International Workshop On Land Cover/Land Use Changes, Forestry, and Agriculture in South/Southeast Asia

Greenhouse Gases Fluxes Across Land-Use Change Gradient in Sabah, Malaysia

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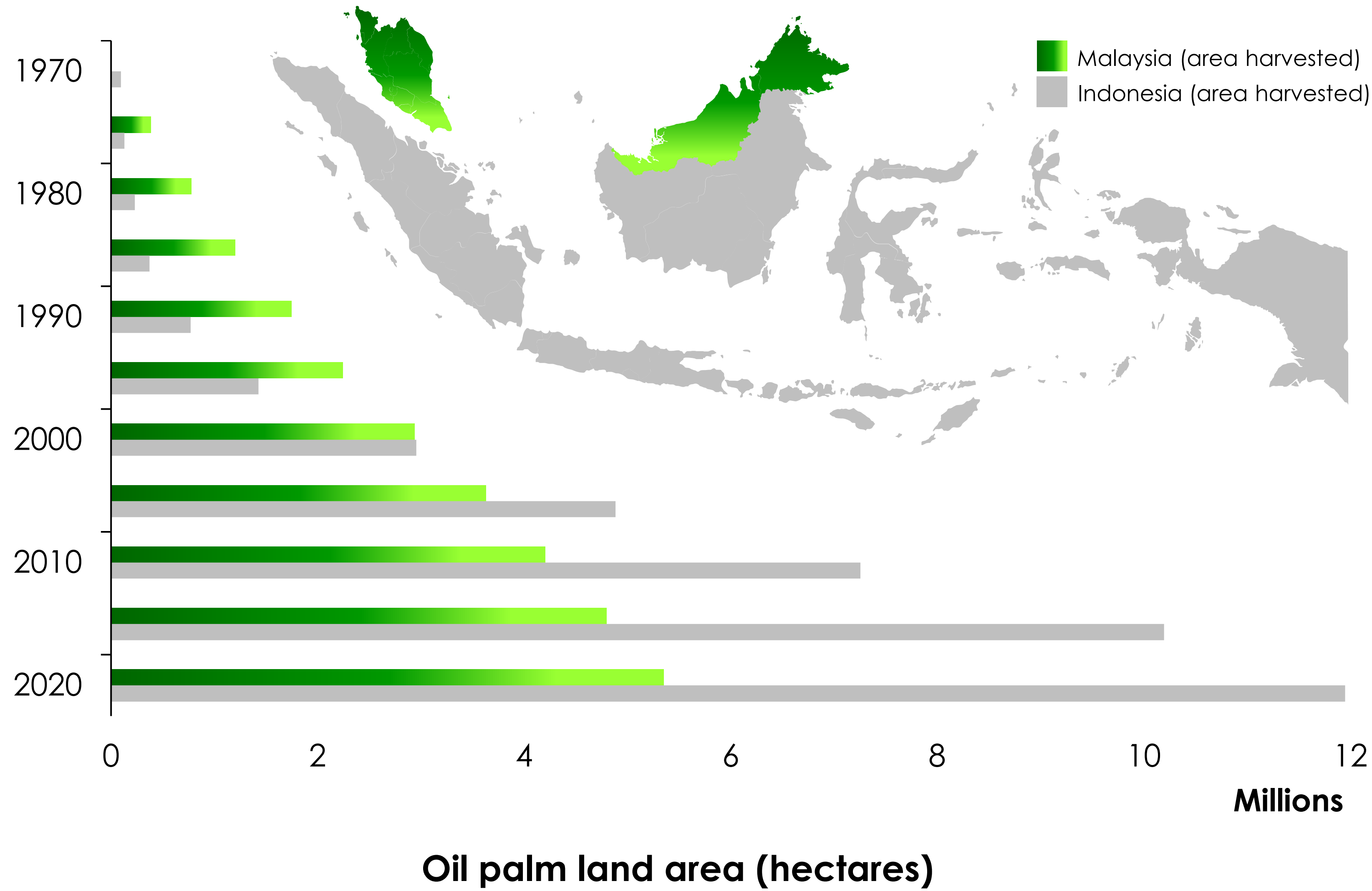
Phnom Phenh, Cambodia, 08-10 August 2022


Kalabakan,
Tawau

Oil palm land area in Malaysia and Indonesia



(Source: USDA, 2020)

What we will know?

Influence of land use changes on GHGs fluxes

- Soil: Carbon and Nitrogen dynamics across land-use gradient

Influence of soil physico-chemical properties on GHGs fluxes

- Physico-chemical: soil moisture conditions, etc

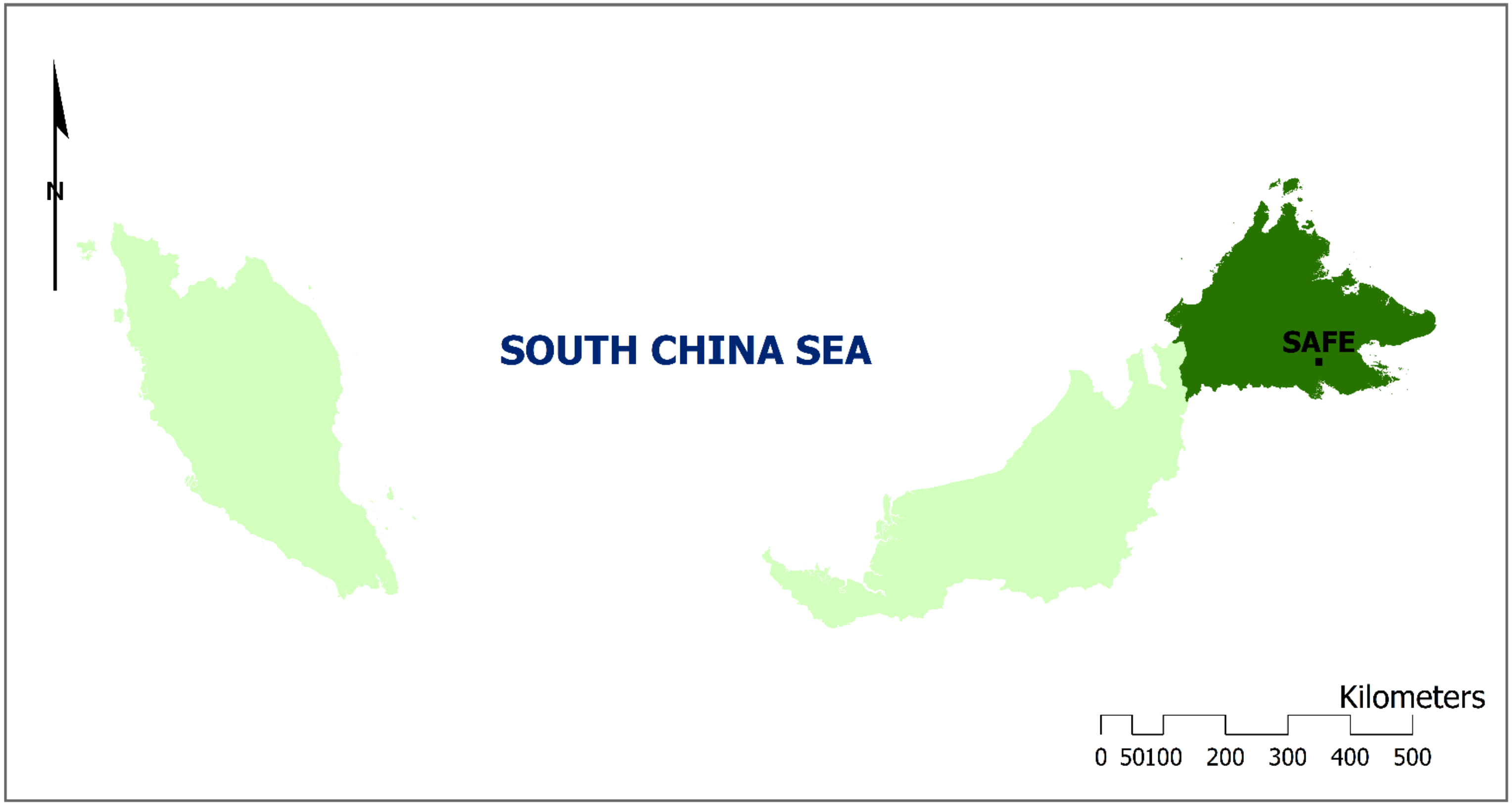
Influence of land use changes on GHG emissions

Year	Title	Authors
2005	The variation of greenhouse gas emissions from soils of various land-use/cover types in Jambi province, Indonesia	Ishizuka *et al.*
2016	Key unknowns in nitrogen budget for oil palm plantations. A review	Pardon *et al.*
2017	Soil nitrogen oxide fluxes from lowland forests converted to smallholder rubber and oil palm plantations in Sumatra, Indonesia	Hassler *et al.*
2017	Impact of Land-use Change on Vertical Soil Bacterial Communities in Sabah	Tin *et al.*
2020	Deforestation for oil palm: impact on microbially mediated methane and nitrous oxide emissions, and soil bacterial communities	Kaupper *et al.*

- Soil N_2O emission rates were varied – but relatively larger in Oil Palm than Forests (Primary & Logged-over Forest)
- Management practices have a significant influence on GHG fluxes

STUDY AREA:
NORTH BORNEO (SABAH), EAST MALAYSIA

Map of SAFE Project Research area in Malaysia



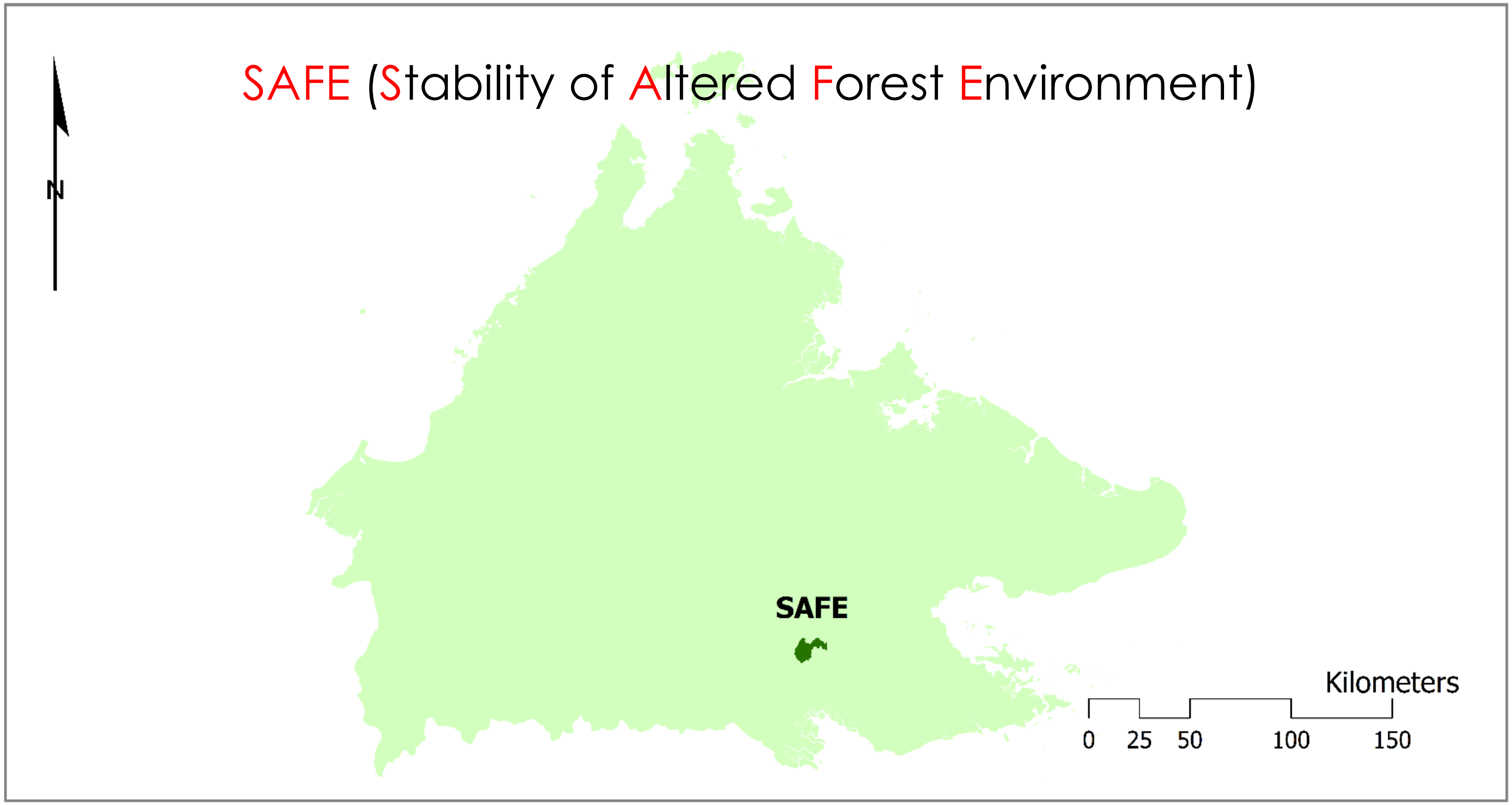
Legend

▪ SAFE Project area

Sabah, North Borneo

STUDY AREA:
NORTH BORNEO (SABAH), EAST MALAYSIA

Map of SAFE Project Research area in Sabah



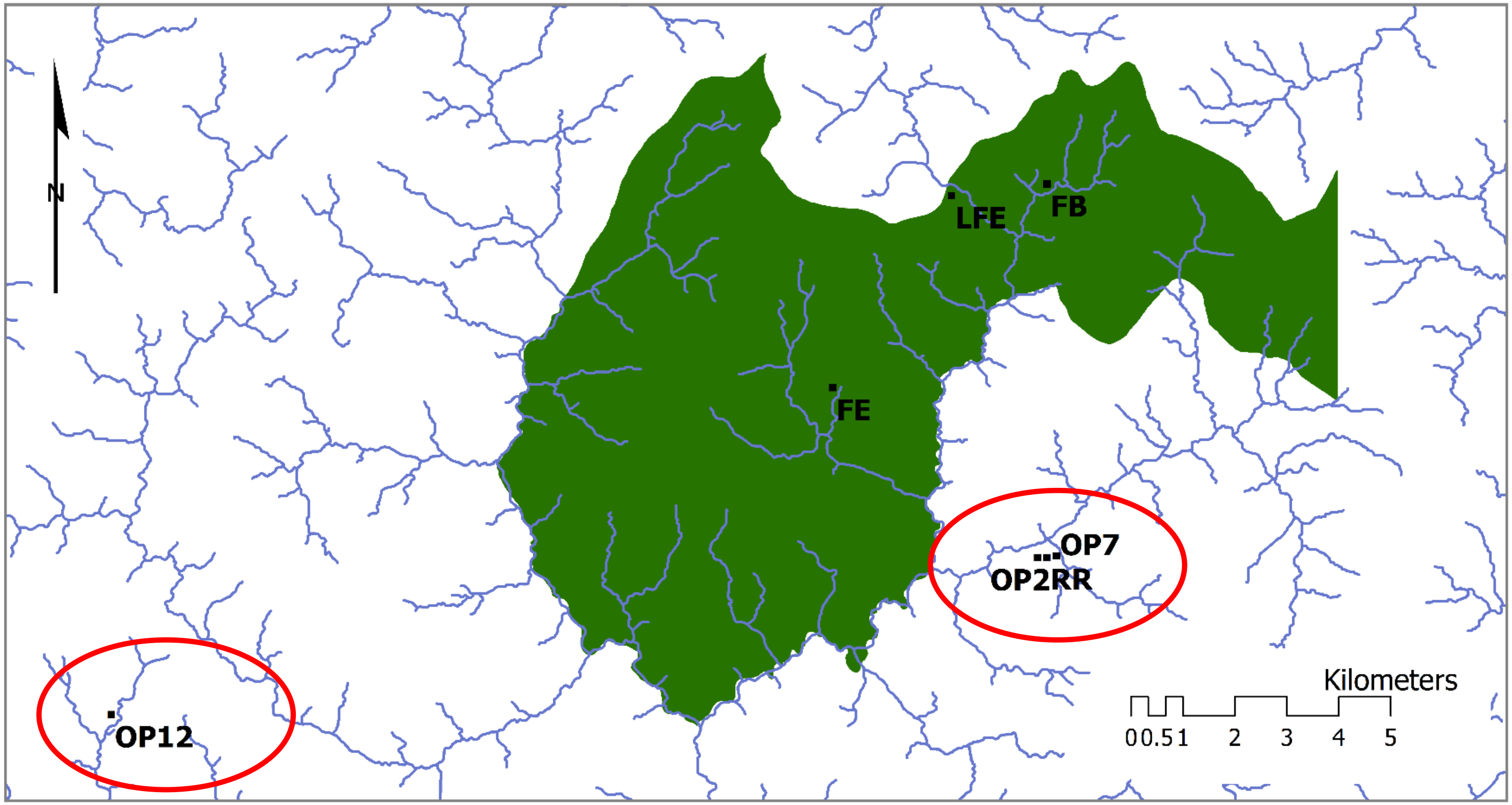
Legend

SAFE Project area

Sabah, North Borneo

STUDY AREA:
SAFE PROJECT RESEARCH SITE

Map of sampling sites in SAFE Project Research area



Legend

- Sampling site
- River
- SAFE Project area

STUDY SITE: FOREST SITES

Logged forest edge (LFE)

Fragmented forest B (FFB)

Fragmented forest E (FFE)

STUDY SITE: OIL PALM PLANTATION

2 years oil palm (OP2)

7 years oil palm (OP7)

12 years oil palm (OP12)

Riparian reserve (RR)

FIELD MEASUREMENTS
(Parameters and sampling frequency)

Soil greenhouse gas	Sampling frequency
N_2O	Bi-monthly
CH_4	Bi-monthly
CO_2	Bi-monthly
Soil volatile organic compounds	Bi-monthly
Environmental variable	
Soil moisture content	Bi-monthly
Soil temperature	Bi-monthly
Ambient temperature	Bi-monthly
Soil NO_3-N	Bi-monthly
Soil NH_4-N	Bi-monthly
Rainfall	Monthly
Soil pH	Initial and final sampling
Soil bulk density	Final sampling
Soil total carbon and total nitrogen	Final sampling
Leaf litter total carbon and total nitrogen	Final sampling
Soil texture	Final sampling
Soil colour	Final sampling

Influence of land use changes on GHGs fluxes

A.

Auxiliary physical and chemical soil measurements

(i) Soil moisture content*
(ii) Soil and air temperature
(iii) Soil nitrate and ammonium
(iv) Soil pH
(v) Soil bulk density
(vi) Soil and leaf total carbon and total nitrogen
(vii) Soil texture
(viii) Soil colour
(xi) Rainfall

B.

Soil greenhouse gas

(i) Soil nitrous oxide and methane fluxes
(ii) Soil respiration (CO_2) fluxes

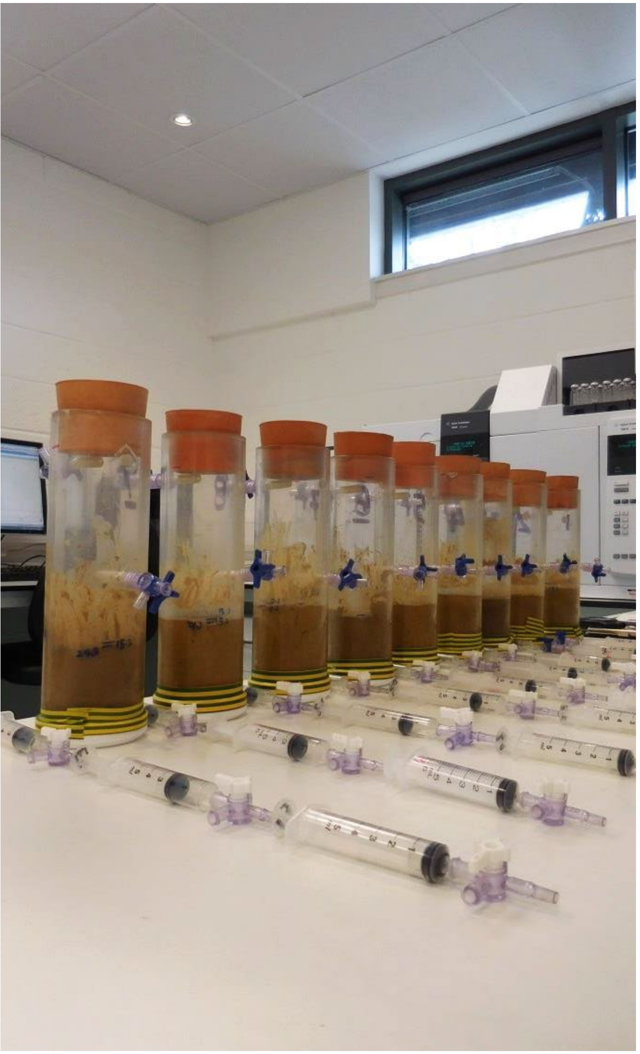
GHGs fluxes measurement

Portable infrared analyser

GHG chamber

Every 2 months for 2 years

- Soil N_2O, CH_4, CO_2 fluxes
- Soil NH_4, NO_3
- Soil moisture, pH, bulk density
- Soil and litter total carbon: total nitrogen
- Soil and air temperature
- Precipitation



Agilent 7694E Headspace sampler

GHG column

Thermo 42C NO-NO_2-NO_x Analyzer

- Soil N_2O, CH_4, CO_2 fluxes
- Soil NH_4, NO_3
- Soil moisture, pH
- Soil total organic carbon

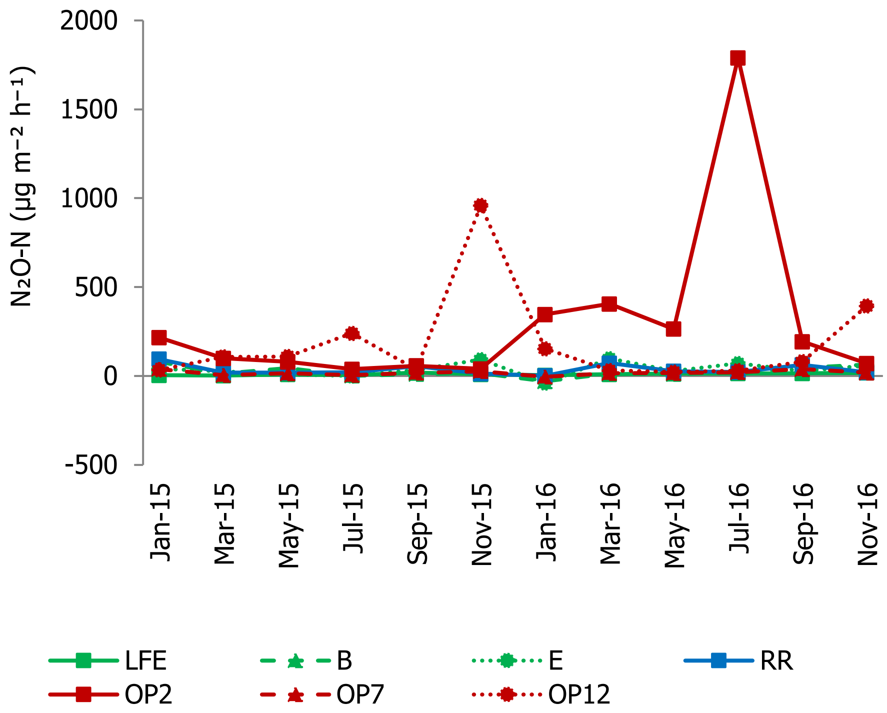
<u>Oil Palm (OP2), Oil Palm (OP7), Riparian (RR1)</u>

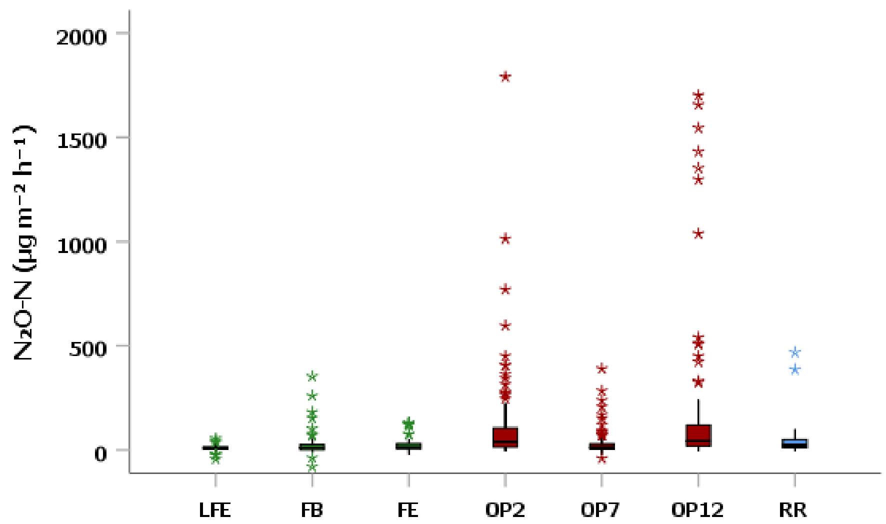
36 days

<u>Logged Forest (FE), Fragmented Forest (FFE), Riparian (RR2)</u>

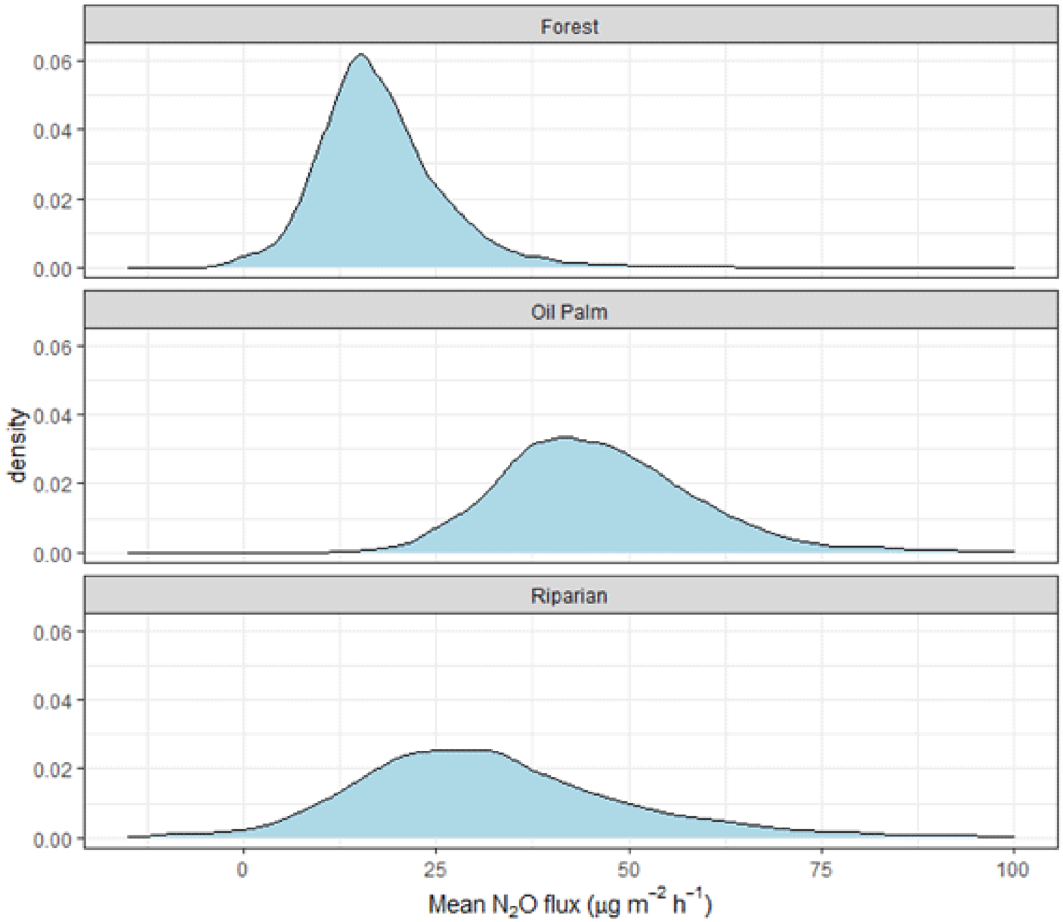
22 days

NITROUS OXIDE (N_2O)
(Spatial & Temporal Variability)



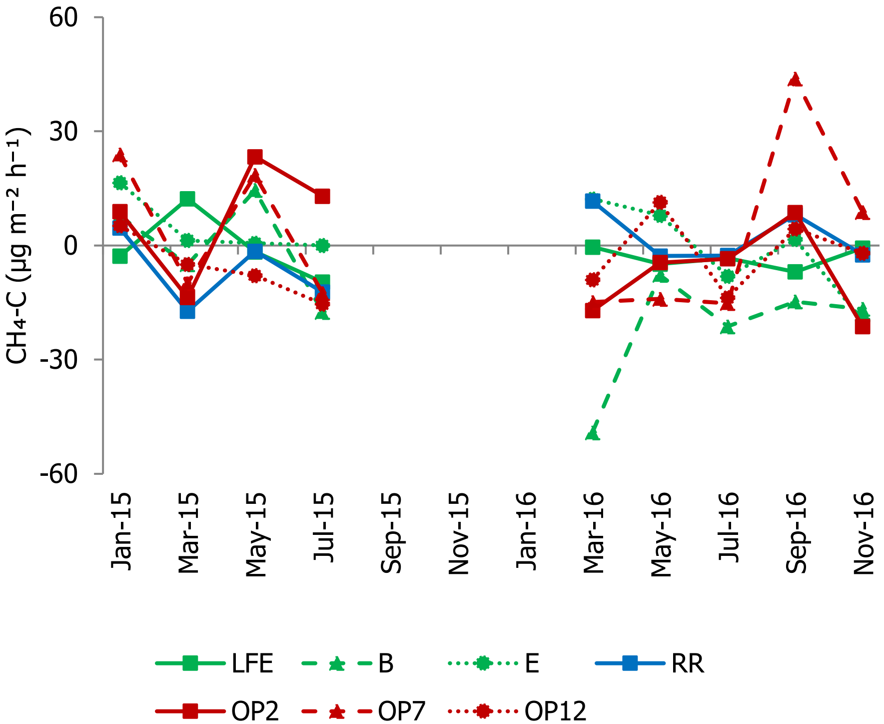


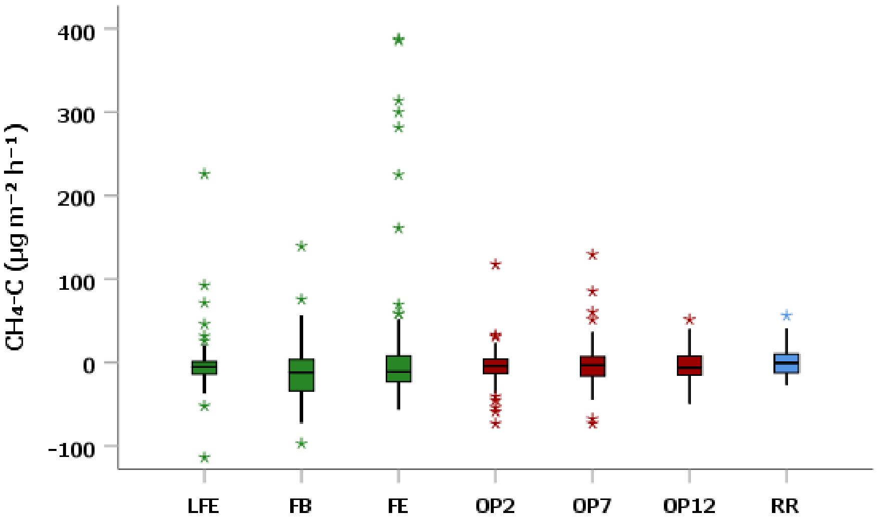
NITROUS OXIDE (N_2O)



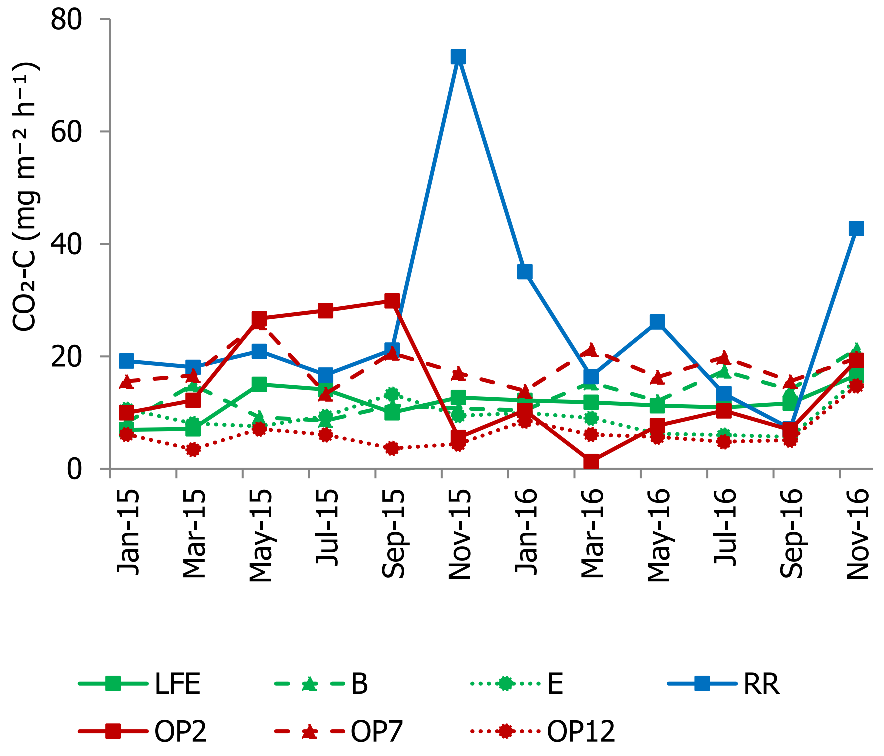
Posterior probability density of the mean nitrous oxide flux from each land use, estimated by the Bayesian GLMM.

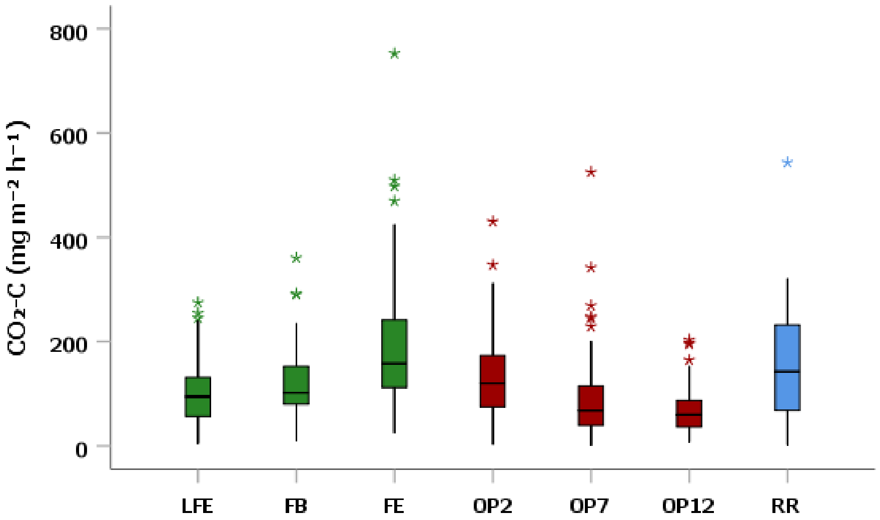
METHANE (CH_4)
(Spatial & Temporal Variability)





CARBON DIOXIDE(CO_2)





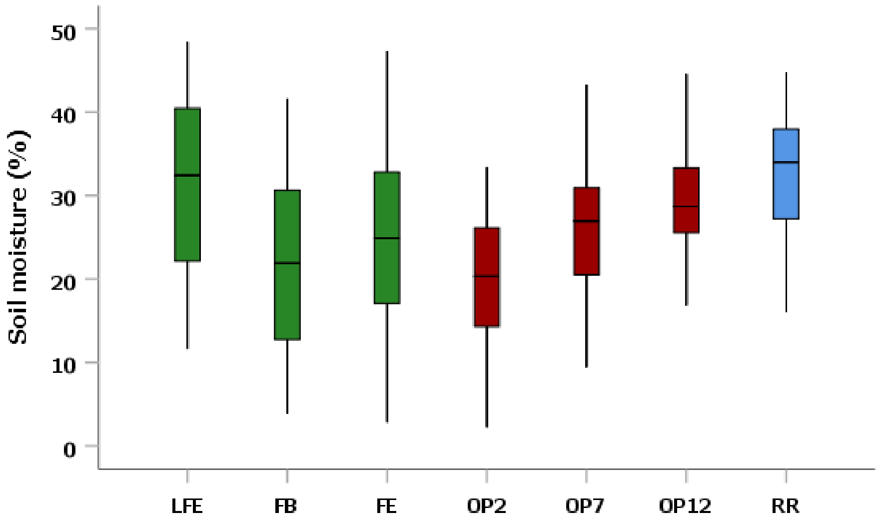
Greenhouse gas, soil respiration, and soil mineral nitrogen

Variable	land use	N	Mean	SD	Median
N_2O-N ($\mu g\ m^{-2}\ h^{-1}$)	Forest	286	13.87	171.49	13.90
	OP	335	46.20	166.35	45.84
	RR	48	31.83	220.40	30.86
CH_4-C ($\mu g\ m^{-2}\ h^{-1}$)	Forest	216	2.20	48.34	-5.63
	OP	251	-2.57	17.18	-3.00
	RR	36	1.27	12.60	-0.38
CO_2-C ($mg\ m^{-2}\ h^{-1}$)	Forest	288	137.39	94.63	115.35
	OP	336	93.30	69.65	75.55
	RR	48	157.70	105.80	142.60
NH_4-N mg g^{-1}	Forest	288	3.92	5.41	2.85
	OP	336	7.99	22.72	2.50
	RR	48	4.50	5.40	2.50
NO_3-N mg g^{-1}	Forest	288	5.30	5.28	3.40
	OP	336	6.32	18.16	1.40
	RR	48	2.25	4.19	1.35

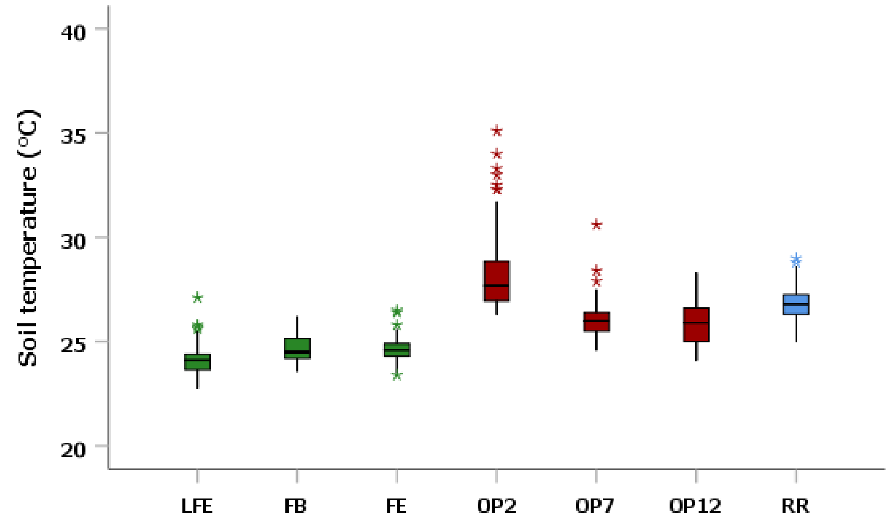
Greenhouse gas fluxes (N_2O-N, CH_4-C, soil respiration CO_2-C) and soil mineral nitrogen (NH_4-N and NO_3-N) averaged over the entire measurement period (Jan 2015 – Nov 2016) by land-use. N = number of individual data points, sd = standard deviation; forest = logged forest, OP = oil palm, RR = riparian reserve.

SOIL MOISTURE CONTENT AND SOIL TEMPERATURE

i. Soil moisture content

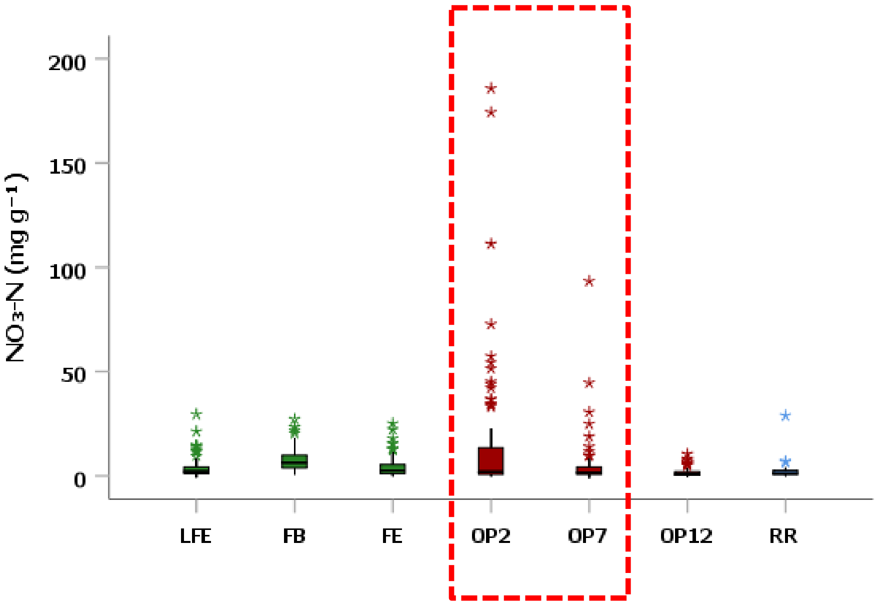


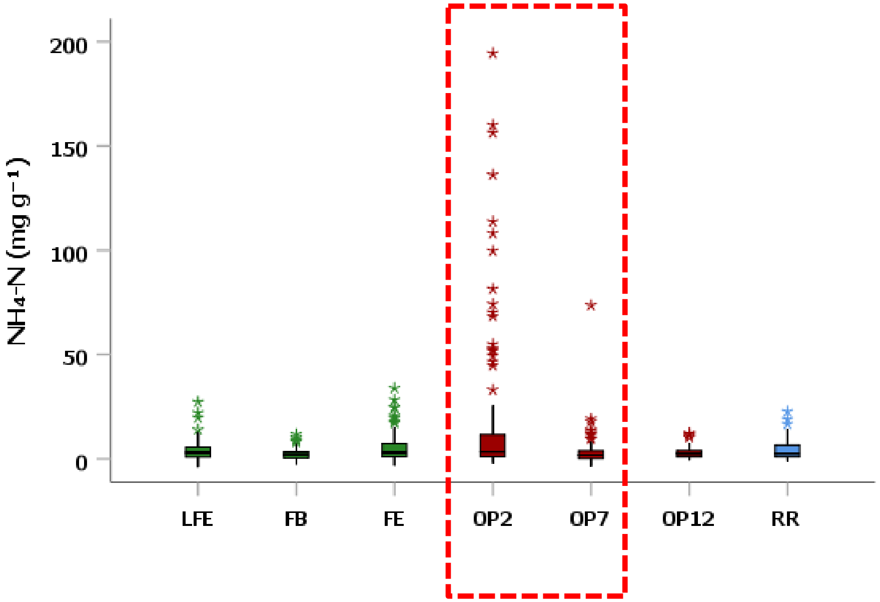
ii. Soil temperature



SOIL NITRATE AND SOIL AMMONIUM

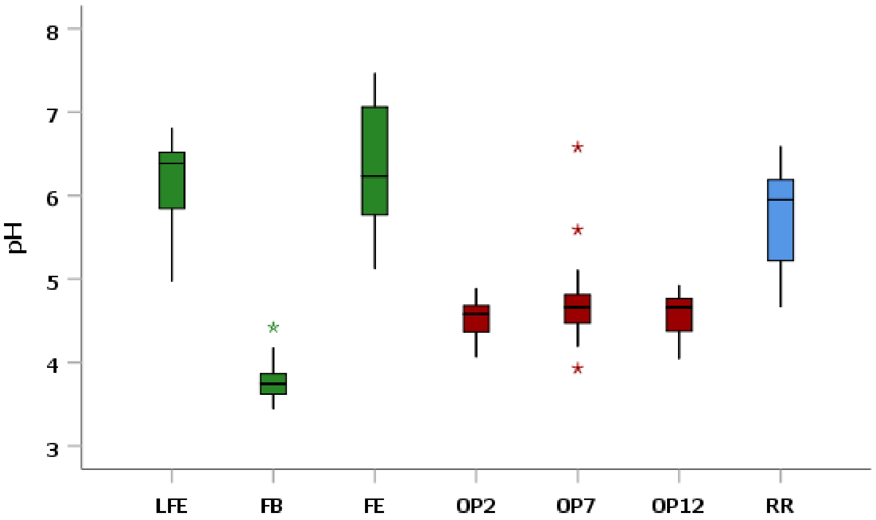
iii. Soil nitrate and ammonium



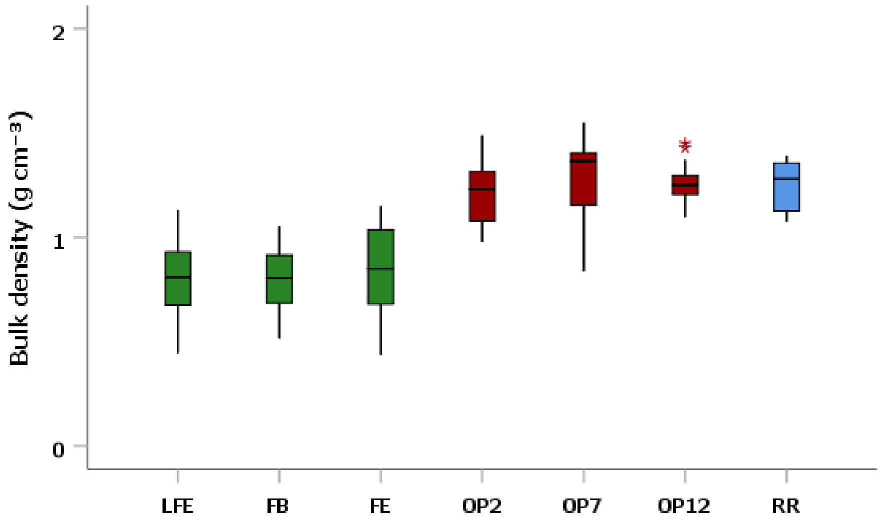


SOIL pH AND SOIL BULK DENSITY

iv. Soil pH

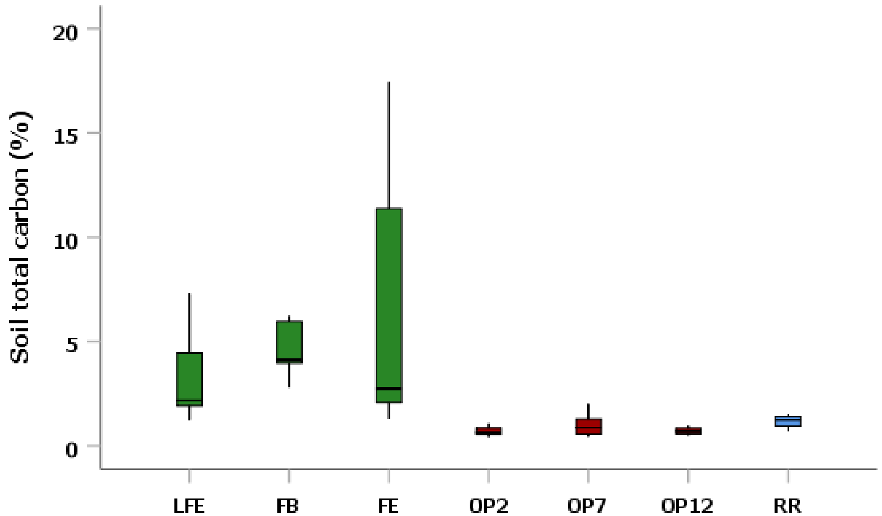


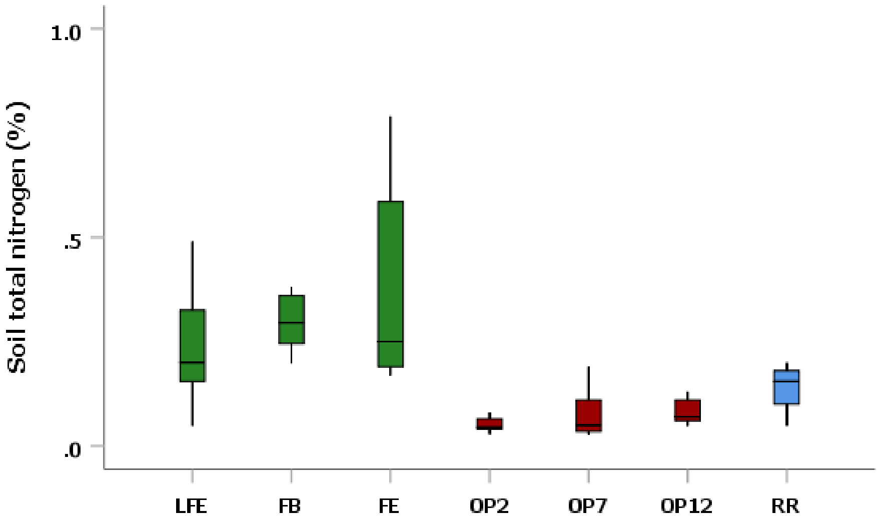
v. Soil bulk density (soil compaction)



SOIL TOTAL CARBON AND SOIL TOTAL NITROGEN

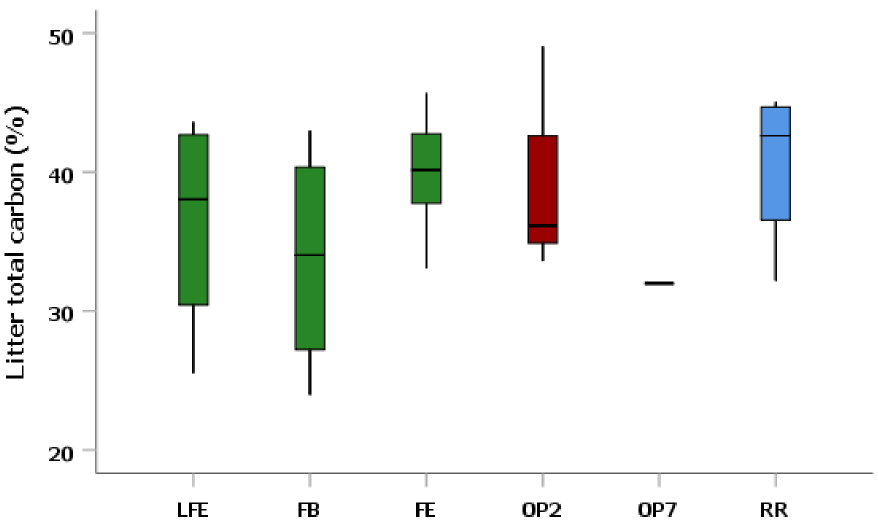
vi. Soil total carbon and total nitrogen

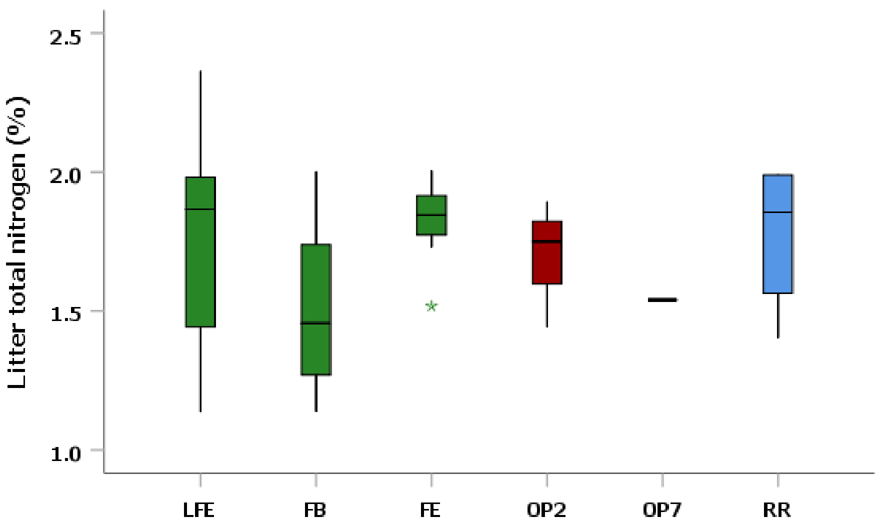




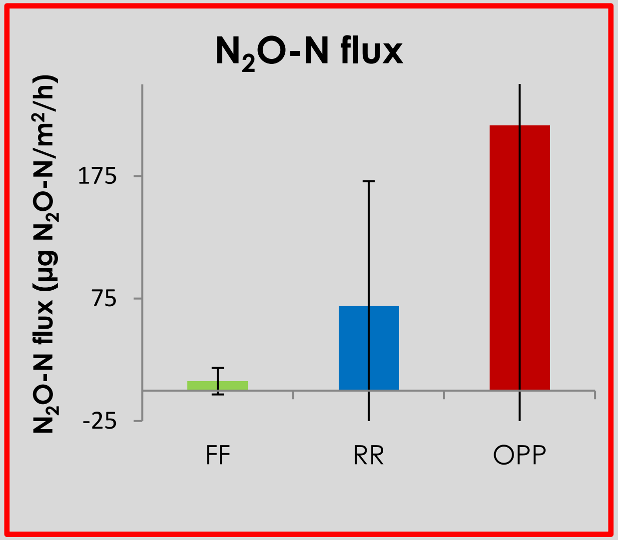
LEAF LITTER TOTAL CARBON AND LEAF TOTAL NITROGEN

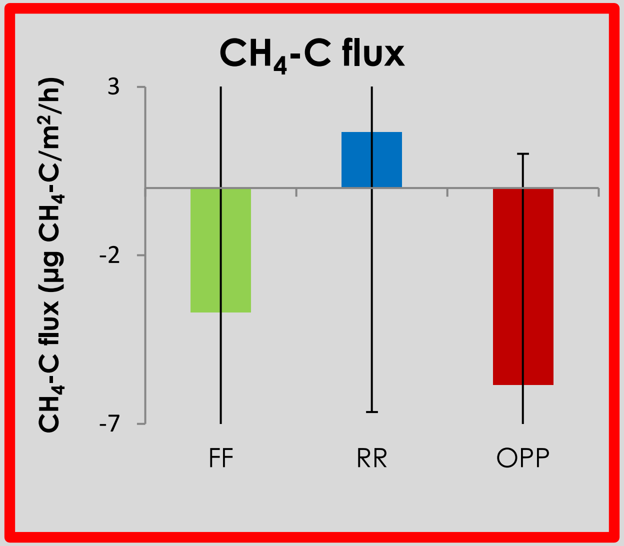
vii. Leaf litter total carbon and total nitrogen

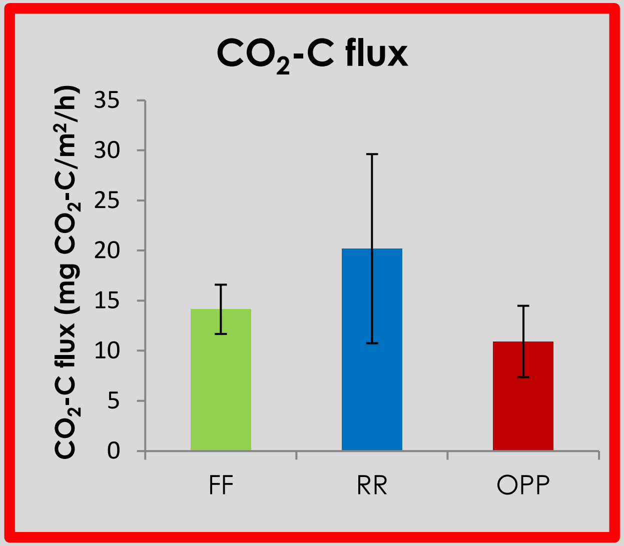


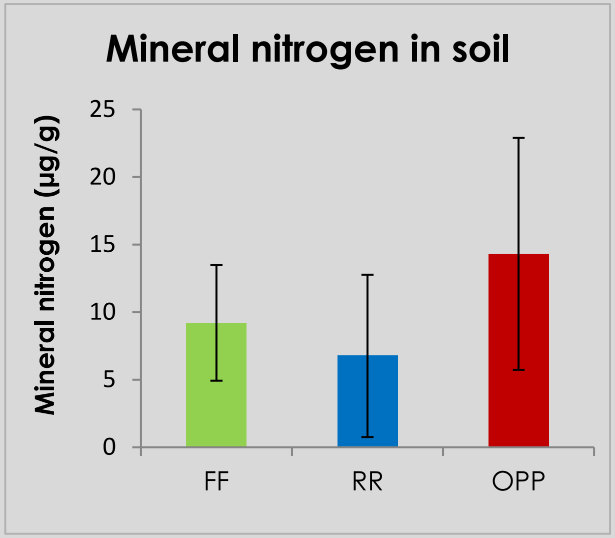


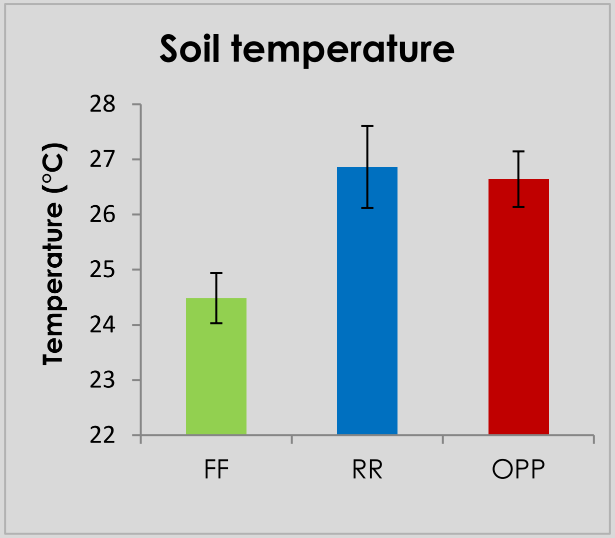
Summary comparison of the different land uses

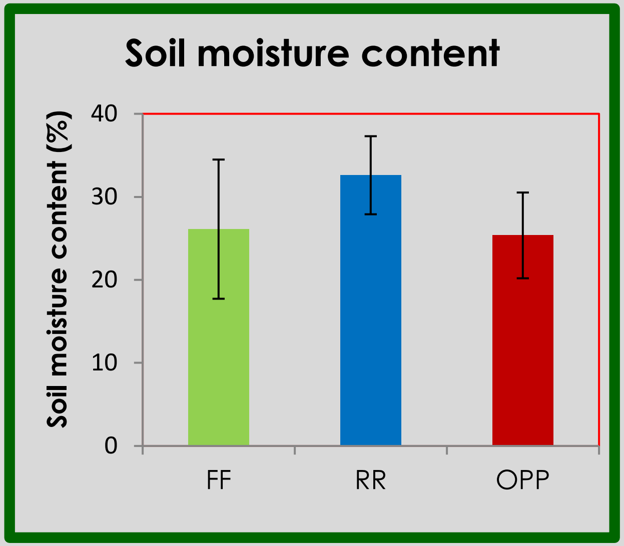




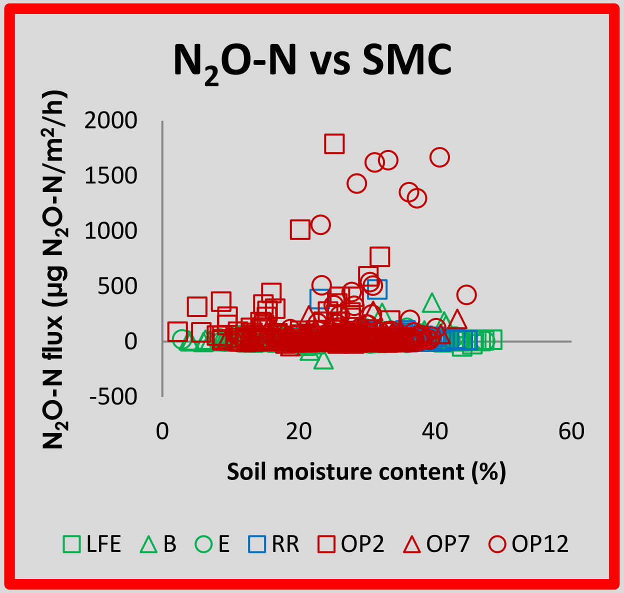


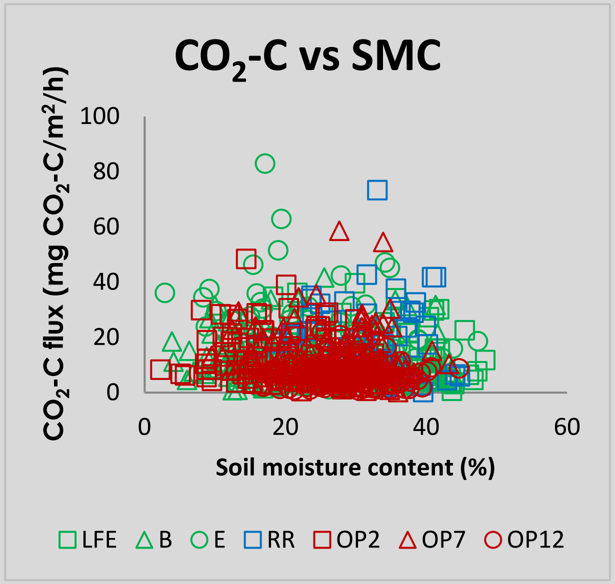


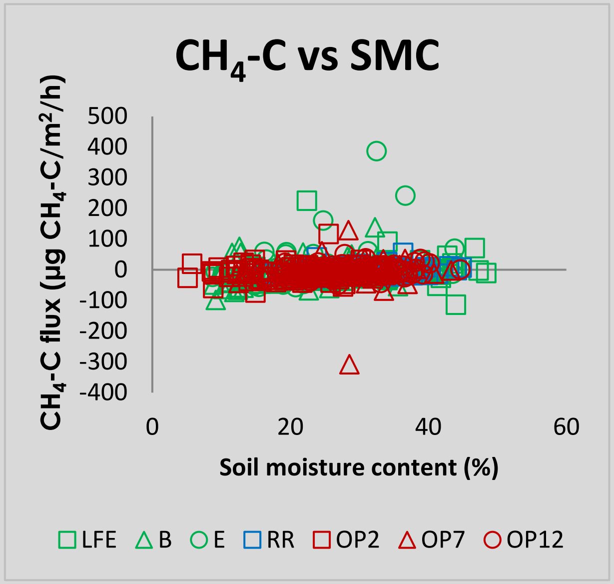




Correlation between GHG fluxes and soil moisture content (SMC)



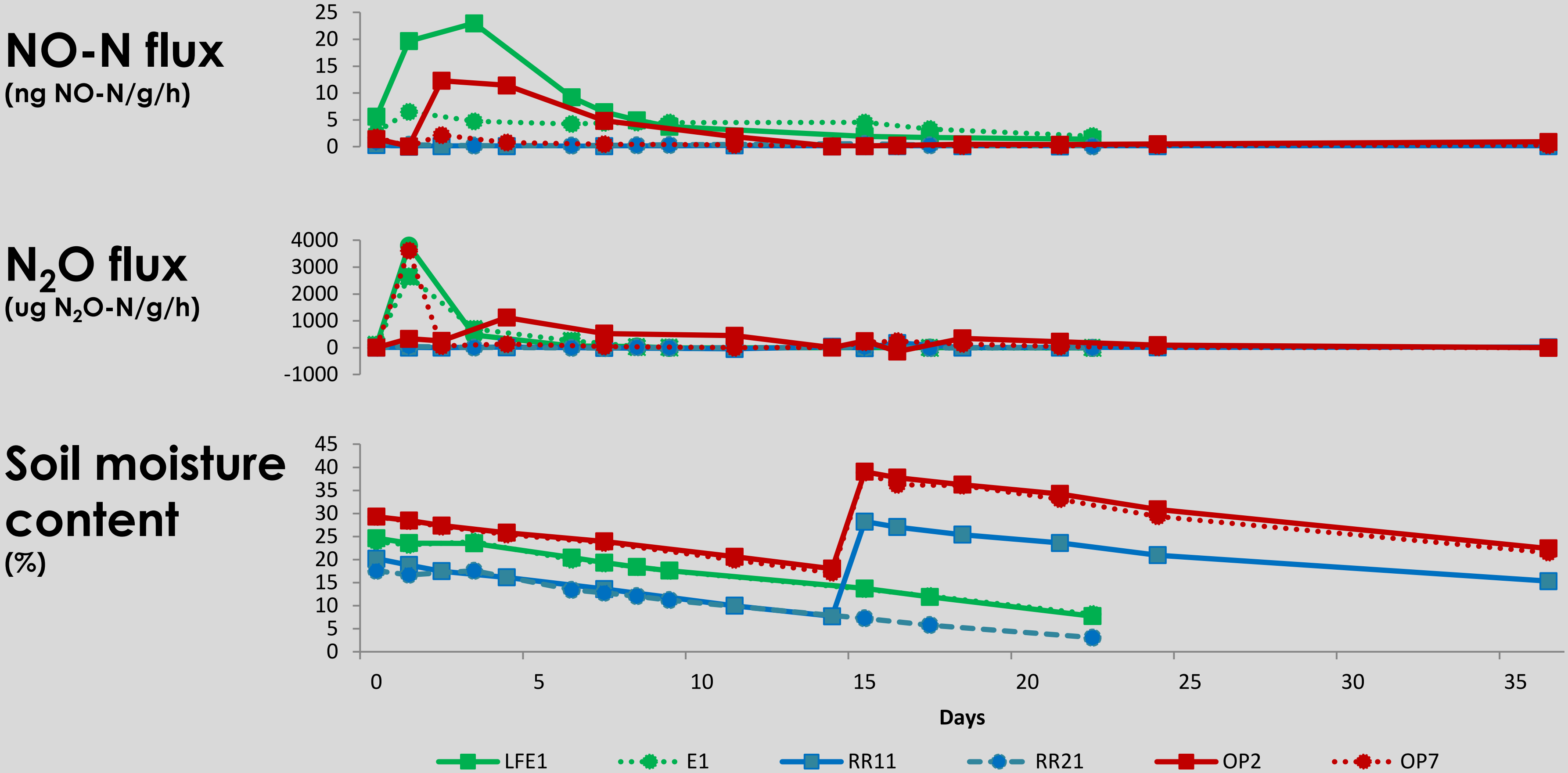




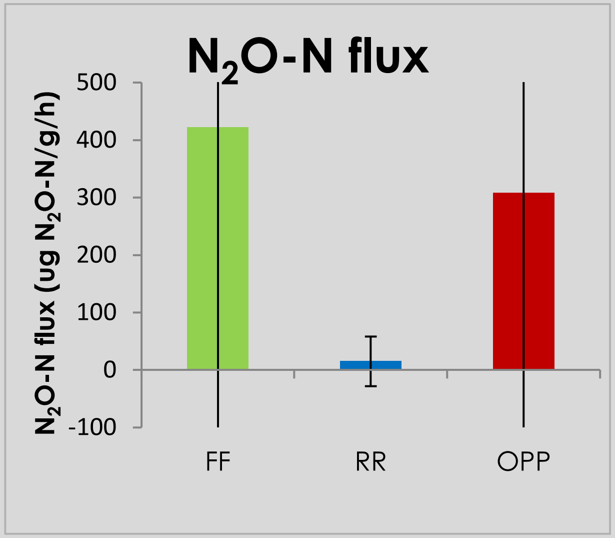
- Soil moisture content range:

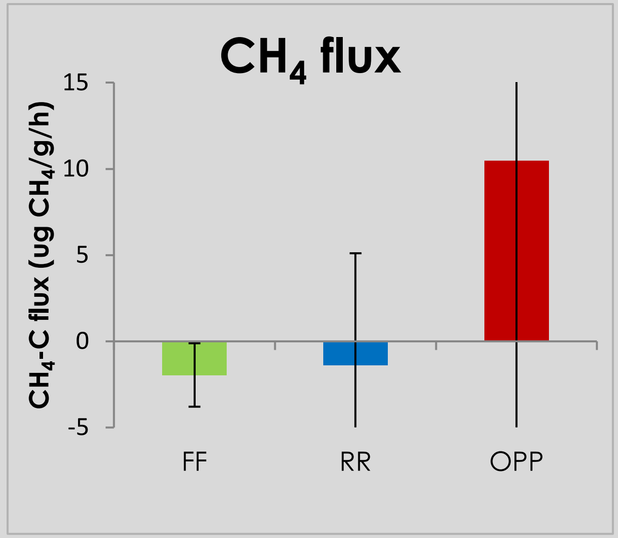
Forest,	3% to 48%
Oil palm,	2% to 45%
Riparian,	16% to 45%

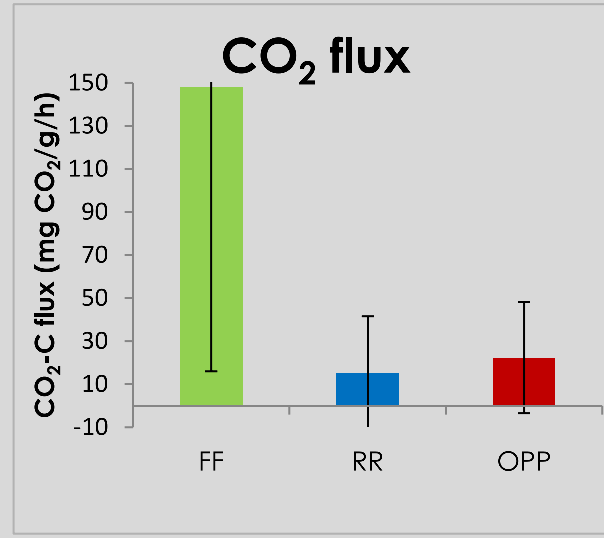
NO and N_2O temporal variability
(Controlled Laboratory Incubations)

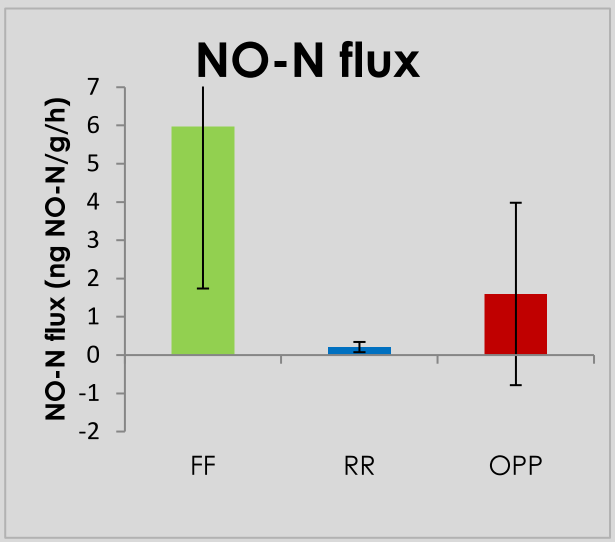


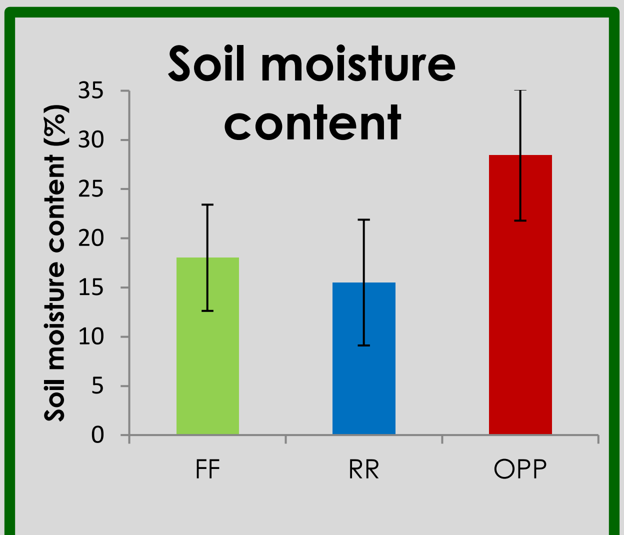
Summary comparison of the different land uses
(Controlled Laboratory Incubations)

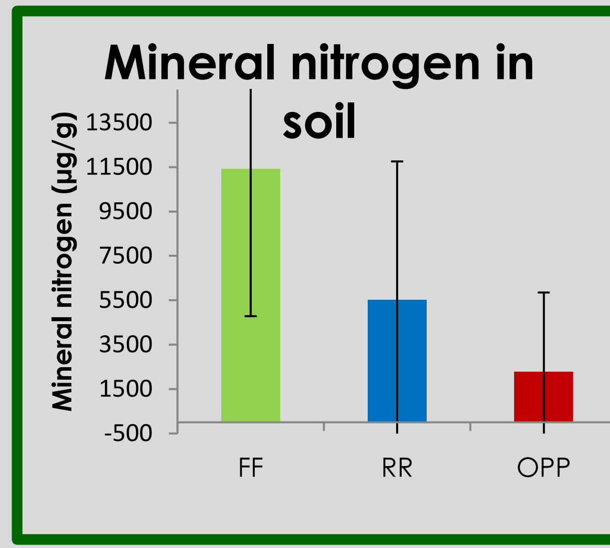












CONCLUSIONS

GHGs Fluxes Variability:

- N_2O fluxes in Sabah from logged forest and OP on mineral soil were higher from oil palm plantation than logged forest
- CH_4 fluxes were relatively higher in logged forest than OP albeit with very high variability.
- CO2 fluxes were relatively higher in logged forest than OP albeit with high variability.

Influence of Physico-chemical Properties:

- Logged forest and oil palm soils have equally high potential for N_2O and NO emissions following an increase in soil moisture, while riparian reserve soil release constantly lower rates of N_2O and NO independently of soil moisture condition.
- The nitrogen based mineral fertilization induced the N_2O emission in soils, suggesting enhanced GHG emission potential after conversion of forest land for agriculture use.

- Microorganisms are key drivers for C-and N-cycling in soils, modulating the emissions of primary GHGs (CO_2, CH_4 & N_2O)

Drewer et al (2021) – Biogeosciences 18(5):1559-1575, DOI 10.5194/bg-1559-2021

SIGNIFICANT FINDINGS

- This 2-year field study of bi-monthly measurements demonstrated that N_2O fluxes from mineral soils in Sabah were relatively: highest from Oil Palm plantations, moderate from riparian area, and lowest from logged forests.

- Very large spatial and temporal variability of GHGs fluxes and soil chemical and physical properties were encountered at all sites. Mean CH_4 fluxes were low with very high variability and showed no clear trend, and the highest range of fluxes was measured in logged forests.

- Under controlled laboratory incubations: Logged forest and oil palm soils have equally high potential for N_2O and NO fluxes following an increase in soil moisture, while riparian reserve soil releases constantly lower rates of N_2O and NO independently of soil moisture condition.

- The nitrogen based mineral fertilization induced the N_2O emission in soils, suggesting enhanced GHG emission potential after conversion of forest land for agriculture use.

Thank You

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- Our collaborators at **CEH:**

  Prof Dr Ute Skiba

  Dr Julia Drewer

- If you have any further questions, you may email me at **leduning.mm@gmail.com**

Drewer et al (2021). Front. For. Glob. Change, Sec. Forests and the Atmosphere
https://doi.org/10.3389/ffgc.2021.738303

Methane is emitted or taken up by the soil depending on the balance between methanotrophy and methanogenesis. The latter is favored by anaerobic conditions and is the anaerobic microbial decomposition of organic material, which occurs in wet and organic rich soils; methanotrophy takes place in parts of the soil where oxygen is available (Dutaur and Verchot, 2007). For example, recent studies have suggested that CH_4 uptake in oil palm and rubber plantation in Indonesia might be higher in riparian forests than plantations (Hassler et al., 2015; Lang et al., 2020).

Methanotrophs are a subset of the methylotrophic bacteria which can use other one-carbon compounds, including methanol, methylated amines, halomethanes, and methylated compounds containing sulfur [1–7]. Methane monooxygenase (MMO), which catalyzes the oxidation of methane to methanol, is a defining feature of methanotrophs.