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Environmental impacts and resource use from Australian pork production assessed using life-cycle assessment. 1. Greenhouse gas emissions

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Grain process modelling

All major diet input commodities in each region were modelled by determining the total market for the product, based on regional and national statistics. Major diet inputs were determined from the total mass contribution to the diet, and from an analysis of the contribution to impacts, using data from Wiedemann et al. (2010). This analysis identified commodity inputs where the total contribution to the diet exceeded 15% contribution to total impacts. In most cases these were the commodities that made up the largest contribution to the diet, and typically four crops accounted for up to 70% of total diet impacts.

In some instances, processes were modified to include new methods, impacts or factors. Standard modifications included updating all crop processes to apply emission factors consistent with the 2013 Australian Inventory (Commonwealth of Australia, 2015), and to include LU and dLUC emissions consistent with national inventory data.

Data processes, sources and modifications are listed in Table S1.

Table S1. Major regional feed grains with data sources and modifications

	Unit processes	Data source	Modifications to data source
Queensland			
Northern wheat market	Modelled from nth NSW dryland process (49%), NSW/QLD irrigated process (6%) and Sth QLD dryland process (45%)	AustLCI unit processes with modification	Irrigation water modified based on ABS[A] Grain market proportions based on ABS[B]
Northern barley market	Modelled from NE NSW dryland process (44%), NSW/QLD irrigated barley process (6%) and sth QLD dryland process (50%).	AustLCI unit processes with modification	MAP and Urea application rates modified to reflect standard practice. Included additional emission sources[C] Grain market proportions based on ABS Post farm transport and handling processes added
Northern sorghum market	Modelled from nth NSW irrigated (8%) and dryland (22%), SE QLD dryland processes (70%).	AustLCI unit processes with modification, Wiedemann et al. (2010) with modification	Included additional emission sources Irrigation water modified based on ABS Grain market proportions based on ABS Post farm transport and handling processes added

NSW / VIC			
Southern wheat market	Modelled from nth NSW irrigated process (8%) and central east NSW dryland process (92%).	AustLCI unit processes with modification	MAP and Urea application rates modified to reflect standard practice. Irrigation water modified based on ABS Grain market proportions based on ABS
Southern barley market	Modelled from NE NSW dryland process (92%), and NSW irrigated barley process (8%).	AustLCI unit processes with modification	MAP and Urea application rates modified to reflect standard practice. Irrigation water modified based on ABS Grain market proportions based on ABS
South Australia			
SA wheat market	Modelled from medium rainfall zone SA process (30%) and low rainfall zone SA process (70%).	AustLCI unit processes with modification	Urea application rates modified to reflect standard practice. Grain market proportions based on ABS
Barley	SA dryland process (100%)	AustLCI unit processes with modification	MAP and Urea application rates modified to reflect standard practice. Yield was modified to reflect SA average yield.
Field pea	SA dryland process (100%)	AustLCI unit processes with modification	Included additional emission sources Post farm transport and handling processes added
Western Australia			
Wheat	Modelled from Narrogin region dryland process (30%) and Kellerberin region dryland process (70%).	AustLCI unit processes with modification	Grain market proportions based on ABS
Barley	WA dryland process (100%)	AustLCI unit processes with modification	MAP and Urea application rates modified to reflect standard practice. Yield was modified to reflect WA average yields.
Lupins	WA dryland process (100%)	AustLCI unit processes with modification	Post farm transport and handling processes added

[A] Total crop yields, by state, sourced from ABS (2013a). Total volume of irrigation water sourced from ABS (ABS, 2013b, ABS, 2011). Average irrigation water determine by dividing total volume of irrigation water by total yield.
[B] ABS (2013a)
[C] Were not included, the following emission sources were added to the unit processes: Nitrous oxide from crop residue, leaching and runoff and ammonia volatilisation.

Australian national integrated emission factors

Manure mass flow data used to determine the Australian national integrated emission factors used for the national herd GHG modelling are provided in Table S2 and Table S3. It was assumed that 10% of conventional piggeries used solids seperation (APL, 2010) with a 25% removal solids removal efficiency. Uncovered pond accounted for 89.4% of total conventional manure management systems, while covered ponds and digesters accounted for 8.6% and short hydraulic retention ime systems accounted for 2% (APL, 2010).

Table S2. Manure mass flow used to determine integrated methane conversion factors for the Australian national pig herd

MMS	Volatile solids mass flow (kg VS)	MCF	Contribution to integrated MCF
Deep litter	0.217		
Housed outdoor	0.051		
Conventional Piggery	0.714		
VS Separation	0.018		
VS to primary system	**1.000**		
Uncovered anaerobic pond	0.638	75.4%	0.485
Covered anaerobic pond / digester	0.062	10.0%	0.005
Short HRT	0.014	3.0%	0.0004
Separated solids (stockpile)[B]	0.018	2.0%	
Spent bedding	0.217	4.0%	0.009
Outdoor (dry lot)	0.051	1.0%	0.001
VS to secondary system	**1.000**		
Secondary pond	0.012	75.4%	0.009
Separated solids (stockpile)	0.224	2.0%	0.004
Integrated factor			**51.2%**

[A] MCF = Methane conversion factor

[B] Contribution to integrated MCF is calculated for the secondary system only (spent deep litter and separated) to avoid double-counting

Table S3. Manure nitrogen mass flow used to determine integrated ammonia and nitrous oxide factors for the Australian national pig herd

MMS	Nitrogen mass flow (kg N)	FracGASM[A]	Total Ammonia lost (kg N)	Direct N_2O EF	Total N_2O (kg N)
Deep litter	0.217				
Housed outdoor	0.051				
Conventional Piggery	0.727				
N Separation	0.006				
N to primary system	**1.000**				
Uncovered anaerobic pond	0.649	55%	0.357	0.000	0.000
Covered anaerobic pond / digester	0.063	0%	0.000	0.000	0.000
Short HRT	0.015	25%	0.004	0.002	0.000
Separated solids (stockpile)	0.006	20%		0.005	
Spent bedding	0.217	13%	0.027	0.010	0.002
Outdoor (dry lot)	0.051	30%	0.015	0.020	0.001
N to secondary system	**1.000**				
Secondary pond	0.063	55%	0.034	0.000	0.000
Solids storage	0.193	20%	0.039	0.005	0.001
Integrated factor			**0.476**		**0.004**

[A] FracGASM = Fraction of total N emitted as NH_3 and NO_x

[B] Contribution to integrated ammonia and nitrous oxide emission factors is calculated for the secondary system only (spent deep litter and separated) to avoid double-counting

Crop allocation fractions

Table S4. Major feed inputs with data sources and modifications, including allocation fractions

	Unit processes	Data source	Modifications to data source
Canola meal	Modelled as one market based on southern NSW production	AustLCI unit processes with modification	Post farm transport and handling processes added Economic allocation applied: canola meal (28%), canola oil (72%)
Soymeal	Modelling based on the locally grown soymeal (5%) and imports of Australian soymeal from the USA (18%) and South America (77%).	EcoInvent (Aus & USA) and AusLCI (Brazil) unit processes	Included transport processes from North or South America to Australia Economic allocation applied: soymeal (62%), soy oil (38%)
Meat and Bone meal, bloodmeal	Modelled as a residue from pork, lamb and beef processing. Impacts associated with Aust. Rendering processes	Modelled by the authors using meat processing data reported in Wiedemann & Yan (2014) and Wiedemann et al. (2015)	No allocation of impacts from the raw product (bone, blood, meat scraps). Impacts only associated with the rendering process
Fishmeal	Modelled as residue from the fish industry	Modelled by the authors using data from rendering of red meat products	No allocation of impacts from the raw product . Impacts only associated with the rendering process
Vegetable oil	Canola oil – modelled from Canola market	AustLCI unit processes with modification	Post farm transport and handling processes added Economic allocation applied: canola meal (28%), canola oil (72%)

Meat processing mass yield factors

Table S5. Mass of reference flows relative to 1000 kilograms of retail product

Product Description	Product	Pork (kg)
Farm-gate product	Live Weight	1618
Intermediate product	Hot Standard Carcase weight	1229
Wholesale/retail product	**Retail Portions (retail cuts and edible offal)**	**1000 (906 and 94)**
	Pet food	84
Rendering material	Unprocessed meat scrap, bone, offal	372

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