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 CO2-e and CH4-e were 1.91 ± 0.42 kg CO2-e/kg fish and 0.122 ± 0.027 kg CH4-e/kg fish, respectively in Andhra Pradesh. The emissions of CO2-e and CH4-e were 0.006 to 2.07 (average 0.72) kg CO2-e/kg fish, and 0.0004 to 0.132 (average 0.046) kg CH4-e/kg fish production, respectively in Moyna, West Bengal.

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 infrared 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...
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. Literature 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/m³) *depth (m)]/100.

The average C content in the fish flesh on dry weight basis was 4.2 %.

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

About 80–90 % of the carbon could be converted into CO₂ 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 CH₄ as an emission (under anaerobic condition). In the present study, it was considered that 85 % of the C could be converted into CO₂ and 15 % of the carbon could be converted into CH₄ 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.

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/m³ with an average of 0.77 ± 0.24 Mg/m³. 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 to 11466 kg/ha/culture with an average of 6216 ± 2291 kg/ha/culture. The fish production levels of these ponds ranged from 5000 to 10000 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/m³ with an average of 0.80 ± 0.11 Mg/m³. The organic carbon content varied from

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**Table 1:** Pond inputs and their respective CE emissions.

| Pond inputs       | CE emission/kg |
|-------------------|----------------|
| Cow dung*         | 30-32 % C (on dry weight basis) |
| Nitrogen          | 1.35/kg fertilizer nutrient (Lal,2004) |
| Phosphorus (P₂O₅) | 0.20/kg fertilizer nutrient (Lal,2004) |
| Pelleted Feed*    | 30-32 % C (on dry weight basis) |
| Oilcakes (GNOC, Mustard)* | 28 % C (on dry weight basis) |
| Lime              | 0.16/kg (Lal,2004) |

* The C content of feed, oilcakes and cow dung has been considered directly as CE emission.
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/m³) | 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      | 6.3                 | 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/m³) | 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                 |
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 ranged from 10959 to 21122 kg/ha/culture period. The emission of kg CO$_2$-e per kg of fish production was 0.075 to 0.158 kg CH$_4$-e/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/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 3307 ± 691 kg/ha. The chance of carbon emission varied from 10 to 3000 kg CE/ha/culture period. The average culture period was 300 days.

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 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

| 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 | CO$_2$-e Emission/kg fish | CH$_4$-e Emission/kg fish |
|---------|---------------------|---------------------|---------------------|-------------------------------|------------------------------------------|--------------------------|--------------------------|
| 1       | 15270               | 5240                | 4200                | 5830                          | 18135                                    | 1163                     | 1.16                     |
| 2       | 15270               | 5292                | 4200                | 5778                          | 17975                                    | 1153                     | 1.16                     |
| 3       | 21122               | 11466               | 3150                | 6056                          | 20240                                    | 1298                     | 2.69                     |
| 4       | 15333               | 10340               | 2625                | 2368                          | 7363                                     | 473                      | 1.17                     |
| 5       | 14720               | 4049                | 4200                | 6481                          | 20162                                    | 1294                     | 2.01                     |
| 6       | 14994               | 5890                | 3150                | 5954                          | 18519                                    | 1189                     | 2.46                     |
| 7       | 10959               | 5170                | 2940                | 2849                          | 8860                                     | 569                      | 1.26                     |
| 8       | 14925               | 5194                | 3675                | 6056                          | 18840                                    | 1208                     | 2.15                     |
| 9       | 13994               | 5046                | 3675                | 5273                          | 16404                                    | 1052                     | 1.87                     |
| 10      | 11495               | 4752                | 2625                | 4118                          | 12811                                    | 821                      | 2.04                     |
| 11      | 12952               | 5420                | 3150                | 4382                          | 13629                                    | 875                      | 1.81                     |
| 12      | 11853               | 6744                | 2100                | 3009                          | 9358                                     | 601                      | 1.87                     |
| Average ± SD | 14407 ± 2651     | 6216 ± 2291         | 3307 ± 691          | 4883 ± 1488                   | 12212 ± 4631                              | 975 ± 296                | 1.91 ± 0.42               |

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 to 10250 kg/ha/culture with an average of 7437 ± 3111 kg/ha/culture. The chance of C emission as CH$_4$-e equivalent (CH$_4$-e) from fish ponds 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/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 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

| 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 | CO$_2$-e Emission/kg fish | CH$_4$-e Emission/kg fish |
|---------|---------------------|---------------------|---------------------|-------------------------------|------------------------------------------|--------------------------|--------------------------|
| 1       | 15270               | 5240                | 4200                | 5830                          | 18135                                    | 1163                     | 1.16                     |
| 2       | 15270               | 5292                | 4200                | 5778                          | 17975                                    | 1153                     | 1.16                     |
| 3       | 21122               | 11466               | 3150                | 6056                          | 20240                                    | 1298                     | 2.69                     |
| 4       | 15333               | 10340               | 2625                | 2368                          | 7363                                     | 473                      | 1.17                     |
| 5       | 14720               | 4049                | 4200                | 6481                          | 20162                                    | 1294                     | 2.01                     |
| 6       | 14994               | 5890                | 3150                | 5954                          | 18519                                    | 1189                     | 2.46                     |
| 7       | 10959               | 5170                | 2940                | 2849                          | 8860                                     | 569                      | 1.26                     |
| 8       | 14925               | 5194                | 3675                | 6056                          | 18840                                    | 1208                     | 2.15                     |
| 9       | 13994               | 5046                | 3675                | 5273                          | 16404                                    | 1052                     | 1.87                     |
| 10      | 11495               | 4752                | 2625                | 4118                          | 12811                                    | 821                      | 2.04                     |
| 11      | 12952               | 5420                | 3150                | 4382                          | 13629                                    | 875                      | 1.81                     |
| 12      | 11853               | 6744                | 2100                | 3009                          | 9358                                     | 601                      | 1.87                     |
| Average ± SD | 14407 ± 2651     | 6216 ± 2291         | 3307 ± 691          | 4883 ± 1488                   | 12212 ± 4631                              | 975 ± 296                | 1.91 ± 0.42               |
Table 7: Carbon footprint and CO₂-e and CH₄-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 CO₂-e | CO₂-e Emission/kg fish | CH₄-e Emission/kg fish |
|---------|---------------------|---------------------|---------------------|-------------------------------|-------------------------------------|------------------------|------------------------|
| 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 CO₂-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 CO₂-e/kg fish. The emission of CH₄-e was 0.122, and 0.046 kg CH₄-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 CO₂-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 14,407 ± 2651 kg/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 CO₂-e per kg of fish production was 1.26 to 2.69 with an average of 1.91 ± 0.42 kg CO₂-e/kg fish production while the emission of kg CH₄-e per kg of fish production was 0.075 to 0.158 kg CH₄-e/kg fish with an average of 0.122 ± 0.027 kg CH₄-e/kg fish in Andhra Pradesh.

(iv). The emission of CO₂-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 CH₄-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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