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Supplemental Material

Healthy and Climate-Friendly Eating Patterns in the New Zealand Context

Jonathan Drew, Cristina Cleghorn, Alexandra Macmillan, and Anja Mizdrak

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Additional File- Excel Document

Box S1: Search strategy

Bibliographic Database: Scopus

Date accessed: 17/03/2017

Search Terms: title, abstract, or keyword list containing:

- at least one of: *greenhouse gas emissions; greenhouse-gas emissions; GHG emissions; greenhouse gas (GHG) emissions; carbon emissions; or climate impact;*

AND

- at least one of: *diet*; food; intake; or eat*;*

AND

- at least one of: *model*; calculat*; analys*; estimat*; or review**

Search Restrictions:

- English language
- 2008 onward

Note: A grey literature search aiming to identify extant NZ-specific food lifecycle assessments that are not published within the peer-reviewed scientific literature was also performed using both Google Search and the New Zealand Lifecycle Management Centre database of publications.

Box S2: Inclusion and Exclusion Criteria

Studies were included if they:

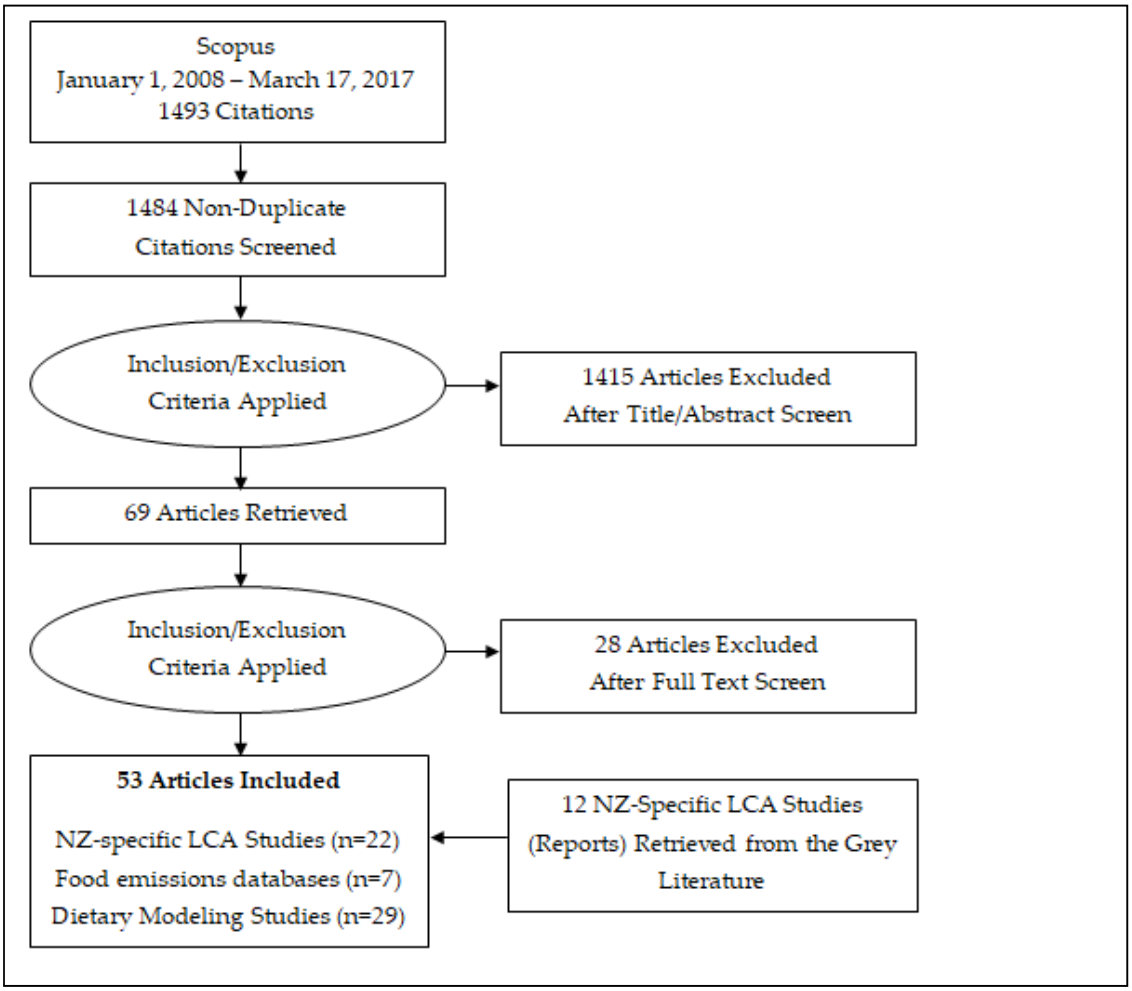
- calculated GHG emissions associated with an individual food item produced in New Zealand (i.e. a single life-cycle assessment)
- compiled a database of foods and their associated lifecycle emissions (i.e. a life-cycle assessment database)
- modeled the climate-related impacts of a specific dietary scenario(s) as compared to average current consumption

Studies were excluded if they:

- did not relate to food or agricultural production
- did not relate food or agricultural production to climate change impacts
- focused on farming techniques or technologies
- calculated GHG emissions associated with an individual food item produced outside New Zealand
- were limited in scope to discussing policy development

Note: refer to Box S1 for our search strategy.

Figure S1: Flow diagram summarizing search results



Note: the breakdown of 'Articles Included' does not appear to sum correctly because five of the studies that compiled food emissions also performed dietary modeling and have thus been counted in both categories; refer to Box S1 for our search strategy and Box S2 for our inclusion and exclusion criteria.

Table S1: Criteria used to select reference lifecycle assessment (LCA) database

Criterion Name	Category	Description
Appropriate functional unit	Essential	The functional unit deemed necessary for this project was unit mass of carbon dioxide equivalents per kilogram of food item with the global warming potential of each component gas measured on a 100-year time horizon. Not only is this the most commonly applied unit within the LCA literature, it can also be easily converted to many of the other units through the use of food composition data (Tilman and Clark 2014).
LCA disaggregated by lifecycle stage	Essential	In order to consider and account for NZ-specific differences in food emissions, it was necessary to select a reference database that provided a breakdown of each LCA by lifecycle stage (e.g. farming and processing, transportation, refrigeration, packaging, etc.). Without this information, relative contributions to each reference emissions estimate could not have been adjusted: any modification could only have been based on a single crude production figure. A breakdown of LCAs by relative contribution also provided guidance on where efforts should be focused (i.e. which components contributed the most to total emissions).
System boundary breadth	Non-essential	LCAs, by definition, attempt to quantify emissions associated with the entire life cycle of a product, extending from the earliest stages of production through to disposal (International Organization for Standardization 2006). However, due to a lack of available data this is not always possible. Broader system boundaries are more inclusive and are more likely to fully capture the climate change impact of various food groups. In this case, LCA databases with system boundaries that considered a wider range of production phases were given priority. The degree of system boundary breadth was assessed as low, medium, or high.
Number of food items	Non-essential	LCA databases that include a greater number of food items (e.g. >50) were given priority. Such databases were more likely to provide a range of foods that reflected those 346 included within our source of consumption data (NZANS), and would, therefore, allow for more representative matching of food groups and accurate dietary modeling.
Relevant to a specific context	Non-essential	Specific production methods are typically associated with certain climatic, geographical, and societal contexts. Knowing where an LCA has been conducted facilitates direct comparison between production methods in that location and production methods in NZ, allowing subsequent modifications to reference values to be made accordingly. While LCA databases that are based on large international systematic reviews are likely to provide a more accurate picture of LCA estimates than other databases, they are not specific to any single context. This makes it difficult to draw comparisons regarding NZ-specific differences or similarities. Selection of a reference database, therefore, that was specific to a particular geographical context was considered important for this project.
Transparent methods	Non-essential	Transparency is considered to be a key principle of LCA. Although assessing the environmental impact of food production is fairly complicated, transparent and easily accessible methodology allows findings to be interpreted accurately so that other researchers may build upon or reproduce results: in this case, to facilitate accurate scaling of LCA data to the NZ context. LCA databases were ranked low, medium, or high, according to their degree of transparency.
Consistent methods	Non-essential	LCA databases are, by nature, compilations of individual LCAs that have been conducted by different research groups at different points in time. While the ISO guidelines aim to standardize LCA methodology, variation in study design, including system boundary breadth and degree of detail, is inevitable. Some LCA databases attempt to minimize such variation by either removing estimates from, or excluding studies with, lifecycle stages beyond the farm gate (i.e. confined to the on-farm stage only), and then recalculating downstream stages (such as transportation, refrigeration, and packaging) for all included LCAs according to a standard method. With greater homogeneity between their constituent LCAs, such databases allow modification of estimates to be performed with greater ease and confidence; these databases were ranked highly. LCA databases that homogenized constituent LCAs to a particular system boundary, but did not recalculate downstream stages were assigned a 'medium' score; while databases that did not set a specific system boundary were ranked 'low'.
Publication date	Non-essential	It is widely acknowledged that the LCA field has undergone significant development in recent years. Caution is advised when comparing older LCAs with newer ones, as the standardized methodology has been refined over time (McManus and Taylor 2015). While more recent LCA databases were considered preferable, it should be noted that a later publication date does not guarantee that more recent individual LCA studies have been used within the database.
Uncertainty reported	Non-essential	LCA estimates are known to be subject to considerable uncertainty, yet measures of uncertainty are rarely disclosed within both individual LCAs and LCA databases (Hallström et al. 2014). According to McManus and Taylor (2015), this is an issue that needs addressing in order to 'bolster credibility and reliability of the approach.' It was, therefore, considered preferable to select a reference database that provided uncertainty ranges around each of its constituent emissions estimates; this would enable diet-level emissions estimates to be interpreted with greater confidence.

Note: NZANS, New Zealand Adult Nutrition Survey 2008/09.

Table S2: Assessment of identified lifecycle assessment (LCA) databases, according to essential and non-essential criteria

LCA Database	Essential Criteria		Non-Essential Criteria							Rank
	Appropriate Functional Unit	LCA disaggregated by lifecycle stage	System Boundary Breadth	Number of Food Items	Relevant to a Specific Context	Transparent Methods	Consistent Methods	Publication Date	Uncertainty Reported	
Hoolohan et al.	Yes ($kgCO_2e/kg$)	Yes	High (cradle to RDC, including associated deforestation)	66	Yes (UK)	High	Medium	2013	No	1
Berners-Lee et al.	Yes ($kgCO_2e/kg$)	Only within diagram	Medium (cradle to RDC, excluding land-use change)	61	Yes (UK)	High	Medium	2012	No	2
Audsley et al.	Yes ($kgCO_2e/t$)	No	High (cradle to RDC, including land-use change)	94	Yes (UK)	Low	High	2009	No	3
Scarborough et al.	Yes ($kgCO_2e/kg$)	No	Medium (cradle to RDC)	289	Yes (UK)	Medium	Medium	2014	No	4
Clune et al.	Yes ($kgCO_2e/kg$)	No	Medium (cradle to RDC)	113	No (Global Review)	Low	Low	2016	Yes	5
Wickrama-singhe et al.	Yes ($kgCO_2e/kg$)	No	Variable	40	No (Global Review)	Low	Low	2016	No	6
Tilman, Clark	No ($kgCO_2e$ per calorie, serving, and gram protein)	No	Low (cradle to farm-gate)	82	No (Global Review)	Low	Low	2014	Yes	7

Note: Descriptions of our criteria are detailed in Table S1; CO_2e, carbon dioxide equivalent; RDC, regional distribution center.

Table S3: Baseline input parameters used in modeling the health gains of the various dietary scenarios

Key parameter	Source of data	Uncertainty	Distribution Heterogeneity
Baseline population	Statistics New Zealand population count estimates for 2011.	Nil uncertainty	Age, Sex Ethnicity
Baseline all-cause mortality rates	Statistics New Zealand mortality rates for 2011.	Nil uncertainty	Age, Sex Ethnicity
Baseline morbidity per capita	The per capita rate of years of life lived with disability (YLD) from the New Zealand Burden of Diseases, Injuries and Risk Factors Study (NZBDS; Ministry of Health 2013).	Uncertainty +/- 10% Standard Deviation (SD)	Log-normal Age, Sex Ethnicity
Disease morbidity rate per capita	2006 NZBDS (projected to 2011). Each disease was assigned a disability rate (DR; by sex and age) equal to YLDs for that disease (scaled down to adjust for comorbidities) from the 2006 NZBDS projected forward to 2011, divided by the disease prevalence. This DR was assigned to the proportion of the cohort in each disease state.	Uncertainty: +/- 10% SD	Normal Age, Sex
Disease-specific prevalence, incidence, case-fatality, and remission rates	Coherent sets of prevalence, incidence rates, case-fatality rates (CFR), and remission rates (zero for non-cancers, the complement of CFR for cancers to give the expected 5-y relative survival) for each disease were estimated using DISMOD II, alongside data from the NZBDS, HealthTracker and the Ministry of Health.	Uncertainty: rates all +/- 5% SD	Log-normal Age, Sex Ethnicity
Disease trends	Trends were applied to incidence, case-fatality and remission. These were switched on until 2026 and then kept constant for the remainder of the lifetimes of the modeled population.	Uncertainty +/- 0.5% absolute change. Diabetes: Uncertainty +/- 1.5% absolute change	Normal Sex, Ethnicity
Health system costs	Linked health data (hospitalizations, inpatient procedures, outpatients, pharmaceuticals, laboratories, and expected primary care usage) for each individual in NZ for the period 2006–2010 had unit costs assigned to each event, and then health system costs (NZ$2011) were estimated.	Estimated at SD = ±10% of the point estimate.	Gamma Age, Sex
Time-lags for intervention effect	Wide windows of time-lag were used to account for uncertainty relating to the time taken for dietary changes to impact on disease incidence. For cancers the time-lag was assumed to range 10-30 years. For coronary heart disease, stroke, diabetes and osteoarthritis, the time-lag was assumed to be shorter and range between 0 and 5 years.	Uncertainty: +/- 20% SD.	Normal
TMREL	The Theoretical Minimum Risk Exposure Level (TMREL) is the level of risk exposure that minimizes overall risk and is theoretically possible. It was derived from the Global Burden of Disease study (Forouzanfar et al. 2013). This allows estimation of how much of the disease burden could be lowered via shifting the distribution of a risk factor to the level that would lead to the greatest improvement in population health.	Uncertainty: Uniform distribution between 0 and 1	Uniform

Table S4: Climate impact of each scenario when measured on a 20-year time horizon and with incomplete compensation for associated energy losses

Dietary Scenario (code)	Daily diet-related emissions ($kgCO_2e$/day)			
	100-year time horizon, 100% energy compensation	100-year time horizon, 75% energy compensation	20-year time horizon, 100% energy compensation	20-year time horizon, 75% energy compensation
New Zealand diet	6.57	6.57	9.43	9.43
New Zealand dietary guidelines (DG1)	6.28	6.08	8.60	8.40
Weekly plant-based meal (DG2)	6.08	5.91	8.27	8.10
Beef and lamb replaced with poultry and pork (DG3)	5.58	5.38	6.39	6.19
Meat replaced with eggs, fish, legumes, nuts, and seeds (‘Pescatarian’; DG4)	5.44	5.23	6.19	5.98
Daily plant-based meal (DG5)	5.07	5.01	6.43	6.37
Meat, seafood replaced with eggs, legumes, nuts, and seeds (‘Lacto-ovo vegetarian’ ; DG6)	5.08	4.91	5.84	5.67
Beef and lamb replaced with legumes, nuts, and seeds (DG7)	5.06	4.87	5.84	5.65
Meat, seafood, eggs replaced with legumes, nuts, and seeds (‘Lacto-vegetarian’ DG8)	4.61	4.45	5.35	5.19
Meat, seafood, eggs replaced with legumes, nuts, and seeds and dairy products exchanged for plant alternatives (‘Vegan’; DG9)	4.42	4.25	4.67	4.50
Waste-free ‘vegan’ (DG10)	3.79	3.65	4.00	3.86

Note: detailed descriptions of scenarios DG1-10 can be found in Table 1; scenarios DG2–10 include minimum change required to meet NZ dietary guidelines (i.e. DG1); CO_2e, carbon dioxide equivalents.

Table S5: Dietary risk factor change associated with shifting average NZ adult consumption to meet each scenario (DG1-10)

Dietary Scenario (code)	Change (Δ) in intake of dietary risk factors used for health and health system cost modeling						
	Δ Fruit (g/day)	Δ Vegetables (g/day)	Δ SSB (g/day)	Δ Sodium (g/day)	Δ Polyunsaturated fat (%total energy)	Δ Red meat (g/day)	Δ Processed meat (g/day)
Meeting Eating & Activity Guidelines (EAGs) with minimal change to baseline consumption (DG1)	214	108	-99	-0.31	0.5%	0.0	-47.3
Weekly plant-based meal (DG2)	198	123	-99	-0.27	0.9%	-4.8	-47.4
Beef and lamb replaced with poultry and pork (DG3)	214	108	-98	-0.35	0.6%	-29.0	-55.2
Meat replaced with eggs, fish, legumes, nuts, and seeds (‘Pescatarian’; DG4)	194	122	-98	-0.26	1.4%	-52.4	-55.9
Daily plant-based meal (DG5)	130	201	-99	-0.09	3.1%	-33.2	-47.8
Meat, seafood replaced with eggs, legumes, nuts, and seeds (‘Lacto-ovo vegetarian’ ; DG6)	204	170	-98	-0.25	1.6%	-52.4	-55.9
Beef and lamb replaced with legumes, nuts, and seeds (DG7)	201	145	-98	-0.32	1.4%	-44.8	-55.5
Meat, seafood, eggs replaced with legumes, nuts, and seeds (‘Lacto-vegetarian’ DG8)	186	224	-98	-0.17	2.7%	-52.4	-56.0
Meat, seafood, eggs replaced with legumes, nuts, and seeds and dairy products exchanged for plant alternatives (‘vegan’; DG9)	192	231	-98	-0.22	5.5%	-52.4	-56.0
Waste-free ‘vegan’ (DG10)	192	231	-98	-0.22	5.5%	-52.4	-56.0

Note: detailed descriptions of scenarios DG1-10 can be found in Table 1; scenarios DG2–10 include minimum change required to meet NZ dietary guidelines (i.e. DG1); SSB, sugar-sweetened beverages

Table S6: Health impacts (in terms of quality-adjusted life years gained) and health system cost savings for meeting dietary guidelines, for the NZ population alive in 2011 (lifetime horizon) with 3% discounting

	Non-Māori	Māori	Māori	Ethnic groups combined	
	QALYs	QALYs	equity analysis QALYs	QALYs	Cost savings (billion)
NZ Eating and Activity Guidelines (DG1)					
Sex groups combined (mean, 95% UI)	758,600 (597,400 to 932,900)	263,900 (216,100 to 318,900)	375,900 (306,900 to 452,900)	1,022,500 (815,200 to 1,251,800)	$13.9 (10.5 to 18.0)
Men	524,000	164,000	233,100	688,000	$9.5
Women	234,600	99,900	142,700	334,500	$4.5
Per capita (QALYs/1000 people & $)	203.3 (200.1)	391.5 (397.8)	557.5 (570.6)	232.1	3165
Once weekly plant-based meal (DG2)					
Sex groups combined (mean, 95% UI)	914,900 (723,600 to 1,127,400)	298,000 (242,600 to 361,500)	364,800 (296,600 to 443,200)	1,213,000 (967,000 to 1,484,000)	$17. (12.9 to 21.9)
Men	597,900	178,800	227,500	776,700	$10.9
Women	317,000	119,200	137,300	436,200	$6.1
Per capita (QALYs/1000 people & $)	245.2 (240.1)	442.1 (450.3)	541.1 (553.6)	275.3	3856
Beef and lamb replaced with poultry and pork (DG3)					
Sex groups combined (mean, 95% UI)	886,900 (706,400 to 1,076,100)	293,600 (239,800 to 349,700)	396,800 (321,500 to 477,500)	1,180,500 (948,500 to 1,423,000)	$16.8 (12.7 to 21.4)
Men	593,800	177,800	241,800	771,600	$11.0
Women	293,100	115,700	155,100	408,900	$5.8
Per capita (QALYs/1000 people & $)	237.7 (234.9)	435.4 (442.4)	588.6 (601.8)	268.0	3817
Meat exchanged for seafood, eggs, legumes, nuts, seeds: 'Pescatarian' (DG4)					
Sex groups combined (mean, 95% UI)	872,800 (696,400 to 1,093,900)	291,400 (238,100 to 351,900)	395,400 (323,200 to 479,100)	1,164,200 (935,500 to 1,440,000)	$16.6 (12.4 to 21.5)
Men	582,200	178,300	243,200	760,500	$10.9
Women	290,600	113,100	152,300	403,700	$5.7
Per capita (QALYs/1000 people & $)	233.9 (231.1)	432.2 (438.6)	586.5 (599.0)	264.3	3758
Once daily plant-based meal (DG5)					
Sex groups combined (mean, 95% UI)	999,600 (802,600 to 1,213,200)	308,600 (255,400 to 366,800)	425,000 (350,400 to 510,600)	1,308,300 (1,058,200 to 1,572,000)	$18.6 (14.1 to 24.2)
Men	643,800	184,200	254,700	828,000	$11.7
Women	355,800	124,400	170,400	480,200	$6.9
Per capita (QALYs/1000 people & $)	267.9 (261.6)	457.8 (466.6)	630.4 (646.7)	297.0	4211
Meat and seafood exchanged for eggs, legumes, nuts, seeds: 'Lacto-ovo vegetarian' (DG6)					
Sex groups combined (mean, 95% UI)	929,500 (734,400 to 1,152,000)	301,100 (245,700 to 361,500)	408,700 (331,500 to 493,400)	1,230,700 (979,600 to 1,510,000)	$17.2 (13.1 to 22.2)
Men	620,000	184,000	251,200	804,000	$11.3
Women	309,500	117,100	157,500	426,600	$5.9
Per capita (QALYs/1000 people & $)	249.1 (245.0)	446.6 (453.9)	606.2 (620.1)	279.4	3902
Beef and lamb replaced with legumes, nuts and seeds (DG7)					
Sex groups combined (mean, 95% UI)	1,021,300 (801,400 to 1,260,200)	326,000 (265,500 to 394,000)	445,900 (361,700 to 539,400)	1,347,200 (1,068,500 to 1,652,000)	$19.1 (14.4 to 24.8)
Men	657,500	193,700	265,700	851,200	$12.1
Women	363,800	132,300	180,200	496,000	$7.0
Per capita (QALYs/1000 people & $)	273.7 (268.5)	483.5 (492.2)	661.4 (677.7)	305.8	4336

	Non-Māori	Māori	Māori	Ethnic groups combined	
	QALYs	QALYs	equity analysis QALYs	QALYs	Cost savings (billion)
Meat, seafood, eggs, exchanged for legumes, nuts, seeds 'Lacto-vegetarian' (DG8)					
Sex groups combined (mean, 95% UI)	1,081,900 (853,300 to 1,314,900)	336,800 (276,400 to 401,200)	465,900 (377,800 to 566,300)	1,418,700 (1,136,200 to 1,716,000)	$19.9 (14.8 to 26.0)
Men	687,300	198,800	275,800	886,100	$12.5
Women	394,600	137,900	190,100	532,600	$7.4
Per capita (QALYs/1000 people & $)	290.0 (283.2)	499.5 (509.3)	691.0 (709.1)	322.0	4512
Meat, seafood, eggs and dairy replaced with plant based alternatives: 'vegan' (DG9)					
Sex groups combined (mean, 95% UI)	1,112,800 (891,100 to 1,366,300)	342,400 (281,400 to 409,600)	472,000 (386,400 to 566,400)	1,455,200 (1,171,600 to 1,773,000)	$20.2 (15.3 to 26.2)
Men	700,700	200,800	277,400	901,500	$12.7
Women	412,100	141,600	194,600	553,700	$7.6
Per capita (QALYs/1000 people & $)	298.2 (290.9)	507.8 (518.1)	700.0 (718.9)	330.3	4593

Note: detailed descriptions of scenarios DG1-10 can be found in Table 1; QALY gains in the equity analysis were calculated using non-Māori background mortality and morbidity rates; UI, uncertainty interval

Equation S1: Summary formula for dairy product emissions using the NZ-specific estimate for milk

$$Dairy\ product\ estimate\ (kgCO_2ekg^{-1}) = NZ\ milk\ estimate\ (kgCO_2ekg^{-1}) \times \frac{Reference\ dairy\ product\ estimate\ (kgCO_2ekg^{-1})}{Reference\ milk\ estimate\ (kgCO_2ekg^{-1})}$$

Note: reference estimates were taken from Hoolohan et al. (2013)

Equation S2: Summary formula for calculating transport-related emissions for individual food items

$$t = f_p e_l d_{NZ} + f_i \left\{ e_l d_{NZ} + \frac{f_{sc}}{f_{tc}} \left[\frac{e_s(d_{s1} f_{s1} + d_{s2} f_{s2} + \dots)}{f_{sc}} + \frac{e_l(d_{ls1} f_{s1} + d_{ls2} f_{s2} + \dots)}{f_{sc}} \right] + \frac{f_{ac}}{f_{tc}} \left[\frac{e_a(d_{a1} f_{a1} + d_{a2} f_{a2} + \dots)}{f_{ac}} + \frac{e_l(d_{la1} f_{a1} + d_{la2} f_{a2} + \dots)}{f_{ac}} \right] \right\}$$

Where:

t = transportation emissions
f_p = fraction of total supply produced
f_i = fraction of total supply imported
f_{tc} = fraction of total supply considered in calculations
f_{sc} = fraction of total supply considered that is sea-freighted
f_{ac} = fraction of total supply considered that is air-freighted
f_{s1} = fraction of total imports from first sea-freighting country
f_{s2} = fraction of total imports from second sea-freighting country
f_{a1} = fraction of total imports from first air-freighting country
f_{a2} = fraction of total imports from second air-freighting country
d_{NZ} = average farm-to-city distance in NZ
d_{s1} = seaport-to-seaport distance from first sea-freighting country
d_{s2} = seaport-to-seaport distance from second sea-freighting country
d_{ls1} = farm-to-seaport distance from first sea-freighting country
d_{ls2} = farm-to-seaport distance from second sea-freighting country
d_{a1} = airport-to-airport distance from first air-freighting country
d_{a2} = airport-to-airport distance from second air-freighting country
d_{la1} = farm-to-airport distance from first air-freighting country
d_{la2} = farm-to-airport distance from second air-freighting country
e_s = emissions factor for sea-freight
e_l = emissions factor for land-freight
e_a = emissions factor for air-freight

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