Carbon stocks in agroforestry systems with cocoa (*Theobroma cacao* L.) in Central America

Somarriba E [1*], Deheuvels, O.[1, 2], Cerda, R.[1]

[1]: CATIE, DID, 7170, Cartago, Turrialba 30501, Costa Rica

[2]: CIRAD, UMR System, F-34070 Montpellier, France

* Corresponding author. Tel.: +506 25 58 25 93, fax: +506 25 58 20 45. E-mail address : esomarri@catie.ac.cr

agroforestry systems with perennial crops

CATIE Solutions for environment and development / Soluciones para el ambiente y desarrollo

Mesoamerican Agroenvironmental Program

cirad AGRICULTURAL RESEARCH FOR DEVELOPMENT

INAFORESTA

Human activities increase atmospheric CO_2 causing global warming and climate change which causes major negative economic impacts

Do you want to see the 2013 model?

Rationale

- We need farmers to:
  - Adapt to climate change
  - Mitigate more: emit less and store more CO_2
  - Improve their livelihoods
- Hypotheses
  - Trees can be introduced into cocoa farms to fix additional carbon (+C) and produce other goods and services without adversely affecting cocoa production
  - Fixing, certifying and selling +C can generate complementary income to cocoa households and improve their well being

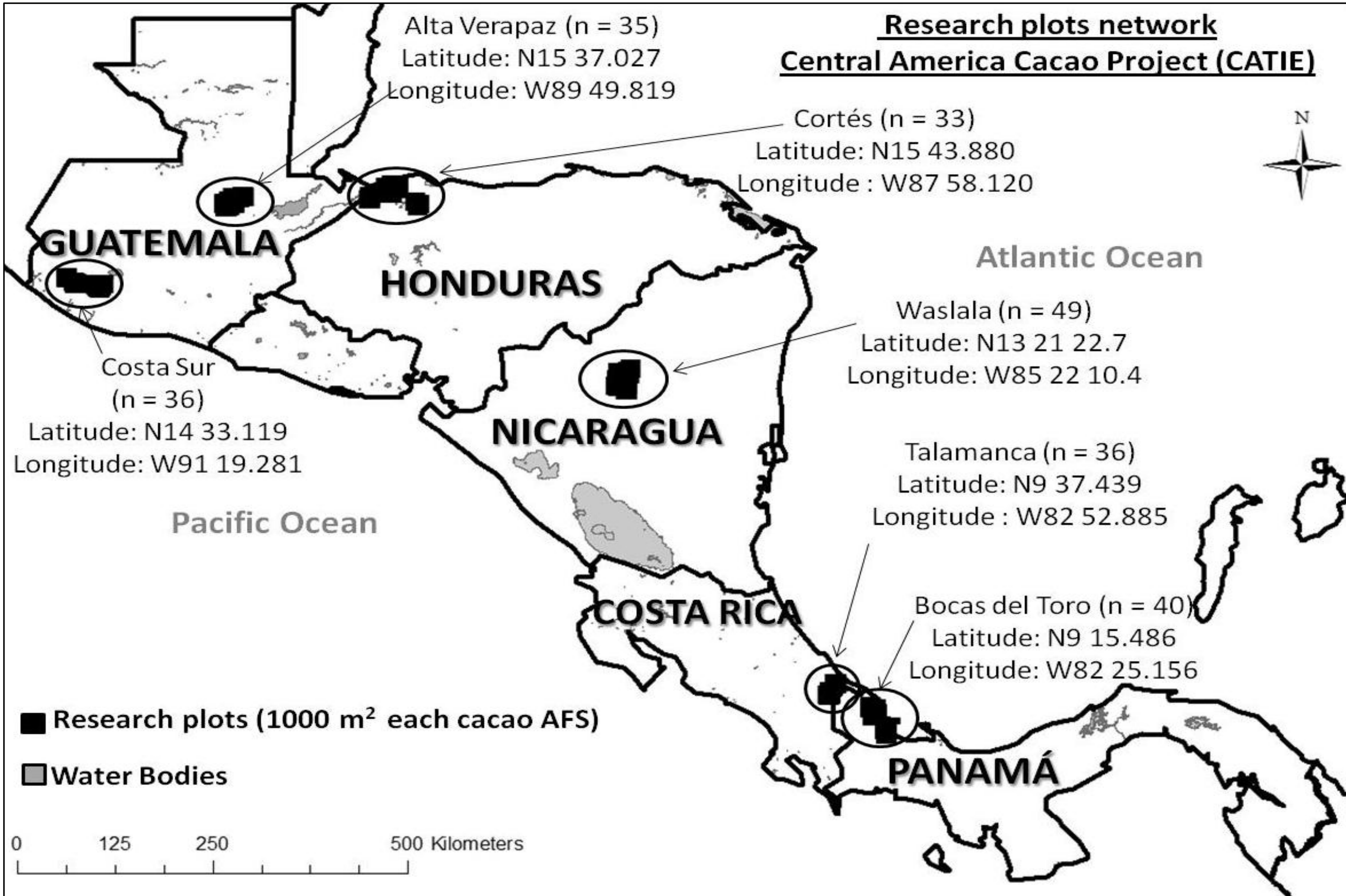
How to do it?

1. Determine how much +C can be fixed and stored in cocoa farms without adversely affecting crop yields
2. Determine markets for +C
3. Determine how to certify +C
4. Determine how to manage the +C bussiness

CATIE
Solutions for environment and development
Soluciones para el ambiente y desarrollo

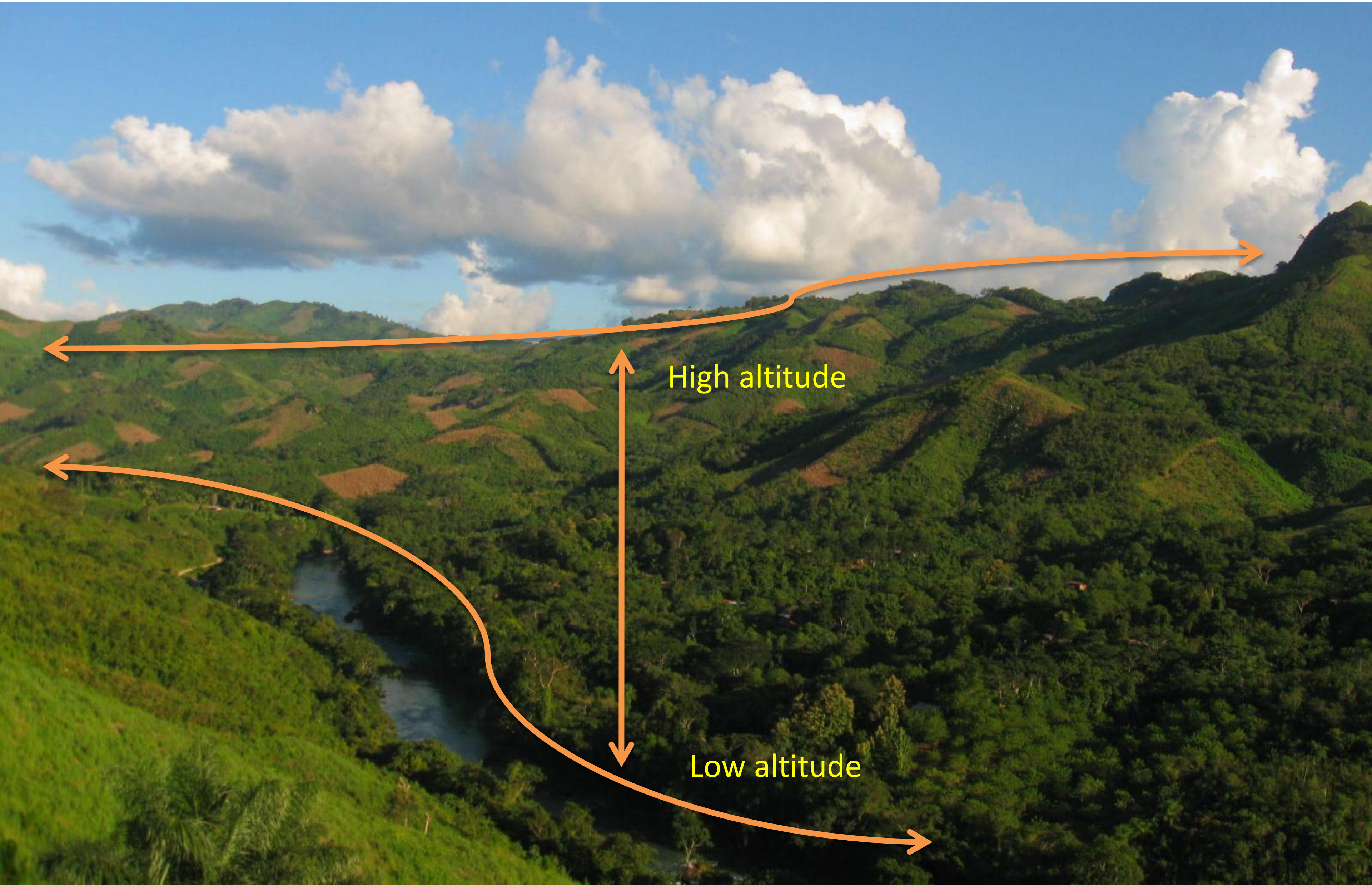
In this presentation we will focus in determining how much carbon is stored in 229 cocoa plantations in Central America

CATIE
Solutions for environment and development
Soluciones para el ambiente y desarrollo

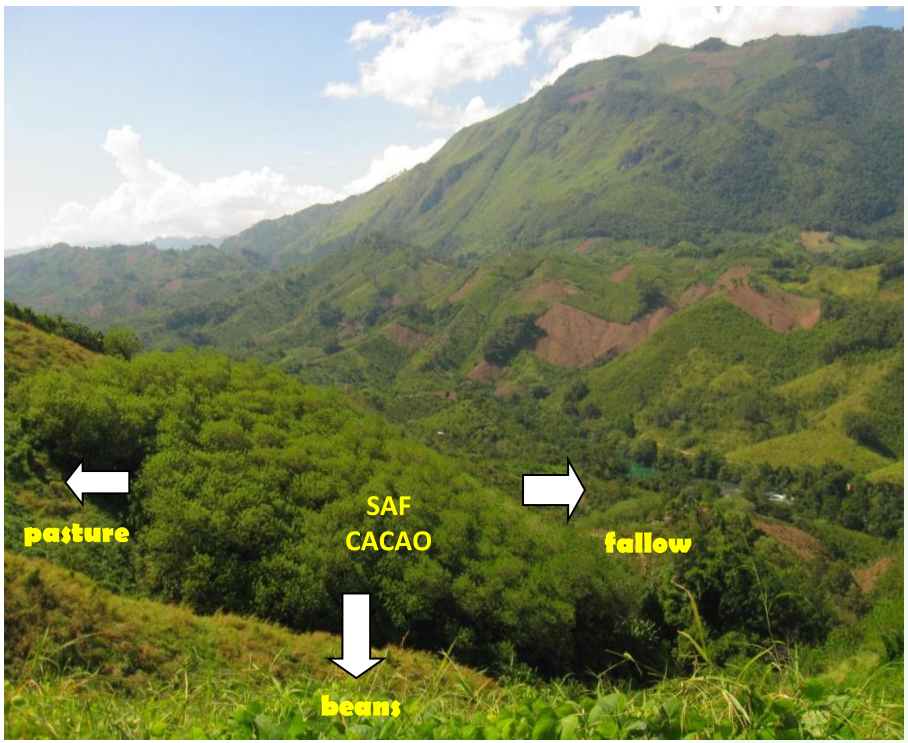


CATIE
Solutions for environment and development
Soluciones para el ambiente y desarrollo

Landscape position of plots



Landscapes with high fragmentation of natural forests

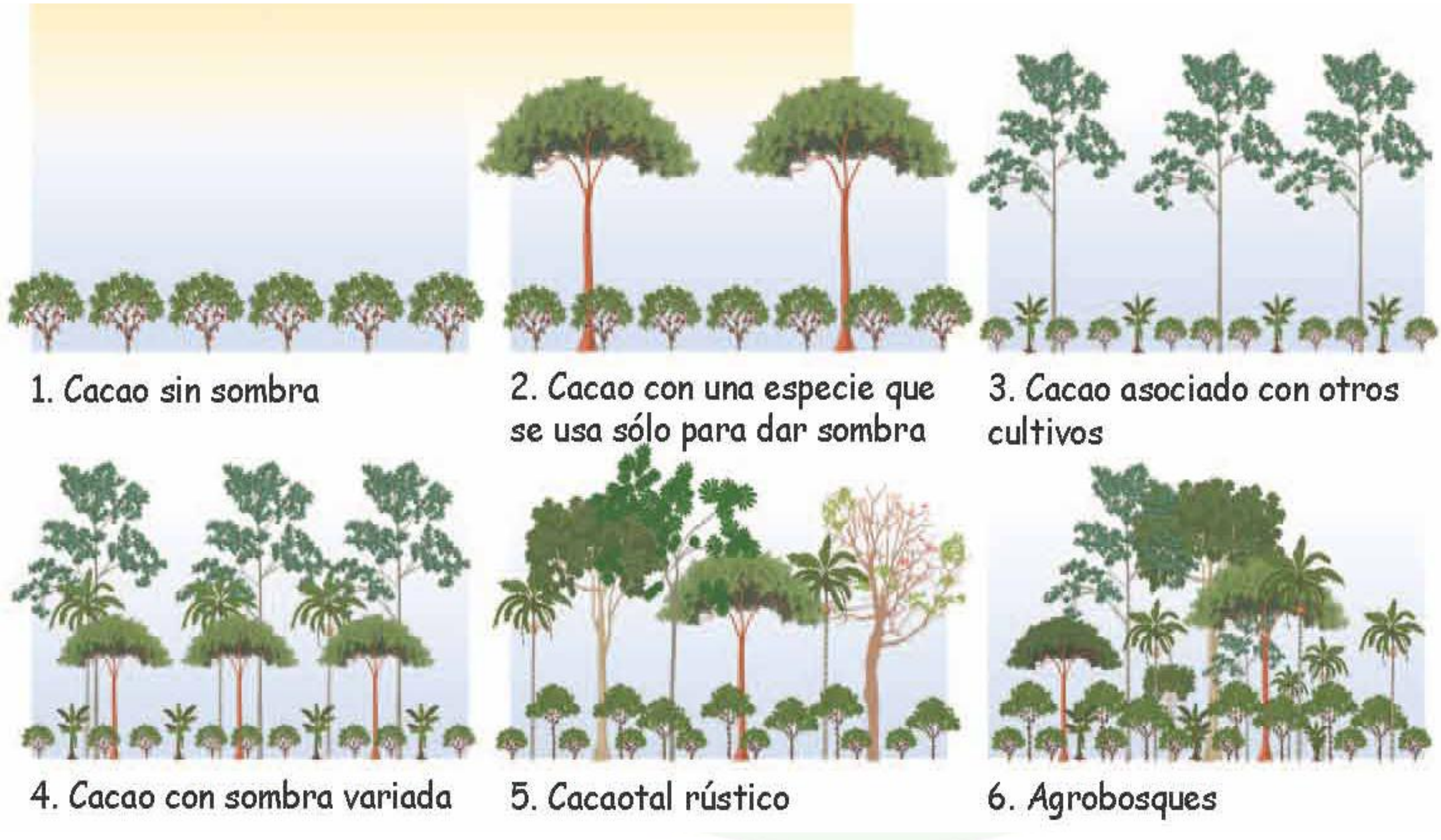


Landscapes with low fragmentation of natural forest

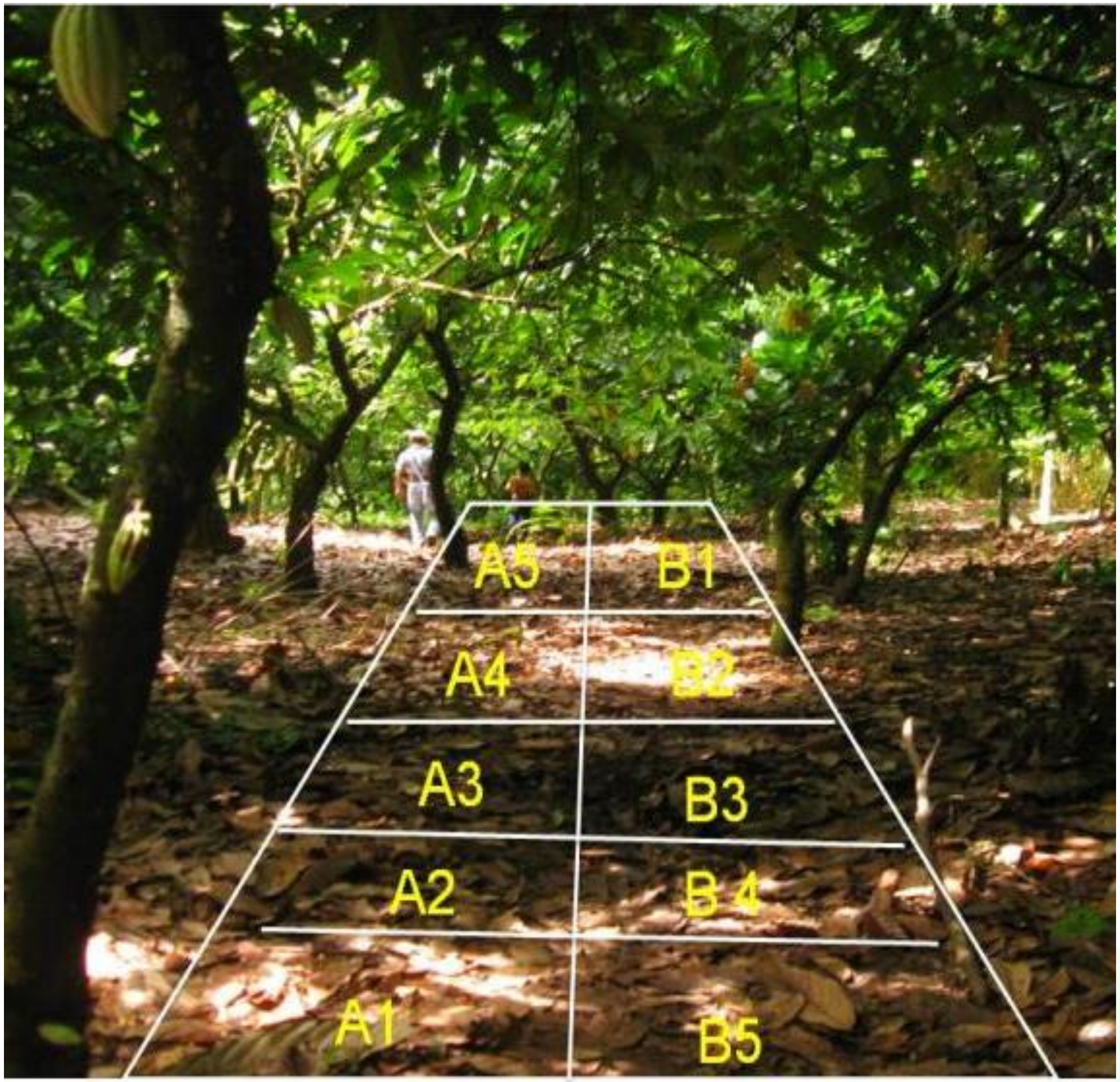
Land uses around cocoa plots – local landscape

CATIE
Solutions for environment and development
Soluciones para el ambiente y desarrollo

Cacao typologies (1 to 5 in this study)



Carbon measured in 1000 m^2 plots



Country	# Plots
Panamá	40
Costa Rica	36
Nicaragua	49
Honduras	34
Guatemala Costa Sur	35
Guatemala Alta Verapaz	35
TOTAL	**229**

CATIE
Solutions for environment and development
Soluciones para el ambiente y desarrollo

Carbon measured in

Litter

Necromass

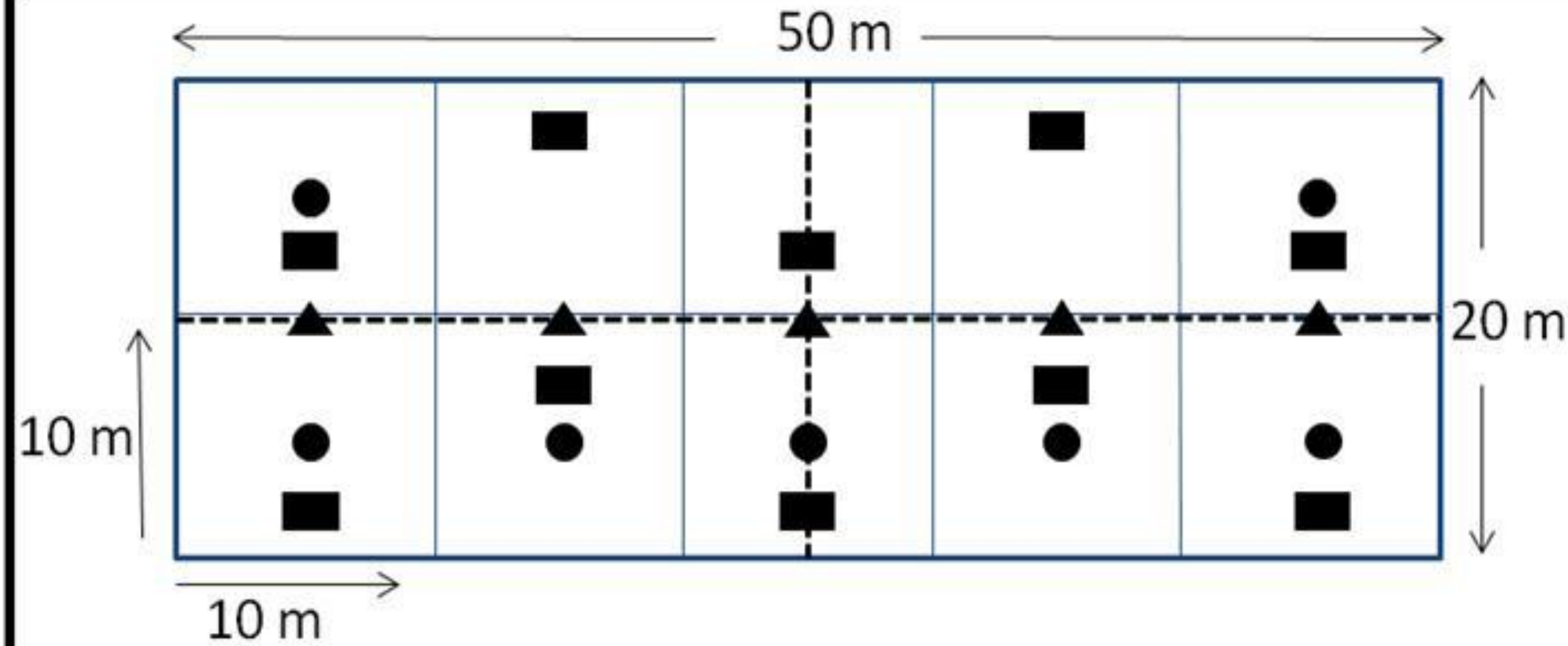
Roots

Soil

Cacao

Shade trees

Sampling points per plot



● Punto de muestreo hojarasca y necromasa delgada

▲ Punto de muestreo raíces finas y densidad aparente

■ Punto de muestreo suelo

- - - Transecto de muestreo necromasa gruesa

CATIE
Solutions for environment and development
Soluciones para el ambiente y desarrollo

Wood specific gravity per species

Scientific name	Specific gravity (g cm^{-3})					
	Stem		Big branches		All	
	Mean	SD	Mean	SD	Mean	SD
C. alliodora	0.47	0.08	0.43	0.07	0.46	0.08
T. cacao	0.51	0.05	--	--	0.51	0.05
Persea americana	0.48	0.09	0.35	N/A	0.46	0.09
Inga sp.	0.48	0.13	0.48	0.15	0.48	0.13
Spondias mombin	0.44	0.11	0.41	0.04	0.44	0.10
Nephelium lappaceum	0.83	0.08	--	--	0.83	0.08
Syzigium malacensis	0.60	0.04	0.63	N/A	0.61	0.04
Other fruit tree species*	0.76	0.09	--	--	0.76	0.09

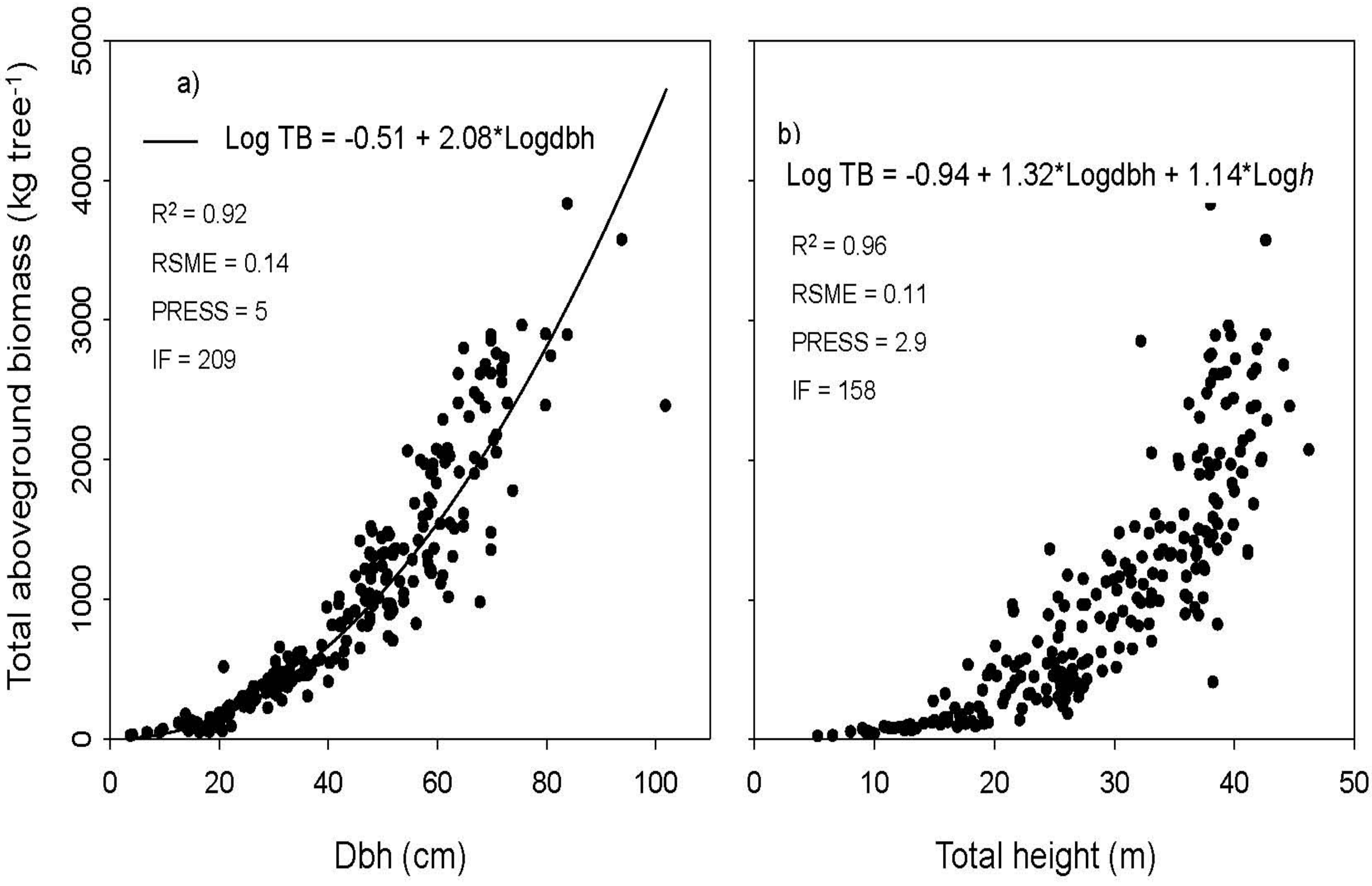
* Includes Citrus (lemon and orange trees), guava, mango and “sapotillo” trees.

Allometric equations to estimate biomass of trees (above ground and below ground)

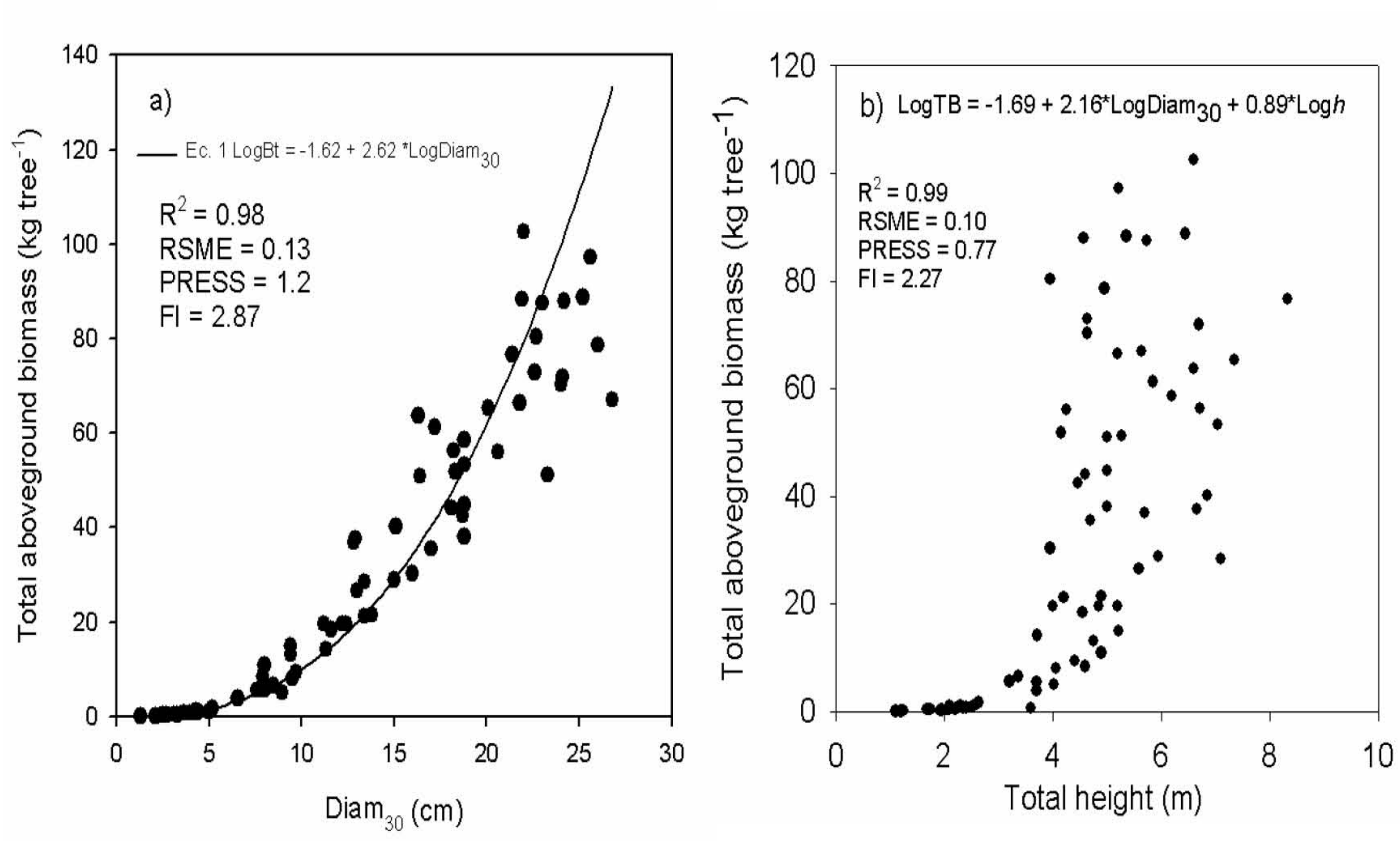
Species	Equation	Source
Theobroma cacao	Log Bt = (-1,684+2,158*Log(dap_{30})+0,892 * Log(alt))	Segura *et* al, 2005
Cordia alliodora	Log Bt =(-0,94+1,32*Log (dap)+1,14*Log(alt))	Segura *et* al, 2005
Bactris gasipaes	Bt = 0,74*alt^2	Szott *et* al, 1993
Timber trees	Bt = (21,3-6,95*(dap)+0,74* (dap2))	(Brown and Iverson, 1992)
Fruit trees	Log Bt = (-1,11+ 2,64 * Log(dap))	Segura *et* al, 2005
Palms	Log Bt = (7,7* (alt)+$4,5^{0,003}$)	Frangi and Lugo, 1985; Cummings *et* al, 2002
Thick roots	*Bt = exp[–1,0587 + 0,8836 x ln (BA)]*	IPCC, 2003
Carbon in biomass	*C = Bt*Fc ; Fc=0,5*	IPCC, 2003
Bananas	1,5 kg de C por cada m de altura	Tanaka and Yamaguchi, 1972

Bt: total biomass (kg/tree); Log: Base 10 logaritm; dap: stem diameter at breast height (cm); dap_{30}: stem diameter at 30 cm aboveground (cm); alt: total height (m); V: volume; Dn: stem or branch diameter (cm); L: length of transect (m); Ln: natural logaritm; C:carbon in biomass; Fc: carbon content (0,5).

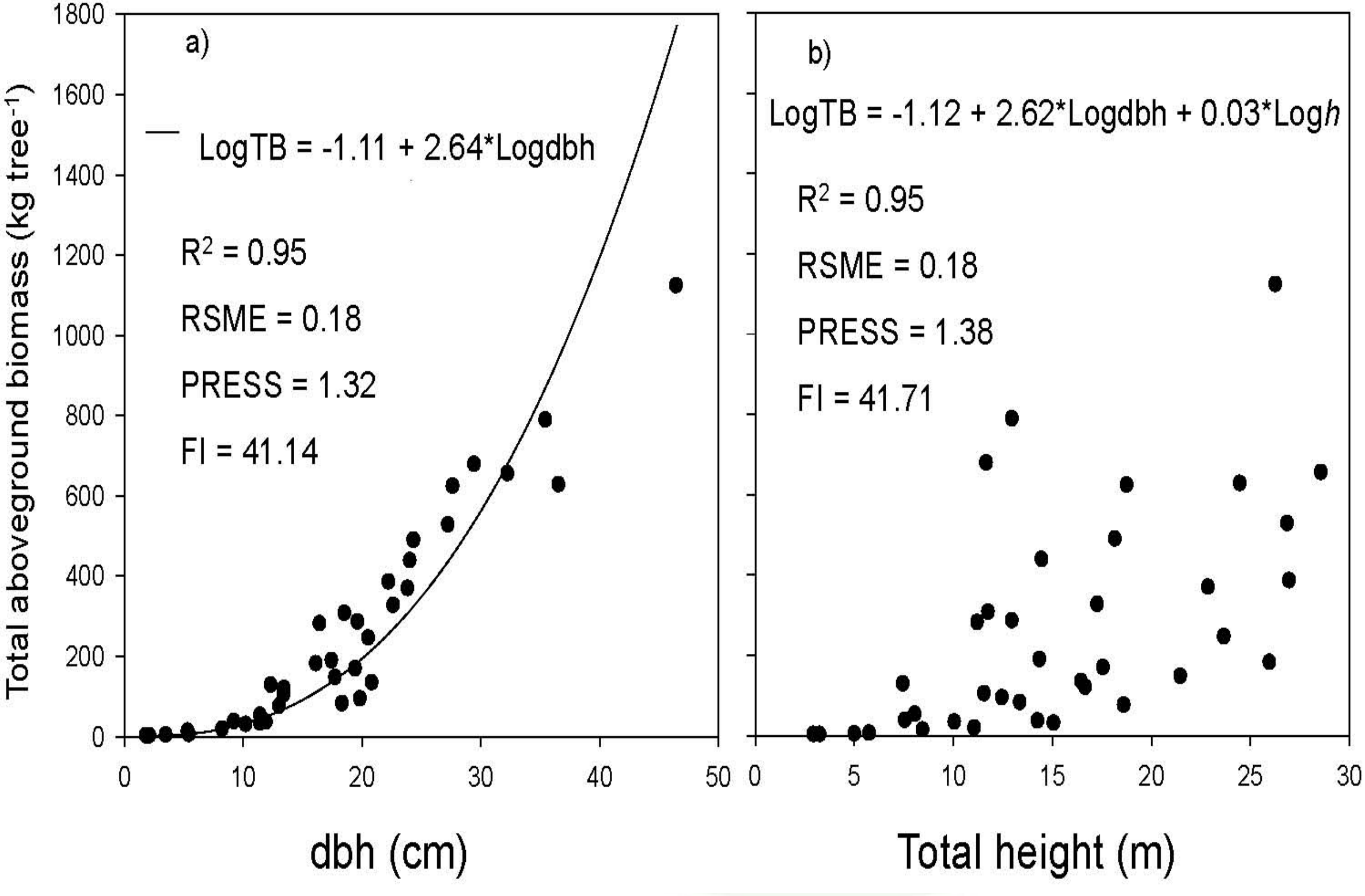
Allometric equations for *Cordia alliodora* – a dominant timber tree



Allometric equations for cacao



Allometric equations for fruit trees

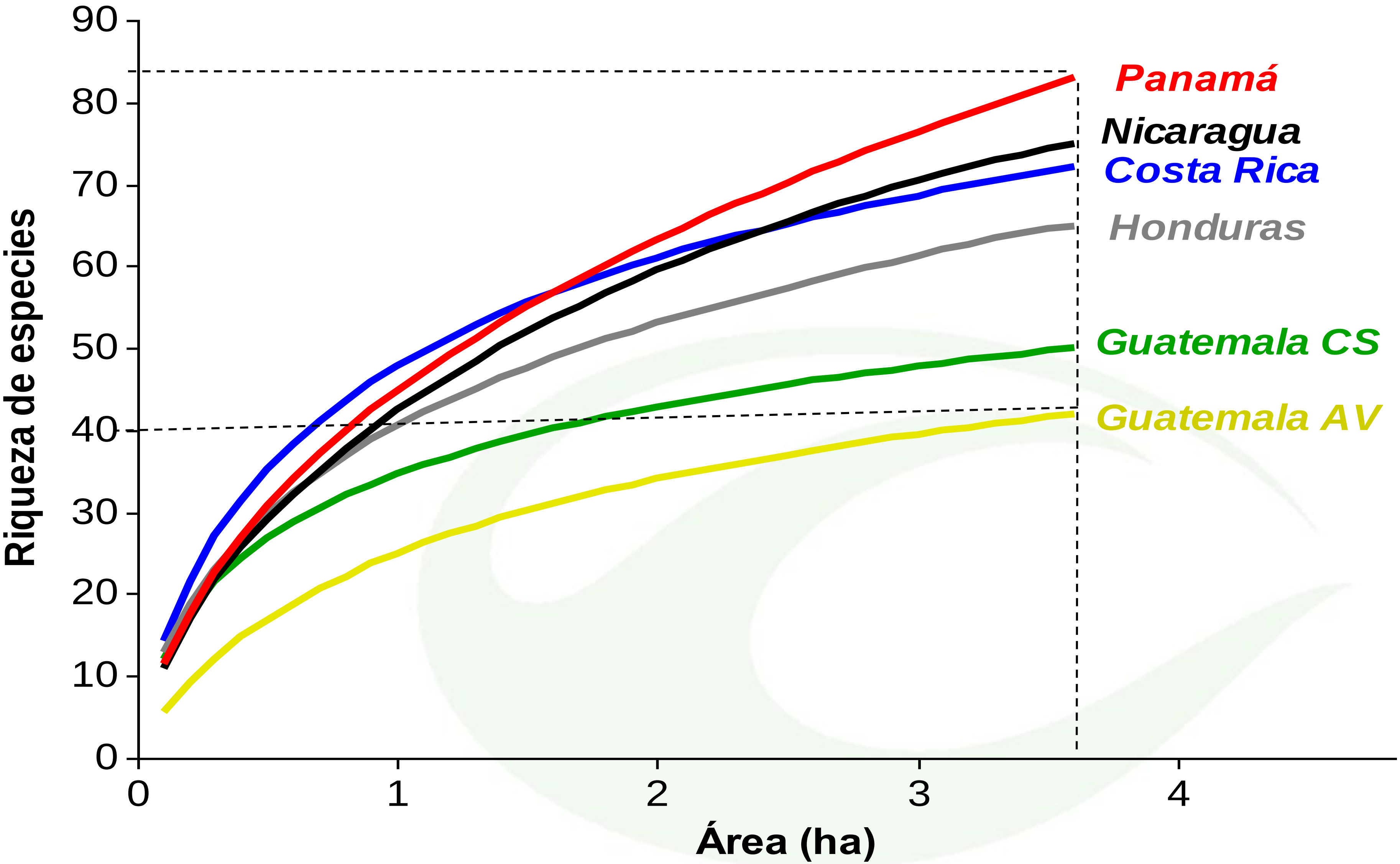


CATIE
Solutions for environment and development
Soluciones para el ambiente y desarrollo

Stand parameters

	Nicaragua	Honduras	Guatemala Alta Verapaz	Costa Rica	Panamá	Guatemala Costa Sur	Mean
			Density (trees ha^{-1})				
Timber trees	42±52 a	91±99 b	170±91 d	119±84 bc	134±77 cd	88±98 b	104±92
Fruit trees	60±57bc	35±65ab	14±23 a	84±63 c	64±149 bc	48±49 abc	52±81
Other trees	24±29 ab	18±28 a	36±43 bc	42±58 c	15±21 a	20±30 ab	25±37
Palms	8±25 ab	37±84 c	1,43±5,5 a	43±48 c	24±34 bc	22±29 bc	22±45
Bananas	158±153 b	42±74 a	0,57±2 a	193±261 bc	240±163 c	31±42 a	117±170
Cacao	**562±98 b**	**583±206 b**	**604±128 b**	**591±218 b**	**588±215 b**	**335±152 a**	**545±194**
Total	**855±192 b**	**808±299 b**	**826±157 b**	**1071±243 c**	**1065±323 c**	**544±199 a**	**866±296**
			Basal area (m^2 ha^{-1})				
Timber trees	2,2±2,9 a	6,3±5,9 b	7,1±3,5 b	8,2±5,6 b	7,5±5,1 b	8,0±7,8 b	6,4±5,8
Fruit trees	3,1±3,5 cd	1,4±3,0ab	0,5±1,0 a	1,9±1,7 bc	1,2±1,5ab	4,3±4,1 d	2,1±3,0
Other trees	1,1±1,6 a	1,1±3,1 a	1,1±1,5 a	0,9±2,2 a	1,8±3,6 ab	3,0±6,1 b	1,5±3,3
Palms	0,2±0,6 a	0,6±1,6 a	0,4±1,6 a	0,9±1,2 a	0,6±0,9 a	2,6±3,5 b	0,8±1,9
Bananas	2,7±2,7 b	0,7±1,3 a	0,02±0,1 a	3,4±4,6 bc	4,3±2,9 c	0,5±0,7 a	2,1±2,9
Cacao	**10,7±5,3 b**	**12,8±5,9 c**	**14,2±4,7 c**	**10,2±4,3 ab**	**8,2±4,1 a**	**8,6±3,2 a**	**10,7±5,1**
Total	**19,9±6,2 a**	**22,9±10,1 ab**	**23,3±7,2 bc**	**25,5±7,4 bc**	**23,6±6,2 bc**	**27,5±14,5 c**	**23,6±8,3**

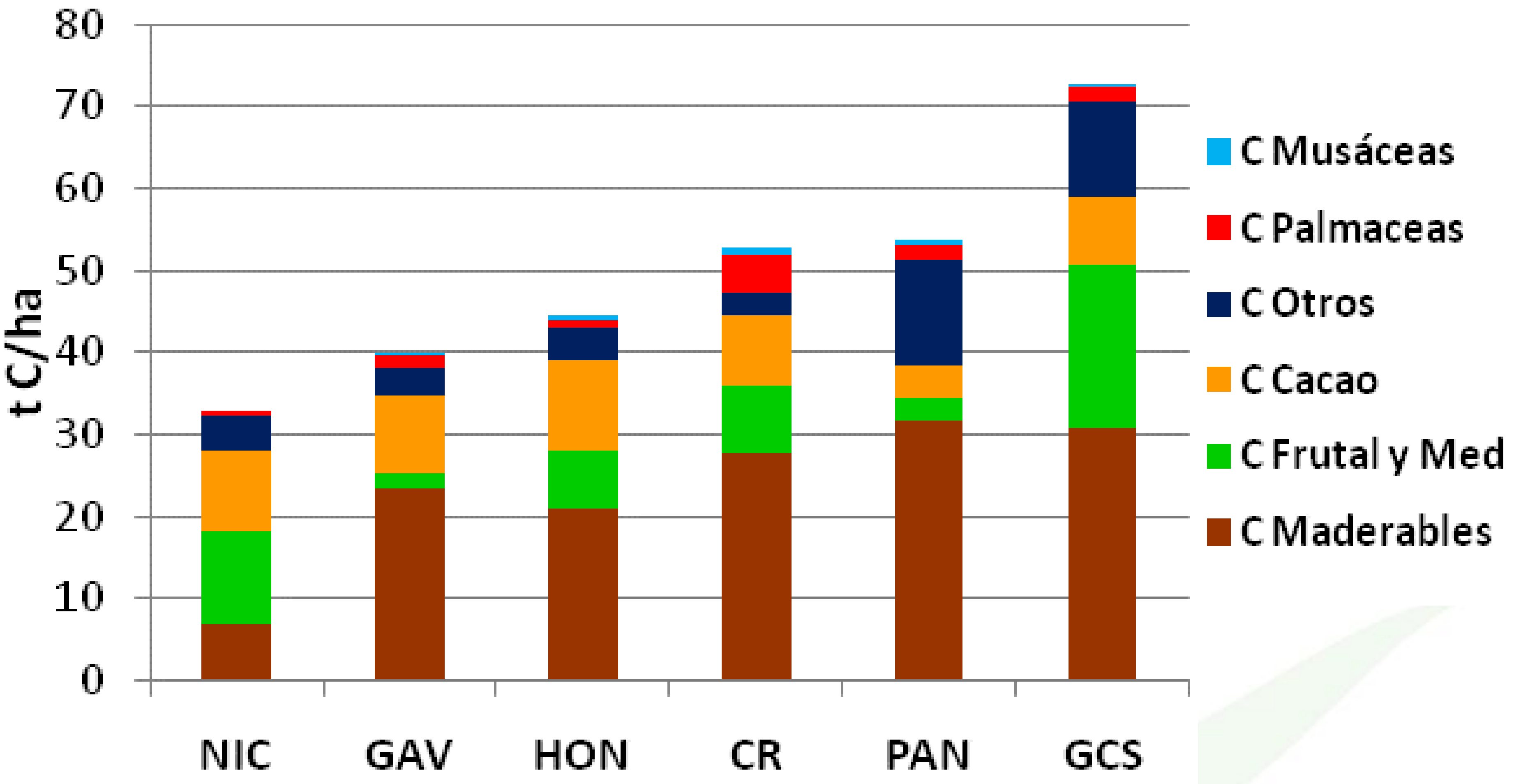
Species richness



Carbon by compartment (Mg C ha^{-1})

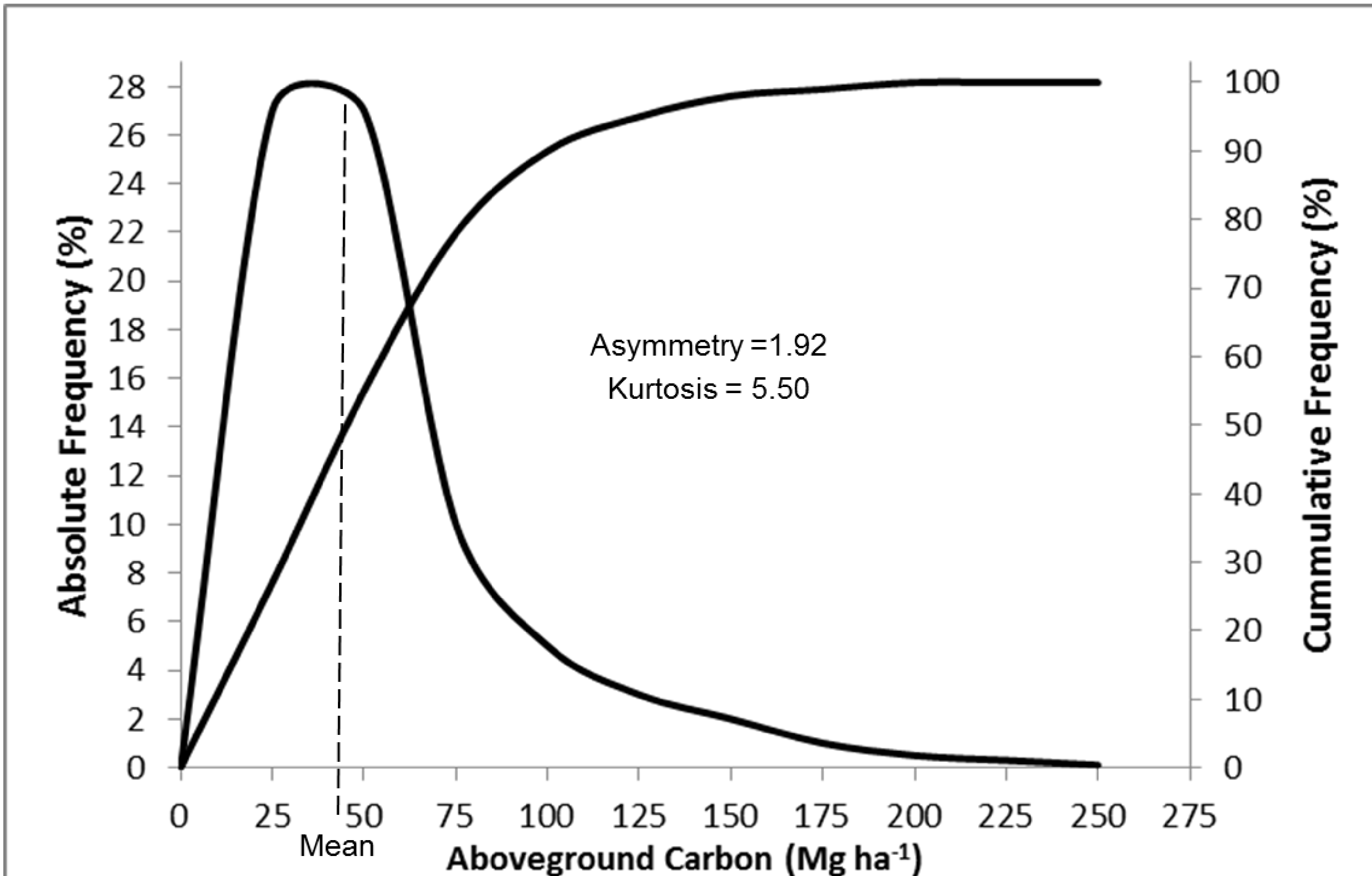
Compartment	Nicaragua	Honduras	Guatemala Alta Verapaz	Costa Rica	Panamá	Guatemala Costa Sur	Mean
Soil	**48,3±14,7 b**	**33,3±11,5a**	**52,8±10,3bc**	**49,3±8,5 b**	**56,9±13,2 c**	**64,1±13,4d**	**51,0±15,2**
Aboveground biomass	**33,1±19,5 a**	**45,1±29,0abc**	**39,4±19,4ab**	**52,7±21,7bc**	**56,7±47,4c**	**74,4±47,0 d**	**49,2±34,9**
Thick roots	6,9±3,6 ab	9,4±5,4 bc	6,6±3,6 a	9,3±3,6 bc	11,5±8,3 cd	13,4±8,0 d	9,6±6,2
Thin roots	3,8±2,5 c	1,3±0,8 a	1,4±1,1 a	1,9±0,9ab	2,1±0,9 b	1,6±0,8 ab	2,1±1,7
Coarse necromass	0,01±0,06 a	6,2±4,8c	3,7±5,1 b	6,2±5,1 c	3,2±4,9 b	0,02±0,07 a	3,0±4,7
Fine necromass	0,3±0,1 b	0,1±0,1 a	1,2±0,1 d	1,2±0,5 d	0,7±0,4 c	0,3±0,1 b	0,6±0,5
Litter	0,3±0,1 a	0,8±0,4bc	0,4±0,2 ab	1,2±0,4 d	0,9±0,3 c	3,6±1,8 e	1,1±1,3
Total	**93±30 a**	**96±37a**	**106±25ab**	**122±24bc**	**132±60 c**	**155±58 d**	**117±47**

Carbon in above ground biomass

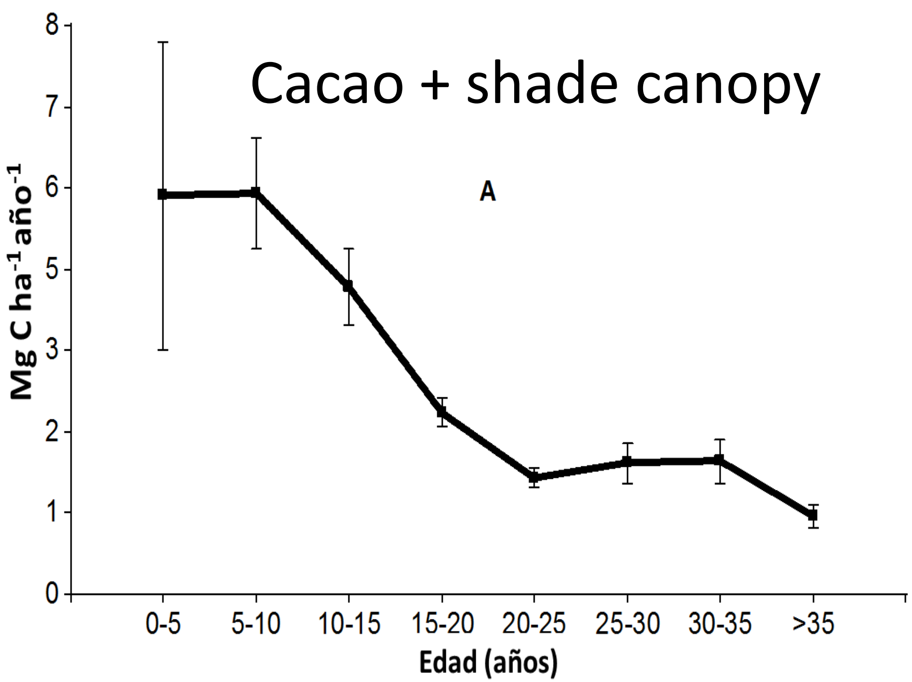


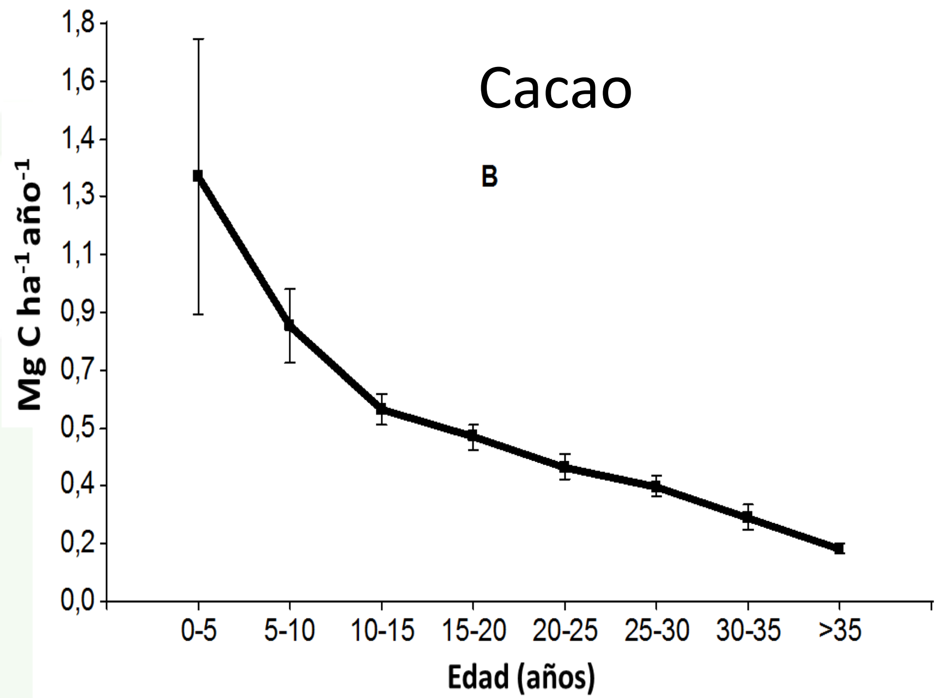
% del C Total	36	38	38	43	42	47

Frequency distribution parameters for above ground biomass



Carbon accumulation rate by plantation age for both above ground vegetation and cocoa biomass (Mg C ha^{-1} año^{-1})





Estimated monetary value of carbon stocks and annual accumulation rates (US$ ha^{-1})

Variables	Nicaragua	Guatemala Alta Verapaz	Honduras	Costa Rica	Panamá	Guatemala Costa Sur	Mean
CO_2 aboveground biomass (Mg CO_2 ha^{-1})	121	143	165	194	209	272	184
Rate CO2 aboveground biomass (Mg CO_2 ha^{-1} $year^{-1}$)	7	10	10	11	8	14	10
Value CO_2 aboveground biomass	605	716	826	972	1046	1358	920
Value accumulation rate CO_2 in aboveground biomass	35	48	48	54	40	71	49

Mg CO_2 = Mg C x 3,67; US$ = Mg CO_2 x 5 us$ [Mg CO_2]$^{-1}$

There is room for improvements

- Properly managing self-shading by timely and well designed cocoa prunings (also positively affecting cocoa yields)
- Optimal shade canopy design
  - Tall timber trees ("sequioia tree model")
  - Light, sparse crowns (e.g. species with small leaves such as Mimosoidae; reversed phenology)

Conclusions

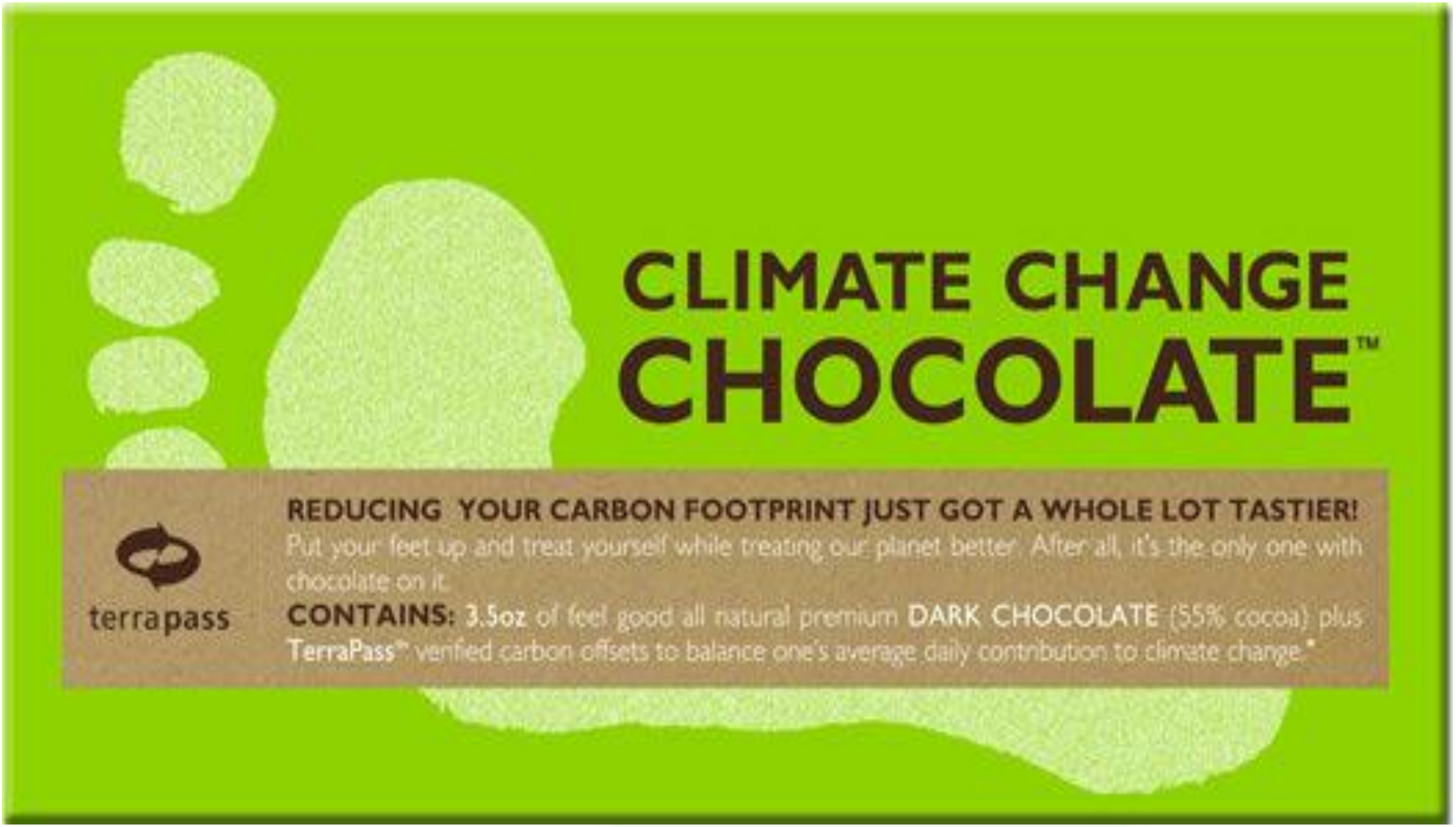
1. Carbon stocks measured in Central America fall within the range measured in other places around the world (32- 95 Mg C ha^{-1})
   - Stock total carbon total: 117±47 Mg ha^{-1} (93-155 Mg ha^{-1})
   - Accumulation rates: 6.4 Mg C ha-1 $año^{-1}$
   - Aboveground carbon: 49±35 Mg C ha^{-1} (33-74 Mg C ha^{-1})
   - Accumulation rate: 2.6 Mg C ha^{-1} $año^{-1}$
2. Most carbon is stored in trees (specially tall timber trees) and in soil
3. Comparing carbon stored in the soil can not be made due to different sampling schemes (e.g. variable soil depths)

Solutions for environment and development
Soluciones para el ambiente y desarrollo

Reflections

1. Estimating carbon stocks and accumulation rates is expensive and market prices for additional carbon are low.
2. Certifying and selling carbon is equally expensive
   - This may be changing. New market options are opening (including more options for certification)
3. Carbon accumulation rates can provide only a modest complementary income to farmers.
4. Valuing carbon stocks in aboveground biomass and soils could provide a more significant financial income for farmers

Carbon foot-printing and markets



A wide range of certification & standards schemes available

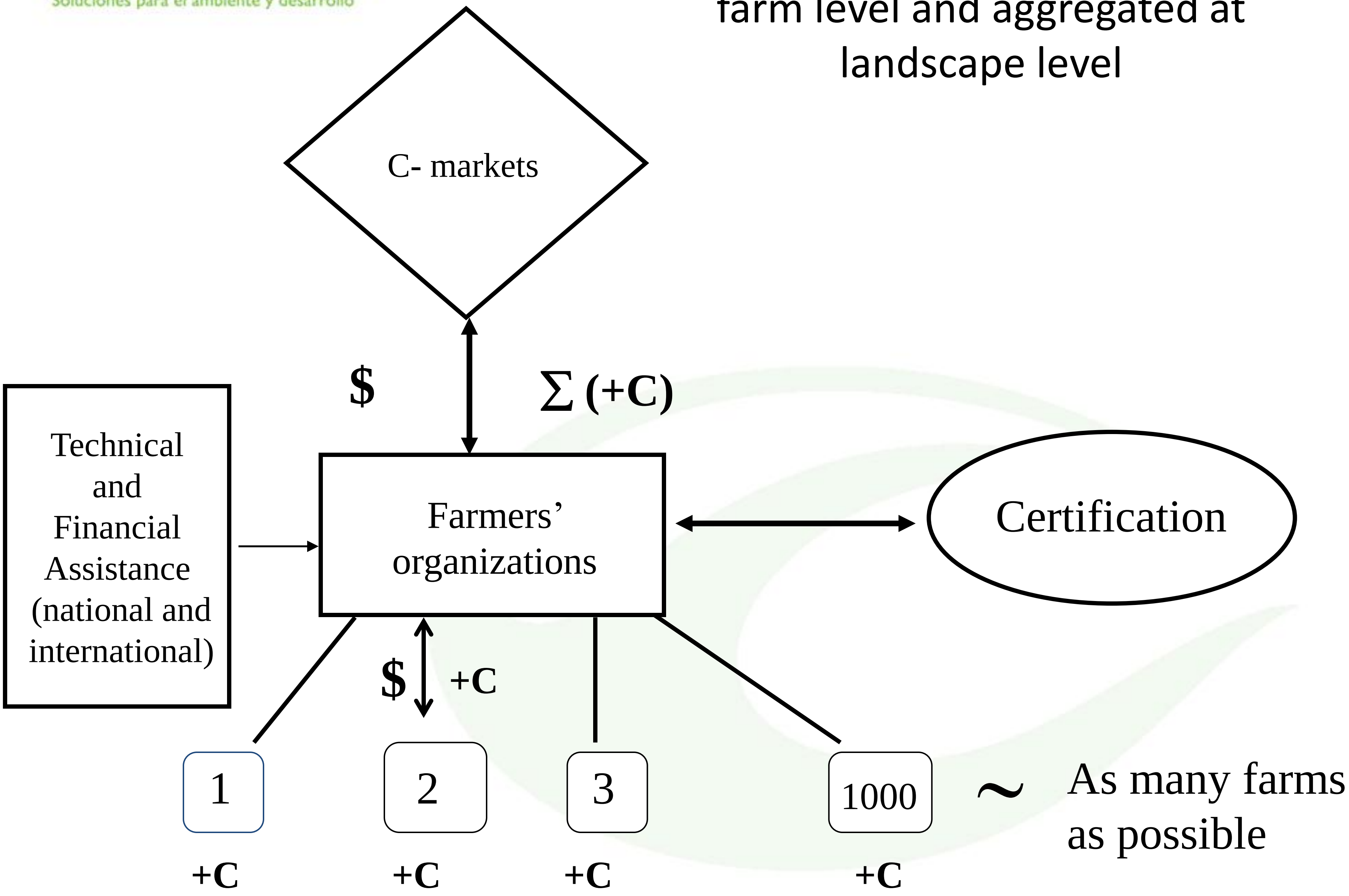
Standard	Mechanism		Involves			Source
	MVC	MDL	C	S	B	
The climate, community & Biodiversity Alliance (CCB)	X	X	X	X	X	http://www.climate-standards.org/index.html
Verified Carbon Standard (VCS)	X		X			http://v-c-s.org/
The gold standard	X	X	X	X	X	http://www.cdmgoldstandard.org/
Social Carbon Standard	X		X	X	X	http://www.socialcarbon.org/
Forest stewardship council (FSC)	X		X	X	X	http://www.fsc.org/77.html
American Carbon Registry Standard (ACRS)	X	X	X	X	X	http://www.americancarbonregistry.org/
Carbco Platinum Carbon Standard	X		X	X	X	http://www.cquestor.com/
Carbon Fix Standard (CFS)	X		X	X	X	http://www.carbonfix.info/
EPA Climate Leaders Offset Guidance	X		X			http://www.epa.gov/
Panda Standard	X		X	X	X	http://www.pandastandard.org/
Plan Vivo	X		X	X	X	http://www.planvivo.org/standard/
VER+ Standard	X	X	X			http://www.tuev-sued.de/
Chicago Climate Exchange (CCX)	X		X			https://www.theice.com/ccx.jhtml
Green-e Climate	X		X			http://www.green-e.org/
WRI/WBCSD GHG Protocol for Project Accounting	X	X	X			http://www.ghgprotocol.org/
Rain Forest Alliance	X	X	X	X	X	http://www.rainforest-alliance.org/

C: carbon; S: social; B: biodiversity

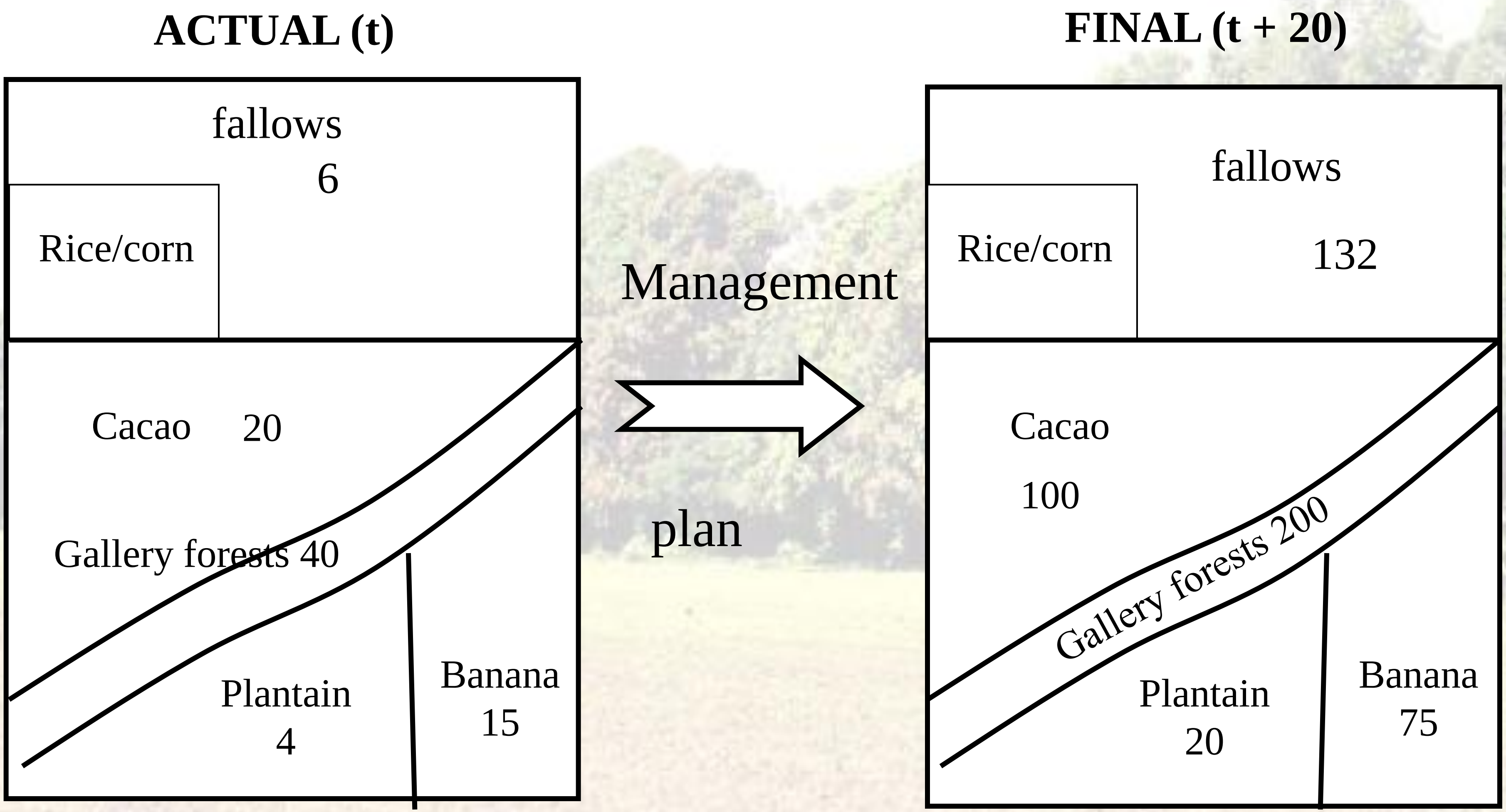
Reflections

- Appropriate market models for small cocoa farmers to benefit from stored carbon are badly needed
- Results from this study may help:
  – Farmers to access “environmental markets” for their cocoa and other goods and services from their cocoa plantations
  – Governments fo formulate national strategies for adaptation and mitigation to climate change
  – Governments to comply with international agreements regarding climate change

For trading, +C must be fixed at farm level and aggregated at landscape level



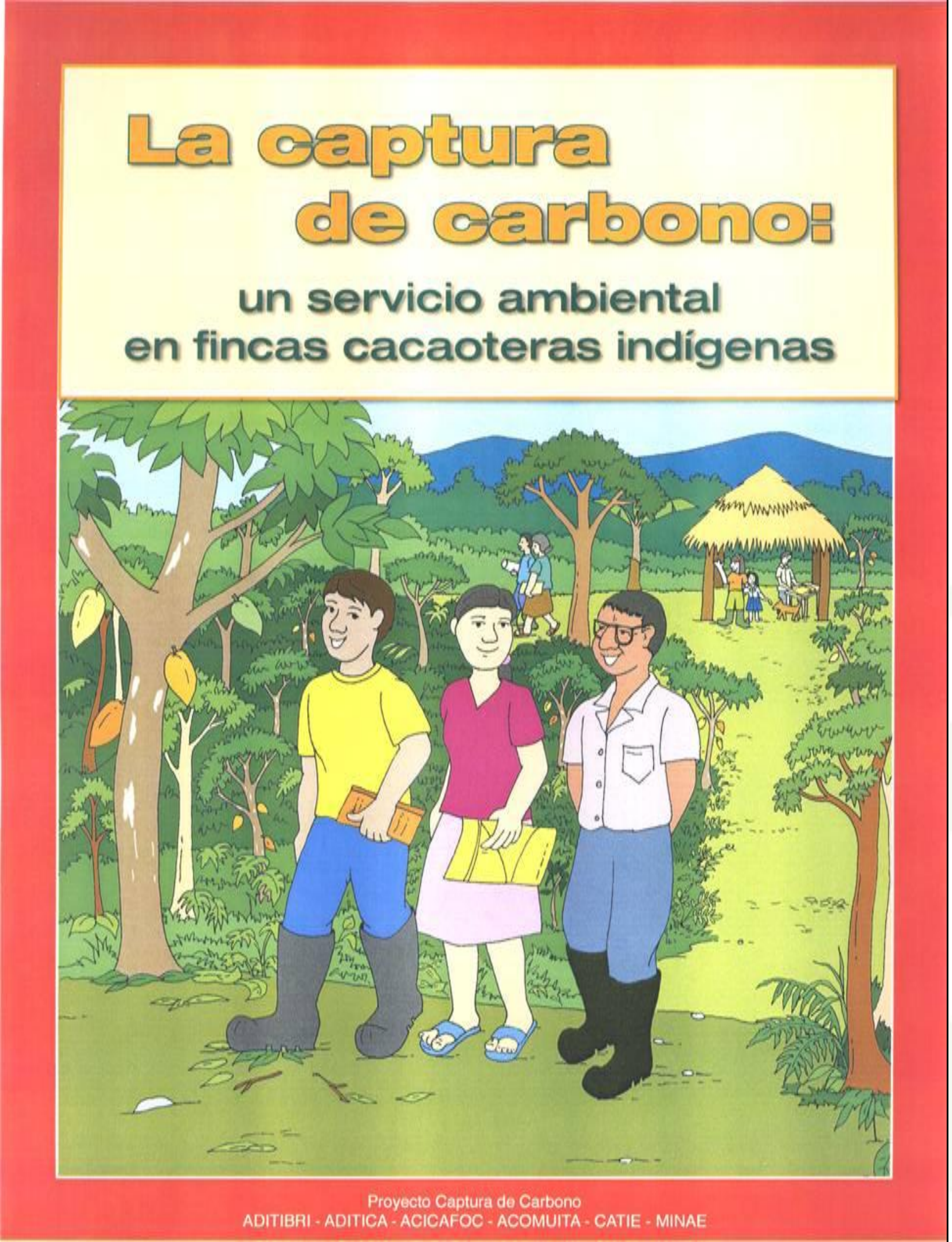
+C at the farm level



C Total = 85

Total = 527

+C = 442



- Both scientific and popular publications on Carbon sequestration and other environmental services are urgently needed
- We need better forestry laws to estimulate the planting and use of trees in farms


NEED CASH
FOR ALCOHOL
RESEARCH
Thank you