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Gaseous emission estimations from earth's land Fishponds, Cameroon

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Abstract

Global warming is an important determinant of life on the earth. Estimating the effect of management practices on gas emissions (ammonia and greenhouse) is a new challenge for the sustainable development of fish farming and increase productivity of fish ponds. This work presents a simple method to compare various fish ponds where input levels or number of fish species varies. Air was collected during 24 hours in tedlar bags rainy season and dry season, either outside and just above the water level of eight earth's land fish ponds at the aquaculture experimental platform of the University of Dschang-Cameroon (5°26.69-71'NL and 10°04.187-315'). The air was analyzed for CO_2, CH_4, NH_3, N_2O using photo acoustic spectrometry. The fish ponds had various input levels. Concentration gradients were calculated and interpreted based on the mass balance of the system. Results showed that CO_2 gradients were higher with higher temperatures (26°C), and higher in the fish ponds with higher organic inputs and CH_4 sinks related to a higher oxygen level in the water due to higher photosynthesis and the large deposit of death plankton on the bottom. NH_3 and N_2O gradients were significantly correlated while no correlation was detected between NH_3 and CO_2. It is assumed that higher nitrogen input or higher fish population induced higher NH_3 emission and higher nitrogen turn-over inducing limited N_2O emission and nitrite accumulation below toxic levels. Pond management can both improve feed efficiency of fish production and reduce NH_3, N_2O and CH_4 emissions.

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Introduction

The phenomenon of Global warming due to emission of greenhouse gases is not only related to the consumption of fossil fuels due to the heavy industrialization, but also to human activities (Dobrescu, 2009, Bonnefoy *et al.* 2010). These activities emit large quantities of carbon which is ranked first in accelerating global warming (Dobrescu *et al.* 2009, Bonnefoy *et al.* 2010).

Animal farming as a human activity is not left out; it emits greenhouse gases which accumulate because of the increasing development to meet with the constantly growing food needs, consequently the rampant degradation of the ozone layer (Koneswaran and Nierenberg, 2008).

Fish farming is the fastest growing animal food-producing sector in the world, due to the joint effect of an increase in demand of fish products and a stagnation of fisheries captures (Little *et al.* 2012, FAO, 2014, Béné *et al.* 2016, Troell *et al.* 2017).

Fish farming, however, also faces some environmental challenges (Ponds combined water and sediment to have unique carbon dynamics and are important sources of the dominant greenhouse gases (GHG), carbon dioxide (CO_2) and methane (CH_4),(CH_4), (Boyd *et al.* 1994, Wu *et al.* 2007, Bambace *et al.* 2007, Fabio Roland *et al.* 2010, William *et al.* 2010, Yvon.

Durocher, 2011, Duc *et al.* 2013). Regional and global pond gas emissions contributing to the greenhouse effect are poorly known.

Some methods for estimating these emissions especially in land animal farms and even ways of reducing emissions from their wastes were developed and implemented in different environmental and economical contexts (Hobson *et al.* 2005; Loyon *et al.* 2007; Houssana *et al.* 2010, Lute, 2011).

Very few of these studies had interest in wetland (Wang *et al.* 1996, Wu *et al.* 2007, Bambace *et al.* 2007, Huai, 2013, Duc *et al.* 2013) and less in fish farm (Boyd *et al.* 1994), which by their daily functioning export substances in the form of gas.

These gases come from fish metabolism, mineralization of fecal wastes and organic manures and photosynthetic activity which is more pronounced in semi-intensive fish production in ponds where production base on the natural productivity of the medium.

Most identified are carbon dioxide (CO_2) from respiration, oxygen (O_2) from photosynthetic activity, ammonia (NH_3), excreta of fish resulting from protein digestion, methane (CH_4) and nitrous oxide (N_2O) from the incomplete mineralization of organic matter.

Their quantities are related to the biotransformation processes within the ponds and depends on different systems (Efole Ewoukem *et al.* 2012). The development of a method for estimating gaseous emissions is not only to assess the contribution of fish farms to Global warming but also to help implement sustainable models of fish farms guarantee for the achievement of the Millennium Development goals. The objective of this study was to contribute to the reduction of greenhouse gas emissions from fish-farming ponds through the development of a simple and low-cost method of gas collection and analysis.

Materials and methods

Study Area

Thestudy was conducted in raining season (Jun, Jul, Aug) in 2009 and dry season (Feb, Mar, Apr) in 2010 at the aquaculture experimental platform of the Application and Research farm of the University of Dschang, Cameroon (5°26.69-71'l attitude North and 10°04187-315' longitude East) at an average altitude of 1400m (Fig. 1).

The climate is tropical humid modified by altitude with two seasons the dry (November to March) and the rainy (April to October). The average ambient temperature is18and 27°C, the relative humidity is 47 and 90%, the average annual rainfallis about 800 and 2400mm for the dry and rainy season respectively.

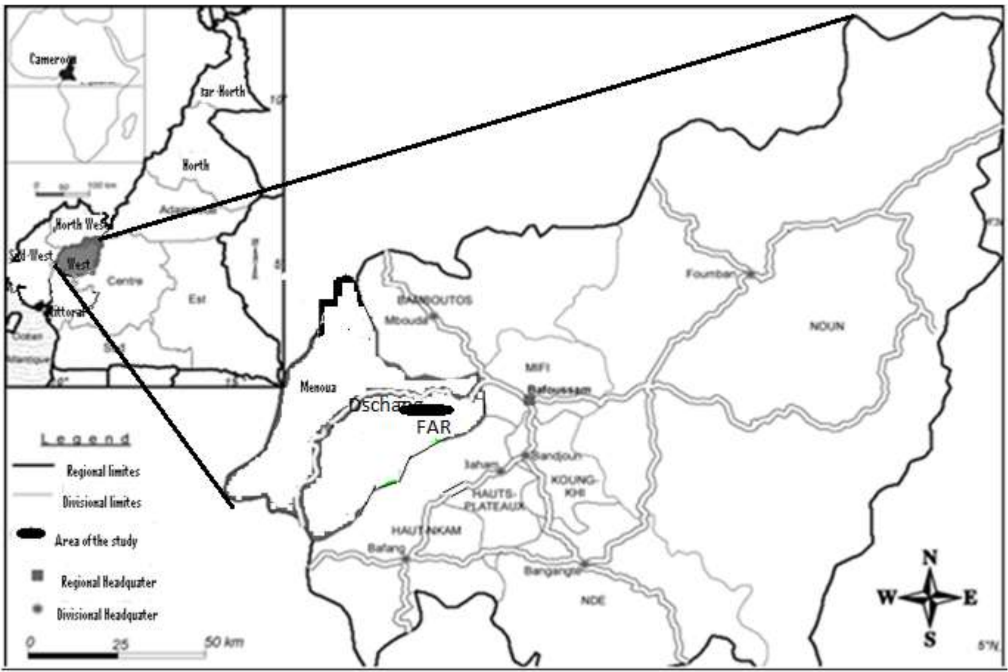

Fig. 1. Location of the Study Area in Cameroon.

Methods

The gases measurement was initially associated to a biotechnical optimization trial of semi-intensive pond system based on a fractional factorial design using "confounding" principle (Dagnelie, 2003) carried out by season (three months per season). It was conducted on 8 ponds of 25 m², sheeted on the bottom,receiving different combinations of production factors according to farming practices in Cameroon and literature (Coche *et al.* 1997). Based on this, ponds chose were range in three groups of semi-intensive Ponds: Law pisciculture (one input, 2 fish species, small density), Medium pisciculture (inputs, 2 fish species, small density), Highsemi-intensive pisciculture (high inputs, 3 fish species or high stocking density), their trophic and species compositions are summarized in Table 1. The concentration of chlorophyla a were determine each month by the Standard methods for the examination of water and waste-water (APHA, 1985) and the fish biomass gain at the end of the experiment using the formula:

- Fish Biomass gain (g)

- $FBg = Bf - Bi$

Where, Bf: total fish final biomass, Bi: initial total fish biomass.

Table 1. Trophic and species composition of fish ponds sampled. Tilapia = *Oreochromis niloticus*, catfish1 = *Clarias gariepinus*, catfish 2 = *Clarias jaensis*, Carp = *Cyprinus carpio*, Chla = Chlorophyl a, manure= Chicken manure.

Ponds	Fish association	Fish density (Ind/m²)	Mineral enrichment	Fertilizer and feed	Chla (mg/m³)	Fish Biomass gain (g)
1	Tilapia + catfish1	1.2	None	manure	2,7	1938
2	Tilapia+ catfish1+2	1.4	wood ash	manure + Urea+ bread	8,3	1955
3	Tilapia +catfish1	1.2	Lime + wood ash	manure + bread+ wheatbran	6,0	2046
4	Tilapia + catfish1 + carp	1.4	None	manure + Urea+ bread+ wheatbran	25,8	2771
5	Tilapia + catfish1 + carp	1.4	Lime + wood ash	manure + Urea	2,1	2157
6	Tilapia + catfish1	2.2	Lime	manure + Urea+ bread	0,5	4332

Ponds	Fish association	Fish density (Ind/m²)	Mineral enrichment	Fertilizer and feed	Chla (mg/m³)	Fish Biomass gain (g)
7	Tilapia + catfish1+2	1.4	Lime	manure + Urea+ wheatbran	2,6	3890
8	Tilapia +catfish1+ catfish2 + carp	1.6	wood ash	manure + wheatbran	4,3	2859

Air was collected continuously during 24 hours because respiration and photo synthesis in duce contrasted gradients of CO_2, and variable pH between day and nightfrom random locations on pond surface and from the surrounding environment in two 10-l Theldar bags (SKC sample bag 232) ((1) between the water and a plastic sheet floating on the pond; (2) outside the pond))using a floating chamber (Light raft for surface gas sampling of liquids (slurries, lagoons, fish farms)) contruted and tested before the experiment and were suitable adapted for the measurement of an outside air/air concentration gradient in contact with the liquid. The chamber was made of 0.5 x 0.5 x 0.3m PVC plates covered on one side to form a chamber. Floats were attached on the sides.

A battery-powered aquarium pump (pump BK) was linked to the chamber to fill the bag via a flexible tube equipped with a micro filteras shown in the conceptual framework (Fig. 2).

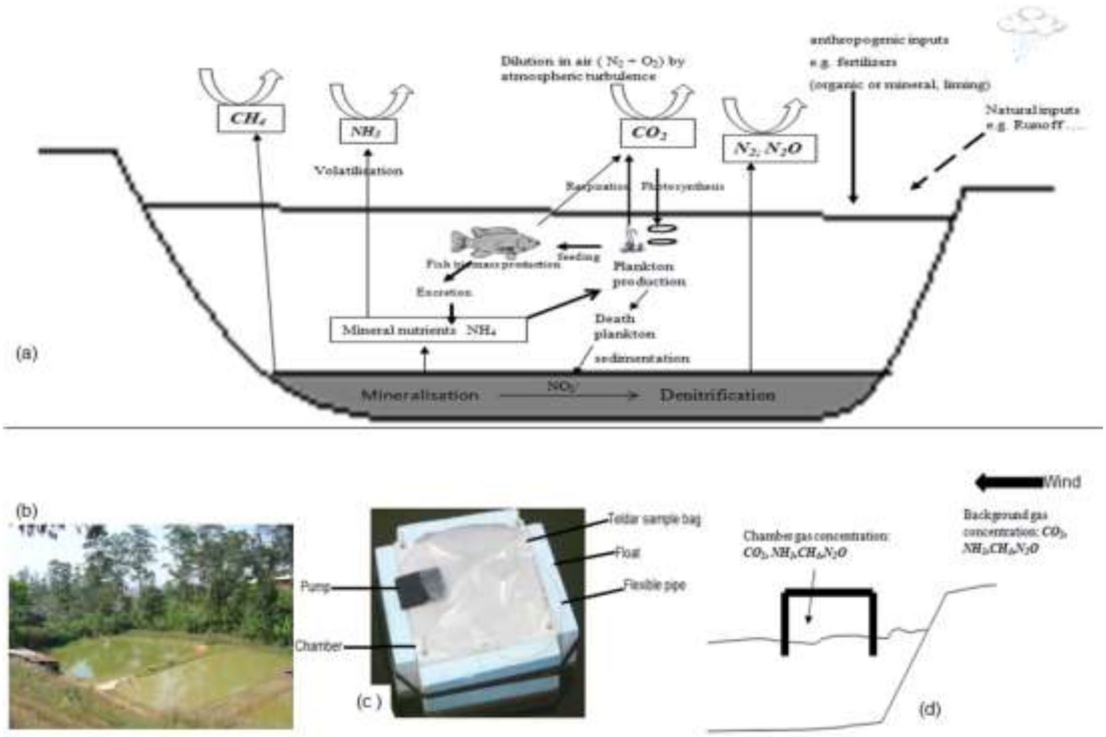

Fig. 2. Conceptualisation of a simple indicator of gas emission. (a) fluxes and stocks, (b) fishpond, (c) chamber with sample bag for 24h sampling, (d) concentrations difference between chamber and background.

Gas analysis was carried using an INNOVA 1412 photo acoustic gas analyzer (Fig. 3). The calculation of concentration gradient of emission (s) is made using the ratio between the gases whose emission is sought to be known and one (several) gases of which the emission is known, Gas emissions were calculated by the difference between the concentrations of the gas collected in the ponds and the ambient air surrounding environment. The gradient of gas is retained if its absolute value is greater than the standard deviation of the average concentrations. Analysis of gradients and ratios between gases provides a better understanding of the hydrodynamique and biological functioning of the medium.

Fig. 3. Photoacoustic Analyser (INNOVA 1412) with an air sample bag.

Resultand discussion

The concentration gradients of gas samples and their ratios are summarized in Table 2. The net positive CO_2 gradient shown in the table indicates that the air collected from the chamber-concentrated pond emissions was not contaminated by outside air. Globaly, the presence of gases show that the method is suitable adapted for the gas sampling from fish pond and the results are comparable by those obtained by Bambace *et al.* (2007) using metal box and sliding CH_4 emission mitigation system for turbine intakes method, different analytical approaches for measurement of CO_2 partial.

Pressure use by Fabio *et al.* (2010) in tropical hydroelectrically dams or prediction method in lake (Bastviken *et al.* 2004), wetland (Wang *et al.* 2007).

Table 2. Gas concentration gradients and their ratios.

Ponds	Gas gradients (mg/m³)				Ratios of gas gradients			
	CO_2	CH_4	NH_3	N_2O	NH_3/N_2O	NH_3/CH_4	CO_2/CH_4	CO_2/NH_3
1	586.7	0.8	0.2	0.2	1.3	0.27	698	2541
2	789.4	-2.1	0.2	0.3	0.9	-0.11	-367	3338
3	920.9	0.9	0.3	0.4	0.9	0.37	1007	2742
4	870.9	-1.1	0.4	1.3	0.3	-0.41	-810	1991
5	482.3	nd	0.2	0.2	1.5	nd	nd	2097
6	7104.9	-1.5	0.5	1.2	0.4	-0.31	-4805	15530
7	920.9	-0.7	0.4	0.7	0.6	nd	0.0	nd
8	620.0	nd	0.2	0.3	0.9	nd	0.0	nd

It same as physicochemical method in river (Wu *et al.* 2007), gas chromatograph method (Yvon-Durocher *et al.* 2011) or the combination of physico-chemical and partial pressure method in ponds (Boyd *et al.* 1994). However emissions from these pond systems overall remain low compared to other equivalent production systems.

Generally, CO_2 emissions observed in dry Season were much higher than previous samples in 2009 (30-80 mg/m³). This high level is explained by a better rearing temperature for the fish associated with high microbial activity in the bottom in dry season (Reynolds and Casterlin, 1980). The gradients of other gases used were generally low and comparable to those found in extensive farms in rainy season (0.7 to 1.3). A positive gradient indicates higher CH_4 emissions in ponds 1 and 3, which had a low fish density (1.2 ind/m²), with a CO_2/CH_4 ratios of 700-1000, indicating low CH_4 emissions compared to those of CO_2. In contrast, negative gradients indicate lower CH_4 in ponds 2, 4, 6 and 7 having higher fish densities (1.4, 1.4, 2.2 and 1.4 ind/m², respectively) and using lime or ash for mineral enrichment. These CH_4 fluxes remain low (-400 to -5000) compared to those of CO_2. This confirms the role of temperature elevation of the sheets, favorable to metabolism where CO_2/CH_4 and CO_2/NH_3 ratios are greater than those observed in rainy season (29-93) and (91-363), respectively. Thus the appearance of methane consumption in these intensive systems would be related to the abundance of oxygen in the middle to the bottom due to the high algal development responsible for the activation of organic matter mineralization of the bottom-soil microorganisms (Loir and Mollo, 2008).

Globaly, these results are comparables in terms of gases emissions to those reported by many authors in water bodies and wetlands (Boyd *et al.* 1994, Bastviken *et al.* 2004, Wu *et al.* 2007, Wang *et al.* 2007, Bambace *et al.* 2007, Fabio *et al.* 2010, William *et al.*2010). In fact, the concentration of these gases varies according to the quantity organic matter in the medium, the importance of the photosynthetic activity of the seasons as well as the cyclic movements of the water masses.

In dead, CH_4 emissions in ponds remained low compare to those observed in wetlands (Wang *et al.* 2007, William *et al.* 2010) and hydroelectric dams (Bambace *et al.* 2007, Fabio *et al.* 2010) this can be explain by the contribution of lime in the mineralization process and the abundance of oxy gene for the bottom-soil microorganisms in ponds On the one hand of the importance of the photosynthetic activities and the low depth in the other hand. The emission of CO_2 is independent to NH_3 and N_2O because no correlation exists between them.

There is a stable gradient of NH_3 (same gradients as in rainning season) and an increase in the N_2O gradient in some ponds. Also additional nitrogen supply with highest values observed when urea and wheat bran were associated or more fish. This result shows that, more nitrogen inputs per unit area leads to more recycling flux but relatively stable concentrations of NH_3 in water. This is especially confirmed by the strong positive correlation between NH_3 and N_2O gradients (Fig. 4).

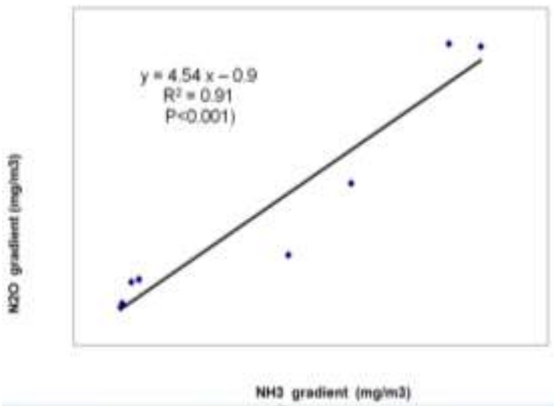

Fig. 4. Correlation between NH_3 and N_2O gradient.

Indeed, more nitrogen in the system would lead to the production of more NH_3 (mineralization and excretion) and hence a higher NH_3 gradient. But in this case ammonia does not accumulate because it is processed more intensively, hence the increased N_2O gradient (nitrification and denitrification). This transformation would result in potentially high concentrations of nitrites toxic to fish, but the high production offish indicates that, quantities of nitrite are small and out of the toxicity limit.

This result in lower emissions of N_2O from fish ponds. The increase nitrogen transformations result in their greater assimilation in the trop hic chain that comforts the choice of good poly culture to optimize available resources (Verdegem, 2007; Rahman *et al.*2008; Verdegem and Bosma, 2009; Efole Ewoukem, 2011), good integration systems (Ogburn and White, 2011) or genetic improvement (Besson *et al.* 2016) and build sustainable fish farms.

Conclusion

Pond management had a clear daily influence on the concentration gradient of CO_2, CH_4, NH_3, N_2O between pond and outside. The CO_2 gradient increased with fish density. The NH_3 and N_2O gradients were correlated and both increased with Nitrogen input. A high CO_2/NH_3 ratio indicated a reduction of NH_3 emission whenever there is Nitrogen feed. Lower Nitrogen-losses were assumed to result from higher Nitrogen recycling. CH_4 sink has been hypothesized to be linked to photosynthetic activity producing O_2 in the water Pond management can both improve feed efficiency of fish production and reduce NH_3, N_2O and CH_4 emissions.

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