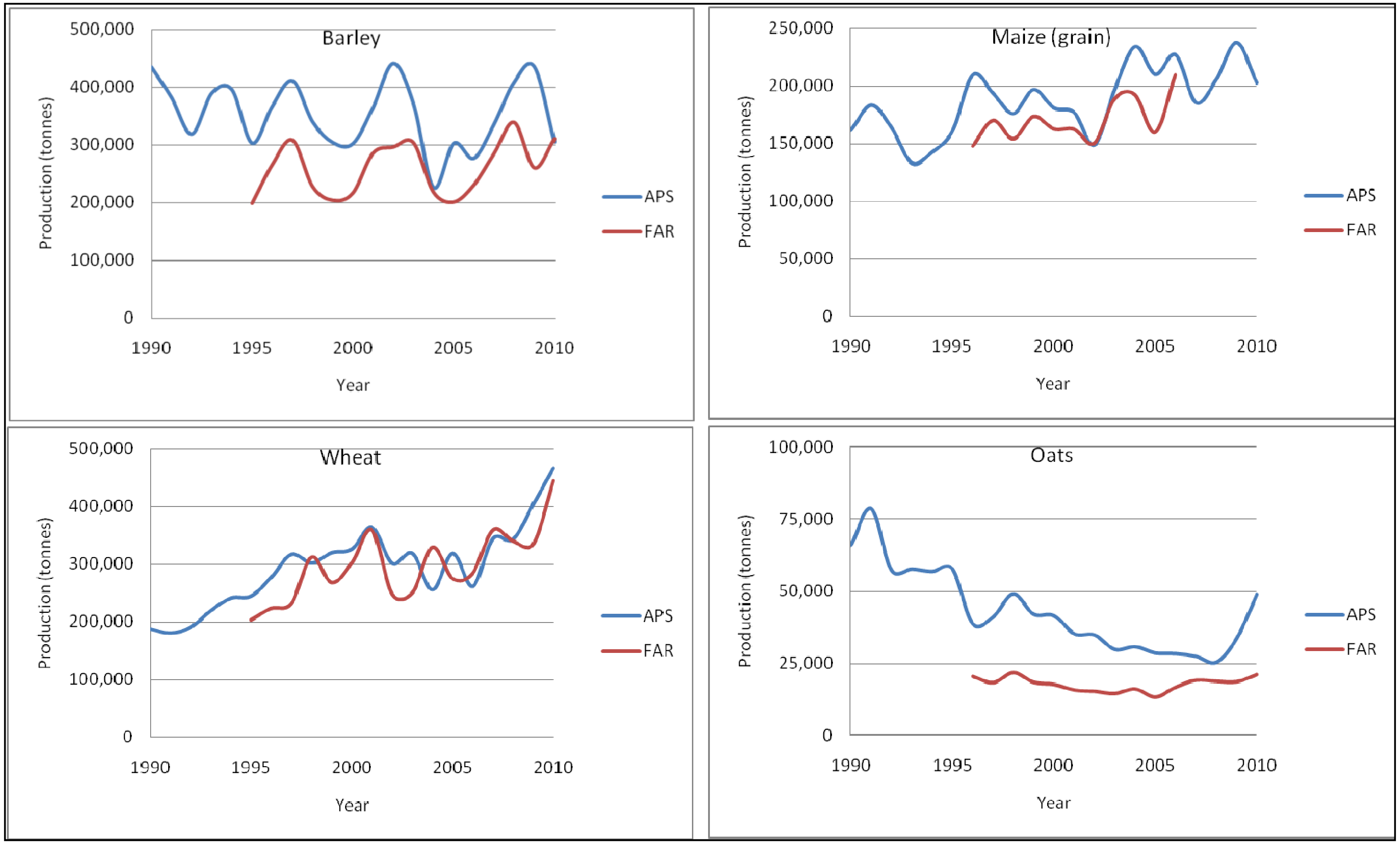

Figure 1: Comparison of production data from Statistics New Zealand Agricultural Production Survey and Foundation for Arable Research databases for barley, wheat, maize (grain) and oats.

2.2 Activity data for sweet corn, onions and squash

Activity data (area grown) for sweet corn, onions, and squash are available from the Statistics NZ database, except for 1991, 1997–99, 2001, 2004, 2006 and 2008. Activity data for squash are also available from Horticulture New Zealand (HortNZ) from 1999 onwards. The HortNZ data for squash compare reasonably well with Statistics NZ data. We therefore recommend that HortNZ data be used to fill in missing values in the Statistics NZ record for the 1999 to 2009 period.

Where the gap in the activity record is a single year, it may be acceptable to get an estimate by averaging data for the preceding and following years. Such an estimate is unlikely to differ significantly from the actual value. Thus, activity data for sweet corn and onions in 1991, 2001, 2004, 2006, and 2008 were calculated as the mean of Statistics NZ's values for the years immediately before and after the missing year. The 3-year gap between 1997 and 1999 is more problematic; however, there does not appear to be an alternative to using an average of the 1996 and 2000 values for each of these years. The production area in 2000 was not greatly different to that in 1996 for either sweet corn or onion, suggesting that production was stable over this period. This provides some justification for basing activity for 1997–99 on data for 1996 and 2000.

Data for squash are not available from either Statistics NZ or HortNZ for 1991 and 1997–98. Data for these years were estimated as described for sweet corn and onions. This interpolation should give realistic estimates of production area because the missing years occurred in periods when squash production appeared to be stable.

If we assume that both sweet corn and squash have an average annual yield of 20 t/ha (Bruce Searle, pers. comm.) and that onions yield on average 60 t/ha, then we can obtain activity data for crop yield from the cropping areas shown in Table 3. These activity data are reported in Table 4.

The amount (tonnes) of sweet corn, onions and squash produced in NZ in 2009 has increased substantially since 1990 (75% more sweet corn, 67% more onions and 86% more squash were produced in 2009 than in 1990). This production increase occurred mainly in the early 1990s (1990–95) and there was evidence of a decrease in output since 2000 for onions and, to a lesser extent, sweet corn.

Table 3: Activity data (area grown, hectares) for sweet corn, onions and squash to 30 June each year from 1990 to 2009, from Statistics NZ and Horticulture NZ (estimated values in red italics).

	Total area (hectares) grown in New Zealand				
Year	Sweet corn (Statistics NZ)	Onions (Statistics NZ)	Onions (HortNZ)	Squash (Statistics NZ)	Squash (HortNZ)
1990	2,898	2,704	..	3,677	..
1991	*3,192*	*2,815*		*4,037*	..
1992	3,485	2,925	..	4,396	..
1993	3,655	3,127	..	5,829	..
1994	5,526	4,929	..	7,509	..
1995	7,383	5,697	..	6,831	..
1996	7,168	5,772	..	6,466	..
1997	*6,774*	*6,408*		*6,590*	..
1998	*6,774*	*6,408*		*6,590*	..
1999	*6,774*	*6,408*			**7,008**
2000	6,380	7,044	..	6,713	7,996
2001	*6,085*	*6,333*			**6,968**
2002	5,790	5,621	..	6,560	7,800
2003	7,041	5,748	..	6,804	8,011
2004	*7,078*	*5,340*	..		**8,443**
2005	7,115	4,931	..	6,981	6,333
2006	*6,663*	*4,763*	..	..	**8,042**
2007	6,210	4,594	..	7,774	6,676
2008	*5,635*	*4,553*	4,676	..	**6,601**
2009	5,059	4,511	..	6,825	6,853

There was no agricultural survey in 1997, 1998 or 2001. Horticulture was excluded from the agricultural production surveys in 1991, 1999, 2004, 2006 and 2008.

Prior to 1994, the population base for the agricultural production surveys was businesses recorded on Statistics New Zealand's Business Directory that engaged in horticulture, cropping, livestock farming or exotic forestry operations.

From 1994 onwards, the population base for the agricultural production surveys was those businesses registered for GST and recorded on Statistics New Zealand's Business Frame as being engaged in agricultural activity (e.g. horticulture, cropping, livestock farming, forestry). The survey in 2000 was also supplemented with information from AgriBase.

HortNZ squash data (bolded) recommended to fill gaps in the Statistics NZ record.

Table 4: Estimated activity values (tonnes) for sweet corn, onions and squash grown in New Zealand from 1990 to 2009 (see text for assumptions used in estimations).

	Tonnes of crop produced in NZ		
Year	Sweet corn	Onions	Squash
1990	57,960	162,240	73,540
1991	63,830	168,870	80,730
1992	69,700	175,500	87,920
1993	73,100	187,620	116,580
1994	110,520	295,740	150,180
1995	147,660	341,820	136,620
1996	143,360	346,320	129,320
1997	135,480	384,480	131,790
1998	135,480	384,480	131,790
1999	135,480	384,480	140,160
2000	127,600	422,640	134,260
2001	121,700	379,950	139,360
2002	115,800	337,260	131,200
2003	140,820	344,880	136,080
2004	141,560	320,370	168,860
2005	142,300	295,860	139,620
2006	133,250	285,750	160,840
2007	124,200	275,640	155,480
2008	112,690	273,150	132,020
2009	101,180	270,660	136,500
2009 production as % of 1990	175	167	186

2.3 Production of seed crops

Detailed records of areas occupied by certified seed crops have been maintained for certification purposes and are available from AsureQuality. Table 5 provides a summary of the total areas of certified herbage, pastoral legume and brassica seed crops. Overall, the area of land used for growing these seed crops in 2008/09 was approximately 40% less than in 1990. The greatest reduction was in pastoral legume seed production (50% reduction in area under legume seeds between 1990 and 2009).The area under herbage seeds decreased by about one-third between 1990 and 2009. On average, white clover seed represented approximately 90% of the pastoral legume seed area. The brassica seed crop area steadily increased from 700 hectares in 1990 to approximately 1500 hectares in 2009. As a proportion of the total land area annually devoted to these seed crops, 53% was under herbage seed production, 43% under legume seeds, with only around 4% on average under brassica seed production (8% in 2008/09). Since 2009, FAR has separated oil seed rape from other brassicas in their database. According to FAR data (Table 2) there was a marked increase in the production of oil seed rape seed in 2010. This is likely to be related to the recent upsurge in biofuel production (Glen Judson, pers. comm.).

If we assume that herbage seeds generally produce 1.8 t/ha (Phil Rolston, pers. comm.), that legume seeds produce approximately 0.5 t/ha (largely based on white clover since it constitutes 90% of the seed legumes produced), and that on average brassica seed crops yield around 1.5 t/ha (E. Chakwizira, pers. comm.), then we can estimate the annual tonnage of each seed crop category from the area data in Table 5.

Estimates of the tonnage of certified herbage seeds (Table 6) are substantially less than the values for herbage seeds in FAR's database (shown in Table 2). The difference presumably partly reflects the amount of non-certified ("commons") herbage seed grown. It is estimated that about 60% of the current herbage seed production is classified as "proprietary" (certified) with 40% considered "commons" (non-certified) (Glen Judson, pers. comm.). Nui ryegrass represents a major part of the latter category.

We were unable to find historic activity data for herbage seed crops (certified plus un-certified) prior to 1997. Grass and clover seed production has recently been separated out by FAR in their data collection (Table 2). Data are now available for grass seed and clover seed for the years of 2009 and 2010. In those years clover seed represented approximately 9–10% of the total herbage seed (grass plus clover) production.

No historical activity data could be found for vegetable seed crops. However, since 2008 FAR has collected data for vegetable seed production, now since 2010 divided into hybrid and open pollinated categories (Table 7). In future years (from 2011) they intend to collect much more detailed information on all crops grown by their farmers than they have in the past (not just detailing vegetable seed, rather they will collect information on the areas of individual vegetable seed crops grown, e.g. carrots, onions).

Table 5: Area (hectares) occupied by certified seed crops in New Zealand from 1990 to 2009 (February to January year), from AsureQuality.

Year	Area grown (hectares)			
	Herbage seeds	Legume seeds	Brassica seeds	Total
1990/91	15,829	13,463	708	30,000
1991/92	15,587	18,248	849	34,684
1992/93	15,644	17,316	652	33,612
1993/94	14,280	18,661	876	33,817
1994/95	13,577	16,693	632	30,902
1995/96	18,737	16,837	1,104	36,678
1996/97	19,873	17,175	881	37,929
1997/98	21,974	16,784	364	39,122
1998/99	23,368	12,535	1,469	37,372
1999/00	21,896	11,663	1,060	34,619
2000/01	15,994	8,726	739	25,459
2001/02	13,635	6,952	539	21,126
2002/03	18,058	7,980	868	26,906
2003/04	21,920	8,452	1,185	31,557
2004/05	11,860	9,145	1,622	22,627
2005/06	9,543	11,107	1,301	21,951
2006/07	6,689	10,055	846	17,590
2007/08	8,458	7,155	1,519	17,132
2008/09	9,897	6,473	1,458	17,828
2008/09 area as % of 1990/91	63	48	206	59

Table 6: Activity data (tonnes) for certified seed crops grown in New Zealand from 1990 to 2009 (February to January year) (estimates calculated using AsureQuality area data and expert opinion for average yields per hectare – see text for assumptions used).

	Tonnes of seed produced		
Year	Herbage	Legume	Brassica
1990/91	28,492	6,732	1,062
1991/92	28,057	9,124	1,274
1992/93	28,159	8,658	978
1993/94	25,704	9,331	1,314
1994/95	24,439	8,347	948
1995/96	33,727	8,419	1,656
1996/97	35,771	8,588	1,322
1997/98	39,553	8,392	546
1998/99	42,062	6,268	2,204
1999/00	39,413	5,832	1,590
2000/01	28,789	4,363	1,109
2001/02	24,543	3,476	809
2002/03	32,504	3,990	1,302
2003/04	39,456	4,226	1,778
2004/05	21,348	4,573	2,433
2005/06	17,177	5,554	1,952
2006/07	12,040	5,028	1,269
2007/08	15,224	3,578	2,279
2008/09	17,815	3,237	2,187
Average	28,120	6,195	1,474

Table 7: Production data (tonnes) for vegetable seed crops (hybrid and open-pollinated seed crops) from 2008 to 2010 (calendar year), from Foundation for Arable Research database. *NA* = not available.

Year	Hybrid vegetable seed (tonnes)	Open-pollinated vegetable seed (tonnes)
2008	1,250	*NA*
2009	909	*NA*
2010	1,181	3,426

2.4 Forage brassica activity data

There is a lack of historical activity data for forage brassicas. Gowers & Nichol (1989) estimated the forage brassica area in the late 1980s at 144,000 ha. The only other published information we have found for forage brassica areas grown in NZ come from White et al. (1999), who estimate the area in 1990 to be 140,000 ha and 160,000 ha in 1997 (Table 8). They do not record how they have estimated these figures.

Table 8: Forage brassica areas (hectares) grown in NZ and the percentage of total area represented by each crop (White et al. (1999)).

Crop	1990	1997
Turnips	50,000 (36 %)	60,000 (38 %)
Swedes	35,000 (25 %)	40,000 (25 %)
Kale	20,000 (14 %)	25,000 (16 %)
Rape	35,000 (25 %)	35,000 (21 %)
Total	140,000	160,000

Statistics NZ APS recently began to collect activity data for forage brassicas. The data showed that the area grown in 2008/09 was 222,877 ha and 235,993 ha in the 2009/10 season. However, the surveys do not break down the area into the different brassica crops. These APS values are somewhat lower than previous estimates based on expert opinion, i.e. 300,000 ha (de Ruiter et al. 2009). It is not clear why there appears to be such a discrepancy, but incorrect reporting or misinterpretation of the survey question could be an issue. The expert opinion was estimated from certified seed sold at that time and typical seed sowing rates. We are unable to provide accurate information for national forage brassica seed sales (current or historic) as the companies are not prepared to divulge this information as it is commercially sensitive. However, expert opinion from Plant & Food Research staff who work closely with the largest NZ commercial forage brassica seed producers have estimated that the current area grown is at least 365,000 ha. Their estimate is based on access to certified seed sales (tonnes) information (July 2011), assumed market share and conservative (i.e. low) sowing rates for the range of brassica crops. The area grown with uncertified seed (e.g. giant or rangi rape) is unknown but it is believed to be small, perhaps 10,000 ha or more. We recommend that further investigation is required to verify the accuracy of the survey estimates.

We recommend that the APS continue to collect information on forage brassica production. In addition, data for each of the major forage brassica categories (rape, kale, turnip, swede) are required, given that biomass yield and amounts of plant residues returned to the soil can differ markedly between the brassica types (discussed further below).

One approach to estimating forage brassica areas is to use brassica seed production data (the underlying assumption is that seed production is related to seed demand which in turn depends on the area of forage to be grown). Estimates of certified brassica seed production (estimated from AsureQuality area data) are shown in Table 6 for the 1990 to 2010 period. Since 1990, there has been a two-fold increase in the production of brassica seeds. Almost all forage brassica seed is grown for the domestic market, with minor exports to Chile, Australia and USA. These values suggest that the area of forage brassicas may also have doubled over that timeframe, supporting estimates and expert opinion that the forage brassica area has doubled since 1990.

Given the very large uncertainties in this very small dataset, our suggested approach is to simply estimate the area of forage brassica grown by using: (i) the areas estimated for 1990 and 1997 by White et al. (1999) and (ii) either the recent Statistics NZ APS data or the area based on expert opinion and seed sales and (iii) compare these to the increase in dairy cattle numbers since 1990, and use this relationship to estimate forage areas for the intervening years. Our forage brassica experts at Plant & Food Research agree that most of the increase in brassica production between 1990 and 2010 is driven by the growth in dairying. Brassicas are also grazed by beef cattle and sheep, but the change in land area is small in comparison to the demands made by dairying.

Using this approach, fitting the forage area estimates to increasing dairy cow numbers (Figure 2), we can estimate the change in forage brassica area based in changes in cow numbers over time (Figure 3).

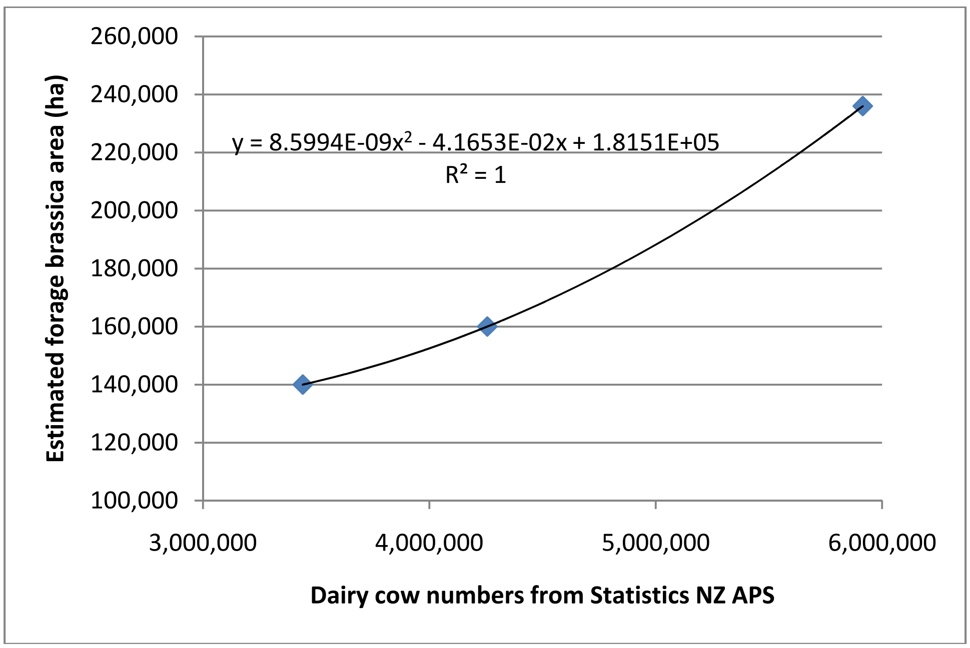

Figure 2: Relationship between increasing dairy cow numbers and estimates of the forage brassica area from White et al. (1999) and from the 2010 Statistics NZ survey.

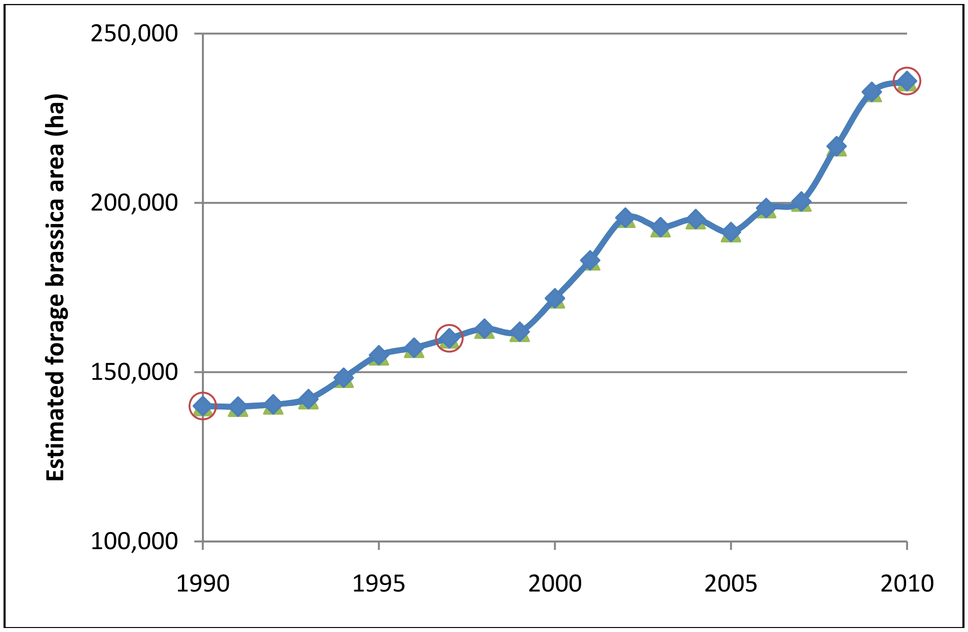

Figure 3: Estimated area of forage brassicas between 1990 and 2010. Estimates are based on a simple relationship between forage area estimates in 1990, 1997 and 2010 and dairy cattle numbers in these years. Circles represent estimates in forage area from White et al. (1999) and Statistics NZ APS survey.

Apart from the estimates from White et al. (1999) there is no published information for the proportion of the different crops grown. We suggest these data in Table 8 are used to estimate crop areas between 1990 and 2000.

Consensus opinion from experts at Plant & Food Research is that kale and swede crops for winter forage have increased more rapidly since 2000 commensurate with the increase in dairying in South Island. Our best estimates are that the current proportions of forage brassicas based on seed sale estimates (July 2011) are: turnips – 25%, swedes – 34%, kale – 27% and rape – 14 %. These proportions could be applied to the total forage brassica area since 2000 to estimate the areas for key forage brassica crops.

3 Harvest Index and root:shoot ratios

Harvest index (HI) values for all key crops have been reviewed and updated (Table 9). Additional information is provided for forage brassicas (Table 10).

An extensive database of HI values for NZ crops has recently been compiled by scientists working on the OVERSEER model (Cichota et al. 2010). We suggest that the OVERSEER HI values, which were derived from available published and unpublished data for NZ-grown crops, be used to estimate crop residue production. In most cases, the OVERSEER values are the same as, or only slightly different to, the values recommended by Thomas et al. (2008).

For a perennial crop (lucerne) use of the HI approach may not be an appropriate way of estimating annual returns of above-plant residues. Expert opinion suggests that, for mown lucerne crops, ~5% of annual dry matter production is returned to the soil, whereas for grazed crops, a larger proportion (20%) is returned (H. Brown, pers. comm.). We suggest that these values be used in conjunction with activity data for lucerne production to estimate annual inputs of above-ground residues.

Table 10 shows typical yields and harvest index values for each of the five forage brassica types (kale, rape, swedes, bulb turnips, and leaf turnips). For these crops, the harvest index is assumed to be the proportion of the crop used as animal feed. The HI of these crops is negatively related to dry matter yield (Chakwizira et al. 2010a). This is because higher yielding crops are likely to suffer greater trampling losses. Linear equations to estimate HI (y) from dry matter yield (x) are shown for each crop type in Table 11. These equations show that the HI of kale, rape and leaf turnips can decrease substantially at higher yields, whereas the HI of swedes and bulb turnips changes relatively little with yield. For crops with a typical yield, the HI of rape, swedes, bulb turnips and leaf turnips is about 0.80 with a lower value (0.6) for kale.

Root:shoot ratio values are needed to estimate inputs of below-ground residues. Thomas et al. (2008) recommended use of a root:shoot ratio of 0.1 for cereals, peas, and potatoes. Root data were not (and still are not) available for other crops. The OVERSEER database uses a value of 0.1 as the default root:shoot ratio for all NZ-grown crops and we recommend that the same default value be adopted to estimate below-ground residues (Table 9). Lack of root data for the entire range of crops is a serious knowledge gap in relation to the estimation of N_2O emissions from crop residues.

Table 9: Summary of recommended factors used to estimate N inputs from crop residues using a modified IPCC 2006 methodology for NZ conditions. Values for harvest index, root:shoot ratio, residue N content, and dry matter (DM) factor taken from the OVERSEER database, except where otherwise indicated.

Key crops	Production (t/ha)	Harvest index	Root:shoot ratio	Above-ground residue N (%)	Below-ground residue N (%)	Factor for residue DM content
Barley	6.8-10.2	0.46	0.1	0.5	0.9	0.86
Wheat	5.6-11.8	0.46 (0.41)[1]	0.1	0.5	0.9	0.86
Maize (grain)	11.5	0.5	0.1	0.7	0.7	0.86
Maize (silage)	16-20	0.95	0.1	0.7	0.7	0.86
Oats	4.5-6.5	0.30 (0.32)[1]	0.1	0.5	0.9	0.86
Fresh/garden peas	5.5-6.0	0.45	0.1	3	1.5	0.86
Field peas	3.5-4.0	0.5	0.1	2	1.5	0.21
Potatoes	40-50	0.9	0.1	2	1	0.22
Clover seed	0.6	0.09	0.1	4	1	0.85
Lucerne	15-20	*NR*	*NR*	1.8[2]	*	1
Grass seed	1.8-2.5	0.11	0.1	1.5	1	0.85
Lentil	2.0	0.50	0.1	2	1.5	0.86
Brassica seed	1.0-3.0[3]	0.2[3]	0.1	*	*	*
Onions	50-80[4]	0.8	0.1	2	1	0.11
Sweet corn	20[4]	0.55	0.1	0.9	0.7	0.24
Squash	18-30[4]	0.8	0.1	2	1	0.20

[1] First value is for spring-sown crops, value in brackets is for autumn-sown crops

[2] Brown & Moot (2004)

[3] E. Chakwizira (pers. comm.)

[4] B. Searle (pers. comm.)

NR = not relevant

Table 10: Yield data and recommended factors to estimate N inputs from residues of forage brassicas using a modified IPCC 2006 methodology for NZ conditions.

Crop	Yield range (t DM/ha)	Typical yield (t DM/ha)[1]	Harvest index[2]	Root:shoot ratio[1]	Above-ground residue N (%)[1]	Below-ground residue N (%)[1]	Factor for residue DM content
Kale	7–15[3]	12	0.58	0.4	1.0	0.80	1
Rape	5–9[4]	6	0.81	0.4	1.0	0.80	1
Swedes	7–15[5]	12	0.83	0.1	0.6	0.80	1
Bulb turnips	5–11[6]	8	0.84	0.1	0.6	0.80	1
Leaf turnips	5–8[7]	6	0.78	0.05	1.5	0.90	1

[1] (Chakwizira et al. 2010b)

[2] Harvest index calculated at a typical yield of each crop type, based on the equations in Table 11.

[3] (Chakwizira et al. 2010c; Gowers & Armstrong 1994; Wilson et al. 2006)

[4] (Adams et al. 2005; Percival et al. 1986)

[5] (Percival et al. 1986; Stevens & Carruthers 2008)

[6] (Adams et al. 2005; Collie & McKenzie 1998)

[7] (Chakwizira et al. 2009; Wilson et al. 2006)

Table 11: Relationship between harvest index (y) and dry matter yield (x; t/ha) for forage brassica crops.

Crop	Equation
Kale	y = 0.94 – 0.03 x
Rape	y = 1.03 – 0.037 x
Swedes	y = 0.99 – 0.013 x
Bulb turnips	y = 0.97 – 0.016 x
Leaf turnips	y = 1.29 – 0.085 x

4 Nitrogen inputs from crop residues

The OVERSEER database contains ‘typical’ values for N content of above- and below-ground crop residues (Cichota et al. 2010). These values were compiled from published and un-published reports for NZ-grown crops. Generally, the OVERSEER N values are quite similar to the IPCC default values for cereals. Thus, cereal residues all contain <1% N. The other non-legume crops usually have between 1 and 2% N in the residue, with higher values for the grain legumes. The very high N content (4%) for residue from clover seed cropping may need to be checked and verified.

We recommend that the OVERSEER values be adopted for estimation of N inputs from above- and below-ground residues (Table 9).

5 Activity data and methodology for quantifying emissions from stubble and tussock burning from 1990

5.1 Activity data collected by Statistics NZ for crop residue and tussock burning

Information on the burning of vegetation on agricultural land has been collected by Statistics NZ from 2003 onwards (excluding 2004) (Table 12, Table 13).

Table 12: Summary of the documentation of agricultural vegetation burning in Statistics NZ Agricultural Production Survey/Census (where documentation is indicated by N = no and Y = yes).

Year[1]	Burning categories						Comments
	Crop residue (ha)			Other standing vegetation (ha)			
	Cereal	Other	All incl. cereal	Tussock	Other	All incl. tussock	
2002	N	N	N	N	N	N	Not included – Census
2003[2]	N	N	Y	N	N	Y	Q36
2004	N	N	N	N	N	N	Not included
2005[2]	N	N	Y	N	N	Y	Q37
2006[2]	N	N	Y	N	N	Y	Q25
2007[3]	N	N	Y	Y	Y	N	Q44 – Census
2008[3]	Y	Y	N	Y	Y	N	Q66 & 67
2009[3]	Y	Y	N	Y	Y	N	Q85 & 86
2010[3]	Y	Y	N	Y	Y	N	Q68 & 69

[1] Farming year is the 12 months up to 30 June of the specified survey year.

[2] Conditions as defined by Statistics NZ for burning other standing vegetation:

- Documents *total area* of vegetation burnt on the farm
- Does not include:
  - burning on land leased to others
  - areas < 0.5 ha (2005/06 only)
- Includes burning on land leased from others
- Careful estimates given if exact figures unavailable

[3] Conditions as defined by Statistics NZ for burning other standing vegetation:

- Documents *controlled burning* of vegetation on the farm *only*
- Does not include:
  - burning on land leased to others
  - areas < 0.5 ha
  - burning of felled trees
- Includes burning on land leased from others
- 'Tussock' includes oversown tussock
- Careful estimates given if exact figures unavailable

Table 13: Summary of data from the Statistics NZ Agricultural Production Survey/Census, to 30th June year, on the burning of vegetation on agricultural land (C = confidential, R = restricted, *NA* = not available).

Year	Burning of crop residue (ha)									Burning of other standing vegetation (ha)								
	Cereals			Other			All incl. Cereals			Tussock grasslands			Other			All incl. Tussock		
	NI[1]	SI[2]	all NZ	NI	SI	all NZ	NI	SI	all NZ	NI	SI	all NZ	NI	SI	all NZ	NI	SI	all NZ
2005	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	R	R	52,841	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	R	R	R
2006	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	R	R	56,157	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	1,293	22,630	23,922
2007[3]	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	3,081	56,418	59,498	188	23,195	23,383	3,258	9,927	13,184	*NA*	*NA*	*NA*
2008	3,699	43,743	47,442	532	5,321	5,853	*NA*	*NA*	*NA*	R	R	18,297	2,408	11,383	13,790	*NA*	*NA*	*NA*
2009	R	R	53,782	R	R	R	*NA*	*NA*	*NA*	C	C	R	2,403	6,418	8,821	*NA*	*NA*	*NA*

[1] North Island

[2] South Island

[3] No sampling error as census year

5.2 Stubble burning

5.2.1 IPCC calculations

NZ annual greenhouse gas emissions from the burning of agricultural crop residues are currently calculated according to the 1996 IPCC guidelines (IPCC 1996):

Total N_2O emissions (t N) = $\sum_{\text{(all crop types)}}$ (annual production (t/yr) x residue:crop ratio x average dry matter fraction of residue x fraction residue actually burned in field x fraction oxidised x C fraction x N:C ratio x N_2O emission ratio x 44/28)

Thomas et al. (2008) recommended altering this equation to incorporate the more readily used harvest index to calculate above-ground residue dry matter. Thomas et al. (2008) also highlighted the ambiguity and uncertainty of the values currently used in the inventory to represent the fraction of residue actually burned.

The value used for fraction of residue actually burned in the IPCC equation needs to encompass three aspects:

1. The overall area burned in NZ
2. The amount of residue remaining in this area after harvest and any residue removal
3. The extent of the burn in the field.

MAF officials estimated that 50% of stubble was burned from 1990 to 2003, which then decreased to 30% burning from 2004 to present (Thomas et al. 2008). This factor was applied to all cereal crops in the IPCC calculation. There was no explanation provided of which crops the values were derived from, why they changed after 2003, and whether they encompassed the three aspects above.

We have re-assessed the available activity information for crop residue burning. We recommend that modifications be made to the IPCC calculation for crop residue burning to take into account differences in the available activity data between 1990 and 2004, and 2005 to present.

5.2.2 Recommendations for calculating N_2O emissions from the burning of crop residues from 1990 to 2004

We recommend that the following steps, equations and values be used (see Figure 4, Table 18):

1. Use Statistics NZ APS annual crop production values for wheat, barley and oats (Table 1).

   As previously recommended, the three crops that should be included are wheat, barley and oats (residues of other crops are not usually burned). Thomas et al. (2008) recommended that N-fixing crops (peas) should not be included in inventory burning calculations and experts from FAR and Plant & Food Research have confirmed that pea residues are not usually burned in NZ.

2. Convert to dry matter using correction factor for grain moisture content. Multiply total crop production values by a dry matter fraction; 0.86 is appropriate for NZ cereal crops (Table 9).

3. Calculate above-ground residue dry matter for each crop by applying a NZ crop-specific harvest index (Table 9).

4. Account for the fraction of residue actually burned.

    a. The area burned as a proportion of total production area of wheat, barley and oat crops.

    There are no data for the area of crop residue burned in NZ prior to the recent Statistics NZ APS information. Therefore, assumptions must be made about the areas burned in terms of the total production area of cereal crops. Thomas et al. (2008) discussed the variation in burning practices between the three crops (wheat, barley and oats), and concluded that the differences in burning between the crops was likely to be driven by potential market opportunities for residues of these crops. Barley and oat straws are more palatable and digestible for animals than wheat straw, so there is a greater tendency for these crop residues to be baled and used for other purposes such as animal feeding. For example, recent significant increases in dairy production have resulted in a concomitant increase in market demand for barley straw, as it is used as a high fibre feed supplement for dairy cows. However, there are no quantitative data documenting these changes in use of barley straw.

    We recommend using Canterbury values reported from a farmer survey for the proportion of cereal crops that are burned (Lawrence et al. 2007). The survey showed that 70% of wheat crops and 50% of barley crops were burned in Canterbury. We also recommend that the barley value (50%) be applied to oats. We believe these values from Canterbury are appropriate as approximately 80% of cereal production is in Canterbury and, based on the residue burning information collected through the APS between 2005 and 2009, an average of 86% of residue burning occurs in Canterbury.

    We have compared the data from the Statistics NZ APS documenting the total area of crop residue burned from 2005 to 2009 with our estimates based on the crop areas grown and the assumed proportions of burning for wheat (70%) and barley and oats (50%). There is good agreement between the two data sets from 2005 to 2007: Statistics NZ data averaged 56,165 ha of crop residues burned, compared with an average of 55,086 ha estimated using our assumed proportions of burned residues. However, in 2008 and 2009, the use of assumed proportions overestimated the burned area determined by Statistics NZ data; by 23% in 2008 (and data is restricted in 2009). We are unable to explain why this difference arose; however, it may represent a short-term change in farmer practice, perhaps due to an increased demand for animal feed.

    A new farmer survey that has been distributed to all FAR levy payers (~1800 cropping farmers) should provide better information on crop residue burning. A question has been included to elicit information on the extent of cereal stubble burning:

“What proportion of your cereal stubbles do you burn?

Wheat? ___%

Barley? ___%

Other? ___%”

The survey forms part of a Crop Sequence Survey project, which is partly funded by the MAF Sustainable Farming Fund. The report is expected to be available in September 2011. We recommend that these survey data be evaluated and an assessment made to determine whether they should be used to refine the approach we have proposed above.

b. The proportion of residue remaining after harvest and residue removal for feed and bedding.

There is no available information on the amount of residue that is baled for feed and bedding. Thomas et al. (2008) recommended that residue removal should be ignored until the necessary information is collected. We have sought further expert opinion from FAR and Plant & Food Research staff. This suggests that, if crop residues are to be burned, there is generally no prior removal for feed and bedding, i.e. all the residue is remaining for burning (100%).

c. The proportion of remaining residue actually burned in this area.

An average figure of 70% is used to describe the extent of each burn (i.e. 30% of residues will be largely unaffected by the burn) (Thomas et al. 2008). This value accounts for the required fire break areas and differences in the methods of burning used, both of which can result in residue being unaffected by the burn.

5. Apply an oxidation factor of 0.9 (IPCC 1996). Although “estimates of losses of N to the atmosphere during burning are in the order of 30–90% depending upon the extent of the combustion” (Thomas et al. 2008) we can assume that farmers will generally be aiming to have as close to complete combustion as possible.

6. Apply a NZ crop-specific value for the N concentration of above-ground residue (Table 9).

7. Apply a N_2O emission factor of 0.007 (IPCC 1996).

8. Multiply by 44/28 to convert to full molecular weight of N_2O (IPCC 1996).

Please note that to calculate CH_4 emissions from crop residue burning, the N fraction of biomass, N_2O emission factor and N_2O molecular weight conversion (44/28) in Equation 4 (Figure 4) should be replaced with the appropriate CH_4 factors, i.e. C fraction of biomass (0.4853 for wheat; 0.4567 for barley and oats), CH_4 emission factor (0.005), and CH_4 molecular weight conversion (16/12) (IPCC 1996).

Equation 1: Annual production (t dry matter) =

Annual production (t) x Dry matter fraction

Equation 2: Above-ground residue (t dry matter) =

(Annual production (t dm) / Harvest Index) – Annual production (t dm)

Equation 3: Biomass burned (Gg) =

Above-ground residue (t dm) x Area burned as proportion of total production area x Proportion of residue remaining after any removal x Proportion of remaining residue actually burned x 10^{-3}

Equation 4: N_2O emissions (Gg) =

Biomass burned (Gg) x Fraction oxidised x N fraction of biomass x N_2O emission factor x 44/28

Equation 5: Total N_2O emissions from the burning of all NZ crop residues (Gg) =

$\sum_{\text{all crops}}$ (N_2O emissions)

Figure 4: Recommended equations for calculating N_2O emissions from the burning of crop residues (1990 to 2004). Calculate N_2O emissions for each crop burned (i.e. wheat, barley and oats) in a given year and then sum to give the total NZ annual emissions from crop residue burning.

5.2.3 Recommendations for calculating N_2O emissions from the burning of crop residues from 2005 onwards

From 2005, Statistics NZ has collected information on the area of crop residue burning through the APS and the 2007 census. These are the first NZ-wide values for the area of crop residues burned (see Table 14. Note Table 14 includes restricted data for 2009). We recommend that these data are used to calculate emissions from 2005 onwards.

The Statistics NZ data show total residue burning at a regional and national level, but they do not differentiate cereal crop types. Furthermore, there is a small area of non-cereal crops burned (i.e. 11.0% of total crop residue burning in 2008 (2009 data is restricted)), without any information on the identity of these crops. Since the area of non-cereal crops burned is relatively small, we recommend that the total burned area be attributed to cereal crops and that crop residue burning be estimated individually for wheat, barley and oats, following the steps recommended from 1990 to 2004 with some additional assumptions as documented below.

Table 14: Summary of data from the Statistics NZ Agricultural Production Survey/Census on the area (hectares) of crop residues burned in NZ (R = restricted, purple = assumptions, *NA* = not available) (extracted from Table 13).

Year	Cereals (ha)	Other (ha)	All incl. Cereals (ha)
2005	*NA*	*NA*	52,841
2006	*NA*	*NA*	56,157
2007	*NA*	*NA*	59,498
2008	47,442	5,853	53,295
2009	53,782	R	R

We recommend that the following steps, equations and values are used (see Figure 5, Table 18):

1. Use Statistics NZ APS information for total area of crop residues burned in NZ (Table 14).

2. Estimate the areas of wheat, barley and oat crops that are burned (see Table 16). Since there are no data from 2005 to 2009 for the proportion of each crop that is burned, we recommend assuming that:

    a. 70% of the wheat crop is burned (as assumed for 1990 to 2004); and

    b. The remaining area of residue burning is allocated to barley and oats. Note that the same factors are assumed for barley and oats.

    This approach of assuming a constant value for wheat is based on the relatively lower feed value of wheat crop residues than barley and oats.

    Therefore, the calculations required are:

    - Area of wheat burned = Total area of wheat grown in NZ (Table 15) x 0.7;
    - Area of barley and oats burned = Total area burned in NZ (Table 14) – Area of wheat burned; and
    - Areas of barley and oats that are burned are in proportion to the total area of these crops that are grown (Table 15).

Table 15: Annual area grown (hectares) by crop to 30 June each year from 2005 to 2009, from Statistics NZ.

Year	Wheat	Barley	Oats (grain)	*Total*
2005	39,415	49,825	5,000	*94,240*
2006	37,962	47,078	6,278	*91,318*
2007	40,538	51,481	5,773	*97,792*
2008	42,326	67,435	5,159	*114,920*
2009	53,885	77,669	7,425	*138,979*
Average	*42,825*	*58,698*	*5,927*	*107,450*

Table 16: Estimates of the annual area (hectares) burned by crop to 30 June each year from 2005 to 2009. Estimates assume that (i) 70% of the total area of wheat grown is burned, (ii) the difference between this area and the total cereal area burned that is recorded in the APS is the area of barley and oats that is burned, (iii) the estimated areas of barley and oats burned are in proportion to the total area of these crops grown (R = restricted).

Year	Wheat	Barley	Oats (grain)	*Total area burned*[1]
2005	27,591	22,948	2,303	52,841
2006	26,573	26,103	3,481	56,157
2007	28,377	27,983	3,138	59,498
2008	29,628	21,985	1,682	53,295
2009	R	R	R	R

[1] From Table 14 (APS data)

3. Apply a NZ-specific average crop yield to determine the production of the areas burned. We recommend the use of annual values from Statistics NZ (Table 17) calculated from total crop production and areas grown.

Table 17: Annual yield (tonnes/hectare) by crop to 30 June each year from 2005 to 2009, calculated from total production and total areas of crops grown from Statistics NZ APS.

Year	Wheat	Barley	Oats (grain)
2005	8.09	6.06	5.00
2006	6.90	5.88	4.54
2007	8.50	6.91	4.77
2008	8.11	6.06	4.94
2009	7.49	5.60	4.54
Average	*7.82*	*6.10*	*4.76*

Next follow steps 2 to 8 as outlined above for 1990 to 2004 (Section 5.2.2) to determine the total N_2O emissions from the burning of crop residues. However, omit the value used for the 'area burned as a proportion of total production area' of wheat, barley and oat crops, as this has already been accounted for in step 2 of the method for 2005 to present (Table 16, see also Figure 5).

Equation 1: Production of area burned (t dry matter) =

Estimated area burned (ha) x Average crop yield (t/ha) x Dry matter fraction

Equation 2: Above-ground residue (t dry matter) =

(Production of area burned (t dm) / Harvest Index) − Production of area burned (t dm)

Equation 3: Biomass burned (Gg) =

Above-ground residue (t dm) x Proportion of residue remaining after any removal x Proportion of remaining residue actually burned x 10^{-3}

Equation 4: N_2O emissions (Gg) =

Biomass burned (Gg) x Fraction oxidised x N fraction of biomass x N_2O emission factor x 44/28

Equation 5: Total N_2O emissions from the burning of all NZ crop residues (Gg) =

$\sum_{\text{all crops}}$ (N_2O emissions)

Figure 5: Recommended equations for calculating N_2O emissions from the burning of crop residues (2005 to present). Calculate N_2O emissions for each crop burned (i.e. wheat, barley and oats) in a given year and then sum to give the total New Zealand annual emissions from crop residue burning.

5.2.4 Recommendations for future refinements

We recommend that refinements be made to data collection through the Statistics NZ APS. To increase the accuracy of national N_2O estimates farmers could be asked to provide information detailing:

1. The area burned for each crop type; and

2. The amount of residue (ideally as a proportion of the total above-ground residue) that is removed before burning (e.g. baled for feed).

This would improve the certainty surrounding the emission calculations (each crop has different average yield and above-ground residue biomass), and also provide clarification about burning of non-cereal residues (e.g. quantified in the “Other” category in Table 14).

The survey of FAR growers being undertaken in the SFF project described above will provide important information about current crop residue practices. A comparison of this information with that from the survey of growers reported by Lawrence et al. (2007) may provide evidence of changing burning practices.

Table 18: Summary of recommended values for calculating N_2O emissions from the burning of crop residues, from 1990 to 2004 (Figure 4), and 2005 to present (Figure 5).

Crop	Dry matter fraction[1]	Harvest index[1]	Area burned as a proportion of total production area[2]	Proportion of residue remaining after any removal	Proportion of remaining residue actually burned	Fraction oxidised[3]	N fraction of biomass[1]	N_2O emission factor[3]
Wheat	0.86	0.46	0.7	1	0.7	0.9	0.005	0.007
Barley	0.86	0.46	0.5	1	0.7	0.9	0.005	0.007
Oats	0.86	0.30	0.5	1	0.7	0.9	0.005	0.007

[1] Table 9

[2] This figure is only used for calculations from 1990 to 2004, not from 2005 onwards.

[3] IPCC (1996)

5.3 Tussock burning

5.3.1 Area of tussock burned

For IPCC reporting, New Zealand activity data for the annual area of tussock grassland burned are currently based on South Island Regional Council burning consents from 1990 to 2005. The South Island regions of Canterbury, Otago and Southland are the predominant tussock burning regions in NZ, with burning in the North Island being negligible (e.g. 0.80% of total tussock burning in NZ in 2007 (Table 19)).

Based on expert opinion from Southland, an assumption has been applied to these national burning consent figures that only 20% of the consented area is burned in a given year. These estimated area values are then used in the national greenhouse gas inventory to calculate N_2O emissions.

Burning consent data from 2003 onwards provide less information than previously, as burning has become a permitted activity in some regions. However, since 2005 data on the area of tussock grassland burned annually have been collected through the Statistics NZ APS (Table 19). Based on this information, there has been a dramatic reduction in the area of tussock grassland burned from 2007 to 2009 and a smaller reduction (33%) in the burning of other (non-tussock) standing vegetation over the same time period.

Based on Statistics NZ APS data and expert opinion, we have evaluated the appropriateness of using adjusted consent data to estimate the area of tussock burned annually.

Table 19: Summary of data from the Statistics NZ Agricultural Production Survey/Census on the area (hectares) of "other standing vegetation" burned on agricultural land in NZ (C = confidential, R = restricted, purple = estimated, *NA* = not available) (extracted from Table 13).

Year	Burning of other standing vegetation (ha)										
	Tussock grasslands			Other			All incl. Tussock			Total burning	Tussock/total burning
	NI	SI	all NZ	NI	SI	all NZ	NI	SI	all NZ	all NZ	all NZ
2005	*NA*	*NA*	R	*NA*	*NA*	*NA*	R	R	R	R	0.639
2006	*NA*	*NA*	15,297[1]	*NA*	*NA*	*NA*	1,293	22,630	23,922	23,922	0.639
2007	188	23,195	23,383	3,258	9,927	13,184	*NA*	*NA*	*NA*	36,567	0.639
2008	R	R	18,297	2,408	11,383	13,790	*NA*	*NA*	*NA*	32,087	0.570
2009	C	C	R	2,403	6,418	8,821	*NA*	*NA*	*NA*	R	R

[1] Estimated using ratio of tussock burning to total burning from 2007 census. There were no data collected specifically on tussock burning in 2005 and 2006.

5.3.2 Assessment of the available information of area of tussock burned

Thomas et al. (2008) concluded that burning consent information from local authorities provides the best option for estimating tussock burning activity from 1990 up until 2003. However, they also noted that in 2007 there was a large discrepancy between the Statistics NZ census information and the values used in inventory calculations based on the consent data and assumed burning proportion (i.e. 20% of the consented area). Further APS data (2005–09) appear to support this observation (Figure 6). In addition, the current inventory assumes that the areas burned from 2006 to 2009 are the same as the 2005 burning consent data. The large inter-annual variation evident from the APS data (Figure 6) suggests that this is not a valid assumption and updated consent values should be obtained.

Paragraph removed as it contained restricted data.

Please note that the APS information collected for 2005 and 2006 does not include a specific area for tussock burning, but records all standing vegetation burned. For these 2 years, we have assumed that the proportion of tussock grassland burned to total standing vegetation burned was the same (64%) as the 2007 census (i.e. no sample error in values), when tussock area burned was specifically recorded (Table 19).

We note that there are significant areas of other standing vegetation (excluding tussock grassland) included in the APS burn data (Table 19). Incorporating these values into our recommended calculations of N_2O emissions is beyond the scope of our study. However, we recommend that emissions from this non-tussock category be investigated further so that these emissions can be accounted for in the national inventory.

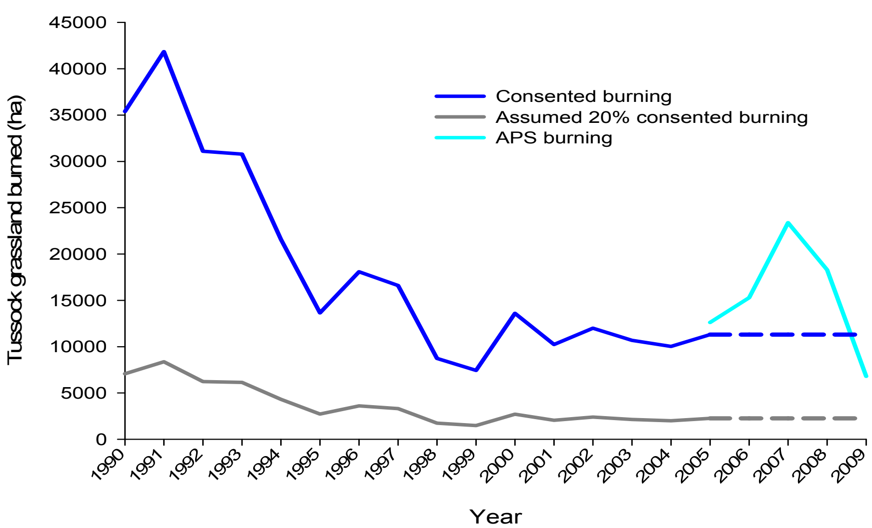

Figure 6: Summary of the three approaches to quantifying tussock burning since 1990: areas for burning that are consented by local authorities, the assumed 20% burning of these consented areas (currently used in the national inventory), and data collected through the APS on areas burned.

5.3.3 Summary of survey of experts

To further investigate the suitability of using consented burning areas, data and opinions from experts at South Island local authorities were collected through a tussock burning questionnaire (Appendix 2).

In Canterbury, burning has been controlled by the Land and Vegetation Management Regional Plan Part IV (Land Management Fires, Canterbury Hill and High Country) since 2005, when a significant proportion of burning became a permitted activity (Cathie Brumley, pers. comm.). Burning most commonly occurs in Canterbury from July to September, but can occur outside of these months (although consents are a requirement for burns in late spring/early summer and in autumn) (Neil MacDonald, pers. comm.). Environment Canterbury (ECan) must be notified of an intention to burn and provided with maps of the proposed location, in order for a burn to comply with the rules of a permitted activity. ECan is currently unable to access the files documenting these proposed burning activities.

Burning is generally a permitted activity in Otago also, under the Code of Practice for the Management of Vegetation Burning in the Otago High Country created in 2002. The Otago Regional Council could not provide any data related to areas burned annually. Furthermore, the District Councils in Otago which act as the Rural Fire Authorities do not manage vegetation burning under their plans so are also unable to provide data on the area burned.

Environment Southland requires consents for burning in two zones of the Southland region: one which requires year-round consent for burning, and the other which requires consent only in the summer season (October to March). Burning is a permitted activity outside of these zones provided that a fire ban is not in place from the Rural Fire Authority, with the majority of burning occurring in September (Gary Morgan, pers. comm.). Environment Southland has provided information on the areas consented for burning for the period from 2006 to 2010 (Appendix 3).

There is no intentional burning of tussock grassland on Public Conservation Land (PCL) for conservation management. However, burning in these areas can occur from accidental wildfires and out of control land clearing burns (Tony Teeling, pers. comm.).

There are many potential explanations for why consented burning areas provided by Regional Councils may be different to those areas collected through the Statistics NZ APS (Figure 6). Table 20 summarises the main differences between the data collection methods. As stated earlier, most burning in NZ is now a permitted activity provided that the conditions set by the local authorities are met, and these areas burned are not currently included in the consent values provided by Regional Councils. Entire regions are not necessarily controlled by Regional Councils. For example, Environment Southland control the burning in two zones by issuing burning consents, but the remainder of the region is controlled by the Southern Rural Fire Authority who permit burning and focus on the safety and control aspects of the burn. There will also be land users who neglect to apply for burning consents. Permitted activities are not exempt from compliance issues either, as although there are legal requirements to submit burning plans, not all land users comply with the regulations. ECan check compliance by undertaking aerial surveys with further investigation carried out if any suspicious activity is noted (Neil MacDonald, pers. comm.). A flyover survey in 2007 of the Southern Canterbury region indicated that less than half of the burns occurring had burning plans submitted to ECan, but compliance was expected to improve over the years with wider publication of the requirements to burn (Thomas et al. 2008).

Table 20: Differences between collection methods of data on the area of tussock burned annually: burning consent data from local authorities vs. data collected through the Statistics NZ Agricultural Production Survey/Census.

Consented burn data	APS burn data
Submitted in advance – not necessarily what is burned in specified year (consents can be valid for up to 10 years)	Submitted after burning event – are what has actually occurred during the previous 12 months
Consents provide legal controls on burning – often checked for compliance with fines for non-compliance	Confidential data with no penalties or rewards for correct or under/over-reporting
Rely on farming community to obey by-laws and requirements of region	Rely on farming community to accurately fill-in and return survey/census forms
Do not include accidental burns	May include accidental burns in initial years but only include 'controlled burning of vegetation' from 2007 to present
Are for the calendar year	Are for the farming year i.e. 12 months up to 30 June of the specified survey year
20% of the area consented for burning is used to represent the actual annual area burned	Not all farms are reviewed in 'survey' years (vs. census years) – extrapolation required

The annual data provided by local authorities represent the area of grassland that, in the given year, was consented to be burned. However, the majority of consents are valid for more than a year (e.g. 5 or 10 year consents), with the consented area able to be burned only once (but at anytime during that time period provided there are no fire restrictions in place). The strong influence that seasonal environmental conditions have on this type of burn means that the majority of land users who have long-term consents will burn in the same 'good condition' years, resulting in peaks in the area burned every few years. This issue is further complicated by the changes in requirements for consented and permitted burns since 1990, creating inconsistencies when comparing data between years and regions. For example, since 2005 in Canterbury there have been both permitted burns and consented burns occurring under the Land and Vegetation Management Regional Plan Part IV, but also burns on 10-year consents that were issued before this plan came into force (Neil MacDonald, pers. comm.). As a result, information on the actual area burned in each year is unattainable through the burning consents method of data collection.

Furthermore, the national greenhouse gas inventory assumes that only 20% of the consented area is actually burned. This figure is based on expert opinion from Environment Southland with the majority of burning in Southland being only to clear patches of bracken, fern and heavy tussock (Gary Morgan, pers. comm.). Burning in this region represents, on average, 23% of the area of all consented burns in New Zealand (from 1990 to 2005). However, the situation is clearly different in Canterbury with experts citing that fluctuating environmental conditions and financial considerations can dictate whether burning can occur in a given year; the vast majority of consented burns occur within the consented time period (Cathie Brumley and Neil MacDonald, pers. comm.). The large discrepancy between the '20% burned assumption' data and the APS data further highlights that tussock burning is likely to have been underreported in the past and that the 20% assumption does not provide an accurate estimate of tussock burning in New Zealand. ECan has records of the areas burned as a permitted activity, as well as compliance monitoring and consent data since 2006. These data could be used to compare actual versus consented burn areas. However, until this information can be accessed and provided to us we are limited in our ability to evaluate the extent of miss-reporting and fully assess the methods of data collection. Discrepancies in the consistency of the follow-up information may also limit its usefulness (Cathie Brumley, pers. comm.).

5.3.4 Recommendations for tussock area burned activity data

In the absence of further information, **we recommend using total consented burn area values from 1990 to 2005** (Table 21), while acknowledging that:

- The total area consented for burning in a given year is not necessarily burned in that year (longer term consents are common)
- Not all of the consented areas will necessarily be burned
- Some burns will occur without prior consent (e.g. illegal and accidental burns)
- Permitted burns occurred from 2003 onwards, which have not been recorded.

We recommend that, from 2005, burn data collected through the Statistics NZ APS be used (Table 21), as they are the most accurate documentation of the actual occurrence of burning over the specified years.

Table 21: Recommended NZ values for area (hectares) of tussock grassland burned annually from 1990 to 2009.

Year	Area burned (ha)[1]	Source
1990	35,392	Total consented burning areas (Regional Councils)
1991	41,841	
1992	31,091	
1993	30,783	
1994	21,585	
1995	13,651	
1996	18,076	
1997	16,600	
1998	8,724	
1999	7,434	
2000	13,606	
2001	10,233	
2002	11,992	
2003	10,691	
2004	10,022	
2005	R	APS burned areas[2] (R = restricted data)
2006	15,297	
2007	23,383	
2008	18,297	
2009	R	

[1] Note that the 2006 IPCC Guidelines for National Greenhouse Gas Inventories recommend that annual data be used to calculate the emission of non-CO_2 gases, rather than averaging the activity data over a set period (e.g. 3-year average recommended in the 1996 IPCC guidelines), so that inter-annual fluctuations due to climatic variability are portrayed (IPCC 2006).

[2] These values include the small amount of burning (<1%) that occurs in the North Island (see Table 19).

5.3.5 Recommendations for calculating N_2O emissions from the burning of tussock grasslands

We recommend that the following equations, refined from the IPCC 1996 guidelines, be used to calculate N_2O emissions from the burning of tussock grasslands (Figure 7). Values for the area burned annually can be obtained from Table 21, and the remaining values are in Table 22 with a discussion below.

Equation 1: **Biomass burned (Gg dry matter) =**

Area burned annually (ha) x Above-ground biomass density (t dm/ha) x Above-ground biomass fraction burned x 10^{-3}

Equation 2: **Total C released (Gg) =**

Biomass burned (Gg dm) x Fraction live and dead biomass x Fraction biomass oxidised x Ratio of C loss to biomass loss

Equation 3: **Total N_2O emissions (Gg) =**

Total C released (Gg) x Ratio of N:C loss x N_2O emission factor x 44/28

Figure 7: Refined IPCC 1996 equations for calculating N_2O emissions from the burning of tussock grasslands (1990 to present).

Please note that to calculate CH_4 emissions from tussock grassland burning, in Equation 3 of Figure 7 remove the ratio of N:C loss and replace the N_2O emission factor and N_2O molecular weight conversion (44/28) with the CH_4 emission factor (0.005) and CH_4 molecular weight conversion (16/12), respectively (IPCC 1996).

Table 22: Recommended values for calculating N_2O emissions from the burning of tussock grasslands (1990 to present) for the refined IPCC 1996 equations in Figure 7.

Description	Factor	Source
Tussock above-ground biomass density (t dm/ha)	28	(Payton & Pearce 2001)
Above-ground biomass fraction burned ($Frac_{BURN}$)	0.356	(Payton & Pearce 2009)
Fraction of live and dead biomass	1 (-)	
Fraction biomass oxidised	1 (-)	
Ratio of C loss to above-ground biomass loss	0.45	(Payton & Pearce 2009)
Ratio of N:C loss	0.015	(Payton & Pearce 2009)
N_2O emission factor	0.007	(IPCC 1996)
Conversion factor to full molecular weight of N_2O	44/28	(IPCC 1996)
CH_4 emission factor	0.005	(IPCC 1996)
Conversion factor to full molecular weight of CH_4	16/12	(IPCC 1996)

The NZ-specific values used in Table 22 originate from a study of the burning of tall tussock grassland (more specifically *Chionochloa rigida*) (Payton & Pearce 2001; Payton & Pearce 2009). In the absence of further information we have assumed that these values apply to all types of tussock grassland that are burned in New Zealand. However, more information is required on the amount and type of other tussock grasslands that are burned, and the biomass and nutrient losses upon burning, before the appropriate values can be incorporated into the reporting of N_2O emissions. Although there are no official records, burning in Southland is usually short tussock associations and some *C. rubra* (Gary Morgan, pers. comm.).

The above-ground biomass fraction burned (i.e. $Frac_{BURN}$) assumes a spring burning (the recommended management practice in New Zealand). The current inventory value for the above-ground biomass fraction burned is 0.32 and this value is based on spring burning at Mt. Benger, Otago (Payton & Pearce 2001). However, Payton & Pearce (2009) published a full report of the data from this trial and the average value reported for spring burning at Mt. Benger is 0.356. We recommend that the inventory value be updated to the latest figure.

Above-ground biomass nutrient contents of tussock grasslands were discussed in Thomas et al. (2008) (Table 23).

Table 23: Nitrogen contents and N:C ratios in live and dead above-ground biomass (from data reported by O'Connor et al. (1999)[1] and Payton & Pearce (2009)[2]) (revised Table 25 from Thomas et al. 2008).

	N contents (kg/ha)			N:C ratios		
Site	**Live**	**Dead**	**Live + Dead[3]**	**Live**	**Dead**	**Live+ Dead**
Tall tussock grassland:						
Craigieburn[1]	75	153	228	0.017	0.009	0.010
Hakatere Basin[1]	61	115	176	0.012	0.008	0.009
Tekapo[1]	63	62	125	0.011	0.007	0.008
Deep Stream[2]	77	91	168	0.015	0.013	0.014
Mt. Benger[2]	67	86	152	0.016	0.009	0.011
Average of tall tussock grassland	*69*	*101*	*170*	*0.015*	*0.010*	*0.011*
Short tussock grassland:						
Tekapo[1]	38	31	69	0.017	0.012	0.014
Mixed tussock grassland:						
Hakatere[1]	52	59	111	0.016	0.012	0.014
Weedy short grassland:						
Craigieburn[1]	30	8	38	0.018	0.010	0.015
Hakatere[1]	7	4	11	0.018	0.008	0.012
Tekapo[1]	15	10	25	0.017	0.014	0.016
Average of weedy short grassland	17	7	25	0.017	0.011	0.014

[3] "Live + dead" N contents may not exactly equal N contents of "live" plus N contents of "dead" due to rounding errors.

Summary of key nutrient and tussock composition considerations for assessing these data:

1. O'Connor et al. (1999) report a compilation of tussock grassland studies, most of which were carried out in the late 1970s. The N content of the vegetation was chemically analysed, but the C content of the vegetation was assumed to be 50% of the above-ground biomass. In contrast, Payton & Pearce (2009) measured both the C and N content of the vegetation.

2. O'Connor et al. (1999) present nutrient values for tussock vegetation only, whereas Payton & Pearce (2009) present nutrient values for tussock vegetation as well as the many other above-ground vegetative components of a tussock grassland. As it is the whole tussock grassland that is burned, not exclusively tussocks, it is deemed important to incorporate all vegetation in the biomass and nutrient values.

Furthermore, Payton & Pearce (2009) have measured the actual nutrient losses in tussock grasslands due to fire. As both C and N losses are proportional to above-ground biomass losses we consider it to be more appropriate to use these data (rather than the values in Table 23) to provide New Zealand-specific values of nutrient losses from the burning of tussock grasslands.

Upon burning of tall tussock grassland an average of 0.45 t C is lost per tonne of biomass lost (Payton & Pearce 2009). This value aligns well with the range of previously reported and recommended values (range of 0.4 to 0.5 t C/t dm) (IPCC 1996; O'Connor et al. 1999; Payton & Pearce 2009). Furthermore, this value describes exactly how much C has been lost from the vegetation (both live and dead material) through burning. Therefore, the partitioning of biomass into live and dead fractions and the reporting of the fraction of biomass oxidised (i.e. oxidation factor) is not necessary. This is why, for input into the refined IPCC 1996 equations (Figure 7), the fraction of live and dead biomass and the fraction of biomass oxidised are both considered to be 1. Alternatively, both factors can be removed from the equation.

IPCC (1996) suggest that a default factor of 0.006 should be used for the N to C ratio. We recommend that this be altered to a New Zealand-specific value of 0.015, as this is the average ratio of N loss to C loss upon burning of tussock grasslands (Payton & Pearce 2009).

5.3.6 Recommendations for future refinements

- A major source of uncertainty in calculating N_2O emissions from the burning of tussock grasslands is the area burned each year. Further access to data from local authorities is needed to explain the discrepancy between of methods used to estimate the area burned. As suggested by Thomas et al. (2008), the use of aerial surveys and satellite remote sensing techniques in the future may improve accuracy of the data.
- Tussock burning studies conducted in a variety of locations in the full range of tussock grassland types would provide greater certainty regarding the appropriateness of the current values (based on Payton & Pearce 2009) for above-ground biomass, biomass fraction burned, and nutrient loss.
- Non-tussock grassland appears to represent a large part of the area of standing vegetation that is burned (as recorded by APS). Work is needed to estimate nitrous oxide emissions from burning of this non-tussock vegetation.

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- Tony Teeling (DOC) for information about tussock burning in relation to Public Conservation Land.

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8 Appendices

Appendix 1

Seed certification figures on areas grown (ha) from AsureQuality Seed Certification Statistics 2008–09 for the data 2004/05 to 2008/09 and from AgriQuality Seed Certification Statistics for the years prior to 2004/05.

Herbage/ Amenity grasses	1990 /91	1991 /92	1992 /93	1993 /94	1994 /95	1995 /96	1996 /97	1997 /98	1998 /99	1999/ 2000	2000 /01	2001 /02	2002 /03	2000 3/04	2004 /05	2005 /06	2006 /07	2007 /08	2008 /09
Alaska brome											13								
Annual ryegrass					4														
Browntop	381	787	713	178	110	194	409	512	462	421	206	217	290	291					
California Brome/ Brome grass				11							10	30	18		24	47	22	12	12
Cocksfoot	1660	1100	1015	1001	1000	1225	1014	376	454	348	460	676	559	626	668	683	655	816	958
Creeping Bent	19	25		32	52	41	29	9		30	53	35							
Crested Dogstail	309	249	209	122	209	220	77		336	279	102	8	49	174	131	206	262	19	17
Crested Hairgrass				1	1														
Dryland browntop							4	4	4	16	19	19	21	14	8	6	6	6	6
Festulolium spp															700	1237	1057	734	768
Fescue – fine/red	45	80	62	77	89	57	26	3		21	9	9			20	45	15	14	58
Fescue – meadow				56	57	4													
Fescue – tall	3134	2609	919	174	143	209	361	598		1027	1245	1638	1549	1260	1028	892	989	924	749
Grazing brome	8	98	56		50	129	272	300					77	55		32			
Kentucky Bluegrass				7	11														
Meadow Brome															7				
Mountain Brome																10	18		6

Herbage/ Amenity grasses	1990/ 91	1991/ 92	1992/ 93	1993/ 94	1994/ 95	1995/ 96	1996/ 97	1997/ 98	1998/ 99	1999/ 2000	2000/ 01	2001/ 02	2002/ 03	20003 /04	2004/ 05	2005/ 06	2006/ 07	2007/ 08	2008/ 09
Phalaris	110	83	98	100	114	95	67	59		74	45	34	50	57	29	19	19	19	
Prairie Grass	178	154	283	708	354	709	381	240		13	48	124	147	136	115	48		61	51
Reed canary grass											1								
Ryegrass – annual			4	4															
Ryegrass – hybrid	624	689	760	1110	1196	1210	1381	2031	2078	2010	1383	1668	2517	2846	2629	2181	1245	2066	1624
Ryegrass – italian	2324	3291	3003	2273	1296	3141	4077	3142	3222	2459	2103	3061	4787	5727	6257	4049	2276	3663	5544
Ryegrass – perennial	6937	6383	8485	8375	8742	11355	11639	14583	16631	15033	10127	5872	7687	10434					
Smooth Brome	7	6																	
Timothy	92	33	30	46	111	111	96	111	144	130	117	171	254	218	155	55	41	32	29
xFestulium spp																16	16	16	27
Upland Brome			7					6	24	24	41	73	53	82	84	2	58	69	48
Yorkshire Fog	1			5	38	37	40		13	11	12				5	15	10	7	
HERBAGE TOTAL	**15829**	**15587**	**15644**	**14280**	**13577**	**18737**	**19873**	**21974**	**23368**	**21896**	**15994**	**13635**	**18058**	**21920**	**11860**	**9543**	**6689**	**8458**	**9897**

Legumes	1990/ 91	1991/ 92	1992/ 93	1993/ 94	1994/ 95	1995/ 96	1996/ 97	1997/ 98	1998/ 99	1999/20 00	2000/ 01	2001/ 02	2002/ 03	20003/ 04	2004/ 05	2005/ 06	2006/ 07	2007/ 08	2008/ 09
Birdsfoot trefoil	4	6	6	12	12	19	31	58	58	8	8	8	4	6	6	9			
Caucasian clover						21	51	62	49	63	54		13				15	15	7
Clover – red	721	1019	1057	1290	1151	1401	1366	1203	860	1268	899	781	780	594	579	666	882	691	380
Clover – strawberry			3	3						3	3	2							
Clover – white	12016	16705	15941	16995	15201	14973	15366	15217	11304	10055	7583	6059	7053	7714	8339	10160	8946	6282	5915
Persian clover																1			
Dorycnium													1						
Hybrid Serradella						30	20												
Lentil								11	24	79	47	19							
Lotus	423	192	81	142	222	303	274	188	206	122	91	25	18	14	6	17	19	13	3
Lucerne	288	316	223	219	107	90	67	45	34	65	41	58	111	124	213	252	193	154	168
Sulla	11	10	5												2	2			
LEGUMES TOTAL	**13463**	**18248**	**17316**	**18661**	**16693**	**16837**	**17175**	**16784**	**12535**	**11663**	**8726**	**6952**	**7980**	**8452**	**9145**	**11107**	**10055**	**7155**	**6473**

	1990 /91	1991 /92	1992 /93	1993 /94	1994 /95	1995 /96	1996 /97	1997 /98	1998 /99	1999/2 000	2000 /01	2001 /02	2002 /03	20003 /04	2004 /05	2005 /06	2006 /07	2007 /08	2008 /09
Brassicas																			
Brown Mustard															10	4			
Beet					4		21												
Crambe																26	29	33	59
Ethiopian Cabbage																2	9		14
Kale	147	318	347	359	351	422	207	42	111	277	181	182	364	205	232	143	311	384	411
Rape	431	222	52	275	123	259	291	170	952	537	370	129	136	683	934	888	295	518	569
Swede	27	78	113	115	53	47	18	20	49	33	55	64	47	61	90	41	26	100	89
Turnip	103	231	140	127	101	376	344	132	357	213	133	164	321	236	356	197	176	484	316
BRASSICAS TOTAL	**708**	**849**	**652**	**876**	**632**	**1104**	**881**	**364**	**1469**	**1060**	**739**	**539**	**868**	**1185**	**1622**	**1301**	**846**	**1519**	**1458**

Appendix 2

Sample questionnaire for determining Council-based information on the burning of tussock grasslands

Lincoln office:
Private Bag 4704, Christchurch Mail Centre,
Christchurch, 8140
Tel: 03 977-7340 – Fax: 03 325-2074

Dear

Please find attached a short questionnaire about the burning of tussock grassland in your region.

Why we have sent you this questionnaire:

- Information on the amount of burning of tussock grasslands in NZ is very uncertain.
- We have identified that tussock burning occurs in your region and that your Council may be responsible for the regulation of this type of burning.
- We believe that you are able to provide us with an estimate of the amount of tussock that is burned currently and historically.
- This information has been provided in the past by you or other staff at your Council.

Why this information is required:

- MAF is obliged to provide annual data on New Zealand tussock burning as part of greenhouse gas emission accounting from 1990 to the present.
- Resource consent data provided by South Island Regional Councils is used by MAF and MfE to determine annual tussock burning back to 1990.
- It is currently assumed that the actual area of tussock grassland burned annually is 20% of the consented burning area.
- However, since 2005 Statistics New Zealand has collected annual tussock burning information through the Agricultural Production Survey and Census. This information has generated concern over the accuracy of the resource consent data that is currently used by MAF and MfE for the national greenhouse gas inventory.

Consequently, Plant & Food Research have been contracted by MAF to review information on the amount of burning of tussock grasslands. We would appreciate it if you could please fill out the following questionnaire or pass it on to other appropriate experts in your Council. Although we recognise that there will be gaps in knowledge, we believe that you or other experts at your Council are the best placed to provide expert advice and opinions on the amount of tussock burned and the methods of collecting this information. We are also sending out this questionnaire to other South Island Regional Councils.

How we will assess the information:

We will be making recommendations to MAF regarding the most accurate annual national values of tussock burning to report from 1990, based on a collation of the best available information that you provide, available databases and other expert opinions. We will also make recommendations about the future collection of information. Where a response to this questionnaire has been given as an opinion we will clearly identify this.

We would be grateful if you could return the completed questionnaire as soon as possible. If we haven't heard back from you by   this questionnaire will be followed up by a phone call. Please do not hesitate to contact us should you have any queries (see contact details below). Thank you in advance for your cooperation.

Yours Sincerely,

Tussock Burning Questionnaire

Name: ____

Position: ____

Organisation: ____

Contact email: ____

Contact phone: ____

1. Are land-use consents for burning tussock grasslands in your region issued by your organisation?

Yes / No (*please circle*)

If no, please list the organisation/s responsible for issuing land-use consents for burning tussock grasslands in your region.

2. Is the burning of tussock grasslands in your region a permitted activity?

Yes / No (*please circle*)

If yes, do you require plans stating the proposed burning area to be submitted?

Yes / No (*please circle*)

3. Are land-use consents for burning tussock grasslands in your region a year-round requirement?

Yes / No / Not applicable (*please circle*)

If no, please indicate when consents are required.

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

(*please circle*)

4. During which month/s does the majority of tussock grassland burning take place in your region?

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

(*please circle*)

5. Do you agree with the following information collected from land-use consents and currently used in the national inventory regarding burning of tussock grasslands for your region?

Yes / No (*please circle*)

Please feel free to alter any values and provide comments where appropriate.

Year	*Region* consented tussock burning area (ha)	Assume 20% of consented annual area (ha) is burned	Your comments
1990			
1991			
1992			
1993			
1994			
1995			
1996			
1997			
1998			
1999			
2000			
2001			
2002			
2003			
2004			
2005			
2006			
2007			
2008			
2009			
2010			

6. Can you provide us with data on the consented/approved area for burning tussock grasslands in your region for each year from 2006 to 2010?

Yes / No (*please circle*)

If yes, please add to table above or attach file.

Added to table above / File attached (*please circle*)

7. In your opinion does the current assumption from MfE that 20% of the consented area is burned annually accurately estimate the area of tussock grasslands burned in your region from 1990 to the present day?

Yes / No (*please circle*)

Please comment (e.g. consider factors that may influence this percentage, how this percentage may have changed through time, and whether you can provide more appropriate recommendations for calculating the actual area burned in your region).

8. Since 2005, Statistics NZ has collected national census and survey data for tussock burning. Given that every farmer in NZ is surveyed, we assume that the 2007 Agricultural Production Census is the most accurate source of data. However, when the census data is compared to the national inventory value in 2005 (which is 20% of total consented area for burning and provided by Regional Councils) there is a huge discrepancy, i.e. the area burned in 2007 from the census data is approximately ten times greater than the national inventory value in 2005.

Please comment on this statement. Are you able to provide any evidence that consented areas are likely to be underestimates of the total area burned, e.g. compliance checks?

9. Do you have other methods of collecting information on the area of tussock grassland burned in your region?

Yes / No (*please circle*)

If yes, please describe the method(s) and attach data if available.

10. Do you have records of the type of tussock grasslands that are burned (e.g. tall *Chionochloa* tussock grassland, mixed tussock grassland, short *Festuca*/*Poa* tussock grassland)?

Yes / No (*please circle*)

If yes, for each type of tussock grassland please indicate the areas that are burned annually and attach data if available.

11. Is there any additional information and/or data that you can provide us to quantify the amount of burning from regional tussock grassland burning?

On behalf of the research team at Plant and Food Research, Lincoln, thank you for completing this questionnaire. Please return using the following contact details.

Contact:
Email:
Phone:
Fax:

Postal address:
Plant and Food Research
Private Bag 4704
Christchurch Mail Centre
Christchurch 8140

Physical address:
Plant and Food Research
Canterbury Agriculture & Science Centre
Gerald St
Lincoln 7608

Appendix 3

Areas consented for burning in Southland from 2006 to 2010, provided by Environment Southland

Year	Consented tussock burning area (ha)[1]
2006	2,150
2007	3,560
2008	3,560
2009	7,610
2010	9,200

[1] These are 5-year consents i.e. can only burn any area once during the consent period