agroforestry systems
with perennial crops

Carbon Footprint: What is it and how to measure it?

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cirad AGRICULTURAL RESEARCH FOR DEVELOPMENT

INAFORESTA

Content

- Introduction
  - Concepts
  - Examples of Waslala, Nicaragua
- **Methods**
  - Accumulation rate of Carbon removed (sequestered)
  - Carbon footprint
  - Carbon balance
- Conclusions

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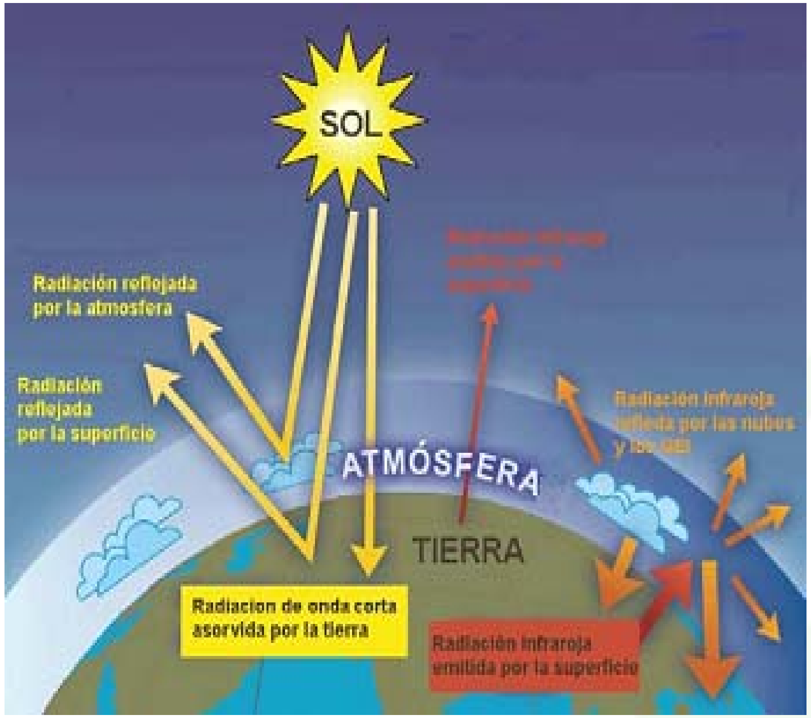
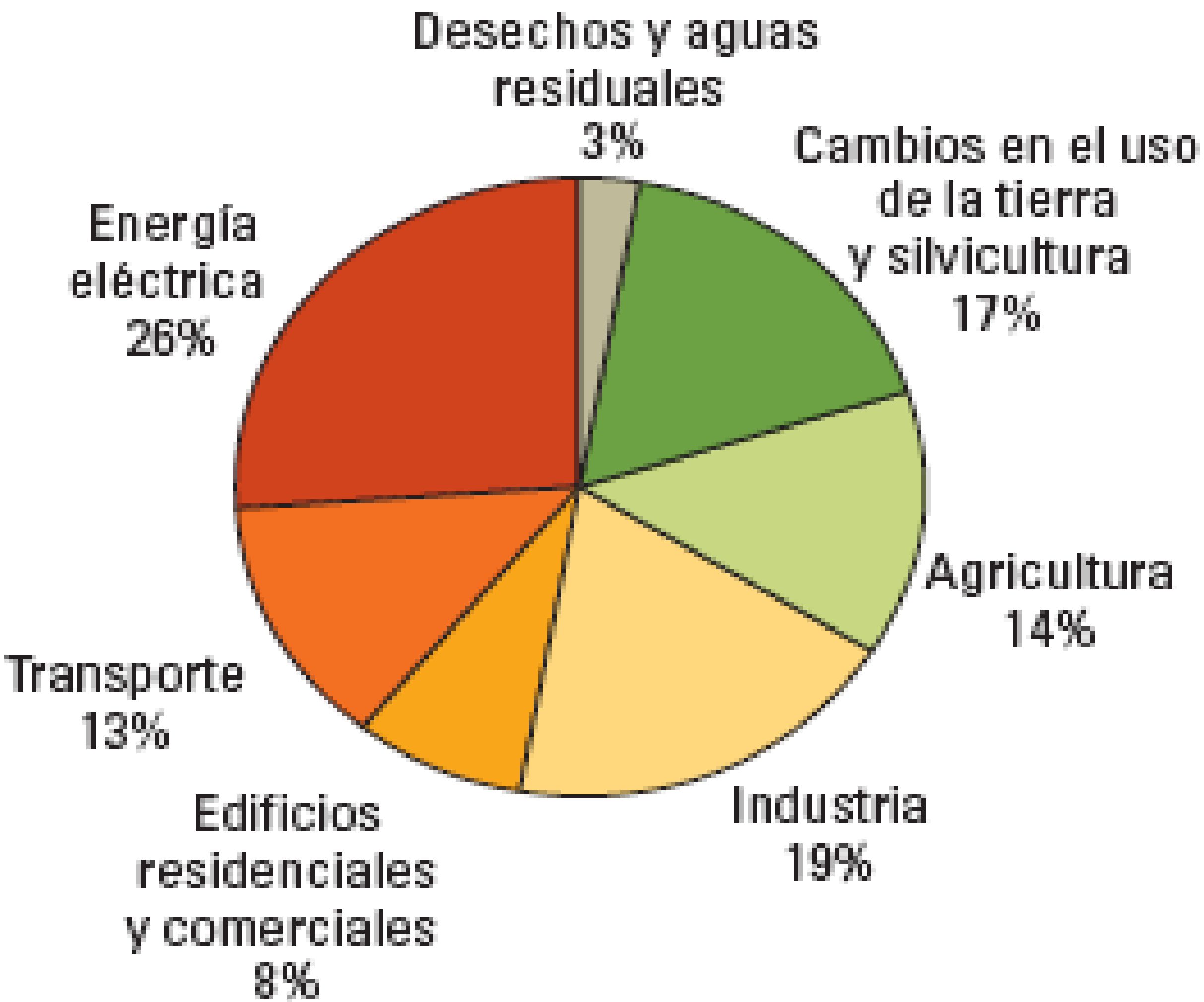
INTRODUCTION



- Temperature is regulated by Green House Gases (GHG)
- Most important GHG: CO_2, CH_4 and N_2O
- GHG were incremented due to different activities
- GHG increments would difficult the adaptation of live organisms and ecosystems to climate change

Human beings contribute to the increment of GHG



Fuente: IPCC, 2007a, Gráfico 2.1.

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Every manufactured product generates emissions of GHG to the atmosphere. Ej. Chocolate bar (Jhones 2008)

How to measure the GHG emissions?

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Carbon footprint:

An indicator of the amount of GHG emitted to the atmosphere, due to activities of production and consumption of goods and services of anthropogenic origin

(PAS 2050; 2008).

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Carbon footprint is expressed as the amount of kg of CO_{2e} emitted to produce one kg of a product

Carbon footprint = kg CO_{2e} / kg dried cacao

$$CO_{2e} = CO_2 + CH_4 + N_2O$$

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Why to measure the carbon footprint of the production?

What is the utility for farmers and their organizations?

What is happening in the international market?

CO2 Labels Proposed for Beer Cans by '09

Consumidores UE sugieren incorporar la etiqueta

72 % want to see C labels

47% think is important to use a label

26% never see labels

Which would be the strategies to reduce the carbon footprint?

100 TONNES EMISSIONS − 50 TONNES REDUCTIONS − 50 TONNES OFFSETS = CARBON NEUTRALITY

- Certificate of emissions reduction
- Plant trees

Carbon Balance

$$CB = \sum CO_{2e} \text{ Removals} - \sum CO_{2e} \text{ Emissions}$$

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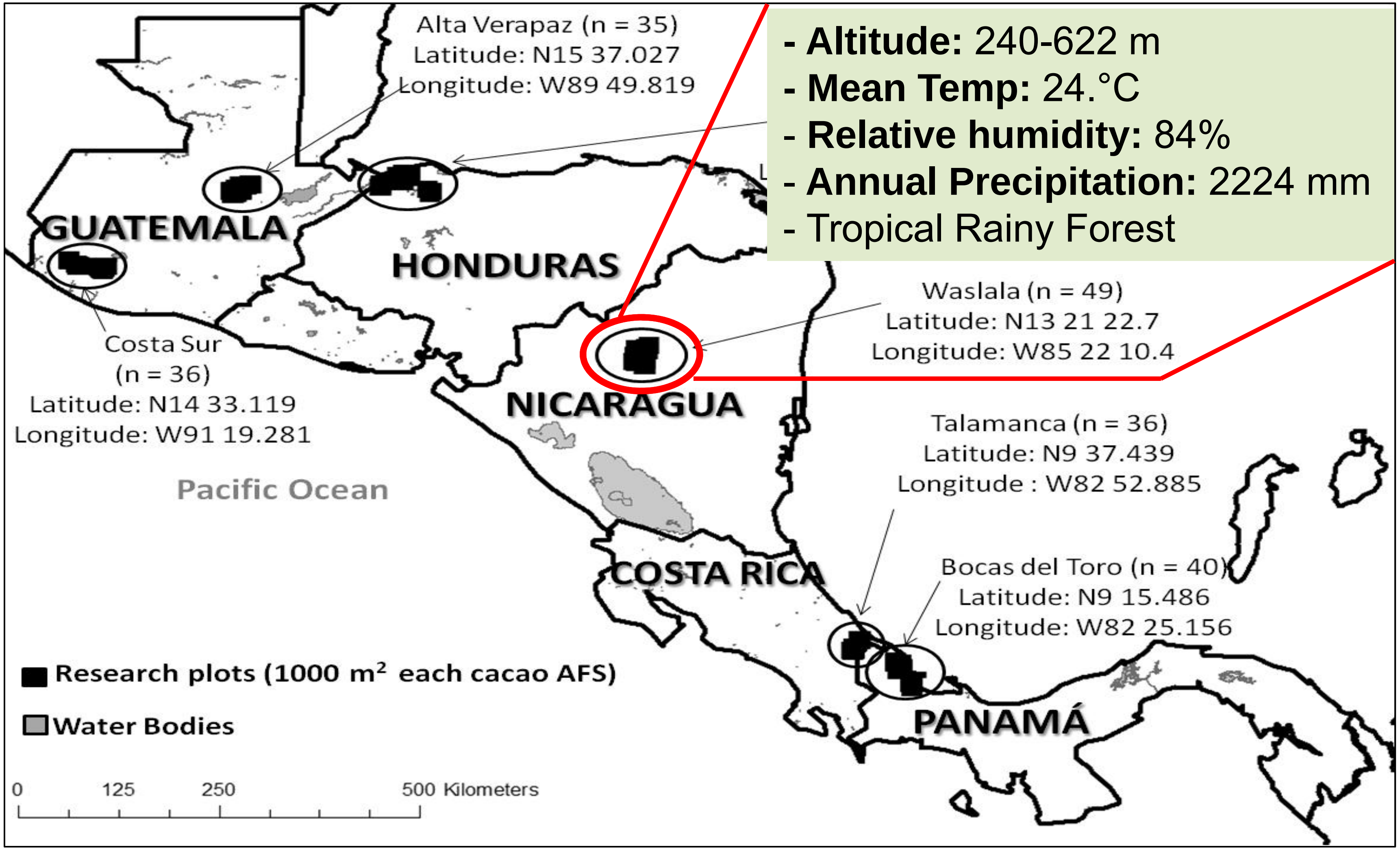
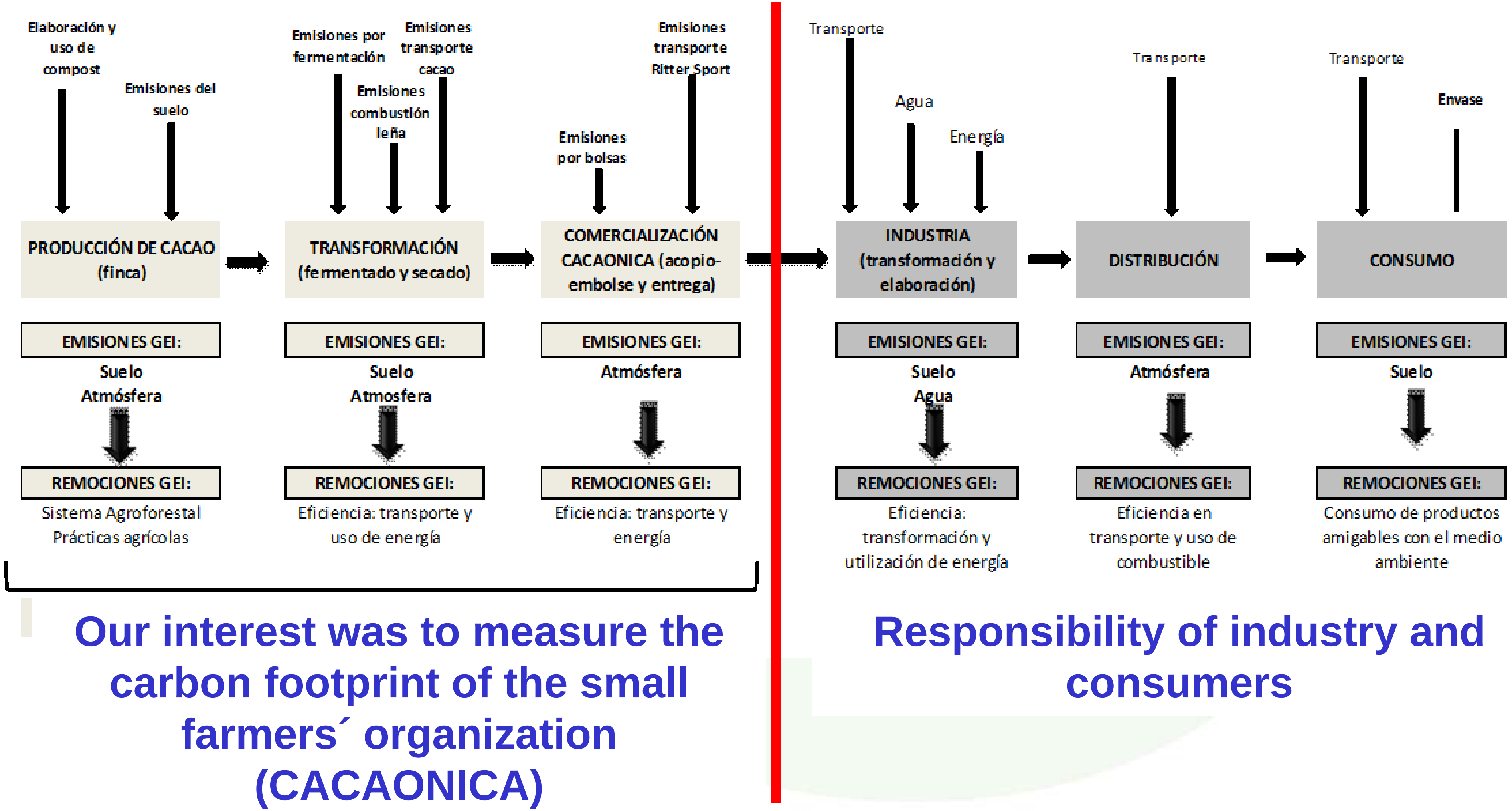
METHODS

Carbon footprint and carbon balance: The case of the cooperative CACAONICA, Waslala, Nicaragua



Important to define the limits of the Carbon footprint assessment!



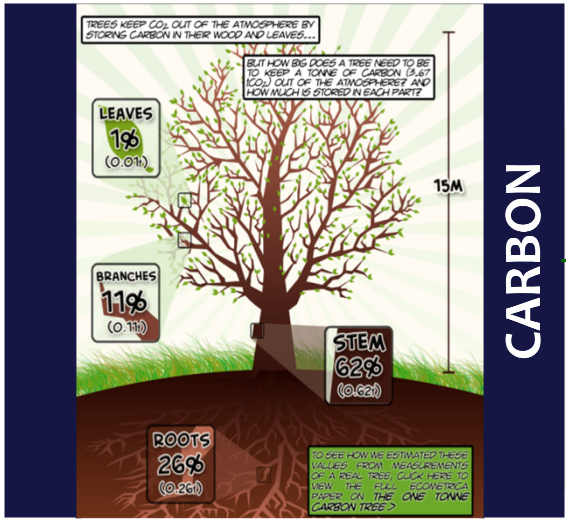
Our interest was to measure the carbon footprint of the small farmers´ organization (CACAONICA)

Responsibility of industry and consumers

Annual accumulation rate of C in the biomass (above and bellow ground)

INCREASE OF C

ΔC : C $_{\text{final time}}$ – C $_{\text{initial time}}$/ final year – initial year



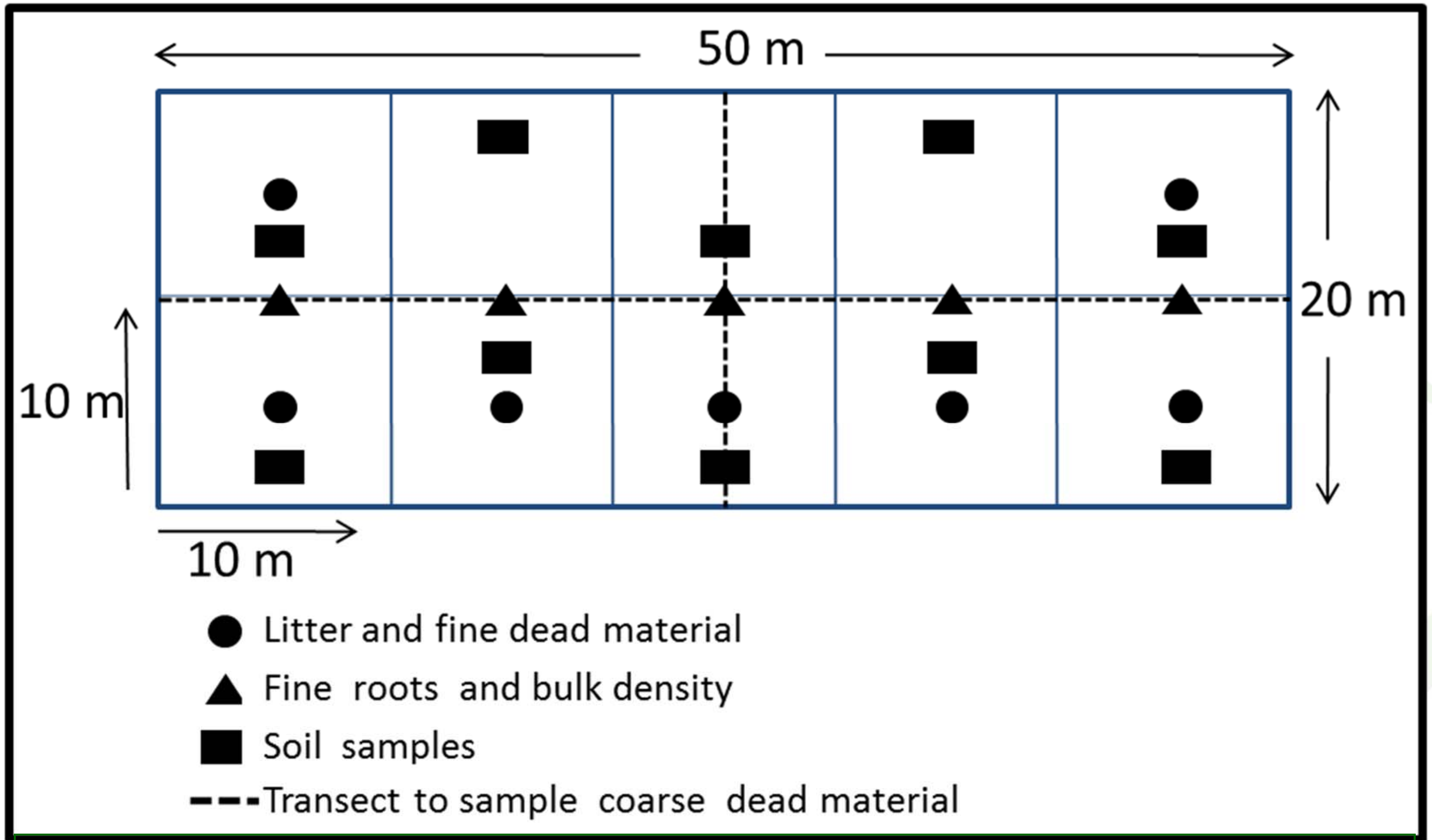
Above ground	Aerial biomass, litter and dead material
Bellow ground	Fine and coarse roots

t C/ha/year * **44/12** = **t CO_2/ha/ year removed**

Measure the C again

INCREASE OF C (e.g. CACAONICA case)

$\Delta C : C_{2011} - C_{2009} / 2$ years



All the trees and palms are measured in all the plot

Above ground C

Biomass of cacao trees and shade canopy trees-palms-others

Cacao
- Trunk diameter at 30 cm
- Alometric equations
- Fc= 0.5 (IPCC)

Shade trees
- Diameter (DHB)
- Height
- Alometric equations
- Fc= 0.5 (IPCC)

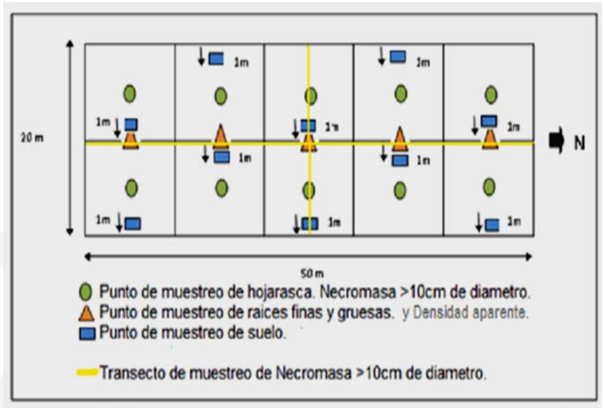
Arriba del suelo

Hojarasca y necromasa fina

Marc (50x50 cm)

- separó cada material colectado
- se homogenizó/PPM
- pesó 250 gr cada material
- fracción C (Lab.)

Necromasa gruesa (> 10cm)



Trazan transecto/ PPM

- midieron diámetro cada pieza
- clasificación dens.:sólido, intermedio descompuesto (0,60;0,42; 0,23 g/cc)
- volumen tronco caído
- fracción C (0.5; IPCC)

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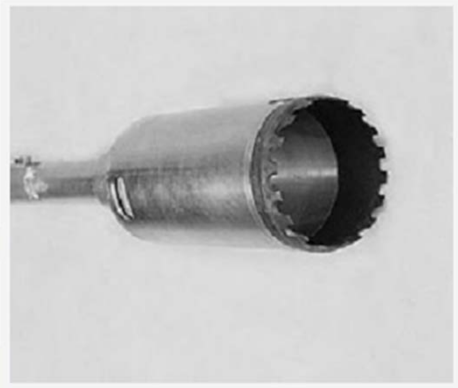
Bellow ground C

Coarse roots

Root biomass of cacao and shade canopy trees
- Ecuations are applied with the aerial biomass of the trees
- FC (0.5; IPCC)

Fine roots



Soil samples
- samples 20 cm depth
- separate fine roots
- dry roots
- Laboratory

Alometric equations to estimate biomass

Especie o tipo de planta	Ecuación o fórmula	Fuente
Theobroma cacao	$Log\ Bt = (-1,684+2,158*Log(dap_{30})+0,892 * Log(alt))$	Segura *et* al, 2005
Cordia alliodora	$Log\ Bt =(-0,94+1,32*Log\ (dap)+1,14*Log(alt))$	Segura *et* al, 2005
Bactris gasipaes	$Bt = 0,74*alt^2$	Szott *et* al, 1993
Árboles maderables	$Bt = (21,3-6,95*(dap)+0,74*\ (dap2))$	(Brown and Iverson, 1992)
Árboles frutales	$Log\ Bt = (-1,11+ 2,64 * Log(dap))$	Segura *et* al, 2005
Palmas	$Log\ Bt = (7,7*\ (alt)+4,5^{0,003})$	Frangi y Lugo, 1985; Cummings *et* al, 2002
Raíces gruesas	$Bt = exp[-1,0587 + 0,8836 \times ln\ (BA)]$	IPCC, 2003
Carbono en biomasas	$C = Bt*Fc\ ;\ Fc=0,5$	IPCC, 2003
Musáceas	1,5 kg de C por cada m de altura	Tanaka y Yamaguchi, 1972

Bt: biomasa total (Kg/árbol); Log: Logaritmo base 10; dap: diámetro (cm) del tronco a la altura del pecho; dap_{30}: diámetro (cm) del tronco a 30cm; alt: altura total (m); V: volumen; Dn: diámetro (cm) de rama o tronco; L: longitud de transecto (m); Ln: logaritmo natural; C:carbono en biomasas; Fc: fracción de carbono (0,5).

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KEY RESULT

Nro. parcela	Edad cacaotal (años)	C-Total aereo				C-Total raices				C-Total necromasa				C- Total Hojarasca		C-Total (Mg ha^{-1})		Fijación (2009-2011)	Fijación anual (Mg ha^{-1}año^{-1})
		Dosel sombra		Arboles cacao		R.finas <5mm		R.grue. >5mm		Necr. < 10 cm		Necr. > 10 cm							
		2009	2011	2009	2011	2009	2011	2009	2011	2009	2011	2009	2011	2013	2015	2017	2019		
N23	25	88.8	93.3	3.2	5.8	0.01	0.97	18.65	19.92	0.10	0.31	0	0.45	0.13	1.08	110.8	121.9	11.0	5.5
N11	22	3.3	3.5	8.3	12.7	0.19	2.16	2.774	3.85	0.12	0.60	0	0	0.16	1.46	14.8	24.2	9.5	4.7
N02	27	12.4	15.4	2.2	5.4	0.02	0.27	4.5	5.996	0.06	0.55	0	0	0.11	0.86	19.3	28.4	9.1	4.6
N09	25	12.5	17.9	12.0	10.1	0.18	0.92	6.847	7.76	0.16	0.57	0.38	1.06	0.48	1.19	32.6	39.5	6.9	3.4
N10	22	37.3	37.6	3.4	6.7	0.15	1.30	10.79	11.46	0.08	0.09	0	0.22	0.20	0.95	51.9	58.3	6.5	3.2
N26	25	7.9	11.5	12.0	11.8	0.27	0.64	5.359	6.407	0.09	0.62	0.001	0	0.22	1.08	25.9	32.1	6.2	3.1
N01	26	18.1	18.0	5.8	7.8	0.00	0.76	6.698	6.814	0.12	0.27	0	0	0.05	1.89	30.7	35.5	4.8	2.4
N07	28	38.6	30.9	7.6	8.5	0.23	1.39	12.57	11.04	0.19	0.50	0	8.28	0.40	1.93	59.6	62.6	2.9	1.5
N18	25	42.8	44.2	11.2	9.4	0.07	0.72	12.27	12.02	0.17	0.46	0	0	0.24	1.74	66.8	68.5	1.8	0.9
C-Total		261.6	272.3	65.7	78.1	1.1	9.1	80.5	85.3	1.1	4.0	0.4	10.0	2.0	12.2	412.3	471.0	58.6	29.3
C promedio		29.1	30.3	7.3	8.7	0.1	1.0	8.9	9.5	0.1	0.4	0.04	1.1	0.2	1.4	45.8	52.3	6.5	3.3
C anual fijado			0.59		0.69		0.44		0.27		0.16		0.54		0.57				3.3
% fijación C			18		21		14		8		5		16		17				100

Annual accumulation rate of C = 3,3 t/ha/year

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HOW TO MEASURE THE GHG EMISSIONS

Important information necessary for the calculations

- Potential of emission
- Factor of emission
- Molecular weights

CACAO PRODUCTION

SOIL EMISSIONS
Closed-Chamber Technique

- 3 samples per plot

$$F = \frac{\Delta C}{\Delta t} \times \frac{V}{A}$$

- Transform to CO2e Ecc. Gases

PREPARATION AND USE OF COMPOST

- Amount of compost (ton)
- F emission
- Total has

Emissions by fertilizers

$$CO_2e = N_{Tn} * (1\text{-}FG) * GWP * EF_N * 44/28$$

- **CO2e:** tons emitted
- **NTn:** tons of Nitrogen applied to soil
- **EFN:** emission factor by Nitrogen (0,01)
- **GWP:** potential of global warming of N2O (by default 310).
- **FG:** fraction volatilized as NH3 y NO3 (0,1).
- **44/28** (1,57): the molecular relationship between CO2 y el N2O.

It is also necessary to include the emissions for producing the fertilizers

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TRANSFORMATION

TRANSPORT (farm-center)

- Registers of cacao
- # communitites
- Interviews and calculation of the distances and fuel
- Factor Emission
-consume of fuel (lt/km)
- FE (kg CO_2/ litros diesel)

FERMENTATION

- Weight of fermented cacao
- Analysis of fructosa and glucosa (molecular weights)

DRY cacao

- Amount of firewood utilized
- Factor Emission

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TRAIDING

CARRIER BAGS

Plástic or yute

- kg cacao
- Factor emission for manufacturing carrier bags

TRANSPORT

(Waslala- Place of sale

- kg cacao
- consume of fuel (lt/km)
- Factor emission

Carbon footprint results

Source of emission	Carbon footprint (kg CO2e / kg cacao) (Majority of standards)	Carbon footprint (kg CO2e / kg cacao) (PAS 2050)
Soil	3,85	-
Compost	0,14	0,14
Transport communities to Waslala center	0,06	0,06
Fermentation	0,07	0,07
Firewood to dry cacao	0,67	0,67
Packing of cacao	0,1	0,1
Transport Waslaal-Place of sale	0,09	0,09
TOTAL	**4,98**	**1,13**

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Carbon balance for CACAONICA

	Mean (kg CO_{2e} / kg cacao)
CO_{2e} removed	39,8
CO_{2e} emitted	4,98
C Balance	**34.8**

Perspectives

- To encourage the cooperative CACAONICA to use this results to obtain better certifications and prices for cacao.

- To measure the carbon footprint and carbon balance in other cooperatives of other countries

- It would be interesting to have similar data from African countries considering that the management of cacao plantations is different compared with American cacao plantations

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LITERATURE

Poroma, D. 2012. Estrategias de reducción de la huella de carbono en la producción del grano de cacao (*Theobroma cacao* L.) para la cooperativa CACAONICA en Waslala, Nicaragua. M.Sc. Tesis. CATIE. Turrialba, CR. (available online)

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THANK YOU

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