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NITROUS OXIDE AND METHANE EMISSIONS FROM HEDGEROW SYSTEMS IN CLAVERIA, MISAMIS ORIENTAL, PHILIPPINES: AN INVENTORY

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Overview

- Nitrous oxide and methane are the important greenhouse gases, contributing 5% and 15% respectively, of the enhanced greenhouse effect.
- Atmospheric concentration of N_2O emission is increasing at a rate of 0.22 +/- 0.02% per year (Bhatia et al., 2004), from a pre-industrial concentration of ~275 to 320 ppm (Verchot *et al*., 2004).
- The rapid increase of N_2O emission is a great concern because of its long atmospheric lifetime of 166 +/- 16 years and higher global warming potential (310 times that of CO_2).

Overview

- Nitrous oxide emissions from agricultural soils are the most important anthropogenic source of this gas.
- Agriculture contributes 6.2 Tg N yr^{-1}, about 78% of the N emissions from anthropogenic activities (Kroeze *et al*., 1999).
- Soil is considered one of the major sources, contributing 65% to the global nitrous oxide emission.

Overview

- Nitrous oxide (N_2O) is a by-product of microbial processes closely associated with anoxic soil conditions and denitrification (Verchot *et al*., 2004).

- N_2O emissions resulting from anthropogenic N input occurs through the direct pathways of nitrification and denitrification from soil, as well as through a number of indirect pathways, including volatilization losses, leaching and run-off from applied N.

Overview

- Biological generation of methane in anaerobic environments, including enteric fermentation in ruminants, flooded rice fields, and anaerobic animal waste processing, is a principal source of methane in agriculture.

- Aerobic soils provide 10-20% of annual methane emissions (IPCC, 2006).

Overview

- Agroforestry is a dynamic, ecologically-based, natural resource management system that, through the integration of trees and livestock in farms, diversifies and sustains smallholder production for increased social, economic and environmental benefits.
- It is a sustainable alternative agricultural system for degraded lands that can best meet smallholder farm household food needs as well as provide environmental services.

Overview

- Agroforestry systems are widely adopted in the uplands of Claveria, Mindanao, Philippines.
- Agroforestry systems may serve as both a source and sink of nitrogen oxides, depending on the management practices and component trees and crops of the system.

Overview

- There are very few reports of N_2O emissions from tree-based tropical agricultural systems, despite these systems being the predominant land use in much of the humid tropics (Millar et al., 2004).
- No study has been conducted in the Philippines to estimate N_2O and CH_4 emissions from agroforestry systems.
- Efforts to estimate nitrous oxide emission from the decomposition of tree litterfall in agroforestry systems has been lacking.

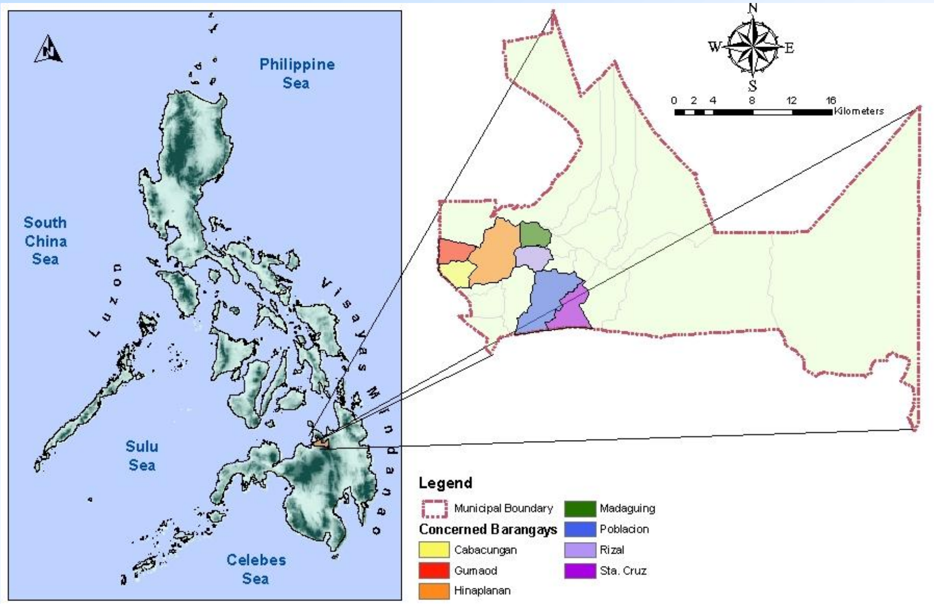
Objectives

- This study sought to estimate nitrous oxide emissions through inorganic fertilizer application, tree litterfall and decomposition, maize residue incorporation and livestock manure in *G. arborea* and *E. deglupta* hedgerow agroforestry systems.
- It also aimed to estimate methane emissions from livestock holdings in smallholder farms in Claveria, Misamis Oriental.
- The study also aims to compare nitrous oxide emissions in agroforestry systems with varying hedgerow spacing, tree age, tree species and rate of fertilizer applied.

Significance

- The results of this study will shed important information on nitrous oxide and methane emissions from agroforestry systems with varying hedgerow spacing, tree components, tree age and fertilizer application.
- Accurate estimates of GHG emissions from these systems are important in the design and composition of agroforestry systems to minimize nitrous oxide and methane emissions.

Description of the Study Area



The SAFODS Philippines Research Site

Claveria is a land-locked agricultural municipality in the province of Misamis Oriental in Northern Mindanao.

It is composed of 24 barangays.

Its topography is generally rugged, characterized by gently rolling hills and mountains with cliffs and escarpments.

The climate of Claveria is classified as having a C2 rainfall distribution, with 5 or 6 wet months (>200 mm/mo) and 2 or 3 dry months (<100 mm/mo).

Methodology

Methodology

General Methodology to calculate nitrous oxide and methane emissions from Agriculture, Forestry and Other Land Use (AFOLU) section of the 2006 IPCC Guidelines

Direct N_2O emissions from soil

$$N_2O_{Direct} - N = \left[N_2O - N_{Ninputs} + N_2O - N_{PRP} \right] \qquad \text{(Eqn 1)}$$

Where:

$$N_2O - N_{NInputs} = \begin{bmatrix} [(F_{SN} + F_{ON} + F_{CR} + F_{SOM}) \bullet EF_1] + \\ [(F_{SN} + F_{ON} + F_{CR} + F_{SOM})_{FR} \bullet EF_{1FR}] \end{bmatrix} \qquad \text{(Eqn 2)}$$

$$N_2O - N_{PRP} = \left[(F_{PRP,CPP} \bullet EF_{3PRP,CPP}) + (F_{PRP,SO} \bullet EF_{3PRP,SO}) \right] \qquad \text{(Eqn 3)}$$

- where:
- N_2O_{Direct}-N = annual direct N_2O-N emissions produced from managed soils, kg N_2O-N yr^{-1}
- N_2O-$N_{N\ inputs}$ = annual direct N_2O-N emissions produced from N inputs to managed soils, kg N_2O-N yr^{-1}
- N_2O-N_{OS} = annual direct N_2O-N emissions produced from managed organic soils, kg N_2O-N yr^{-1}. (Note: Since the soil in the study area is not organic soil, this part was not included in the computation for annual direct N_2O-N emissions)
- N_2O-N_{PRP} = annual direct N_2O-N emissions produced from urine and dung inputs to grazed soils, kg N_2O-N yr^{-1}
- F_{SN} = annual amount of synthetic fertilizer N applied to soils, kg N yr^{-1}
- F_{ON} = annual amount of animal manure, compost sewage sludge and other organic N additions applied to soils, kg N yr^{-1}
- F_{CR} = annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, kg N yr^{-1}

- F_{SOM} = annual amount of N in mineral soils that is mineralized, in association with loss of soil C from soil organic matter as a result of changes to land use or management, kg N yr^{-1}
- F_{OS} = annual area of managed/drained organic soils, ha
- F_{PRP} = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr^{-1}
- EF_1 = emission factor for N_2O emissions from N inputs, kg N_2O-N (kg N input)$^{-1}$
- EF_{1FR} = emission factor for N_2O emissions from N inputs to flooded rice, kg N_2O-N (kg N input)$^{-1}$
- EF_2 = emission factor for N_2O emissions from drained/managed organic soils, kg N_2O-N ha^{-1} yr^{-1}
- EF_{3PRP} = emission factor for N_2O emissions from urine and dung N deposited by grazing animals on pasture, range and paddock, kg N_2O-N (kg N input)$^{-1}$. (Note: the subscripts CPP and SO refer to Cattle, Poultry & Pigs, and Sheep & Other animals, respectively.)

N in urine and dung deposited by grazing animals on pasture, range and paddock (Tier 1)

$$F_{PRP} = \sum_{T} \left[\left(N_{(T)} \bullet Nex_{(T)} \right) \bullet MS_{(T,PRP)} \right] \qquad \text{(Eqn 5)}$$

Where:

F_{PRP} = annual amount of urine and dung N deposited on pasture, range, paddock and by grazing animals, kg N yr^{-1}

$N_{(T)}$ = number of head of livestock species/category *T* in the country

Nex(T) = annual average excretion per head of species/category *T* in the country, kg N $animal^{-1}$ yr^{-1}

$MS_{(T,PRP)}$ = fraction of total annual N excretion for each livestock species/category *T* that is deposited on pasture, range and paddock

Indirect N_2O emissions

N_2O from atmospheric deposition of N volatilized from managed soils (Tier 1)

$$N_2O_{(ATD)}-N=\left[\left(F_{SN}\bullet Frac_{GASF}\right)+\left(F_{ON}+F_{PRP}\right)\bullet Frac_{GASM}\right]\bullet EF_4 \qquad \text{(Eqn 6)}$$

Where:

$N_2O_{(ATD)}$-N = annual amount of N_2O-N produced from atmospheric deposition of N volatilized from managed soils, kg N_2O-N yr^{-1}

F_{SN} = annual amount of synthetic fertilizer N applied to soils, kg N yr^{-1}

$Frac_{GASF}$ = fraction of synthetic fertilizer that volatilizes as NH_3 and NO_x, kg N volatilized (kg of N applied)$^{-1}$

F_{ON} = annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N yr^{-1}

F_{PRP} = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr^{-1}

$Frac_{GASM}$ = fraction of applied organic N fertilizer materials (F_{ON}) and of urine and dung deposited by grazing animals (F_{PRP}) that volatilizes as NH_3 and NO_x, kg N volatilized (kg of N applied or deposited)$^{-1}$

EF_4 = emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces, [kg N-N_2O (kg NH_3-N + NO_x-N volatilized)$^{-1}$]

Leaching/ Runoff, $N_2O(L)$

N_2O from N leaching/runoff from managed soils in regions where leaching/runoff occurs (Tier 1)

$$N_2O_{(L)} - N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \bullet Frac_{LEACH-(H)} \bullet EF_5 \qquad \text{(Eqn 7)}$$

- Where:

$N_2O_{(L)}$-N = annual amount of N_2O-N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs, kg N_2O-N yr^{-1}

F_{SN} = annual amount of synthetic fertilizer N applied to soils, kg N yr^{-1}

F_{ON} = annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N yr^{-1}

F_{PRP} = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr^{-1}

F_{CR} = amount of N in crop residues (above- and below-ground), including N-fixing crops, and from forage/pasture, returned to soils annually in regions where leaching/runoff occurs, kg N yr^{-1}

F_{SOM} = annual amount of N mineralized in mineral soils associated with loss of soil C from soil organic matter as a result of changes to land use or management in regions where leaching/runoff occurs, kg N yr^{-1}

$Frac_{LEACH-(H)}$ = fraction of all N added to/mineralized in managed soils in regions where leaching /runoff occurs that is lost through leaching and runoff, kg N (kg of N additions)$^{-1}$

EF_5 = emission factor for N_2O emissions from N leaching and runoff, kg N_2O-N (kg N leached and runoff)$^{-1}$

METHANE EMISSIONS FROM LIVESTOCK

Methane emissions from enteric fermentation

$$Emissions = EF_{(T)} \bullet \left(\frac{N_{(T)}}{10^6} \right) \qquad \text{(Eqn 8)}$$

Where:

Emissions = methane emissions from enteric fermentation, kg CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg $CH_4 head^{-1} yr^{-1}$

$N_{(T)}$ = the number of head of livestock species/category *T* in the country

T = species/category of livestock

Total emissions from livestock enteric fermentation

$$TotalCH_{4Enteric} = \sum_{i} E_i \qquad \text{(Eqn 9)}$$

Where:

$TotalCH_{4Enteric}$ = total CH_4 emissions for enteric fermentation, Gg $CH_4 yr^{-1}$

E_i = the emissions for the i^{th} livestock categories and subcategories

Methane emissions from manure management

$$CH_{4Manure} = \sum_{(T)} \frac{(EF_{(T)} \bullet N_{(T)})}{10^6} \qquad \text{(Eqn 10)}$$

Where:

$CH_{4Manure}$ = CH_4 emissions from manure management, for a defined population, kg CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}

$N_{(T)}$ = the number of head of livestock species/category *T* in the country

T = species/category of livestock

Experimental treatments

The experimental treatments (tree species, tree age, spacing) and number of replicates employed in the study.

Experiment No. 1 (7 year-old trees, 2 replicates per treatment)	**Experiment No. 2 (1 year-old trees, 3 replicates per treatment)**
Control for *G. arborea*, pure maize (*Z. mays*) 1 x 3 m (*G. arborea* + *Z. mays*) 1 x 9 m (*G. arborea* + *Z. mays*) Control for *E. deplupta*, pure maize (*Z. mays*) 1 x 3 m (*E. deglupta* + *Z. mays*) 1 x 9 m (*E. deglupta* + *Z. mays*)	Control, pure maize (*Z. mays*) 1 x 3 m (*G. arborea* + *Z. mays*) 1 x 9 m (*G. arborea* + *Z. mays*) 1 x 3 m (*E. deglupta* + *Z. mays*) 1 x 9 m (*E. deglupta* + *Z. mays*)



Management practices

- Planting: 1 seed per hill (Pioneer Hybrid 3014) at 60cm between furrows and 25-30cm between rows

- Fertilizer application:

Type of fertilizer	Application rate (kg ha^{-1})	Time of application
1. Solophos (0-18-0)	166.67	Before seed sowing
2. Urea (46-0-0)	195.65	30 DAE

- Other practices:
  - Inter-row cultivation at 30 and 60 DAE
  - Hand weeding

Litterfall

- Set-up: Four (4) litter traps were randomly positioned under the trees per plot.
- Litterfall collection: monthly

Harvesting and biomass determination of maize

- Harvesting: 105-110 days after planting
- Plant Biomass: destructive sampling of 16 sample plants per plot. Root, stalk, leaf and cob were segregated.
- Dry weight: One hundred fifty grams (150g) fresh weight of the sub-sample for each component was taken for oven drying at 70˚ C for 48 hours.

Leaf litter decomposition

- Set-up: A total of eight (8) net bags (12 x 12 in) containing 50g leaf samples were randomly placed inside each plot.
- Collection: Two bags per plot were collected every 21 days. Collected samples were weighed for fresh weight and oven-dried.
- Decomposition rate: percent loss in weight

Livestock survey in Claveria

- Sampling technique: stratified random sampling
- Respondents: 300 farmers were randomly selected for the household interview
- Basis: elevation and agroforestry system classes
- Survey instrument: composed of set of questions related to livestock holdings and feed requirements

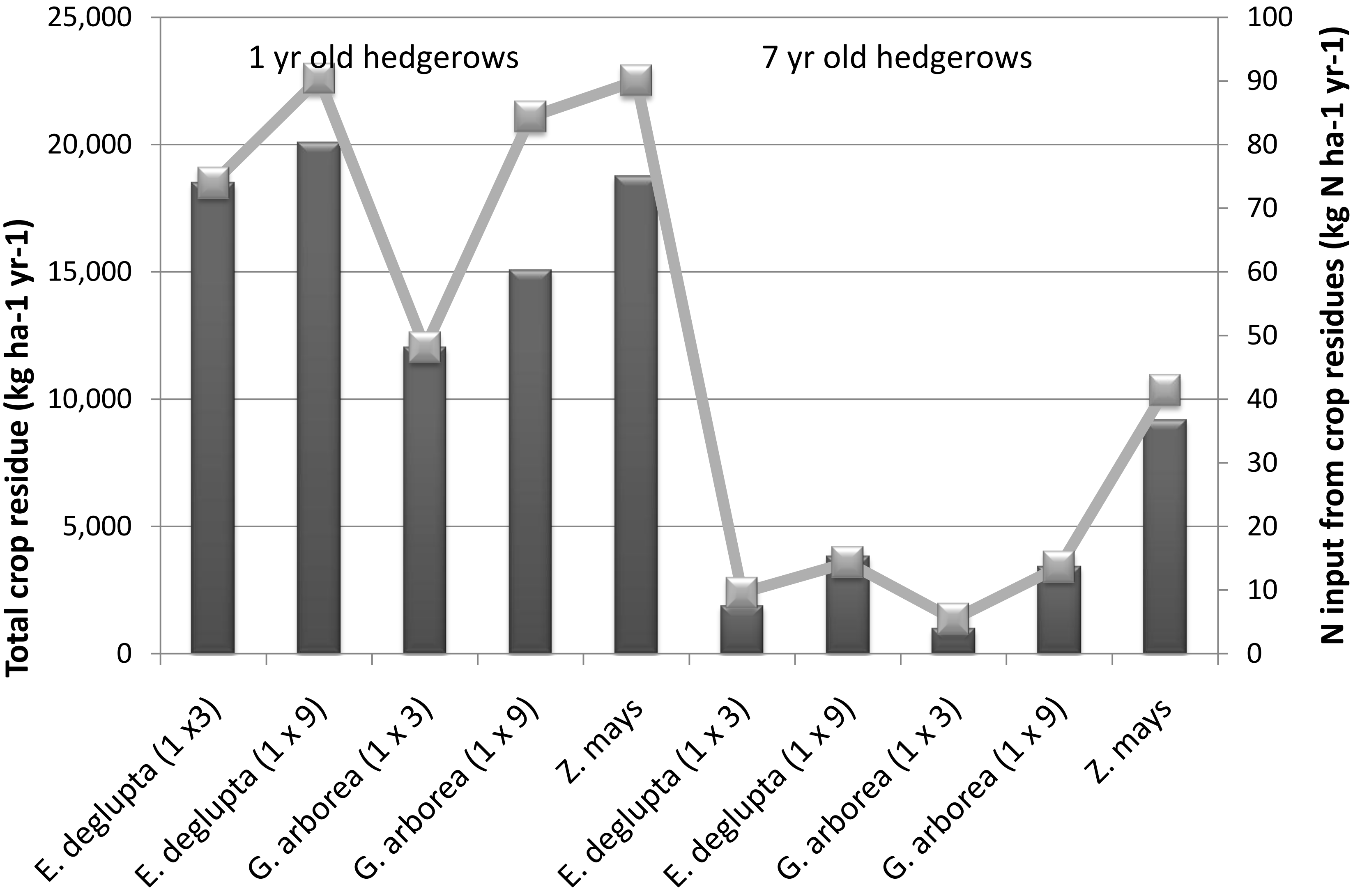


Results

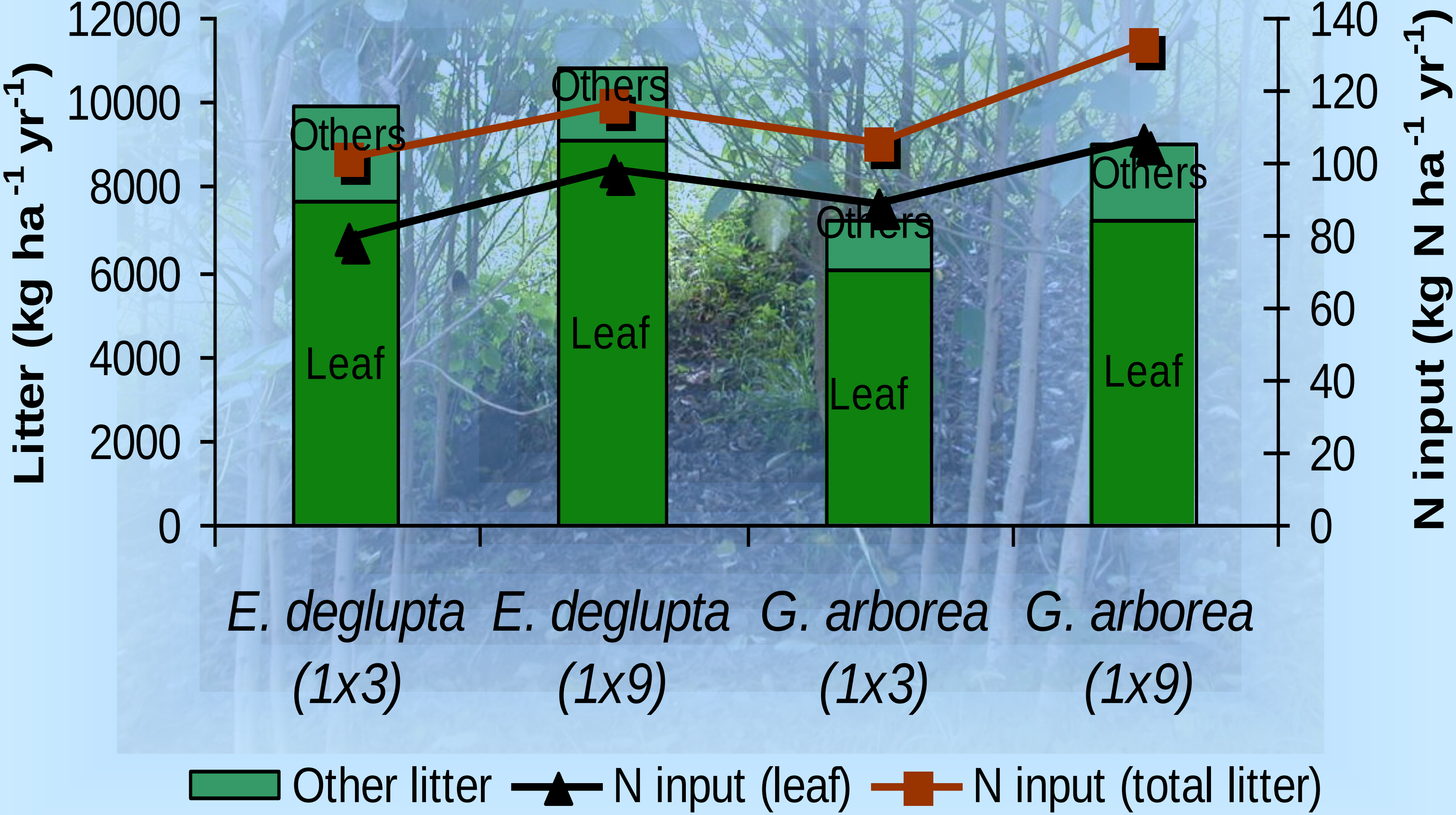
Direct nitrous oxide emissions from fertilizer nitrogen applied in the different plots

Tree Species	Tree Age (yrs)	Tree spacing (m x m)	Plot size (ha)	N applied (kg N ha^{-1} yr^{-1})	1-$Frac_{GASF}$	F_{SN} (kg N ha^{-1} yr^{-1})
E. deglupta	1	1 x 3	0.018	221	0.9	199
E. deglupta	1	1 x 9	0.018	345	0.9	311
G. arborea	1	1 x 3	0.018	221	0.9	199
G. arborea	1	1 x 9	0.018	345	0.9	311
Z. mays			0.018	201	0.9	181
E. deglupta	7	1 x 3	0.032	221	0.9	199
E. deglupta	7	1 x 9	0.032	345	0.9	311
G. arborea	7	1 x 3	0.032	221	0.9	311
G. arborea	7	1 x 9	0.032	345	0.9	199
Z. mays			0.032	201	0.9	181

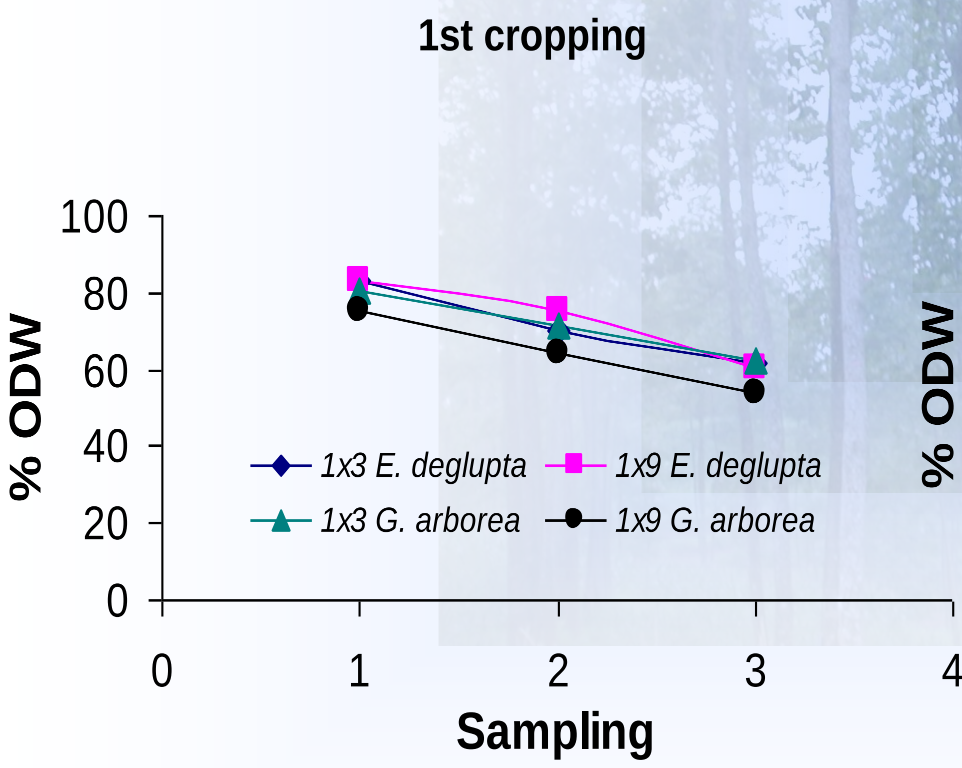
Crop residue and N input

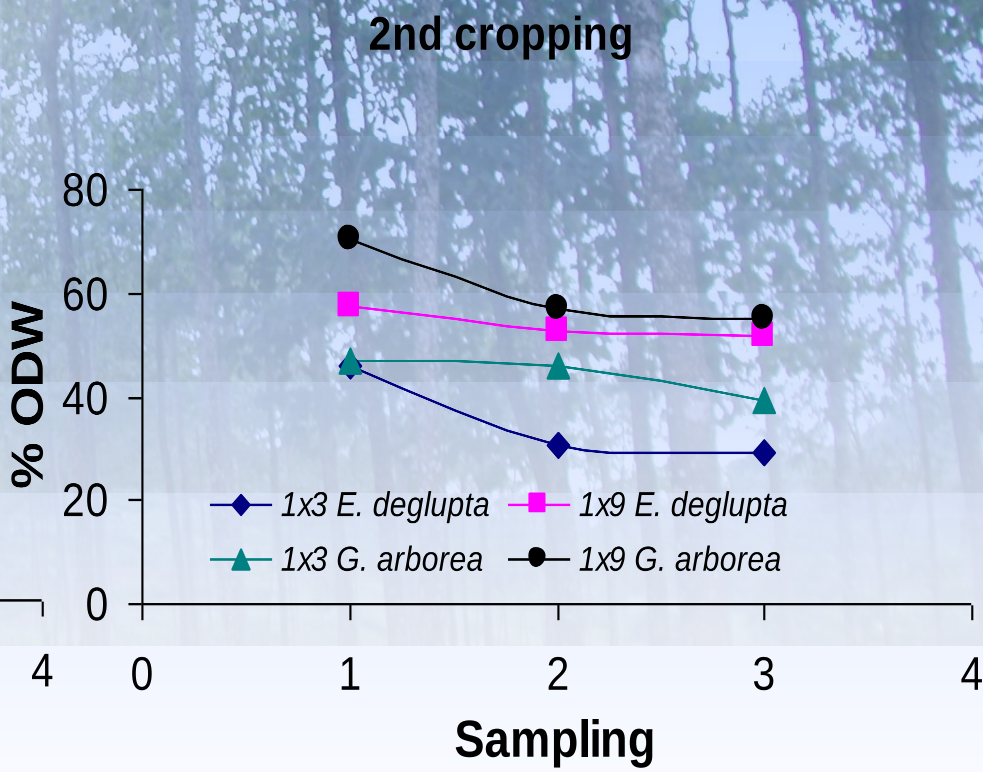


Leaf and total (leaf, twigs, branches) litter from 7-year old E. deglupta and G. arborea



Decomposition of 7 year-old E. deglupta and G. arborea leaf litter





Annual direct nitrous oxide emissions from N inputs to hedgerows systems.

Tree species	Tree spacing (m x m)	F_{SN} (kg N ha-1 yr-1)	F_{CR} (kg N ha-1 yr-1)	F_{LI} (kg N ha-1 yr-1)	EF_1 (kg N_2O-N (kg N input)-1	$N_2O-N_{N\ inputs}$ (kg N_2O ha-1 yr-1)
1 year old						
E. deglupta	1x3	199	74.0		0.01	2.08
E. deglupta	1x9	311	90.4		0.01	3.25
G. arborea	1x3	199	48.1		0.01	2.04
G. arborea	1x9	311	84.4		0.01	3.25
Z. mays		181	90.0		0.01	2.22
7 years old						
E. deglupta	1x3	199	9.5	88.7	0.01	3.62
E. deglupta	1x9	311	14.3	106.3	0.01	5.08
G. arborea	1x3	199	5.4	78.7	0.01	3.26
G. arborea	1x9	311	13.7	97.4	0.01	4.93
Z. mays		181	41.4		0.01	2.71

Indirect nitrous oxide emissions from volatilization.

Tree Species	Tree spacing (m x m)	F_{SN} (kg N ha^{-1} yr^{-1})	Frac GASF	F_{PRP} (kg N ha^{-1} yr^{-1})	Frac GASM	EF_4 (kg N_2O-N kg N^{-1})	$N_2O_{(ADT)}$ – N (kg N_2O-N yr^{-1})	$N_2O_{(ADT)}$ (kg N_2O-N yr^{-1})
1 year old								
E. deglupta	1x3	199	0.1	21.71	0.2	0.01	0.24	0.37
E. deglupta	1x9	311	0.1	21.71	0.2	0.01	0..35	0.54
G. arborea	1x3	199	0.1	21.71	0.2	0.01	0.24	0.37
G. arborea	1x9	311	0.1	21.71	0.2	0.01	0.35	0.54
Z. mays		181	0.1	21.71	0.2	0.01	0.22	0.34
7 years old								
E. deglupta	1x3	199	0.1	21.71	0.2	0.01	0.24	0.37
E. deglupta	1x9	311	0.1	21.71	0.2	0.01	0.35	0.54
G. arborea	1x3	199	0.1	21.71	0.2	0.01	0.24	0.37
G. arborea	1x9	311	0.1	21.71	0.2	0.01	0.35	0.54
Z. mays		181	0.1	21.71	0.2	0.01	0.22	0.34

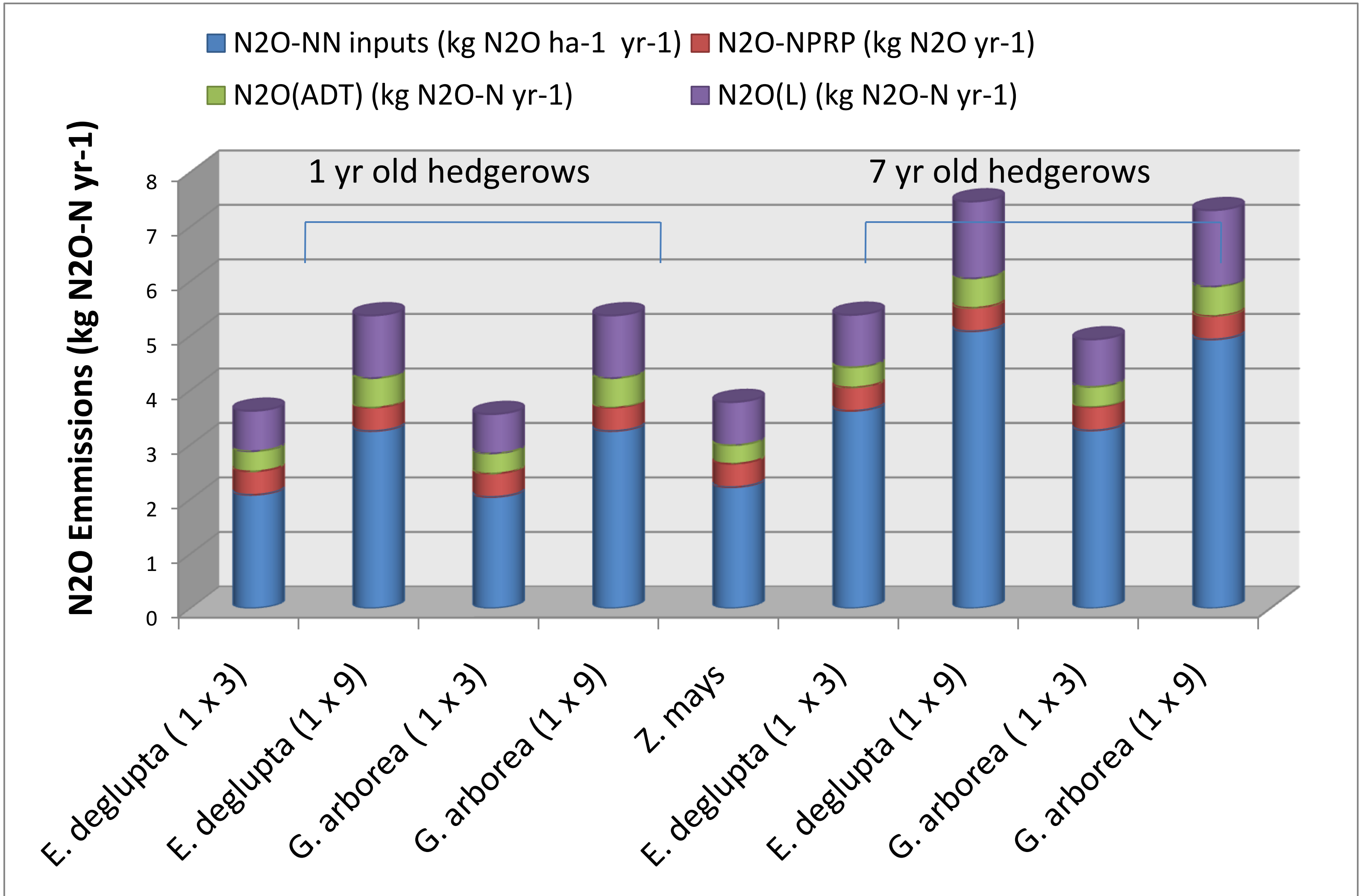
Indirect nitrous oxide emission from leaching.

Tree Species	**Tree spacing (m x m)**	**F_{SN} (kg N ha^{-1} yr^{-1})**	**F_{CR}**	**$FRAC_{LEACH-(H)}$ (kg N (kg N additions)$^{-1}$)**	**EF_5 (kg N_2O-N (kg N leached and runoff)$^{-1}$**	**$N_2O_{(L)}$-N emissions from leaching (kg N_2O-N yr^{-1})**	**$N_2O_{(L)}$ emissions from leaching (kg N_2O-N yr^{-1})**
1 year old							
E. deglupta	1x3	199	9.5	0.3	0.0075	0.469	0.74
E. deglupta	1x9	311	14.3	0.3	0.0075	0.732	1.15
G. arborea	1x3	199	5.4	0.3	0.0075	0.460	0.72
G. arborea	1x9	311	13.7	0.3	0.0075	0.731	1.15
Z. mays		181	41.4	0.3	0.0075	0.500	0.79
7 yrs old							
E. deglupta	1x9	199	74.0	0.3	0.0075	0.614	0.96
E. deglupta	1x3	311	90.4	0.3	0.0075	0.903	1.41
G. arborea	1x9	199	48.1	0.3	0.0075	0.556	0.87
G. arborea	1x3	311	84.4	0.3	0.0075	0.890	1.40
Z. mays		181	90.0	0.3	0.0075	0.609	0.96

Annual direct nitrous oxide emissions from urine and dung inputs to grazed soils (F_{PRP}).

Livestock Type	Number of animals	Nex (T) (kg N animal^{-1} yr^{-1})	Total Nex (T) (kg N yr^{-1}))	EF_3 Kg N_2O-N (kg N input$)^{-1}$	MS ($_{T,PRP}$)	N_2O-N_{PRP} (kg N_2O yr^{-1})
Non-dairy cattle	258	12.3	3,173.4	0.02	1	63.46
Carabao	62	14.2	880.4	0.02	1	17.60
Goat	46	0.6	27.6	0.01	1	0.27
Swine	398	5.8	2,308.4	0.02	1	46.16
Poultry	1,252	0.1	125.2	0.02	1	2.50
Total			6515			129.99

Direct and indirect soil N_2O emissions in *E. deglupta* and *G. arborea* hedgerows



Total methane (CH_4) emissions from enteric fermentation and manure management per animal type

Animal Type	Enteric fermentation (kg CH_4 yr^{-1})	Manure management (kg CH_4 yr^{-1})	Total methane emissions (kg CH_4 yr^{-1})
Non-dairy cattle	12,126	516	12, 642
Carabao	3,410	186	3,596
Goat	230	10	240.1
Swine	398	2,786	3,184
Poultry	-	25	25
Total	16,,164	3,523	19,687

Conclusions

- N_2O emissions from tree-based hedgerow systems vary with tree species, spacing between hedgerows and fertilizer management.
- In the tree-based hedgerow systems studied, inorganic fertilizer applied, maize crop residue incorporation, and leaf litter fall were the major sources of direct N_2O emissions from the soil.

Conclusions

- Under 7-year-old hedgerow systems, maize crop growth and biomass were greater under *E. deglupta* hedgerows than under *G. arborea* hedgerows.

- This implies that there is greater competition for above-ground and below-ground resources between *G. arborea* trees and maize crops.

Conclusions

• The quantity and quality of tree leaf litter fall from the hedgerow species is also a major factor affecting N_2O emissions.

•*E. deglupta* had higher leaf litter fall and higher leaf N content.

•Higher N_2O emissions occurred in *E. deglupta* hedgerow system at both tree age classes and hedgerow spacing treatments.

•However, the rate of decomposition in *E. deglupta* leaf litter is slower compared with the leaf litter of *G. arborea*, resulting to lower influx of N_2O emissions attributed to leaf litter decomposition.

Conclusions

- N_2O emissions from these hedgerow systems can be minimized with the proper design of the hedgerow system, proper component tree species and soil fertility management.
- Direct N_2O emissions from fertilizer application can be minimized by applying organic fertilizer instead of inorganic fertilizer since organic fertilizers bind nitrogen and release them slowly.

Conclusion

- Aboveground and below ground canopy architecture of the tree component is also a very important consideration in the choice of hedgerow tree species to minimize competition between the tree species and the alley crops.

Conclusion

- Enteric fermentation is the major source of methane emissions from domestic livestock in Claveria.
- Non-dairy cattle were the main contributor of CH_4 emissions from enteric fermentation.
- Manure management is another source of CH_4 emissions, and swine manure contributed largely to CH_4 emissions in Claveria.
- Methane from swine manure can be harnessed and utilized as biofuel.

Conclusion

- N_2O emissions from the study site is comparable to reported emissions from improved agroforestry systems and mixed fallow system in tropical areas in Kenya and Peruvian Amazon.
- On the other hand, methane emissions from enteric fermentation of dairy cattle in the study area is low compared to dairy cattle in developed countries.

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END OF PRESENTATION