Benchmark Study

Emissions, Productivity and Employment for Aquaculture and other Types of Land Use in Queensland

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1. Background

The Queensland Government has directed the Queensland Competition Authority (QCA) to investigate the options for reforming regulation of the State's aquaculture industry. Jacobs SKM has been contracted by QCA to provide independent advice on environmental and technical issues for that investigation. One of the aspects Jacobs SKM has been asked to address is an environmental and economic benchmarking study of aquaculture versus other types of (agricultural) land use in Queensland. This technical memo presents the results of that exercise.

2. Approach

This benchmarking study is based on a review of available literature and datasets, scientific papers, technical reports and other relevant documents on the extent, productivity, emissions and employment of aquaculture and other types of land use in Queensland. The purpose of the review is to make a (preliminary) benchmark comparison of the environmental and economic performance of different types of (agricultural) land use (incl. terrestrial aquaculture), with particular emphasis on the discharges of nutrients, sediments and pesticides (where available) into adjacent coastal waters.

3. Current land use: classification and extent

In order to provide context, we analysed the total areal extent and break-up of current land use for a representative coastal area in Queensland, i.e. a 5-km-wide coastal strip between Mossman and Gladstone/Hervey Bay (see figure in Appendix 1). This area was primarily chosen for the purpose of illustration, but was also selected for further analysis because of data availability and the likelihood of this region to be considered for any new aquaculture developments in the near future. Data were derived from the Queensland Land Use Mapping Program (QLUMP) GIS database (State of Queensland, 2012).

Table 1 provides a break-up overview of the areal extent for each (primary) land use class in that area. The total area covered by the selected coastal strip is approximately 1.2 million hectares (total, incl. water) or 880,000 hectares (land, excl. water). Out of this total land area (excl. water), some 284,000 ha (32%) is currently used for grazing, ~81,000 ha (~9%) for the farming of agricultural crops, ~7,300 ha for horticulture (<1%), ~27,000 ha (3%) for forestry and 1908 ha (0.2%) for aquaculture.

Table 1. Current land use in coastal Queensland (based on 2009 data from QLUMP database) for a 5 km strip of coastal land between Mossman and Gladstone (Queensland).

Land Use Categories	**Area (ha)**	**% of total**	% of total
		(incl. water)	*(excl. water)*
Conservation and Natural Environments	420,301	34.65	47.72
Aquaculture	1908	0.16	0.22
Animal production (other)	79	0.01	0.01
Cropping	81,204	6.69	9.22
Horticulture	7,279	0.60	0.83
Grazing	284,191	23.43	32.26
Forestry (plantation+production)	26,997	2.23	3.06
Land in transition	2,050	0.17	0.23
Other	56,847	4.69	6.45
Water	332,277	27.39	
Total	**1,213,133**	100	100

These data are obviously site-specific and will undoubtedly be somewhat different for other parts of the Queensland coast. However, these results fall within a range similar to figures reported in previous studies for the Herbert River Catchment (NE Australia) and several other Queensland East Coast Catchments (Young et al., 1996; McPhee, 2001; Brodie et al., 2007) and hence provide some context to the relative magnitudes of relevance for this benchmarking study.

4. Emissions of nutrients and sediments

Data on the emissions of nutrients and sediments for this review were primarily derived from peer-reviewed scientific literature (including publications from an intensive aquaculture research program by CSIRO and the Paddock-to-Reef water quality monitoring & research program by GBRMPA). These data were supplemented with information from grey literature (where applicable and considered relevant). Preference was given to data and literature pertaining to studies in Queensland, but data from other parts of the world are also presented to provide context and add further confidence in the values reported for Queensland. To allow for comparison across the various studies and reports, discharge data were all converted into the same units (i.e. kg hectare^{-1} year^{-1}). All discharge data reported in the various sub-sections below refer to loads per production area (for all types of land use), and do not take into consideration additional areas of land that may be required, e.g. for the treatment of effluent and/or sludge, processing facilities or offsets.

4.1 Emissions from (shrimp) aquaculture

The total area currently classified in the QLUMP 2009 database as terrestrial (shrimp) aquaculture in the State of Queensland is 4567 hectares (State of Queensland, 2012).

Values reported in the literature for the total nutrient and sediment emissions by shrimp aquaculture are summarised in Table 2.

Table 2. Values reported in the literature for total nutrient and sediment emissions by shrimp aquaculture.

	N (kg ha^{-1} yr^{-1})	P (kg ha^{-1} yr^{-1})	TSS (kg ha^{-1} yr^{-1})	Comment	Reference
Prawn aquaculture	430.7	-	-		Burford et al., (unpublished)
(Queensland)	361.4	-	-		Burford et al., (unpublished)
	377.9				Tyre et al., (unpublished)
	365	40.2	1752		Jackson et al., 2004
	657	80.3	31281		Jackson et al., 2004
	178.9	18.3	178.9		Thomas et al., 2010
	175.2	21.9	4380		McPhee, 2001
Prawn aquaculture	16	6	-	Extensive	Wahab et al., 2003
(other geographic regions)	32.8	-5.3	-	Semi-intensive	Bangladesh; Islam *et al*., 2004
	33	4.6	-	Semi-intensive	Honduras; (cited in Islam *et al*., 2004)
	24	-	-	Semi-intensive	Phillips, 1994 (cited by Islam *et al*., 2004).
	71	20	-	Semi-intensive	NW Mexico; Paez_Osuna *et al*., 1999
	112	32	-	Semi-intensive	NW Mexico; Paez_Osuna *et al*., 1999
	244	28	920	Semi-intensive	Mexico; Miranda et al., 2007
	248.2	29.2	-	Semi-intensive	New Caledonia; Thomas et al., 2010
	104	17	-	Semi-intensive	NW Mexico; Paez_Osuna *et al*., 1997
	356	48	-	Semi-intensive	Honduras; Teichert-Coddington et al., 2000
	64	-	-	Semi-intensive	Columbia; Rivera-Monroy et al., 1999
	91	-	-	Semi-intensive	Venezuela; cited in Rivera Moonroy et al., 1999.
	128	40	-	Semi-intensive	Vietnam; Robertson and Phillips, 1995
	29	27	-	Semi-intensive	Thailand: Phillips 1994, cited by Beveridge et al., 1997
	167.9 - 368.	-	-	Semi-intensive	New Caledonia; Lemonnier & Faninoz, 2006
	496.4	80.3	-	Intensive	New Caledonia; Thomas et al., 2010
	19	2.3	-	Intensive	NE Brazil; de Lacerda et al., 2006
	319	13	-	Intensive	China; Herbeck et al., 2013
	602	61	-	Intensive	Thailand; Briggs & Funge-Smith, 1994
	1434	424	-	Intensive	Thailand: Phillips 1994, cited by Beveridge et al., 1997
	199	39	-	Intensive	Thailand; Robertson and Phillips, 1995
	362	-	-	Intensive	Australia; Jackson et al., 2003
	1198	81	-	Intensive	USA; Hopkins et al., 1993

Values for the total nitrogen emission from pond aquaculture reported from studies in Queensland range from 121 – 657 kg N ha^{-1} yr^{-1}. Values for nitrogen emissions by shrimp aquaculture reported from other parts of the world show much greater variability, ranging from as low as 16 kg N ha^{-1} yr^{-1} for extensive shrimp farms to as high as 1434 kg N ha^{-1} yr^{-1} for some of the most intensive farms. Total nitrogen emission from any shrimp farm is likely to depend on stocking density, farm management and feed addition.

Values for the total phosphorus emission from pond aquaculture reported from studies in Queensland range from 12.1 – 80.3 kg P ha^{-1} yr^{-1}. Values for the phosphorus emission by shrimp aquaculture reported from other parts of the world show much greater variability, ranging from as low as -5.3 kg P ha^{-1} yr^{-1} (implying a net reduction of total P between intake and discharge water) for some semi-intensive farms to as high as 424 kg P ha^{-1} yr^{-1} for some of the most intensive shrimp farms. As noted for nitrogen loads, the total emission of phosphorus from any shrimp farm is likely to depend on stocking density, farm management and feed addition.

Values for the total suspended solids (TSS) discharged from pond aquaculture, as reported in the peer-reviewed literature from scientific studies in Queensland vary widely, ranging from 179 – 31,281 kg TSS ha^{-1} yr^{-1}. Information on TSS emission by shrimp aquaculture from other parts of the world is relatively limited, with reported values ranging from 920 – 4380 kg TSS ha^{-1} yr^{-1}, which is within the range of values reported from Queensland prawn farms. As noted for nitrogen and phosphorus loads, the total emission of TSS from any shrimp farm is likely to depend on stocking density, farm management and feed addition.

4.2 Emissions from sugar cane

The total area of sugar cane cultivation in the Great Barrier Reef catchment (Queensland) has been reported to be in the order of 4300 to 5700 km^2 (Brodie et al., 2007; Brodie et al., 2012). Values reported in the literature for the total nutrient and sediment emissions by sugar cane farms are summarised in Table 3.

Table 3. Values reported in the literature for total nutrient and sediment emissions by sugar cane farms.

Geographic Region	N (kg/ha/yr)	P (kg/ha/yr)	TSS (kg/ha/yr)	Reference
Queensland (conventional farming)			148000	McPhee (2001)
Queensland (improved tillage/management)			1000-15000	McPhee (2001)
Burkedin (Delta 2005)	10			Thorburn et al. (2011)
Burkedin (Delta 2006)	2			Thorburn et al. (2011)
Burkedin (Delta 2007)	9			Thorburn et al. (2011)
Burkedin (Mulgrave 2005)	5			Thorburn et al. (2011)
Burkedin (Mulgrave 2006)	2			Thorburn et al. (2011)
Burkedin (Mulgrave 2007)	1			Thorburn et al. (2011)
Mackay-Whitsunday region (Victoria Plains)	0.01 - 3.90	0.01 - 0.55	217	Rohde et al. 2013
Mackay-Whitsunday region (Marian)	4.8	1.9	117	Rohde et al. 2013
Wet Tropics (Mossman)	53-137			Webster et al. 2012
Wet Tropics (Mossman) 2004	57-136			Webster et al. 2012
Wet Tropics (Mossman) 2005	40-136			Webster et al. 2012
Wet Tropics (Mossman) 2006	61-138			Webster et al. 2012
Far North (Daintree River basin)	15.8	2.5	2532	Brodie et al 2007
Far North (Mossman River basin)	19.9	2.9	3801	Brodie et al 2007
Far North (Barron River Basin)	3.5			Brodie et al 2007
Far North (Russell-Mulgrave river basin)	25.6	4.4	2711	Brodie et al 2007
Far North (Johnstone River basin)	32.1	4.0	3046	Brodie et al 2007
Far North (Tully river basin)	26.3	2.5	2281	Brodie et al 2007
Far North (Murray river basin)	15.8	1.5	1521	Brodie et al 2007
Far North (Herbert River Basin)	7.9	0.6	910	Brodie et al 2007
Northern (Black river basin)	4.9	1.2	1235	Brodie et al 2007
Northern (Haughton River basin)	5.9	1.2	1327	Brodie et al 2007
Northern (Burdekin River)	5.5	1.2	2810	Brodie et al 2007
Northern (Don River Basin)	3.0	0.6	1190	Brodie et al 2007
Mackay (Proserpine River)	8.4	1.8	2410	Brodie et al 2007
Mackay (O'Connell River)	12.1	2.7	4514	Brodie et al 2007
Mackay (Pioneer River)	12.1	2.8	3513	Brodie et al 2007
Mackay (Plane River)	11.2	3.0	3167	Brodie et al 2007
Fitzroy (Shoalwater River)	4.3			Brodie et al 2007
Wide Bay - Burnett (Baffle Creek)	2.1			Brodie et al 2007
Wide Bay - Burnett (Kolan River)	3.0	0.8	485	Brodie et al 2007
Wide Bay - Burnett (Bumett River)	3.2	0.7	709	Brodie et al 2007
Wide Bay - Burnett (Burrum River)	2.9	0.4	457	Brodie et al 2007
Brisbane and Moreton (Mary River)	2.2	0.3	745	Brodie et al 2007

Values for the total nitrogen emission from sugar cane farms reported from studies in Queensland range from <1 to 138 kg N ha^{-1} yr^{-1}. Values for the total phosphorus emission from sugar cane farms reported from studies in Queensland range from <0.1 to 4.4 kg P ha^{-1} yr^{-1}. Values for the TSS emission from sugar cane farms reported from studies in Queensland range from 117 to 148,000 kg TSS ha^{-1} yr^{-1} (with most values <3000 kg ha^{-1} yr^{-1}).

The total emission of Nitrogen, Phosphorus and TSS from sugar cane farming areas is likely to depend on tillage, cultivation practices (incl. application of fertilizer) and harvesting technique (Brodie et al., 2007).

4.3 Emissions from grazing

The total area of grazing land has been reported to be in the order of 314,000 km^2 for the Great Barrier Reef catchment (Brodie et al., 2012) and 1.4 million km^2 for the whole of Queensland (McPhee, 2001). Values reported in the literature for the total nutrient and sediment emissions from land used for grazing are summarised in Table 4.

Table 4. Values reported in the literature for total nutrient and sediment emissions from land used for grazing.

Geographic Region	N (kg/ha/yr)	P (kg/ha/yr)	TSS (kg/ha/yr)	Reference
Far North (Jacky Jacky Creek)	6.78	0.56	547	Brodie et al 2007
Far North (Olive-Pascoe)	7.05	0.78	872	Brodie et al 2007
Far North (Lockhart River Basin)	4.36	0.65	856	Brodie et al 2007
Far North (Stewart River basin)	3.30	0.42	540	Brodie et al 2007
Far North (Normanby River basin)	4.75	0.52	558	Brodie et al 2007
Far North (Jeannie River basin)	7.69	0.70	1355	Brodie et al 2007
Far North (Endevour River Basin)	8.51	1.07	2233	Brodie et al 2007
Far North (Daintree River basin)	52.83	2.11	2389	Brodie et al 2007
Far North (Mossman River basin)	11.80	1.55	2484	Brodie et al 2007
Far North (Barron River Basin)	3.53	0.66	414	Brodie et al 2007
Far North (Russell-Mulgrave river basin)	10.25		932	Brodie et al 2007
Far North (Johnstone River basin)	31.88	2.58	1456	Brodie et al 2007
Far North (Tully river basin)	15.31	1.67	1253	Brodie et al 2007
Far North (Herbert River Basin)	2.16	0.34	635	Brodie et al 2007
Far North (Murray river basin)	9.26	0.99	628	Brodie et al 2007
Northern (Black river basin)	8.50	1.35	2111	Brodie et al 2007
Northern (Ross river basin)	6.63	0.93	617	Brodie et al 2007
Northern (Haughton River basin)	1.57	0.32	356	Brodie et al 2007
Northern (Burdekin River)	1.60	0.43	205	Brodie et al 2007
Northern (Don River Basin)	4.38	0.95	1245	Brodie et al 2007
Mackay (Proserpine River)	5.27	1.06	1531	Brodie et al 2007
Mackay (O'Connell River)	9.70	2.40	3758	Brodie et al 2007
Mackay (Pioneer River)	8.05	2.59	2372	Brodie et al 2007
Mackay (Plane River)	11.59	3.77	3546	Brodie et al 2007
Northern (Styx River)	3.40	1.63	994	Brodie et al 2007
Fitzroy (Shoalwater River)	6.13	0.86	1015	Brodie et al 2007
Northern (WaterPark Creek)	1.38	0.46	488	Brodie et al 2007
Fitzroy (Fitzroy River)	1.52	0.48	221	Brodie et al 2007
Fitzroy (Calliope River)	4.27	1.12	1038	Brodie et al 2007
Fitzroy (Boyne River)	6.04	1.39	187	Brodie et al 2007
Wide Bay - Burnett (Baffle Creek)	3.80	0.55	900	Brodie et al 2007
Wide Bay - Burnett (Kolan River)	3.47	0.59	237	Brodie et al 2007
Wide Bay - Burnett (Bumett River)	1.84	0.52	149	Brodie et al 2007
Wide Bay - Burnett (Burrum River)	2.48	0.43	335	Brodie et al 2007
Brisbane and Moreton (Mary River)	1.73	0.31	663	Brodie et al 2007
Queensland			200	McPhee, 2001

Values for the total nitrogen emission from land used for grazing reported from studies in Queensland range from 1.4 to 52.8 kg N ha^{-1} yr^{-1}. Values for the total phosphorus emission from grazing lands reported from studies in Queensland range from 0.3 to 3.8 kg P ha^{-1} yr^{-1}. Values for the TSS emission from land used for grazing reported from studies in Queensland range from 159 to 3758 kg TSS ha^{-1} yr^{-1}.

Modelling work clearly points to grazing lands as the major source of suspended sediments to the Queensland east coast, with 66% of sediment input to the Great Barrier Reef lagoon attributable to grazing (through soil erosion), 26% to natural processes and 8% from cropping (McKergow et al., 2005; Brodie et al., 2007). The total emissions of Nitrogen, Phosphorus and TSS from grazing lands are likely to depend on stocking density, slope and rainfall (McPhee, 2001; Brodie et al., 2007).

4.4 Emissions from forestry

Values reported in the literature for the total nutrient and sediment emissions from land areas covered by natural and production forest and (ungrazed) savannah are summarised in Table 5.

Table 5. Values reported in the literature for total nutrient and sediment emissions from land areas covered by natural and production forest and (ungrazed) savannah.

Geographic Region	N (kg/ha/yr)	P (kg/ha/yr)	TSS (kg/ha/yr)	Reference
Far North (Jacky Jacky Creek)	2.69	0.33	211	Brodie et al. (2007)
Far North (Olive-Pascoe)	4.63	0.65	591	Brodie et al. (2007)
Far North (Lockhart River Basin)	3.06	0.39	493	Brodie et al. (2007)
Far North (Stewart River basin)	1.92	0.20	223	Brodie et al. (2007)
Far North (Normanby River basin)	0.84	0.11	91	Brodie et al. (2007)
Far North (Jeannie River basin)	2.55	0.28	436	Brodie et al. (2007)
Far North (Endevour River Basin)	5.40	0.78	1150	Brodie et al. (2007)
Far North (Daintree River basin)	5.28	0.76	667	Brodie et al. (2007)
Far North (Mossman River basin)	7.12	0.68	1114	Brodie et al. (2007)
Far North (Barron River Basin)	2.50	0.35	205	Brodie et al. (2007)
Far North (Russell-Mulgrave river basin)	14.55	2.34	1485	Brodie et al. (2007)
Far North (Johnstone River basin)	12.89	1.88	1362	Brodie et al. (2007)
Far North (Tully river basin)	8.53	1.06	844	Brodie et al. (2007)
Far North (Herbert River Basin)	5.46	0.66	472	Brodie et al. (2007)
Far North (Murray river basin)	3.40	0.45	808	Brodie et al. (2007)
Northern (Black river basin)	5.56	1.13	1403	Brodie et al. (2007)
Northern (Ross river basin)	29.16	4.10	2716	Brodie et al. (2007)
Northern (Haughton River basin)	3.12	0.72	646	Brodie et al. (2007)
Northern (Burdekin River)	3.35	0.89	458	Brodie et al. (2007)
Northern (Don River Basin)	5.57	1.25	1569	Brodie et al. (2007)
Mackay (Proserpine River)	6.18	1.33	1730	Brodie et al. (2007)
Mackay (O'Connell River)	9.83	2.63	3577	Brodie et al. (2007)
Mackay (Pioneer River)	6.29	1.92	1601	Brodie et al. (2007)
Mackay (Plane River)	11.32	4.28	3555	Brodie et al. (2007)
Northern (Styx River)	4.08	2.12	1307	Brodie et al. (2007)
Fitzroy (Shoalwater River)	4.97	0.64	764	Brodie et al. (2007)
Northern (WaterPark Creek)	0.90	0.24	169	Brodie et al. (2007)
Fitzroy (Fitzroy River)	1.23	0.31	96	Brodie et al. (2007)
Fitzroy (Calliope River)	3.68	1.03	1031	Brodie et al. (2007)
Fitzroy (Boyne River)	5.24	1.13	124	Brodie et al. (2007)
Wide Bay - Burnett (Baffle Creek)	3.08	0.48	664	Brodie et al. (2007)
Wide Bay - Burnett (Kolan River)	3.64	0.71	89	Brodie et al. (2007)
Wide Bay - Burnett (Bumett River)	1.21	0.32	68	Brodie et al. (2007)
Wide Bay - Burnett (Burrum River)	1.60	0.23	138	Brodie et al. (2007)
Brisbane and Moreton (Mary River)	1.30	0.20	315	Brodie et al. (2007)

Values for the total nitrogen emission from land areas covered by natural and production forest and (ungrazed) savannah reported from studies in Queensland range from <1 to 29 kg N ha^{-1} yr^{-1}. Values for the total phosphorus emission from forest and savannah land reported from studies in Queensland range from 0.1 to 4.3 kg P ha^{-1} yr^{-1}. Values for the TSS emission from forest and savannah land reported from studies in Queensland range from 68 to 3555 kg TSS ha^{-1} yr^{-1}.

4.5 Emissions from other agriculture and horticulture

Values reported in the literature for the total nutrient and sediment emissions from land used for other forms of agriculture - such as bananas, cotton and grains (not sugar cane) - and horticulture (combined) are summarised in Table 6.

Table 6. Values reported in the literature for total nutrient and sediment emissions from land used for other forms of agriculture (not sugar cane) and horticulture.

Geographic Region	N (kg/ha/yr)	P (kg/ha/yr)	TSS (kg/ha/yr)	Reference
Far North (Jacky Jacky Creek)	5.46	0.55		Brodie et al. (2007)
Far North (Olive-Pascoe)	9.03	1.29	2581	Brodie et al. (2007)
Far North (Stewart River basin)	1.20			Brodie et al. (2007)
Far North (Normanby River basin)	1.37	0.14	273	Brodie et al. (2007)
Far North (Jeannie River basin)	2.53	0.27	274	Brodie et al. (2007)
Far North (Endevour River Basin)	8.82			Brodie et al. (2007)
Far North (Daintree River basin)	8.33			Brodie et al. (2007)
Far North (Barron River Basin)	5.02	0.68	340	Brodie et al. (2007)
Far North (Russell-Mulgrave river basin)	18.80	2.32	1221	Brodie et al. (2007)
Far North (Johnstone River basin)	17.76	2.24	1194	Brodie et al. (2007)
Far North (Tully river basin)	19.80	1.82	825	Brodie et al. (2007)
Far North (Herbert River Basin)	4.81	0.46	650	Brodie et al. (2007)
Far North (Murray river basin)	14.18	1.42	1418	Brodie et al. (2007)
Northern (Black river basin)	5.84	0.39	1167	Brodie et al. (2007)
Northern (Ross river basin)	4.18	0.59	719	Brodie et al. (2007)
Northern (Haughton River basin)	3.86	0.72	906	Brodie et al. (2007)
Northern (Burdekin River)	1.64	0.38	320	Brodie et al. (2007)
Northern (Don River Basin)	1.71	0.36	711	Brodie et al. (2007)
Mackay (Proserpine River)	5.35	1.03	1315	Brodie et al. (2007)
Mackay (O'Connell River)	10.13	1.83	3094	Brodie et al. (2007)
Mackay (Pioneer River)	9.79	2.06	2749	Brodie et al. (2007)
Mackay (Plane River)	8.23	2.29	2159	Brodie et al. (2007)
Northern (Styx River)	1.43	0.36	478	Brodie et al. (2007)
Fitzroy (Shoalwater River)	4.45	1.11	1114	Brodie et al. (2007)
Northern (WaterPark Creek)	0.72	0.22	287	Brodie et al. (2007)
Fitzroy (Fitzroy River)	1.02	0.34	219	Brodie et al. (2007)
Fitzroy (Calliope River)	1.88	0.63	625	Brodie et al. (2007)
Fitzroy (Boyne River)	2.54	0.63	211	Brodie et al. (2007)
Wide Bay - Burnett (Baffle Creek)	2.19	0.20	398	Brodie et al. (2007)
Wide Bay - Burnett (Kolan River)	1.98	0.31		Brodie et al. (2007)
Wide Bay - Burnett (Bumett River)	1.55	0.36	194	Brodie et al. (2007)
Wide Bay - Burnett (Burrum River)	1.80	0.20	200	Brodie et al. (2007)
Brisbane and Moreton (Mary River)	2.28	0.37	503	Brodie et al. (2007)

Values for the total nitrogen emission from land used for other forms of agriculture (not sugar) and horticulture (combined) reported from studies in Queensland range from <1 to 19.8 kg N ha^{-1} yr^{-1}. Values for the total phosphorus emission from land used for agriculture (not sugar) and horticulture reported from studies in Queensland range from 0.14 to 2.32 kg P ha^{-1} yr^{-1}. Values for the TSS emission from forest and savannah land reported from studies in Queensland range from 194 to 3094 kg TSS ha^{-1} yr^{-1}.

5. Comparison of emissions between different land use types

Table 7 summarises the results of the previous sections. The results show that the discharge of nitrogen and phosphorus from aquaculture are an order of magnitude higher than most of the other types of land use. The emission of suspended solids from shrimp farms, however, is potentially lower than the emission from sugarcane farms. It should be noted here, that although special effort was made to provide a like-for-like comparison, the discharge from shrimp farms is a point source (easier to measure, control and monitor), while the other forms of land use constitute diffuse sources (more difficult to measure/estimate, control or monitor).

Table 7. The emission of nutrients and suspended solids from different types of land use in Queensland

Type of land use	N (kg/ha/yr)	P (kg/ha/yr)	TSS (kg/ha/yr)
Aquaculture (Queensland)	121 – 657	12.1 – 80.3	179 – 31,281
Sugarcane farming	<1 – 138	<0.1 – 4.4	117 – 148,000
Grazing	1.4 – 52.8	0.3 – 3.8	159 – 3758
Forestry	<1 – 29	0.1 – 4.3	68 – 3555
Other Agriculture (not sugar) and horticulture (combined)	<1 – 19.8	0.14 – 2.32	194 – 3094

6. Pesticides and other chemical additives

There is a general paucity of data on discharges/emissions of pesticides and other chemicals (hormones, vitamins, etc.) for the various types of land use, which makes a comparison difficult. Values reported for the emission of herbicides/pesticides from sugar cane farms in Queensland (derived from Rohde et al., 2013) are summarised in Table 8.

Table 8. Values reported in literature for herbicide/pesticide emissions from sugar cane farms in Queensland

Herbicides/Pesticides (Queensland)	Herbicide/Pesticide emissions (kg/ha/yr)
Imazapic	770
Diuron	10-189
Hexazinone	10-107
Ametryn	300
Atrazine	9100
Diuron	12000
Hexazinone	900

The emission of herbicides/pesticides from grazing land and forested areas are probably negligible, but quantitative data on this from field measurements are lacking.

There is a range of chemical additives that are used in (shrimp) aquaculture to various degrees, depending on the type and intensity of farming. These may include: antibiotics, growth hormones, desinfectants, paraciticides, vitamins and others. There is little published information on the emission of these chemicals into the ambient environment in Queensland or indeed elsewhere. However, unless specific circumstances emerge (e.g. disease outbreaks or major water quality changes in the ponds), their levels are likely to be low. Many of these substances are biodegradable and not bioaccumulative and therefore generally do not tend to cause significant environmental perturbations in natural waters receiving pond effluents (Boyd and Massaud, 1999). However, accidental spills of some of these substances could cause environmental damage.

7. Productivity and employment

Productivity and employment figures reported for aquaculture in Queensland (based on publications by Lobegeiger & Wingfield 2006, 2007, 2008, 2009; and Wingfield & Willett 2011, 2012) are summarised in Table 9.

Table 9. Farm gate value, employment and productivity values for aquaculture in Queensland

AQUACULTURE (ranges between 2002-2012)			
Geographic Region	**Farm gate value ($ millions)**	**Employment (FTEs)**	**Productivity ($/ha/yr)**
Brisbane and Moreton	12--25	99-155	48090
Wide Bay	5--7	56-92	49105
Darling Downs	0-1	4--9	62512
Fitzroy	0-1	6--16	50765
Mackay	7--11	41-71	
Northern	19-44	149-230	
Far Northern	14-22	117-219	

Note: Productivity values not based on same geographic regions as farm gate values

Productivity values reported for sugarcane farming in Queensland (based on ABS 1997-2002; ABS 2003-2013; and Rohde, 2012) are summarised in Table 10.

Table 10. Productivity and economic return values for sugarcane farming in Queensland

SUGARCANE (ranges between 1993-2012)			
Geographic Region	**Nominal gross value ($ millions)**	**Production ('000 t)**	**Net Return ($/ha)**
Australia	656.7-1381.7	25182-39531	
Queensland	601.2-1316.2	23615-36790	
Mackay-Whitsunday			1100-2300

Productivity values reported for other agriculture (not sugar) in Queensland (based on ABS 2003-2004; ABS 2005-2013; and DAFF, 2008) are summarised in Table 11.

Table 11. Productivity and economic return values for other agriculture (not sugar) in Queensland

AGRICULTURE (ranges between 2001-2012)			
Geographic Region	**Nominal gross value ($ millions)**	**Production ('000 t)**	**Employment (FTEs)**
Queensland	7261.6-10034.8	-	1138-1193*

8. Final remarks

When considering land-use conversion of certain areas of coastal land (e.g. from sugar cane farming into shrimp aquaculture), it should be borne in mind that for aquaculture development, besides the ponded areas, additional areas of land will be required for the treatment of effluent/sludge, processing facilities and potentially for offsets of the relatively high discharges of nutrients and TSS.

As mentioned above, it was challenging to accomplish a true 'like-for-like' comparison between different forms of land-use, given the fact that the discharge from shrimp farms is a point source (easier to measure, control and monitor), while the other forms of land use constitute diffuse sources (more difficult to measure/estimate, control or monitor). Moreover, the point-source discharge from shrimp ponds is more or less a constant chronic emission, while the diffuse sources of emission from sugar cane farming, grazing lands and other agriculture are very seasonal, with particularly high values during periods of peak rainfall and runoff during the rainy season.

Most importantly, it should be stressed that any new proposed aquaculture (or other) development should be assessed with due consideration of local environmental conditions, in particular the assimilative capacity of the receiving coastal waters in the immediate surroundings of the proposed development, which may differ substantially between sites. Options for potential environmental offsets to mitigate unavoidable (residual) impacts from emissions, in order to achieve net zero emissions (or even net environmental gains) should be given full consideration.

These are all issues that need to be taken into consideration when evaluating the potential environmental pros and cons of different land-use conversion options, besides the other obvious aspects such as potential gains for employment and economic returns.

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Appendix 1

Figure 1 - Location Map Showing Queensland Land Use Mapping Program (QLUMP) Data

WV04880 - QCA ASSMENT. OF TECH ISSUES RE AQUACULTURE REVIEW

JACOBS SKM

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