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RESEARCH ARTICLE

Assessment of Green House Gases (GHGS) Emission from Some Aquaculture Ponds of Andhra Pradesh and West Bengal, India

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ABSTRACT

The Green House Gas Emission (GHGs) from the carp culture ponds (*n* = 12) of West Godavari, Krishna, and Guntur districts of Andhra Pradesh and from the ponds (*n* = 4) of Moyna, East Medinipur district of West Bengal, India was assessed through carbon storage and carbon footprint analysis. The average inputs as Carbon Equivalent (CE) were 14407 ± 2651, and 9231 ± 1007 kg/ha in Andhra Pradesh, and West Bengal, respectively. The average carbon storage were 6216 ± 2291, and 5360 ± 1439 kg/ha, in Andhra Pradesh, and Moyna, West Bengal respectively. The emissions of CO_2-e and CH_4-e were 1.91 ± 0.42 kg CO_2-e/kg fish and 0.122 ± 0.027 kg CH_4-e/kg fish, respectively in Andhra Pradesh. The emissions of CO_2-e and CH_4-e were 0.006 to 2.07 (average 0.72) kg CO_2-e /kg fish, and 0.0004 to 0.132 (average 0.046) kg CH_4-e /kg fish production, respectively in Moyna, West Bengal.

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INTRODUCTION

Global warming is one of the important climate change element. Increase in Greenhouse Gases (GHGs) concentration in the atmosphere is the main reason for climate change as accumulated GHGs in the atmosphere intercepts outgoing infra-red radiation which traps heat and raises the temperature in the atmosphere.

During the last three decades world food fish production of aquaculture has expanded by almost 12 times, with an average annual rate of 8.8 per cent. Presently 600 aquatic species are raised in captivity in about 190 countries for production in farming systems of varying input intensities and technological sophistication [1]. Thus, there is chance of emitting different GHGs from the different aquaculture systems.

From the aquaculture systems, GHGs can be released to the atmosphere in two ways: diffusive emission (emanation) and emission as bubbles. In diffusive emission, gases dissolved in water molecularly diffuse from water to the air. Bubbles form naturally in the bottom and go up periodically. In anaerobic conditions, the gas forms methane, whereas in oxygenated bottoms, carbon dioxide dominates. As methane is not consumed by aquatic organisms, it dissipates in the water column [2].

Gas flow between water and the atmosphere changes by the time of day and can

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be quite variable, and to quantify emission rates, a diffusion chamber can be used. The samples could be analyzed through specific gas-chromatographic analysis. However, the methodology is somewhat complex and the analysis is also expensive.

Indirectly the emission of gases can be predicted through carbon footprint analysis of any culture system or Life Cycle Analysis (LCA) of a crop production system. Literatures of some LCA studies of aquaculture practices are available [3-5]. In the present study, the GHGs emission from the carp culture ponds of Andhra Pradesh and West Bengal, India has been assessed through carbon storage and carbon footprint analysis.

MATERIALS AND METHODS

Twelve aquaculture ponds from West Godavari (16.9174° N, 81.3399° E), Krishna (16.6100° N, 80.7214° E) and Guntur (16.3067° N, 80.4365° E) districts of Andhra Pradesh and four aquaculture ponds from Moyna, East Medinipur district (22.2738° N, 87.7697° E) of West Bengal, India were selected for the present study.

Indian major carp cultures are practiced in all the selected ponds. The culture practice was for 210 to 285 days in Andhra Pradesh while the same was for 300 days in Moyna, West Bengal.

Feed (25-30 % protein), cow dung (organic fertilizer), inorganic fertilizers (urea, single super phosphate, di-ammonium phosphate), and lime are mainly used as inputs to produce the fish.

For carbon footprint analysis, all the inputs added to an aquaculture system are converted into Carbon Equivalence (CE). Amortization of pond construction was done as per [6]. The Pond inputs and their respective CE emissions are presented in (Table 1).

Soil carbon storage was measured by CORE Method. In this method, sediment samples from the pond was collected by a soil sampler (Corer) in such a way that only the sediment core was collected, no bottom soil below the sediment was collected. The sediment dry bulk density was measured and the sediment organic carbon was determined by CHN Analyzer. The carbon storage (Mg C/ha, mega gram C/ha) was calculated as per [7] as follows = [C (%)*dry bulk density (Mg/m^3) *depth (m)* *10^4 m^2]/100.

The average C content in the fish flesh on dry weight basis was 42 %.

The chance of C emission = Total input – Carbon storage- Carbon removal through produce

About 80-90 % of the carbon could be converted into CO_2 as the dissolved oxygen concentration in the pond environment is 5.0 mg/l (aerobic condition) while about 10-20 % chance of the carbon to be converted into CH_4 as an emission (under anaerobic condition). In the present study, it was considered that 85 % of the C could be converted into CO_2 and 15 % of the carbon could be converted into CH_4 as an emission as the dissolved oxygen concentration was 4.5 to 5.5 mg/l in these aquaculture ponds.

The data were presented with the Standard Deviation (SD) except few cases because of wider variations.

Table 1: Pond inputs and their respective CE emissions.

Pond inputs	CE emission/kg
Cow dung[a]	30-32 % C (on dry weight basis)
Nitrogen	1.35/kg fertilizer nutrient (Lal,2004)
Phosphorus (P_2O_5)	0.20/kg fertilizer nutrient (Lal,2004)
Pelleted Feed[a]	30-32 % C (on dry weight basis)
Oilcakes (GNOC, Mustard)[a]	28 % C (on dry weight basis)
Lime	0.16/kg (Lal,2004)

[a]: The C content of feed, oilcakes and cow dung has been considered directly as CE emission.

RESULT AND DISCUSSION

The Carbon Equivalent (CE) of all the inputs used in different aquaculture ponds of Andhra Pradesh are presented in table 2. The amortization for pond construction was 27 kg CE/ha. The CE for lime used in these ponds was 5 to 40 kg CE/ha. The CE for organic (cow dung) and inorganic fertilizers varied from 550 to 4500 kg CE/ha, and from 12 to 4500 kg CE/ha, respectively. The CE for feed used in these ponds ranged from 7326 to 18559 kg CE/ha during the culture period.

The carbon storage of the fish ponds of Andhra Pradesh are given in table 3. The sediment level of the ponds varied from 5.1 to 6.3 cm with an average of 5.78 ± 0.38 cm during the culture period. The dry bulk density of the sediment varied from 0.37 to 1.29 Mg/m^3 with an average of 0.77 ± 0.24 Mg/m^3 .The organic carbon content varied from 0.64 to 2.84 % with an average of 1.55 ± 0.76 %. The carbon storage ranged from 4039 to11466 kg/ha/culture with an average of 6216 ± 2291 kg/ha/culture. The fish production levels of these ponds varied from 5000 to10000 kg/ha/culture with an average of 7875 ± 1646 kg/ha/culture.

The Carbon Equivalent (CE) of all the inputs used in different aquaculture ponds of Moyna, West Bengal are presented in table 4. The amortization for pond construction was 50 to 115 kg CE/ha. The CE for lime used in these ponds was 160 kg CE/ha. The CE for inorganic fertilizers varied from 214 to 2620 kg CE/ha. The CE for feed used in these ponds ranged from 6400 to 8750 kg CE/ha during the culture period.

The carbon storage of the fish ponds of Moyna, West Bengal is given in table 5. The sediment level of the ponds varied from 4.75 to 5.80 cm with an average of 5.16 ± 0.47 cm during the culture period. The dry bulk density of the sediment varied from 0.68 to 0.93 Mg/m^3 with an average of 0.80 ± 0.11 Mg/m^3.The organic carbon content varied from

Table 2: Carbon-footprint of different inputs in aquaculture ponds of West Godavari, Krishna and Guntur districts of Andhra Pradesh.

Sr.No.	Pond area (ha)	Culture period (days)	Different inputs (kg CE/ha)				
			Amortization	Lime	Organic fertilizers	Inorganic fertilizers	Feed
1	16	225	27	8	550	33	14652
2	13.2	225	27	8	550	33	14652
3	6.4	285	27	8	2500	27	18559
4	7	225	28	5	625	23	14652
5	10.8	225	27	17	-	24	14652
6	8	225	27	-	5810	-	9157
7	26	240	27	14	1125	25	9768
8	10	210	27	40	4500	102	10256
9	28	210	27	40	4500	103	9324
10	4	255	27	16	3138	12	8302
11	2.8	225	27	18	3750	-	9157
12	4	225	27	-	-	4500	7326

Table 3: Carbon storage of soil samples from fish ponds of West Godavari, Krishna and Guntur districts Andhra Pradesh.

Sr. No.	Sediment level (cm)	Dry bulk density (Mg/m^3)	Organic carbon (%)	Carbon storage (kg/ha)/ culture	Production (kg/ha)/ culture
1	5.8	0.46	1.96	5240	10000
2	6.0	0.98	0.90	5292	10000
3	6.3	0.70	2.60	11466	7500
4	5.3	0.68	2.84	10340	6250
5	5.1	0.88	0.90	4039	10000
6	6.2	0.95	1.00	5890	7500
7	6.2	1.29	0.64	5170	7000
8	5.3	0.70	1.40	5194	8750
9	5.8	0.87	1.00	5046	8750
10	6.0	0.72	1.10	4752	6250
11	5.7	0.37	2.57	5420	7500
12	5.7	0.68	1.74	6744	5000
Average ± SD	5.78 ± 0.38	0.77 ± 0.24	1.55 ± 0.76	6216 ± 2291	7875 ± 1646

Table 4: Carbon-footprint of different inputs in aquaculture ponds of Moyna, East Medinipur, West Bengal.

Sr.No.	Pond area (ha)	Culture period (days)	Different inputs (kg CE/ha)				
			Amortization	Lime	Organic fertilizers	Inorganic fertilizers	Feed
1	40	300	50	-	-	2620	6400
2	10	300	112	160	-	-	7000
3	4	300	56	-	-	214	8750
4	40	300	115	160	-	538	8750

Table 5: Carbon storage of soil samples from fish pond of Moyna, East Medinipur, West Bengal.

Sr. No.	Sediment level (cm)	Dry bulk density (Mg/m^3)	Organic carbon (%)	Carbon storage (kg/ha)/ culture	Production (kg/ha)/ culture
1	5.80	0.93	0.78	4220	4500
2	4.75	0.85	0.89	3590	10000
3	5.25	0.74	1.78	6910	5000
4	4.85	0.68	1.50	4950	10250
Average ± SD	5.16 ± 0.47	0.80 ± 0.11	1.23 ± 0.48	4917 ± 1439	7437 ± 3111

0.78 to 1.78 % with an average of 1.23 ± 0.48 %. The carbon storage ranged from 3590 to 6910 kg/ha/culture with an average of 4917 ± 1439 kg/ha/culture. The fish production levels of these ponds varied from 4500 to10250 kg/ha/culture with an average of 7437 ± 3111 kg/ha/culture.

The carbon footprint and the emission of CO_2-e and CH_4-e from the fish ponds of West Godavari, Krishna and Guntur districts of Andhra Pradesh are presented in table 6. The average inputs as Carbon Equivalent (CE) in these ponds varied from 10959 to 21122 kg/ha with an average of 14407 ± 2651 kg/ha. Among the different inputs, feed contributed the maximum carbon of 80 percent to aquaculture ponds followed by organic manure (cow dung) as 15 per cent, inorganic fertilizers as 4 per cent and lime as 1.0 per cent. The carbon storage of different ponds ranged from 4039 to 11466 kg/ha during the culture period with an average of 6216 ± 2291 kg/ha. The CE as output/harvest varied from 2100 to 4200 kg/ha with an average of 3307 ± 691 kg/ha. The chance of Carbon (C) emission varied from 2368 to 6506 kg CE/ha/culture period with an average of 4883 ± 1488 kg CE/ha/culture period. The culture period in the present study was 210 to 285 days with an average of 231 days.

The chance of emission as CO_2-equivalent (CO_2-e) varied from 7363 to 20240 kg/ha with an average of 12212 ± 4631 kg/ha. The chance of C emission as CH_4-equivalent (CH_4-e) ranged from 473 to 1298 kg/ha with an average of 975 ± 296 kg/ha/culture period. The emission of kg CO_2-e per kg of fish production was 1.26 to 2.69 with an average of 1.91 ± 0.42 kg CO_2-e/kg fish production while the emission of kg CH_4-e per kg of fish production was 0.075 to 0.158 kg CH_4-e/kg fish with an average of 0.122 ± 0.027 kg CH_4-e/kg fish in Andhra Pradesh.

The carbon footprint and the emission of CO_2-e and CH_4-e from the fish ponds of Moyna, East Medinipur district of West Bengal are presented in table 7. The average inputs as CE in these ponds were 9231 ± 1007 kg CE/ha/culture period. Among the different inputs, feed contributed 86 per cent CE to aquaculture ponds, followed by inorganic fertilizers of 12 per cent and lime around 1.0 per cent. No organic manure was used in these ponds. The carbon storage was 5360 kg/ha excluding one pond whose carbon balances (input-carbon storage-output/harvest) was negative. The CE as output/harvest ranged from 1890 to 4305 kg/ha with an average of 2765 ± 1306 kg/ha. The chance of carbon emission varied from 10 to 3000 kg CE/ha/culture period. The average culture period was 300 days.

The chance of CO_2-e emission varied from 31.0 to 9333 kg/ha/culture period with an average of 3441 ± 1647 kg/ha while the chance of CH_4-e emission ranged from 1.99 to 598 kg/ha with an average of 220 kg/ha/culture period. The emission of CO_2-e ranged from 0.006 to 2.07 kg/kg fish production with an average of 0.72 kg/kg fish, while the emission of CH_4-e varied from 0.0004 to 0.132 kg/kg fish with an average of 0.046 kg/ kg fish production in Moyna, West Bengal.

It has been reported from life cycle impact assessment results that Indian shrimp, Viet Nam pangasius and Phillipines milkfish had global warming potential of 3.67 kg CO_2-e/kg shrimp, 1.32 kg CO_2-e/kg fish and 0.006 kg CO_2-e/kg fish, respectively [3,8] reported from a life cycle assessment that the grow-out phase of marine shrimp had a higher carbon footprint of 47.9967 kg CO_2-e/kg shrimp in super-intensive culture than the semi-intensive culture which had a value of 1.0042 kg CO_2-e/kg shrimp [5] reported from life cycle analysis that the production of greenhouse gases by other forms of aquaculture for food production ranged from 3.0 to 15.0 kg CO_2-e/kg fish while [9] reported that tuna fishing emitted 0.0038 kg CO_2-e/kg of tuna landed. It has been reported [10] from a life cycle model that Indian major carps in India, Nile tilapia in Bangladesh and stripped catfish in Viet Nam had the average Emissions Intensities (EI) from cradle to farm-gate, including emissions from

Table 6: Carbon footprint and CO_2-e and CH_4-e emissions in aquaculture ponds of Andhra Pradesh.

Sr. No.	CE as input (kg/ha	C as storage (kg/ha)	CE as output (kg/ha)	Chance of CE emission (kg/ha)	Chance of emission (kg/ha) as CO_2-e	CH_4-e	CO_2-e Emission/kg fish	CH_4-e Emission/kg fish
1	15270	5240	4200	5830	18135	1163	1.81	0.116
2	15270	5292	4200	5778	17975	1153	1.79	0.115
3	21122	11466	3150	6506	20240	1298	2.69	0.173
4	15333	10340	2625	2368	7363	473	1.17	0.075
5	14720	4049	4200	6481	20162	1294	2.01	0.129
6	14994	5890	3150	5954	18519	1189	2.46	0.158
7	10959	5170	2940	2849	8860	569	1.26	0.081
8	14925	5194	3675	6056	18840	1208	2.15	0.138
9	13994	5046	3675	5273	16404	1052	1.87	0.120
10	11495	4752	2625	4118	12811	821	2.04	0.131
11	12952	5420	3150	4382	13629	875	1.81	0.116
12	11853	6744	2100	3009	9358	601	1.87	0.120
Avearge ± SD	14407 ± 2651	6216 ± 2291	3307 ± 691	4883 ± 1488	12212 ± 4631	975 ± 296	1.91 ± 0.42	0.122 ± 0.027

Table 7: Carbon footprint and CO_2-e and CH_4-e emissions in aquaculture ponds of Moyna, East Medinipur, West Bengal.

Sr. No.	CE as input (kg/ha	C as storage (kg/ha)	CE as output (kg/ha)	Chance of CE emission (kg/ha)*	Chance of emission (kg/ha) as		CO_2-e Emission/kg fish	CH_4-e Emission/kg fish
					CO_2-e	CH_4-e		
1	9110	4220	1890	3000	9333	598	2.07	0.132
2	7272	3590	4200	-518	-	-	-	-
3	9020	6910	2100	10	31	1.99	0.006	0.0004
4	9563	4950	4305	308	959	61	0.090	0.006
Average ± SD	9231 ± 1007	5360 ± 1439	2765 ± 1306	1106	3441± 1647	220	0.72	0.046

The average has been calculated excluding the (-) negative chance of emission.

land use change (LUC) of 2.12, 1.81, and 1.61 kg CO_2-e/kg live weight fish, respectively. In the present study, the emission analyzed by carbon storage and carbon footprint including land amortization for the grow-out culture of Indian major carps in Andhra Pradesh, and Moyna, West Bengal was 1.91 and 0.72 kg CO_2-e/kg fish. The emission of CH_4-e was 0.122, and 0.046 kg CH_4-e/kg fish in Andhra Pradesh and Moyna, West Bengal, respectively. It has also been reported from carbon footprint analysis including both direct and indirect green house gas emissions associated with the production that farmed salmon fillet that is eaten in Paris had an emission of around 2.5 kg CO_2-e/kg fish [2,11] reported that approximately 1,683 kg carbon dioxide/ha were released during the whole river prawn grow out cycle which was corresponded to 459.58 kg of carbon equivalent. They also reported that total carbon di-oxide emission was 5.04 to 11.04 kg/ha/day while total methane emission was 0.21 to 0.50 kg/ha/day during grow out cycle of river prawn. They measured these emissions using diffusion chamber and canvas funnel with a submerged flask and measure the gases using specific gas-chromatic analysis.

CONCLUSION

From the present study, the following conclusions can be made:

(i). The average inputs as Carbon Equivalent (CE) in the fish ponds varied from 10959 to 21122 kg/ha with an average of 14407 ± 2651kg/ha in Andhra Pradesh while the same from Moyna was 9231 ± 1007 kg CE/ha/culture period.

(ii). Among the different inputs, feed contributed 80 to 86 per cent CE to aquaculture ponds, followed by inorganic fertilizers of 4-12 per cent, organic fertilizers around 15 per cent, and lime around 1.0 per cent in these ponds.

(iii). The emission of kg CO_2-e per kg of fish production was 1.26 to 2.69 with an average of 1.91 ± 0.42 kg CO_2-e/kg fish production while the emission of kg CH_4-e per kg of fish production was 0.075 to 0.158 kg CH_4-e/kg fish with an average of 0.122 ± 0.027 kg CH_4-e/kg fish in Andhra Pradesh.

(iv). The emission of CO_2-e ranged from 0.006 to 2.07 kg/kg fish production with an average of 0.72 kg/kg fish, while the emission of CH_4-e varied from 0.0004 to 0.132 kg/kg fish with an average of 0.046 kg/ kg fish production in Moyna, West Bengal.

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