An integrated assessment of soil and fire emissions of greenhouse gases from slash-and-burn and chop-and-mulch agriculture in the eastern Amazon

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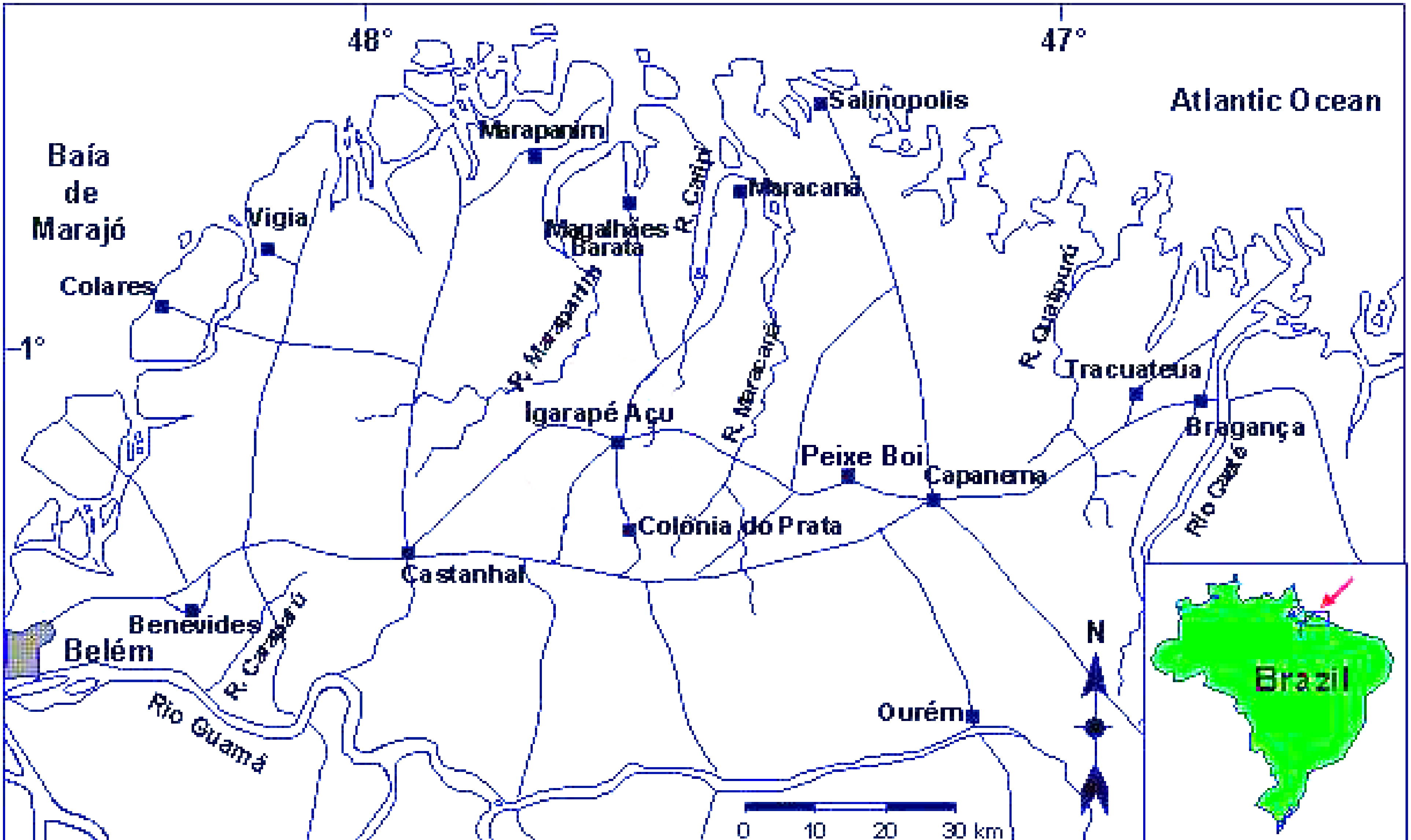
ALTERNATIVAS NA AGRICULTURA AMAZÔNICA (SHIFT – TIPITAMBA)



48°
47°
Atlantic Ocean
Baía de Marajó
Salinópolis
Marapanim
Maracanã
Vigia
Magalhães Barata
R. Caripi
Colares
1°
R. Marapanim
R. Maracanã
R. Quatipuru
Tracuateua
Igarapé Açu
Bragança
Peixe Boi
Capanema
Rio Caeté
Colônia do Prata
Castanhal
Benevides
Belém
R. Caraparú
Rio Guamá
Ourém
N
0 10 20 30 km
Brazil

LBA original over-arching question:

"How do tropical forest conversion, re-growth, and selective logging influence carbon storage, nutrient dynamics, trace gas fluxes and the prospect for sustainable land use in Amazonia?"

Consider sustainability of small-holder agriculture at local scales:

soil fertility, crop yield, water quality, economics

and at global scales:

greenhouse gas emissions, C sequestration

Could improved soil fertility conferred by chop & mulch technology cause unsustainably high emissions of methane and nitrous oxide from soil?

Methods

- A 15-year-old secondary forest contained 99,6 ± 19,5 Mg biomass ha^{-1}.
- Nov/Dec ‘01: one field slash & burned; another chopped & mulched (2 ha each).
- Jan ‘02: both fields planted in maize in January 2002. Mulched plot fertilized with 60 kg N, 60 kg P, and 30 kg K ha^{-1} at planting. An additional 30 kg N ha^{-1} added in the mulched plot 45 days after germination.
- Feb ’02: Cassava planted under the maize.
- May ’02: maize harvested.
- June ’02: Plots weeded, and leguminous trees (*Acacia mangium*, *Sclerolobium paniculatum*l) planted in 2 m x 2m spacing.
- June ’03: Cassava harvested; site allowed to return to fallow enriched with leguminous trees.

Trace gas flux measurements: 8 chambers in each of 2 plots per treatement, plux 8 chambers in adjacent. Approximately bimonthly. Due to non-normal distributions of the flux data, all values were log-transformed prior to statistical analyses.

Soil moisture measured gravimetrically weekly.

Crop Yields

Corn grain:

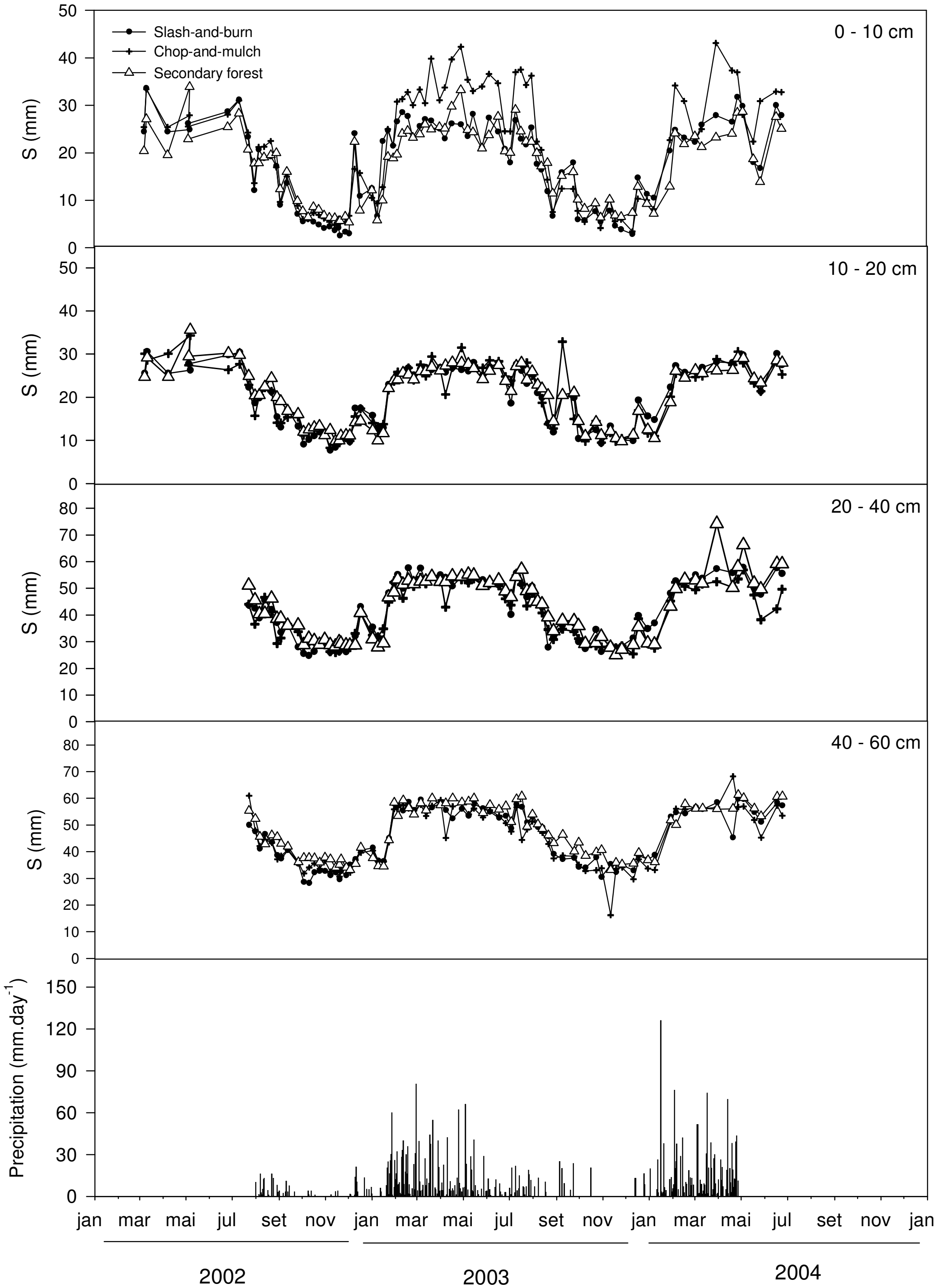
Chop-and-mulch: 1.55 ± 0.09 Mg ha^{-1}

Slash-and-burn: 0.97 ± 0.16 Mg ha^{-1}

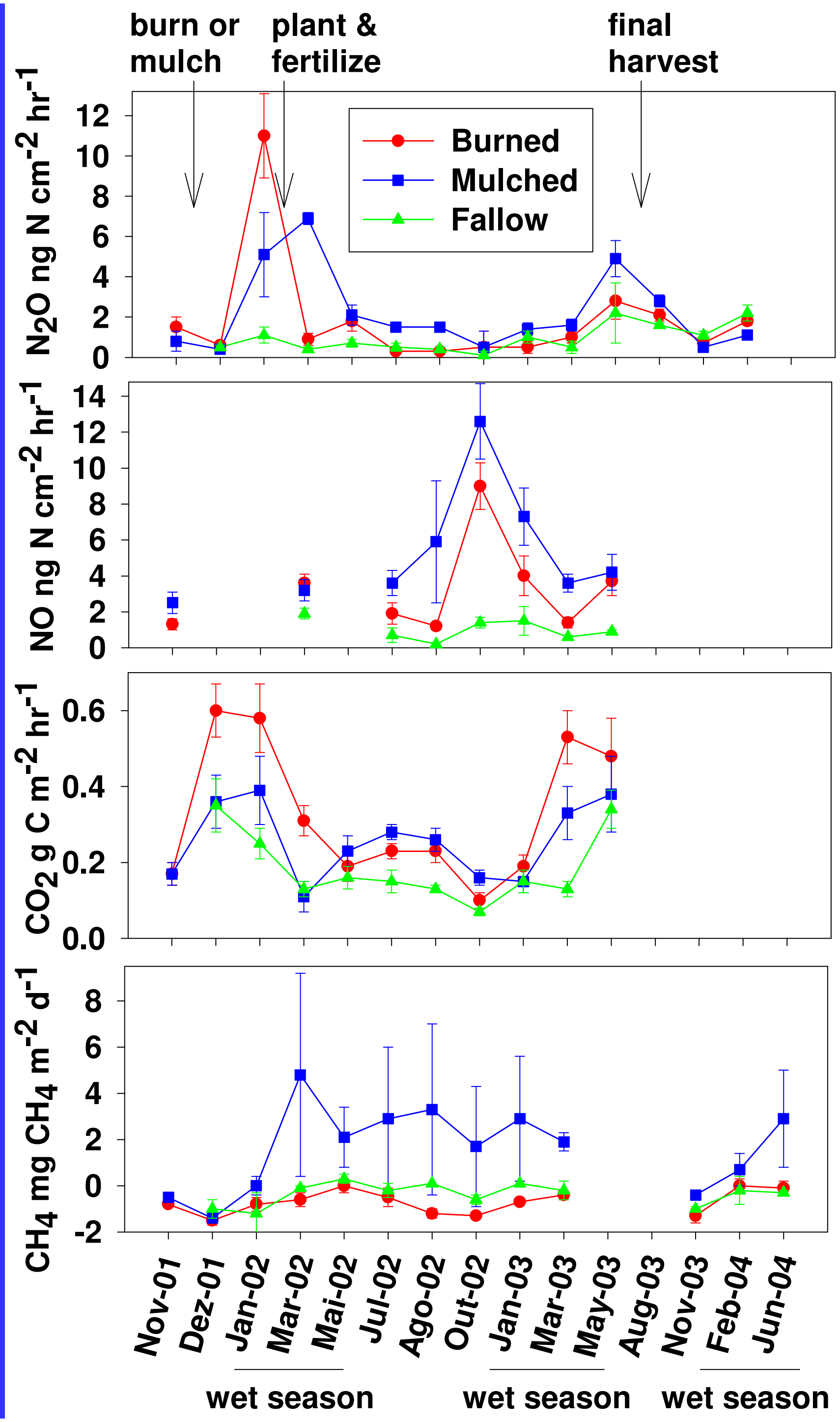
Manioc root:

Chop-and-mulch: 16.2 ± 1.2 Mg ha^{-1}

Slash-and-burn: 14.2 ± 1.1 Mg ha^{-1}



Slash-and-burn
Chop-and-mulch
Secondary forest
0 - 10 cm
10 - 20 cm
20 - 40 cm
40 - 60 cm
S (mm)
Precipitation (mm.day^{-1})
jan
mar
mai
jul
set
nov
2002
2003
2004



burn or mulch
plant & fertilize
final harvest
Burned
Mulched
Fallow
N_2O ng N cm^{-2} hr^{-1}
NO ng N cm^{-2} hr^{-1}
CO_2 g C m^{-2} hr^{-1}
CH_4 mg CH_4 m^{-2} d^{-1}
Nov-01
Dez-01
Jan-02
Mar-02
Mai-02
Jul-02
Ago-02
Out-02
Jan-03
Mar-03
May-03
Aug-03
Nov-03
Feb-04
Jun-04
wet season
wet season
wet season

Table 1. Estimates of soil emissions by management phase. Negative values for CH_4 indicate net uptake of atmospheric CH_4 by the soil; positive values indicate net efflux from the soil to the atmosphere.

	Pre-planting (60 days)	Crops (480 days)	Post-harvest fallow (240 days)	Sum
CH_4 (kg CH_4/ha)				
slash & burn	-0.7	-3.2	-1.1	-5.0
chop & mulch	-0.4	13.4	2.6	+15.6
fallow	-0.7	-0.4	-1.2	-2.3
N_2O (kg N/ha)				
slash & burn	0.8	1.2	0.9	2.9
chop & mulch	0.4	2.9	0.8	4.2
fallow	0.1	0.8	0.9	1.9
NO (kg N/ha)				
slash & burn	0.1	4.1	ND	4.2
chop & mulch	0.0	6.6	ND	6.6
fallow	0.0	1.2	ND	1.2
CO_2 (Mg C/ha)				
slash & burn	8	33	ND	41
chop & mulch	5	27	ND	32
fallow	4	18	ND	22

Table 2. Comparison of calculated emissions from the fire in the slash-and-burn treatment and the difference in soil emissions for the two years of the study (mulching treatment mean – burning treatment mean) due to adopting chop-and-mulch technology. Emission factors (amount of compound released per amount of dry fuel consumed, expressed as g kg^{-1}) are taken from Andreae and Merlet (2001).

	Emission factor	Fire emission	Difference in soil emissions due to mulching
CH_4	6.8 ± 2	630 kg CH_4 ha^{-1}	+21 kg CH_4 ha^{-1}
N_2O	0.20	12 kg N ha^{-1}	+1.3 kg N ha^{-1}
NO	1.6 ± 0.7	59 kg N ha^{-1}	+2.4 kg N ha^{-1}
CO_2	1580 ± 90	40 Mg C ha^{-1}	-9 Mg C ha^{-1}

Table 3. Comparison of greenhouse warming potentials (GWP) for a 100-year time frame of emissions from slash-and-burn and chop-and-mulch cropping systems over approximately a 2-year cycle. All values are in kg ha^{-1}, except for diesel fuel, which is in L ha^{-1}. All values are rounded to two significant figures.

	Slash and Burn		Chop and Mulch	
	flux	CO_2 equivalents	flux	CO_2 equivalents
Soil CH_4 efflux	-5.0	-120	16	370
Fire CH_4 emissions	630	14,000	0	0
Soil N_2O-N efflux	2.9	1,300	4.2	2,000
Fire N_2O-N emissions	12	5,600	0	0
N fertilizer*	0	0	90	370
P fertilizer*	0	0	60	37
K fertilizer*	0	0	30	15
Diesel fuel for mulching	0	0	170	1000
Total CO_2 equivalents		21,000		3,800

*Conversion of fertilizer use to CO_2 equivalents is from West and Marland (2002) and includes energy use for fertilizer manufacture, transportation, and application.

Globally, the contribution of biomass burning to total emissions is estimated at:

- 7% of CH_4
- 3% of N_2O
- 14% of NO
- 45% of CO
- 6% of VOCs

Prather et al. 2001

Conclusions

Despite a large increase in soil emissions of CH_4 in the chop & mulch treatment, the avoided fire emissions of CH_4 were yet another order of magnitude larger.

Accounting for emissions from fire, soil, fertilizer use, and fuel use, the chop & mulch cropping system released 5-times fewer CO_2-equivalents of GWP gases compared to the slash & burn system.

Chop and mulch appears to contribute to sustainability at both local and global scales.