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Land Use Opportunities for Aotearoa

Greenhouse gas emission estimates from within cropping systems

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Overview

The most important non-fossil fuel-based greenhouse gas (GHG) emissions from cropping farms and orchards are the biogenic nitrous oxide (N_2O) emitted from soils, methane (CH_4) emissions from livestock animals grazing of crops, understorey cover or residues, and the carbon dioxide (CO_2) emissions from soil following the application of lime, dolomite and urea. These emissions are reported at a national level in the Aotearoa-New Zealand Greenhouse Gas Inventory ("Inventory") (Ministry for the Environment 2024) to estimate "anthropogenic" GHG emissions. This methodology aligns with the UNFCCC guidelines (IPCC 2006, 2019), distinguishing these emissions from non-anthropogenic emissions or "background emissions". In a farm or orchard context, anthropogenic emissions are related to inputs from managing a crop. While guidance for estimating emissions from livestock farming, which represent the majority of agricultural GHG emissions, is available, there is limited information for estimating GHG emissions from farm or orchard cropping. The International Panel for Climate Change (IPCC) methodology does not provide guidance on estimating emissions from perennial fruit or tree crops. The approach utlised in the Inventory identifies "key crops", considered the most significant contributors to emissions from cropped areas for which data must be collected. In the current inventory, this is limited to 14 arable, vegetable, and forage crops (Ministry for the Environment 2024).

We provide estimates of GHG emissions expected from producing crops on an average or typical farm or orchard. We only estimate gross GHG emissions, meaning we do not estimate the potential carbon sequestration in soil and plant biomass, as sequestration estimates in cropping systems are highly uncertain.

Methodology

We followed the Aotearoa-New Zealand Greenhouse Gas Inventory approach (Ministry for Primary Industries 2022; Ministry for the Environment 2024) to estimate anthropogenic biogenic GHG emissions within the farm or orchard boundary. Direct and indirect N_2O emissions from crops were estimated from nitrogen (N) inputs from synthetic fertlisers, returns of crop residues and livestock excreta deposition. Estimates of CH_4 emissions from ruminants and manure management were derived from New Zealand inventory data for each livestock type, considering feed intake. For crops already included in the inventory, we utlised previously reported factors (Ministry for Primary Industries 2022). However, for the other crops not included in the Inventory, it was necessary to estimate the N returned from crop residues in addition to the application of synthetic N fertliser. There is no complete survey of N fertliser applications to individual crops; national fertliser input data are normally aggregated to land use type that is appropriate for the Inventory.

We gathered information for synthetic fertliser N inputs, residue management and grazing through a range of sources. These included published and unpublished literature, industry recommendations, industry and research experts. The availability and reliability of these estimates is highly variable. Ideally, we used Aotearoa-New Zealand data. Where this was not available, overseas data were used. Where multple sources of information were available and similar, we expect derived estimates to be most robust. In most cases there was limited information for residue management, especially for the residue management of perennial crops.

Using the input data and emission factors (EF) from the Inventory, we estimated both direct and indirect N_2O emissions from soils, and CH_4 emissions. Direct N_2O emissions are those that are emited on the farm or orchard from soil; indirect N_2O emissions are those from leached or run-off N, or from volatlised N deposited off-site.

To enable comparison of GHG emissions between land uses, N_2O and CH_4 were converted to CO_2 equivalents (CO_2-e) using global warming potentals of 265 and 28, respectively, over a 100-year horizon (GWP100) based on the Intergovernmental Panel on Climate Change (IPCC) Fifh Assessment Report (AR5) (IPCC 2014). These values are now used in the latest New Zealand inventory (Ministry for the Environment 2024). Previous inventories used values from the AR4 report (IPCC 2007). GHG emissions are reported on a CO_2-e per hectare basis and are reported on an annual basis. We annualised the emissions from the crop rotations by dividing the cumulative emissions by the length of the rotation.

Crop rotations

Grazed ryegrass/white clover and silage maize.
Broadacre vegetables: squash, onions, beetroot, sweetcorn, beans, and oats (grazed).
Intensive vegetables: lettuce, cabbage, spinach, cauliflower, and oats.

Using the estimates

Our estimates are indicative rather than absolute. They are based on the best information we had available, much of which relies on experts' judgements on what are typical inputs and how they might vary. We provide a range of what we think is reasonable from the range of sites and management where these crops are currently grown, given the limitations of the methodology. These estimates provide information that could be used to compare one crop type or rotation with another.

Caveats:

- Assumed that the adaptation of the Inventory methodology is appropriate at smaller scales. Uncertainty of N_2O emissions is large especially at smaller scales.
- Assumed non-urea N fertiliser was applied. Non-urea-based fertiliser has a higher EF than urea in Aotearoa-New Zealand. Urea is widely used on a range of annual crops and perennial fruit crops. However, there is insufficient information available to apportion the amounts of urea applied and how these vary with different crops. The urea EF is 0.0059 kg N_2O-N/kg N compared with 0.01 kg N_2O-N/kg N for other N fertilisers (Ministry for Primary Industries 2022).
- N in residues returned from mowing is not included in the calculations and would likely increase N_2O emissions.
- N mineralisation from soil organic matter is an important source of N_2O emissions in cropping systems but is not specifically accounted for.
- Whether emission factors for woody material from pruning of fruit and tree crops are appropriate is uncertain.
- There is lack of robust information for emissions from burning of residues.
- CH_4 emissions will vary largely depending on the amount of feed eaten.

Please read the inclusions, exclusions, and assumptions we have identified in Table 1.

Other GHG emissions are associated with growing crops or producing plant and fibre products that occur within and outside the orchard or farm boundaries. Examples within the boundaries include fuel use for farm operations (tillage, fertilising, irrigation, processing and packing). Examples outside the boundaries include the manufacture and transport of fertilisers, agrichemicals and other products, and the transport and processing of food or fibre products.

Tables

Table 1 summarises what has been included in the estimates, what has not been included and important assumptions made to estimate the emissions. There are four tables of estimates of emissions. Two provide only the estimates of typical inputs and emissions (Tables 2 and 4), the other two include the estimates of the range as well as the typical value (Tables 3 and 5).

Table 1 Summary of inclusions, exclusions and assumptions for greenhouse gas emission estimates from cropping systems.

What is included	What is not included	Important assumptions in estimations
Thirty-one exemplar annual and perennial crops, and three crop rotations for intensive vegetable and broadacre arable-vegetable, pasture-maize. Biogenic N_2O and CH_4 and CO_2 from lime (truffles only) from inputs within the orchard or farm boundary, including offsite, indirect N_2O emissions from N applied within the farm and orchard boundary. Direct and indirect N_2O emissions from the inputs of synthetic N fertilisers, return of N in crop residues, including prunings from fruit and tree crops. Direct and indirect N_2O emissions from excreta-N from animals grazing in a crop rotation. This is based on emissions of excreta in the paddock and not manures that may be applied. Estimates of CH_4 emissions from grazing in crop rotations. Estimates for CO_2 emissions from liming of truffières are included because of the large inputs requiredto raise pH to desirable levels compared to other crops.	N_2O and CH_4 emissions from applying or storing organic fertiliser or composts. The inventory does not report on organic fertiliser inputs. N_2O emissions from residues from understory in orchards. There is a lack of information on what emissions from these residues are. N_2O emissions due to soil N mineralisation. The Inventory estimates N_2O emissions from mineralisation from annual net changes in soil organic N for a land use at the national level. CO_2 emissions from liming, dolomite and urea, except for truffles due to the high rate typically applied to establish truffières. N_2O and CH_4 emissions from burning of residues, e.g. cereal stubble or orchard prunings are not included. They are reported for cereal crops in the Inventory. CO_2 emissions from fuel used within the boundary. Emissions outside the farm or orchard boundary, except indirect N_2O emissions. Soil carbon and biomass carbon. There is a lack of robust information on the changes of soil carbon or carbon biomass in New Zealand cropping systems.	Assumed that all N fertiliser was applied as synthetic non-urea fertiliser N only. Used the same residue N EF for all crops as per the Inventory, although it is uncertain whether these are appropriate for woody material from pruning of fruit and tree crops. The Inventory methodology does not account for effects of climate, irrigation, soil type, or management factors affecting soil properties such as compaction, which could significantly affect emissions.

Table 2 Estimates of typical harvested yield, nitrogen inputs from fertiliser and residues (kg N/ha), biogenic greenhouse gas emissions (kg CO_2-e/ha) from selected annual and perennial crops.

	Inputs			Biogenic GHG emissions		
	Harvested Yield	Fertiliser applied	Residues	Fertiliser applied	Residues	Total
	Typical	Typical	Typical	Typical	Range lower	Range lower
Crop	t/ha	kg N/ha	kg N/ha	kg CO2-e/ha	kg CO2-e/ha	kg CO2-e/ha
Apples	63	40	105	196	470	666
Avocados	12	100	3	489	12	501
Barley	7	45	34	220	152	372
Beetroot	60	80	59	391	264	656
Blueberries	7	72	6	352	28	380
Broad beans	7	15	23	73	102	175
Cabbage	57	75	40	367	179	546
Carrot (Fresh)	70	100	91	489	406	895
Carrot (Process)	135	100	167	489	747	1237
Cauliflower	28	115	135	563	604	1166
Cherries	13	45	11	220	50	271
Chestnuts	5	45	5	98	57	155
Citrus	40	60	15	294	67	361
Hops	4	110	75	538	336	874
Kiwifruit	35	100	76	489	340	830
Kūmara	30	50	82	245	366	610
Lettuce	22	50	77	245	345	589
Macadamia	4	42	11	206	47	253
Maize (grain)	11	50	74	245	333	578
Maize (silage)	25	180	10	573	45	619
Mānuka honey	-	0	19	0	84	84
Oats (grain)	6	80	56	391	250	641
Onions	60	150	11	734	50	784
Peas	5	0	23	0	104	104
Potatoes	50	250	31	1223	138	1361
Spinach	20	30	27	147	120	267
Squash	25	80	29	391	129	520
Sweetcorn	25	140	96	685	430	1115
Truffles	-	0	10	0	45	45
Wheat	10	150	53	734	238	972
Wine grapes	9	18	20	88	90	178

Table 3 Estimates of typical, upper and lower range for harvested yield, nitrogen inputs from fertiliser and residues (kg N/ha), biogenic greenhouse gas emissions from selected annual and perennial crops (kg CO_2-e/ha). Colour gradient of green to red represents the low to high emissions.

	Inputs									Outputs (CO_2-e)								
	Yield (FW or DW) (t/ha)			Fertiliser applied (kg N/ha)			Residues (kg N/ha)			N_2O fertiliser (kg CO_2-e/ha)			N_2O residues (kg CO_2-e/ha)			Total N_2O (CO_2-e/ha)		
	Typical	Range lower	Range upper	**Typical**	Range lower	Range upper	**Typical**	Range lower	Range upper	**Typical**	Range lower	Range upper	**Typical**	Range lower	Range upper	**Typical**	Range lower	Range upper
Apples	**63**	40	130	**40**	0	120	**105**	105	105	**196**	0	579	**470**	470	470	**666**	470	1049
Avocados	**12**	7	25	**100**	6	327	**3**	2	4	**489**	29	1600	**12**	8	16	**501**	37	1616
Barley	**7**	5	10	**45**	10	125	**34**	21	46	**220**	49	612	**152**	93	207	**372**	142	818
Beetroot	**60**	40	80	**80**	25	240	**59**	39	79	**391**	122	1174	**264**	176	353	**656**	299	1527
Blueberries	**7**	6	8	**72**	50	86	**6**	6	6	**352**	245	421	**28**	28	28	**380**	272	449
Broad beans	**7**	7	7	**15**	0	46	**23**	14	32	**73**	0	225	**102**	62	141	**175**	62	367
Cabbage	**57**	45	68	**75**	25	195	**40**	32	48	**367**	122	954	**179**	142	215	**546**	265	1169
Carrot (Fresh)	**70**	60	90	**100**	25	125	**91**	74	111	**489**	122	612	**406**	332	498	**895**	454	1110
Carrot (Process)	**135**	120	150	**100**	25	210	**167**	148	185	**489**	122	1028	**747**	664	830	**1237**	787	1858
Cauliflower	**28**	22	33	**115**	25	230	**135**	108	162	**563**	122	1125	**604**	483	724	**1166**	605	1850
Cherries	**13**	10	16	**45**	30	70	**11**	8	18	**220**	147	343	**50**	34	78	**271**	180	421
Chestnuts	**5**	3	10	**45**	25	80	**5**	1	7	**98**	122	391	**57**	70	224	**155**	192	616
Citrus	**40**	25	70	**60**	40	170	**15**	10	43	**294**	196	832	**67**	45	190	**361**	240	1022
Hops	**4**	2	8	**110**	85	170	**75**	55	100	**538**	416	832	**336**	246	448	**874**	662	1279
Kiwifruit	**35**	21	53	**100**	50	220	**76**	60	100	**489**	245	1076	**340**	269	448	**830**	513	1524
Kūmara	**30**	10	48	**50**	25	100	**82**	28	132	**245**	122	489	**366**	124	593	**610**	246	1082
Lettuce	**22**	18	30	**50**	25	120	**77**	58	96	**245**	122	587	**345**	259	431	**589**	381	1018
Macadamia	**4**	1	6	**42**	11	63	**11**	3	16	**206**	51	308	**47**	12	71	**253**	64	379
Maize (grain)	**11**	7	15	**50**	25	230	**74**	46	96	**245**	122	1125	**333**	208	430	**578**	330	1555
Maize (silage)	**25**	20	30	**180**	130	230	**10**	8	12	**573**	414	733	**45**	36	54	**619**	450	787
Mānuka honey	**-**	**-**	**-**	**0**	0	0	**19**	11	25	**0**	0	0	**84**	50	112	**84**	50	112
Oats (grain)	**6**	5	9	**80**	55	150	**56**	40	77	**391**	0	0	**250**	178	344	**641**	178	344
Onions	**60**	60	100	**150**	135	170	**11**	9	15	**734**	661	832	**50**	39	66	**784**	700	897
Peas	**0**	7	7	**0**	0	0	**32**	32	32	**0**	0	0	**141**	141	141	**141**	141	141
Potatoes	**50**	49	100	**250**	25	360	**31**	23	47	**1223**	122	1761	**138**	102	209	**1361**	225	1970
Spinach	**20**	15	25	**30**	25	90	**27**	20	33	**147**	122	440	**120**	90	150	**267**	212	590
Squash	**25**	25	25	**80**	80	80	**29**	29	29	**391**	391	391	**129**	129	129	**520**	520	520
Sweetcorn	**25**	20	30	**140**	20	230	**96**	77	115	**685**	98	1125	**430**	344	516	**1115**	442	1642
Truffles	-	-	-	**0**	0	0	**96**	77	115	**0**	0	0	**45**	45	45	**45**	45	45
Wheat	**10**	6	14	**150**	100	230	**53**	30	76	**734**	489	1125	**238**	134	341	**972**	623	1467
Wine grapes	**9**	8	10	**18**	5	68	**20**	10	30	**88**	24	333	**90**	45	134	**178**	69	467

Table 4 Estimates of typical harvested yield, nitrogen inputs from fertiliser and residues (kg N/ha), biogenic greenhouse gas emissions (BGE, kg CO_2-e/ha) from exemplar crop rotations.

	Inputs (kg N/ha)			Outputs (kg CO_2-e/ha)				
	Fertiliser applied	**Residues**	**Excreta**	**N_2O fertiliser**	**N_2O residues**	**N_2O excreta**	**Methane**	**Total BGE**
Vegetable	135	179	NA	661	803	0	0	**1463**
Broadacre (grazed)	116	73	112	569	328	234	2455	**3585**
Pasture-maize (grazed)	280	53	112	923	238	234	2455	**3850**

Table 5 Estimates of typical, upper and lower range for harvested yield, nitrogen inputs from fertiliser and residues (kg N/ha), biogenic greenhouse gas emissions (kg CO_2-e/ha) for exemplar crop rotations.

	Nitrous oxide																	
	Inputs (kg N/ha)									Outputs (kg CO_2-e/ha)								
	Fertiliser applied			Residues			Excreta			N_2O fertiliser			N_2O residues			N_2O excreta		
	Typical	Range lower	Range upper	**Typical**	Range lower	Range upper	**Typical**	Range lower	Range upper	**Typical**	Range lower	Range upper	**Typical**	Range lower	Range upper	**Typical**	Range lower	Range upper
Vegetable	**135**	50	318	**179**	149	210	**NA**	NA	NA	**661**	245	1554	**803**	667	940	**NA**	NA	NA
Broadacre (grazed)	**116**	59	209	**73**	57	91	**112**	90	135	**569**	220	839	**328**	254	409	**234**	187	281
Pasture-maize (grazed)	**280**	205	355	**53**	51	55	**112**	67	157	**923**	676	1170	**238**	229	247	**234**	140	328

	Methane					
	kg CH_4/ha			kg CO_2-e/ha		
	Typical	Range lower	Range upper	**Typical**	Range lower	Range upper
Vegetable	NA	NA	NA	**NA**	NA	NA
Broadacre (grazed)	88	70	105	**2455**	1964	2946
Pasture-maize (grazed)	88	53	123	**2455**	1473	3437

	Total N_2O + CH_4 (kg CO_2-e/ha)		
	Typical	Range lower	Range upper
Vegetable	**1463**	911	2493
Broadacre (grazed)	**3585**	2625	4474
Pasture-maize (grazed)	**3850**	2519	5181

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