Biogeochemical Cycles in Amazonia: Evolution of Nutrient Cycling in Central Amazonian Agro-forestry Systems

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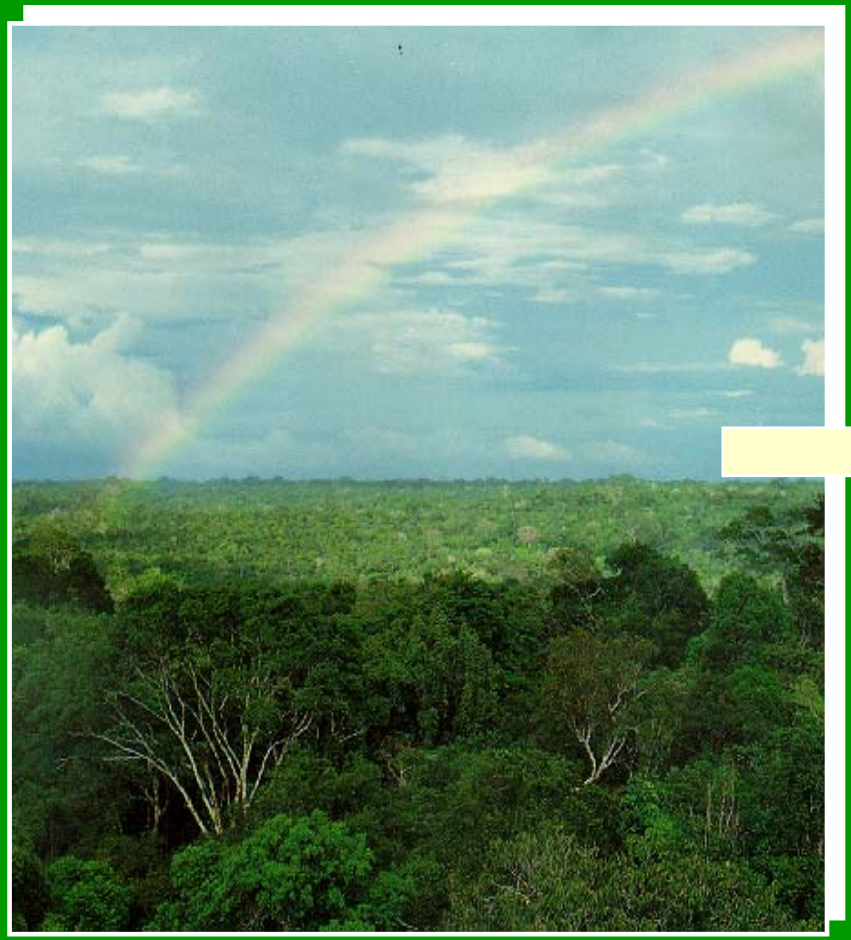
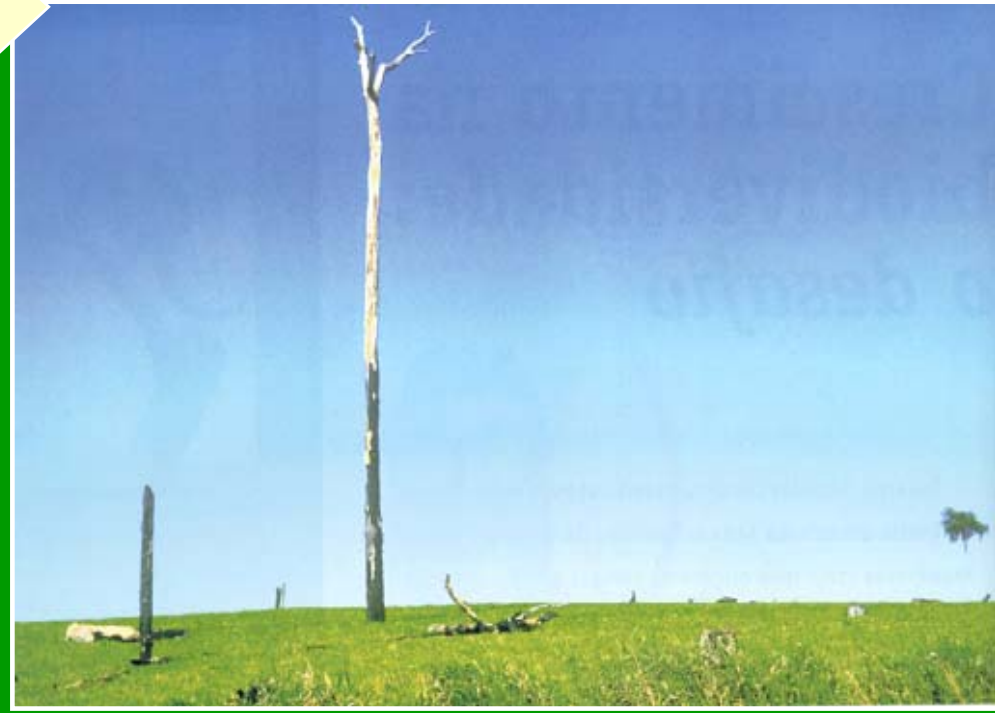
Oxisols: Low cation exchange capacity (CTC)
Low water holding capacity
Good soil aggregation and structure

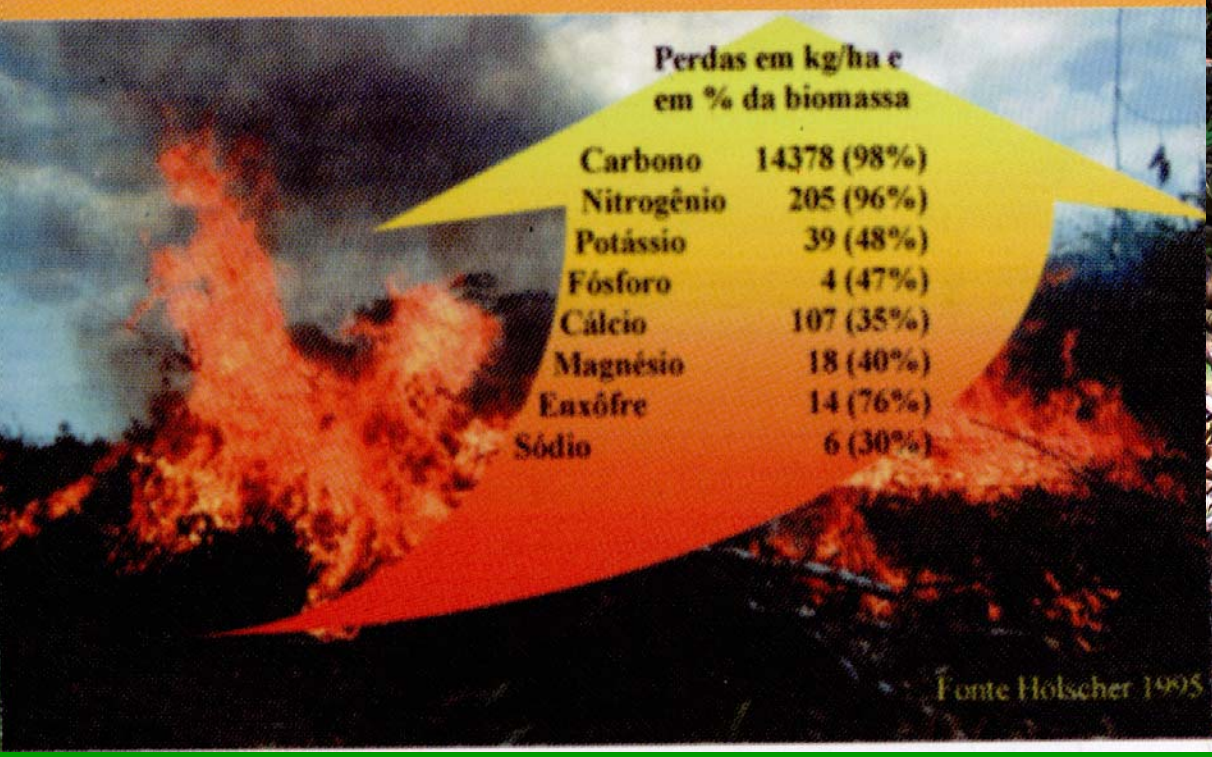
Converting a highly diversified forest…. into a pasture planted with just one (generally exotic) grass species….





Strong impacts expected, because:

Perdas de elementos pela queima de uma capoeira de 7 anos de idade



Nutrient losses from biomass burning
(mainly N, S, K)

No litter cover of soil surface
No litter nutrient inputs

Guidelines for optimizing soil biota and organic matter recycling:

- Keeping soil surface always covered X
- Adding green manures to soil surface X
- Selecting plant species which produces biomass with high nutritional quality X
- Keeping soil and plant biodiversity X

Thus: soil conditions deteriorate quickly!

Fallow system after abandonment

CAPOEIRA (CAP) = natural second growth

Low biomass; low plant diversity; exposed soil surface; very low soil nutrient availability; poor soil structure and biological activity


2 year old AF

Are the AFS sustainable (nutrient cycling mechanisms)

3 year old

5-6 year old

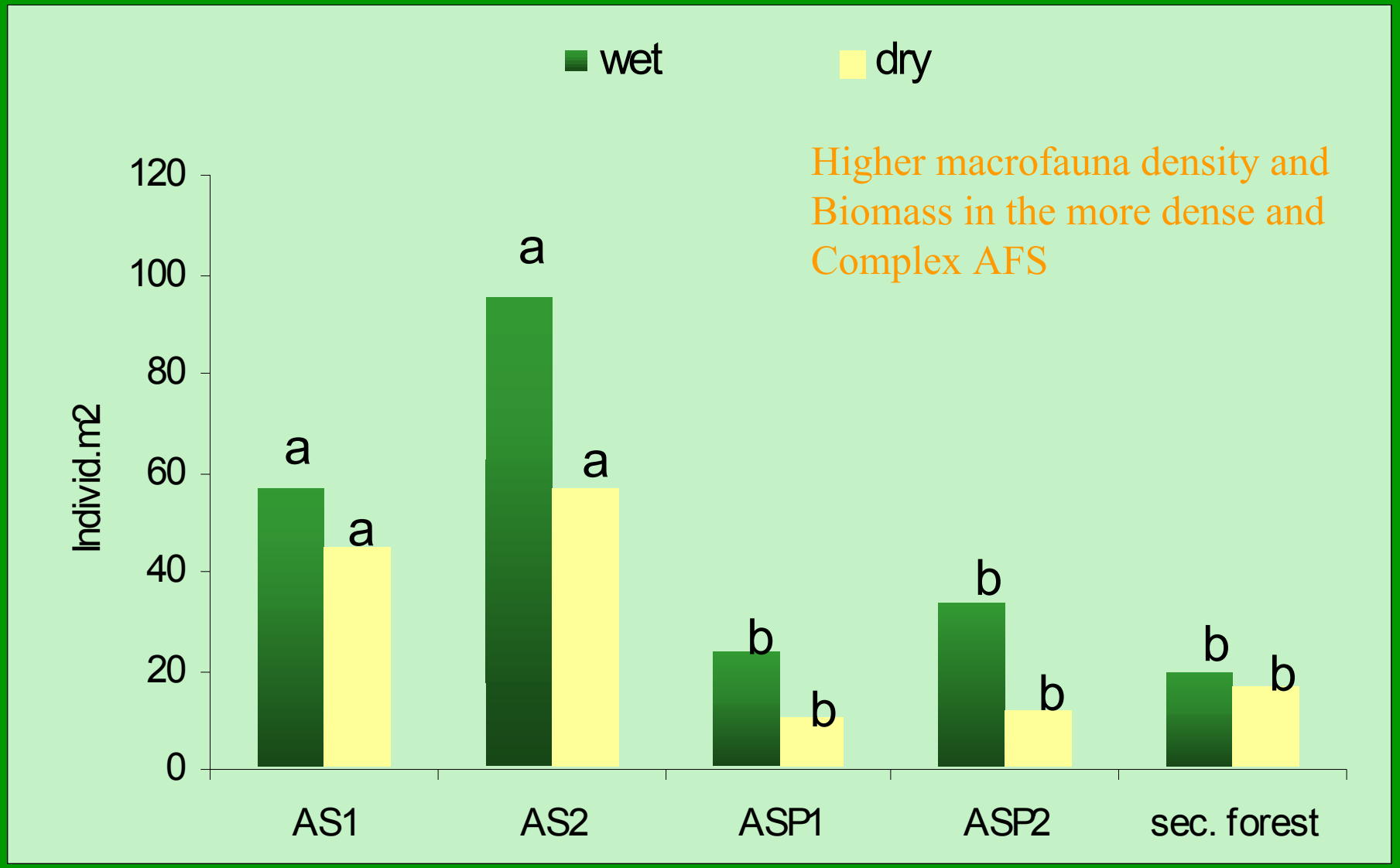
Carbon and nutrient stocks (kg ha^{-1}) in the litter-layer of AFS (AS1 = palm/fruits; ASP1 = grass/legume cover) and second growth, in the dry season.
Tapia-Coral et al. 2005

AFS 5-6 year old

Systems	C	N	P	K	Ca	Mg
AS1	2168	45.1 a	0.57 a	5.75 a	35.5 a	10.6 a
ASP1	1888	52.9 a	0.42 a	4.56 a	41.7 a	7.75 a
CAP	3966	82.6 b	0.68 b	11.8 b	50.2 b	11.8 b

Concentrations of C, N (%), P, K, Ca and Mg (g kg^{-1}) of the litter layer (leaves), in the dry season, under the dominant plant species within the AFS and in the second growth

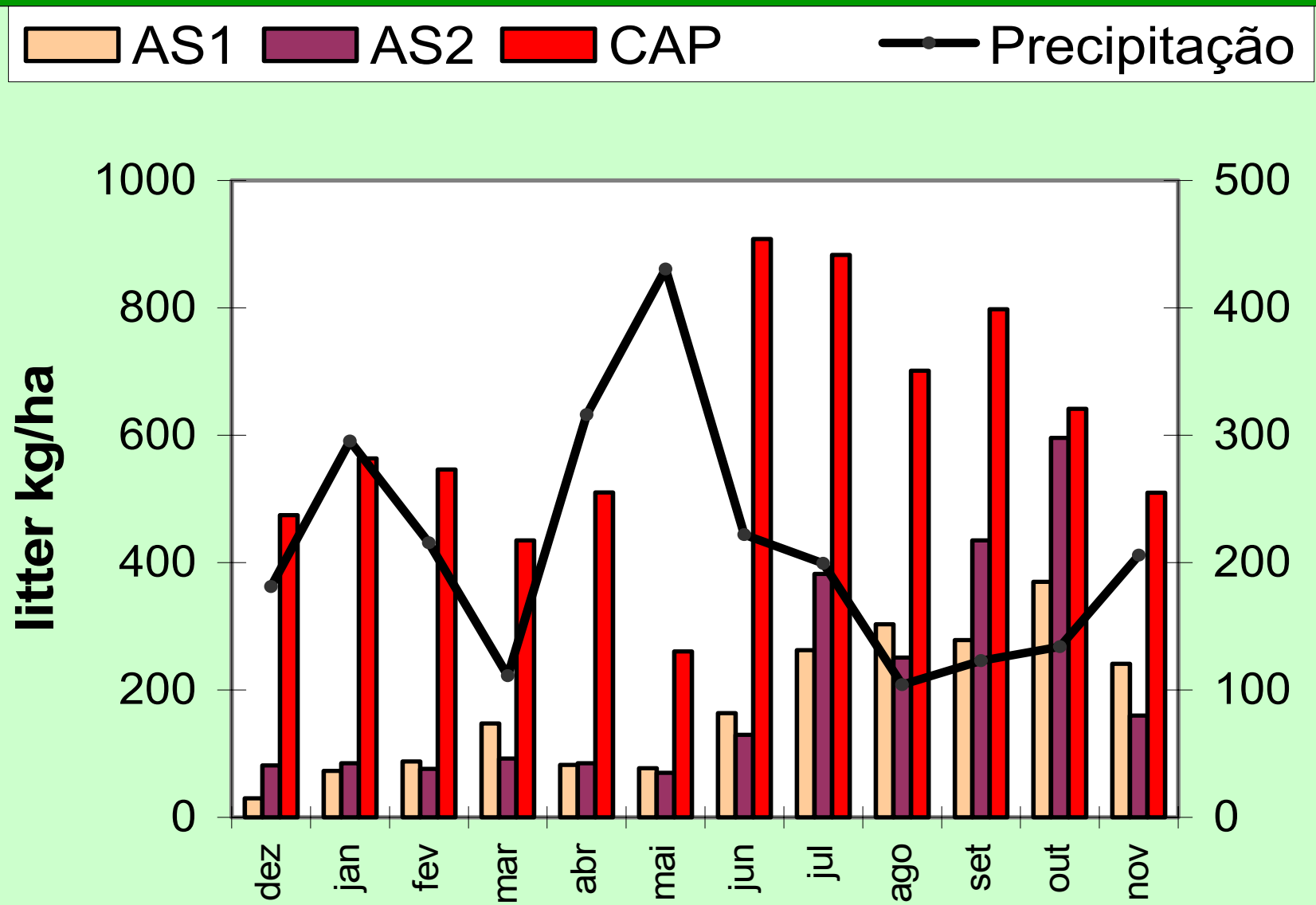
Plant species	C	N	P	K	Ca	Mg
'Cupuaçu'	52.0 ±0.1b	1.20 ±0.3a	0.14 ±0.1a	1.58 ±0.4a	8.99 ±2.2a	1.39 ±0.3a
Palms	45.2 ±0.0a	1.03 ±0.1a	0.16 ±0.0b	1.26 ±0.4a	9.28 ±3.2a	1.45 ±0.3b
Timber spp.	52.4 ±9.1b	1.63 ±0.2b	0.15 ±0.0b	1.94 ±0.6b	11.1 ±0.6a	1.31 ± 0.2b
Desmodium	49.4 ±1.0a	1.62 ±0.3b	0.12 ±0.0a	1.18 ±0.2a	9.0 ±2.5a	1.29 ±0.2a
Brachiaria	47.3 ±0.1a	1.67 ±0.2b	0.12 ±0.0a	1.09 ±0.2a	8.95 ±2.8a	1.34 ±0.3b
Inter-rows	59.6 ±15b	1.15 ±0.2a	0.17 ±0.0b	1.63 ±0.7a	10.7 ±4.9a	1.09 ±0.3a
Pioneer sp	50.6 ±0.0a	1.08 ±0.0a	0.09 ±0.0a	1.55 ±0.4b	6.45 ±0.6a	0.99 ±0.1a



Litter Macrofauna density in agroforestry systems and secondary forest (5 years old). Tapia-Coral et al. 1999.

Litterfall dynamics

6 year old AFS
J. Gallardo 1999



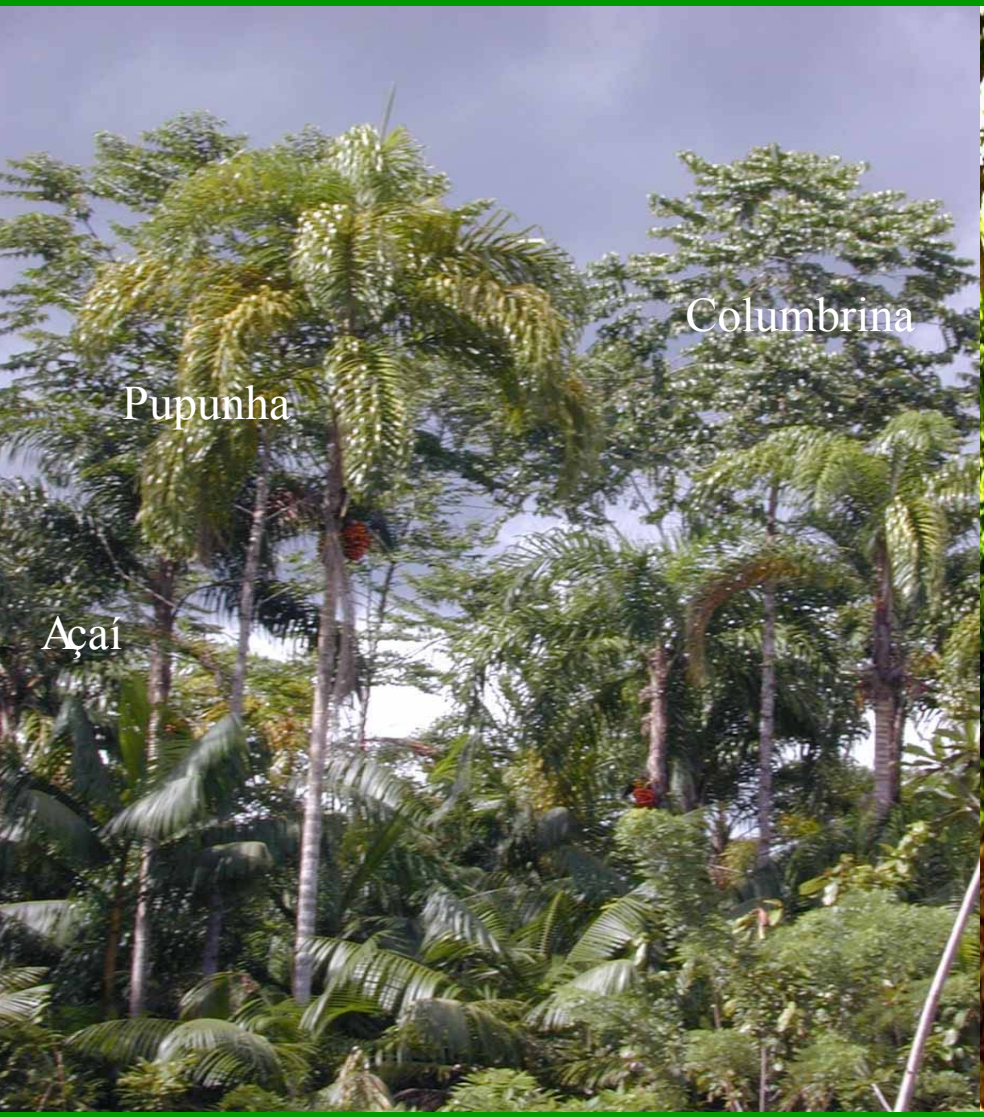
Nutrient input ($kg.ha^{-1}.yr^{-1}$) in two agroforestry systems (AS1 and AS2), and in the second growth (CAP). Values in parentheses represent the proportion (in %) of the contribution of litterfall and prunings for the total nutrient inputs in the SAFs.

Treatment	N	P	K	Ca	Mg
AS1					
Litterfall	36.8 (54%)	2.35 (72%)	5.76 (48%)	32.7 (92%)	8.64 (80%)
Prunings	16.8 (46%)	0.94 (28%)	6.23 (52%)	2.87 (8%)	2.11 (20%)
Total	**53.6**	**3.29**	**12.0**	**35.6**	**10.8**
AS2					
Litterfall	36.3 (60%)	1.90 (59%)	5.01 (37%)	28.7 (84%)	8.58 (45%)
Prunings	24.5 (40%)	1.33 (41%)	8.57 (63%)	5.31 (16%)	10.8 (55%)
Total	**60.8**	**3.23**	**13.6**	**34.0**	**19.4**
CAP					
Litterfall=Total	**64.1**	**3.82**	**12.6**	**45.2**	**13.6**

AFS = 6 year old Source: J. Gallardo 1999

Fine litterfall: AS1 = 2.2 Mg/ha AS2 = 2.1 Mg/ha CAP = 8 Mg/ha per year

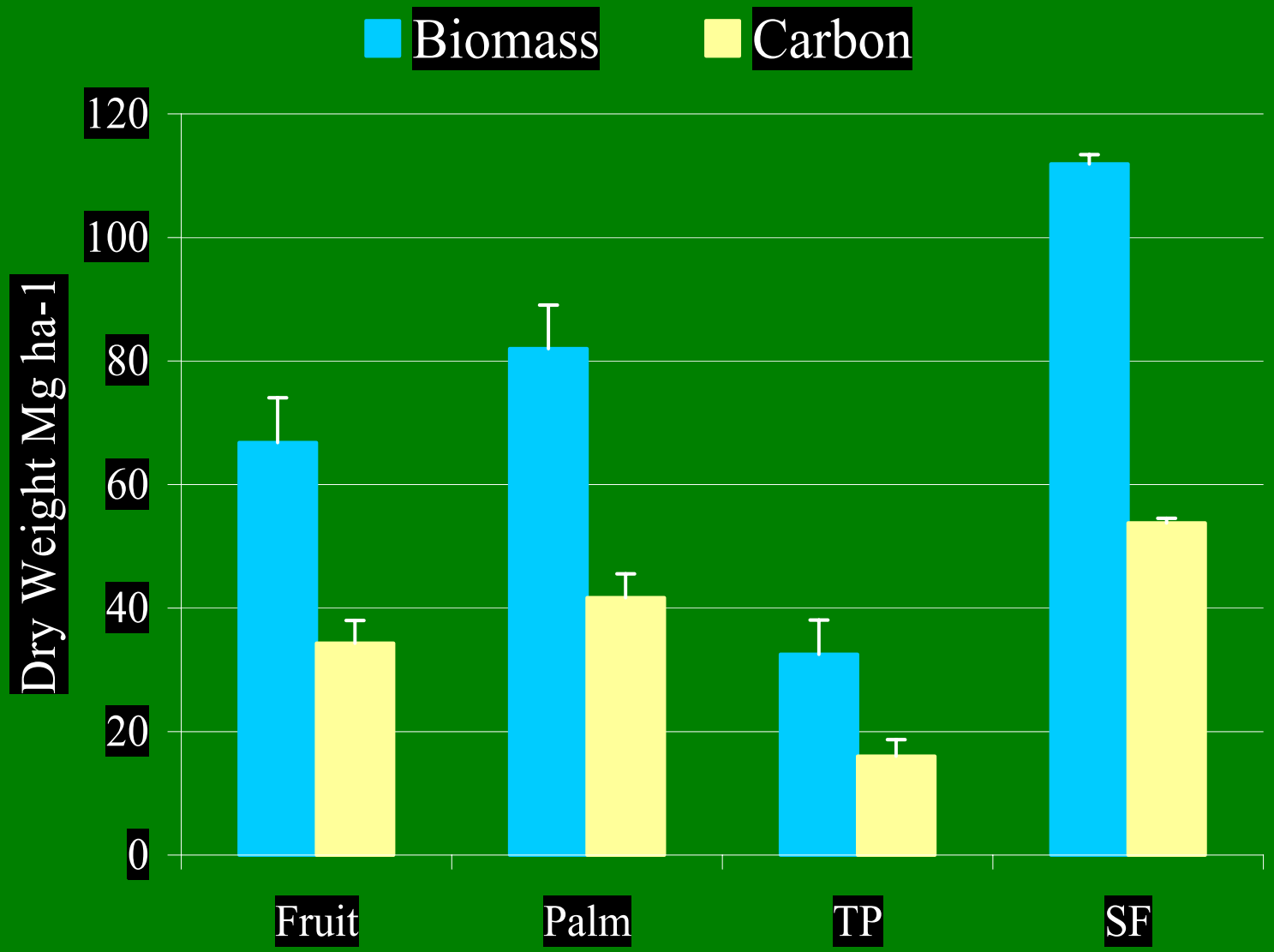
9 year old AFS



Sistema agrossilvicultural AS1

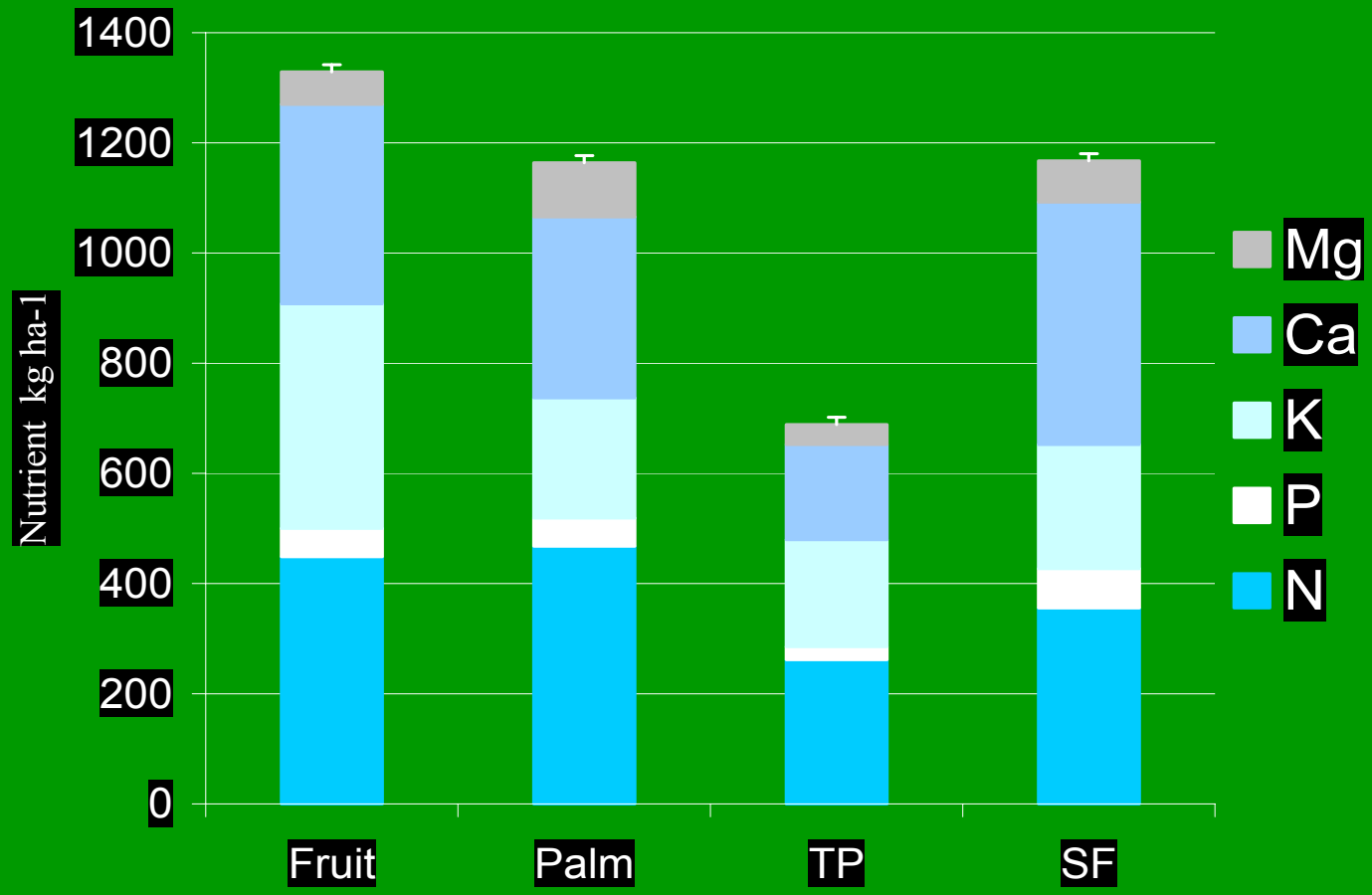
ASP1 – timber trees + pasture

Above Ground Biomass and Carbon in Agroforestry Systems and Secondary Forest at 9 years (*n* = 3)



McCaffery, Fernandes, Wandelli, Rondon, 2002

Nutrient stocks in the aerial biomass in AFS (9 year old) and second growth

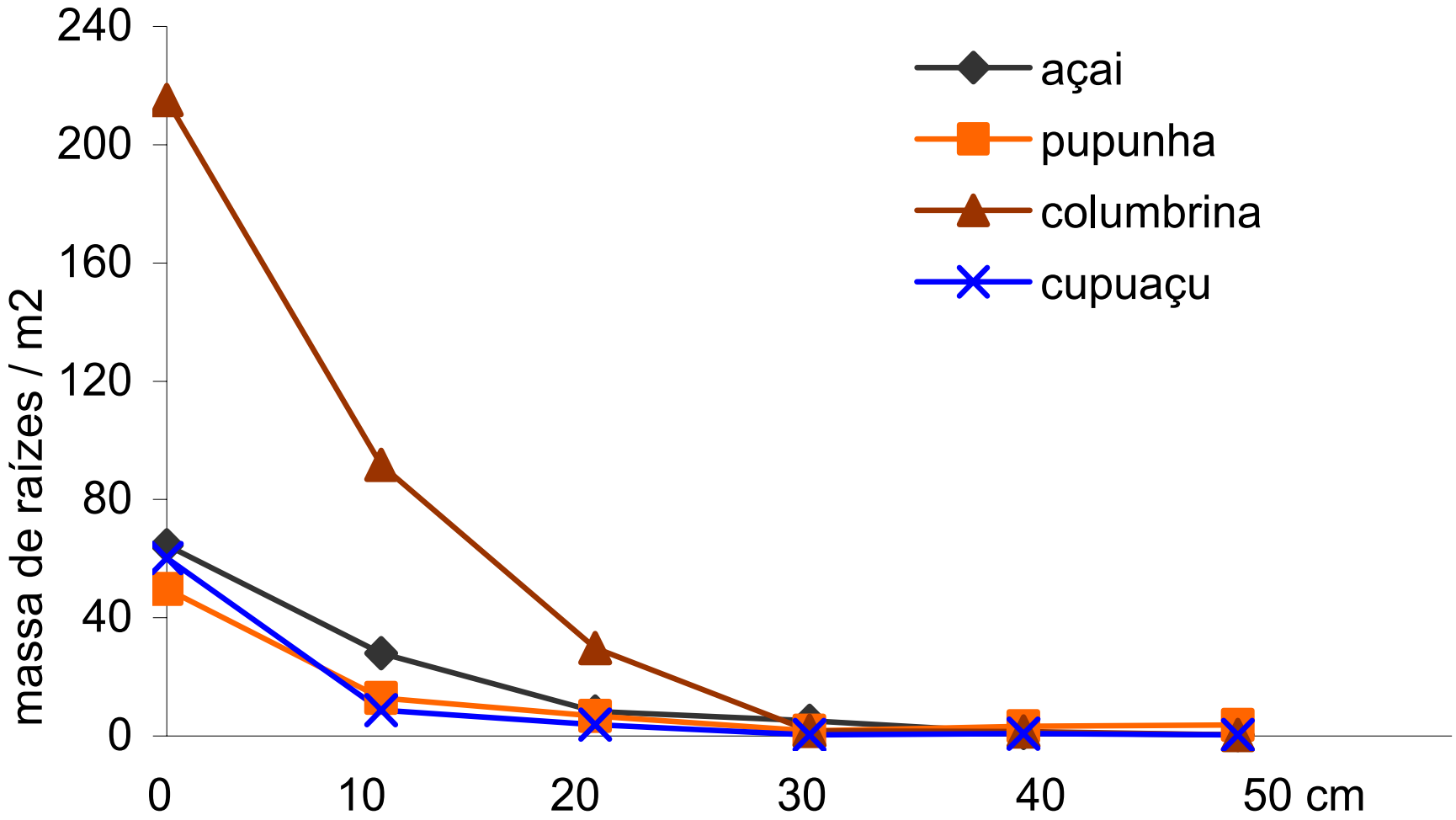


McCaffery, Fernandes, Wandelli, Rondon, 2002

Sampling for coarse root biomass in AFS

Roots x tree species

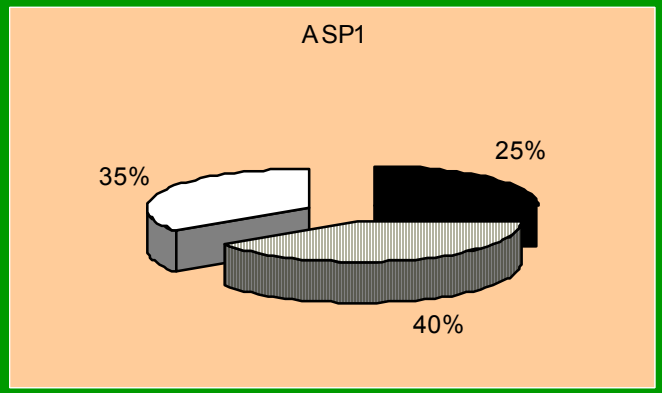
11 year old AFS
Gallardo 2004

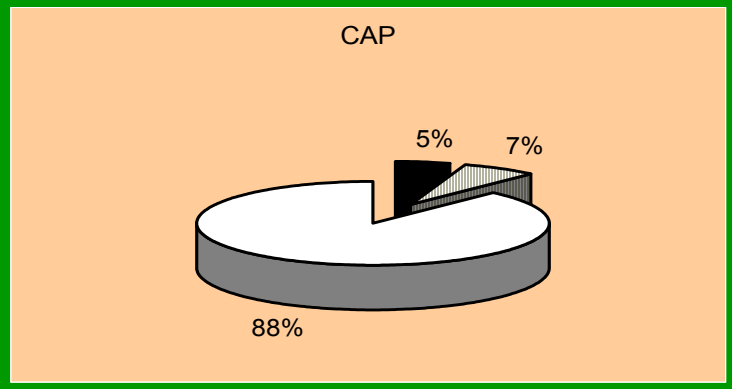


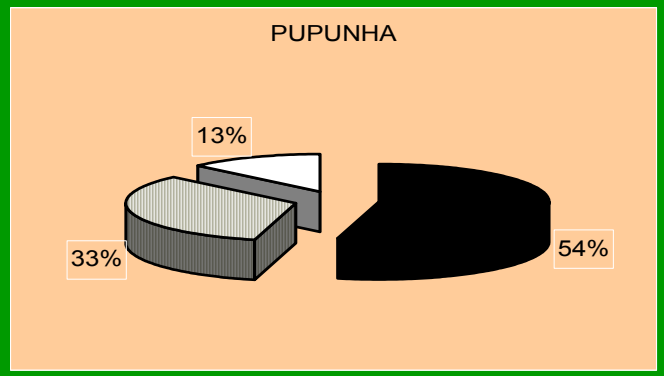
AFS= 11 years Source: Gallardo, 2004

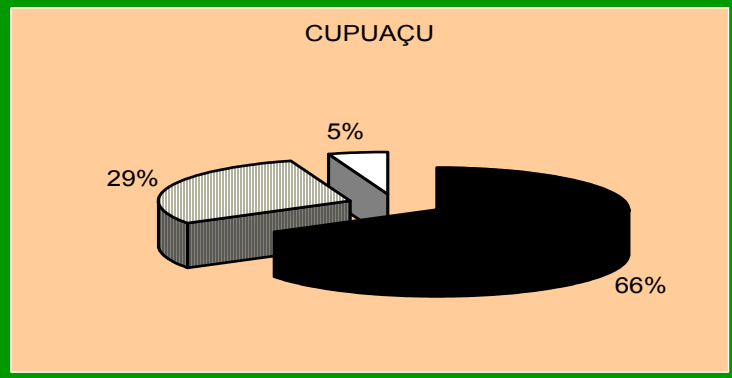
Root carbon and nutrient stocks up to 1 m depth in soil (kg.ha^{-1}) in the AFS based on palms (AS1) and legume-pasture (ASP1), and in second growth (CAP).

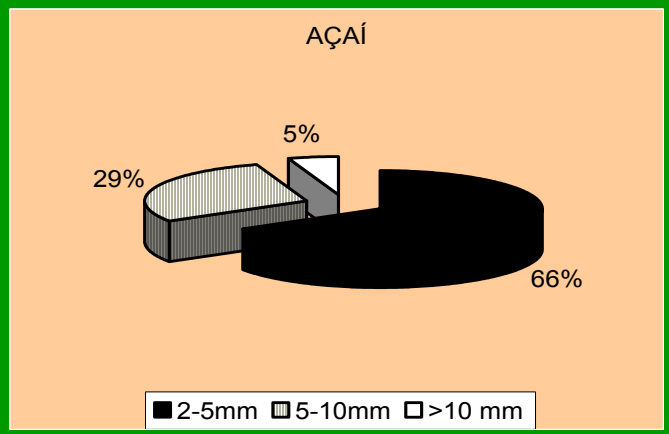
Systems	C	N	P	K	Ca	Mg
AS1	5898	1192	9,13	30,2	45,2	15,2
ASP1	1907	460	1,42	14,0	21,1	5,42
CAP	17206	5615	17,0	44,0	44,0	20,8

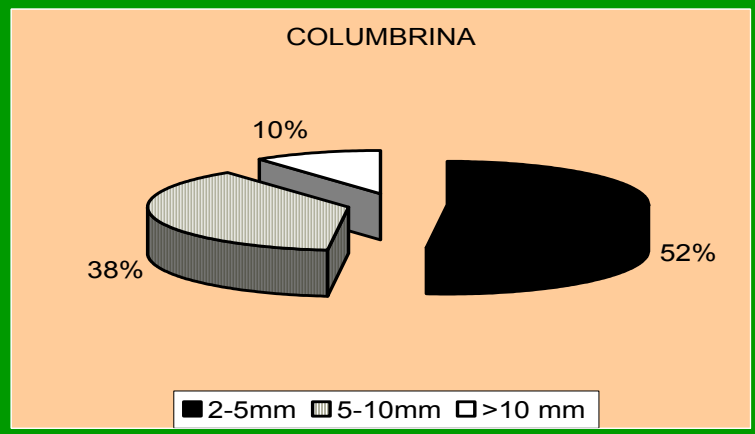




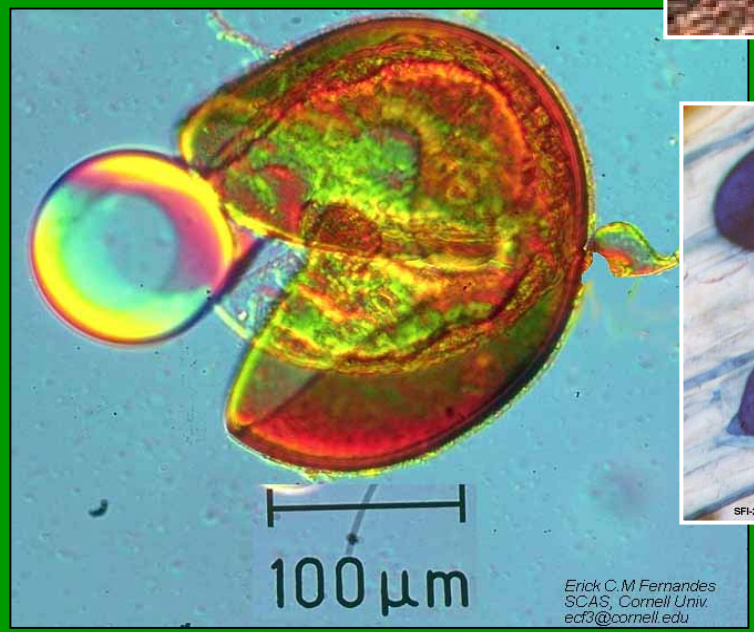








Relative contribution of the different diameter classes to the total root biomass in the systems and species


100 µm
Erick C.M Fernandes
SCAS, Cornell Univ.
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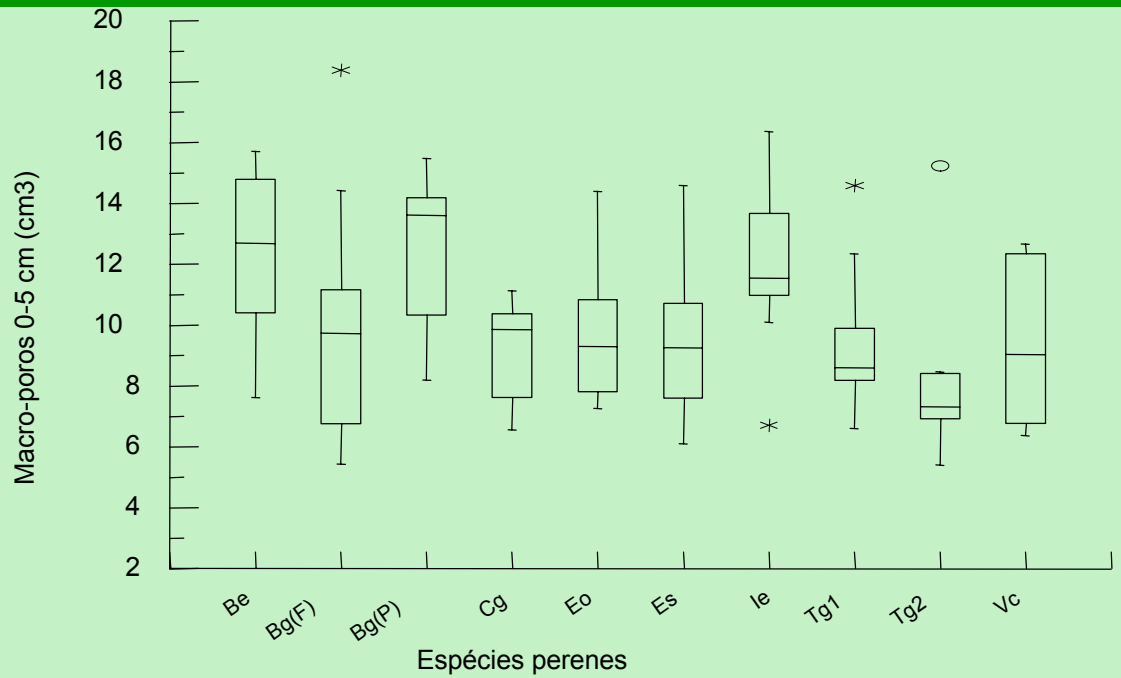
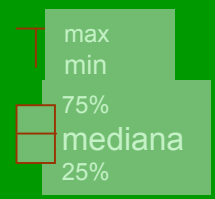
SFI-2



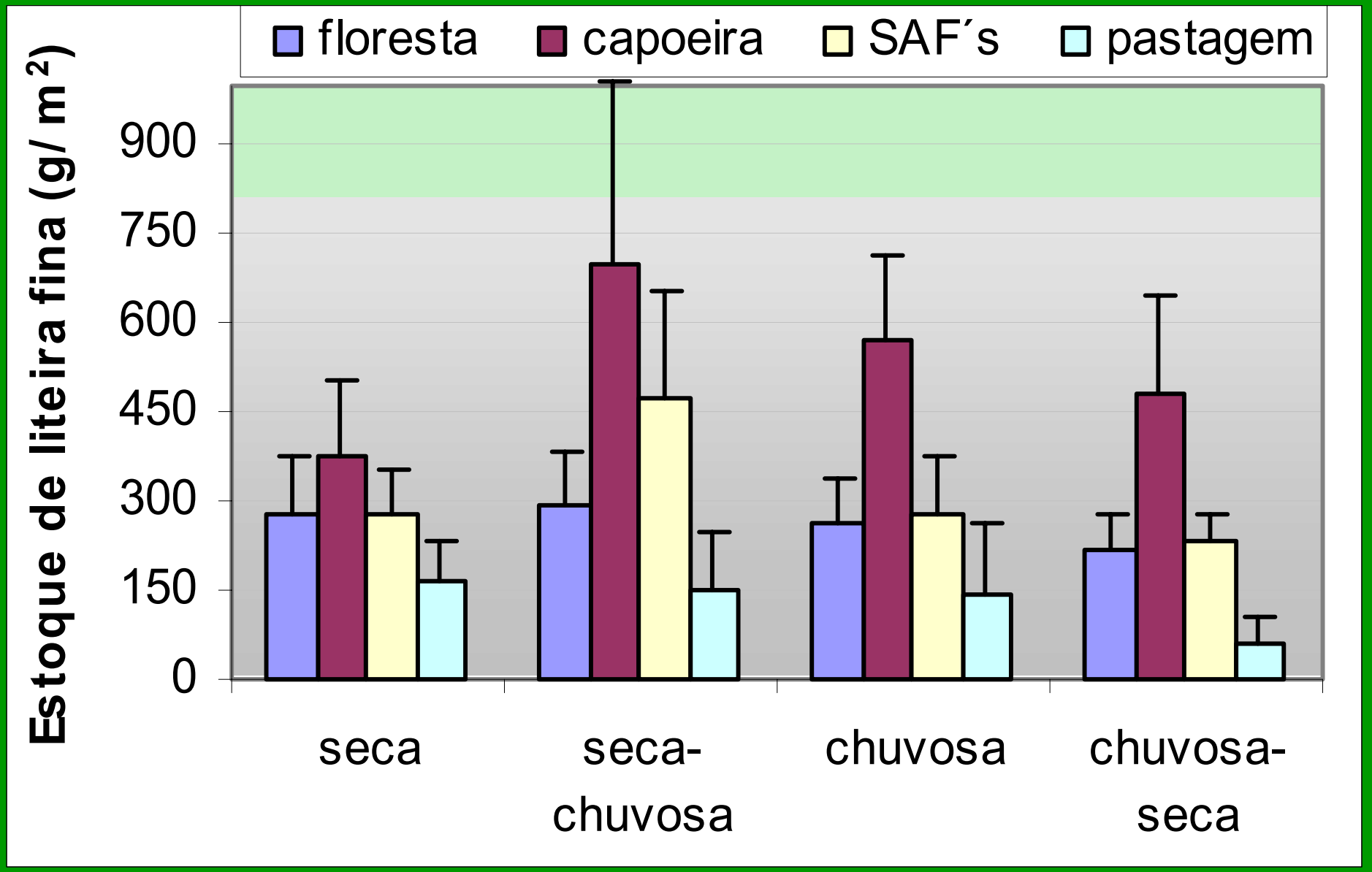
AFs = 11 year old

I. Cortes-Tarra 2003

Be= *Bertholettia excelsa* (AS2)
Bg(P)= *Bactris gasipaes* (Palm heart)
Ie= *Inga edulis* (AS2)
Vc= *Vismia cayenensis* (second growth)



12 years old AFS



Litter-layer mass (n=15) under: forest, second growth, AFs and pasture, in different periods of the year. AFS= 12 years. Trujillo 2004

Nutrient concentrations in the litter layer in mature forest, second growth (CAP), AFS (11-12 year old), pasture

Systems	Nutrients (g/kg)					
	Ca	Mg	K	Fe	Zn	Mn
Forest	4,035	1,075	1,830	0,550	0,023	0,069
CAP	5,105	1,330	1,025	0,331	0,040	0,140
AFS	8,375	1,430	1,790	0,448	0,035	0,170
Pasture	3,135	0,980	0,865	0,648	0,033	0,114

L. Trujillo 2004

Litter-layer mass and nutrient stocks ($kg.ha^{-1}$) in AFS based on palms and mixed fruit trees, compared to pastures and second growth (CAP).
Guilherme Silva 2005

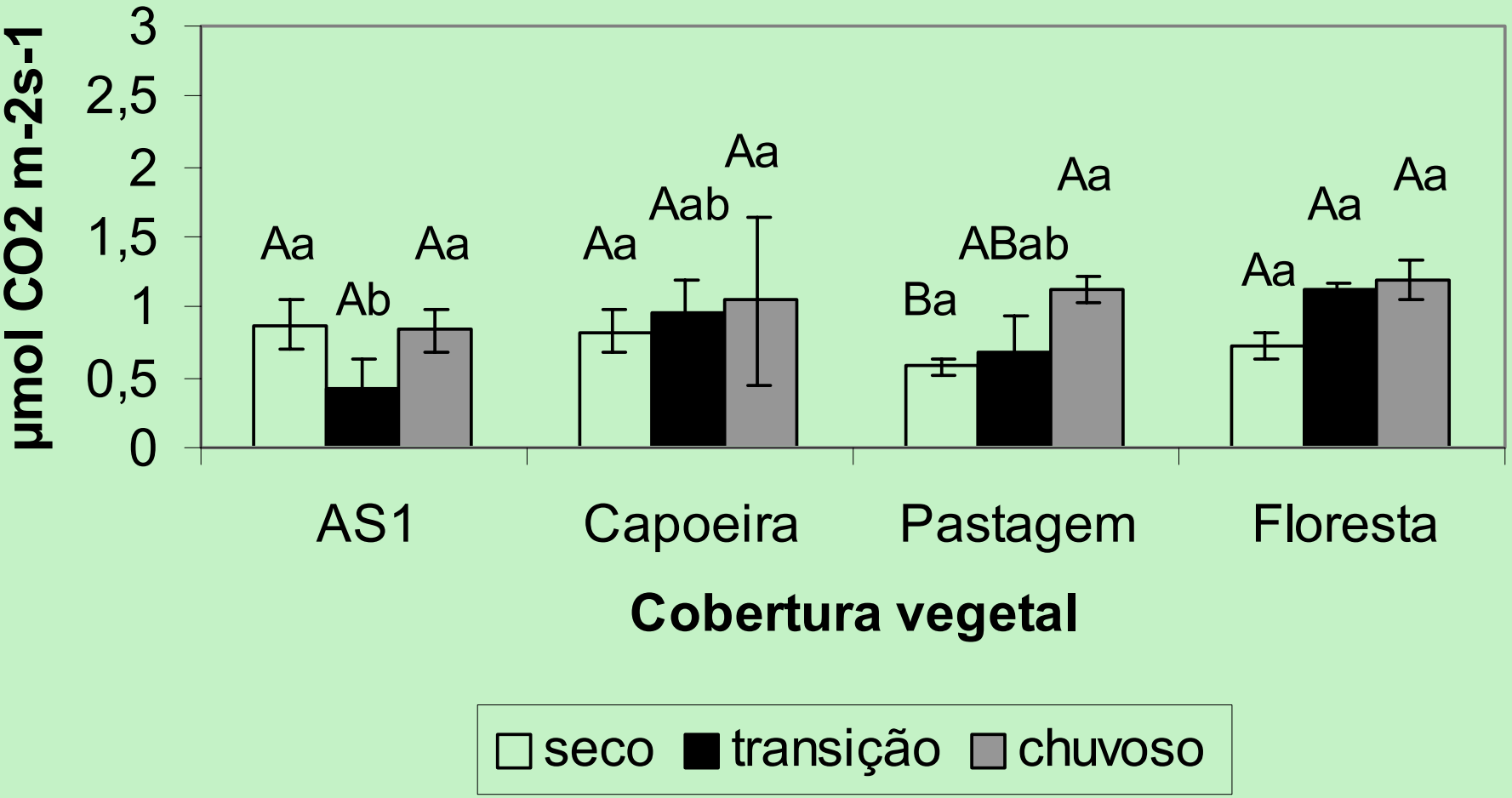
AFS = 12 year old

Nutrients	AFS		Pasture	CAP
	Palms	Fruit trees		
P	3,6 a ± 1,5	4,4 a ± 2,3	4,4 a ± 1,7	1,6 b ± 0,8
K	1,8 ± 2,1	4,8 ± 5,3	3 ± 1,4	3,8 ± 7,8
Ca	44 a ± 8,9	47,8 a ± 1,5	42,5 a ± 12,1	25,1 b ± 6,8
Mg	7,1 a ± 1,2	6,5 a ± 1,1	6 a ± 1,7	4,4 b ± 1,2
Litter mass	3,3 a ± 1,1	3,6 a ± 1,2	1,7 b ± 1,2	5,9 c ± 1,7

Soil surface (0-10 cm depth) characteristics in AFS based on palms and fruit trees, and in pasture and second growth (CAP).
AFS = 12 year old. G. Silva 2005

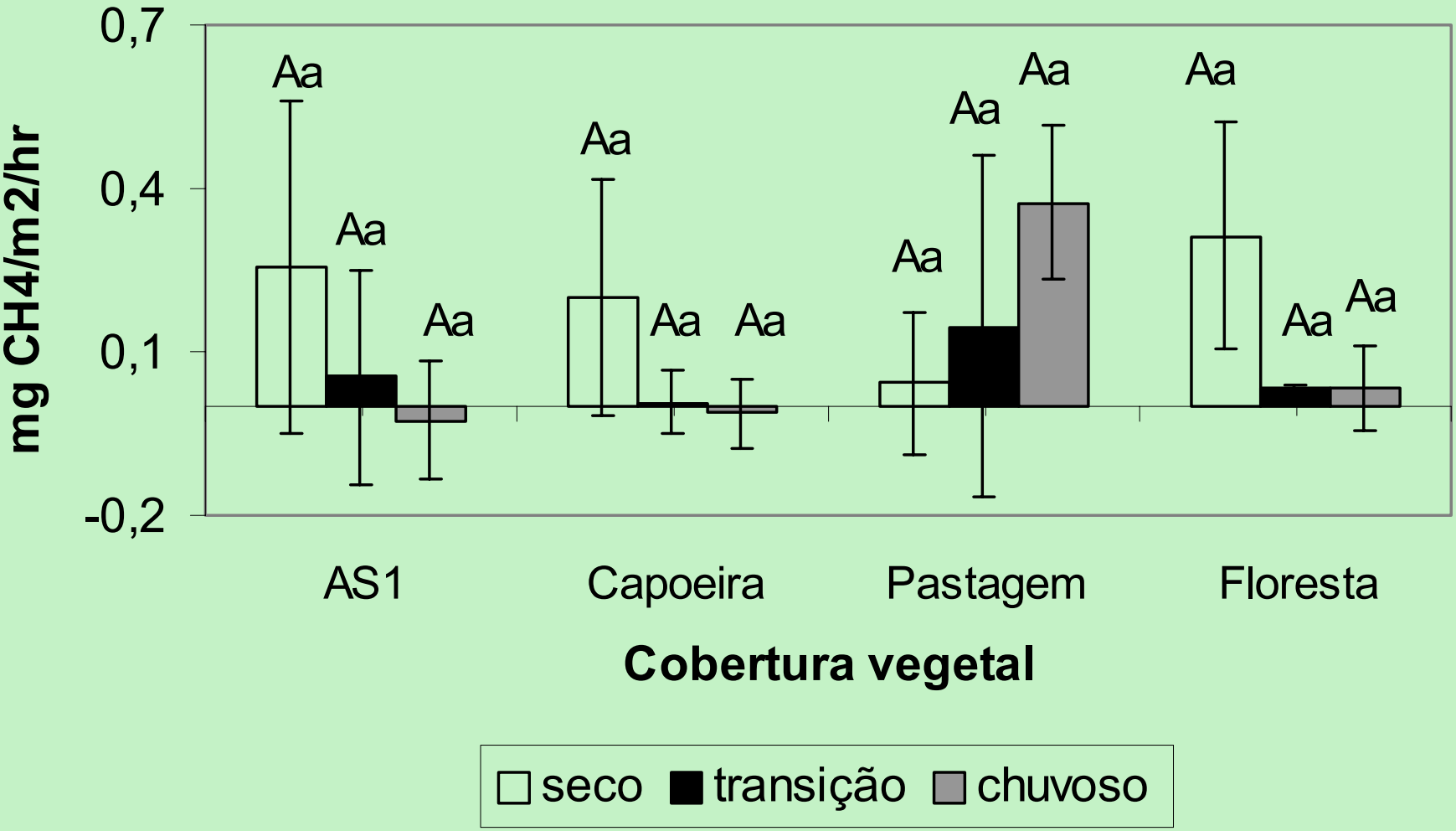
	AFS			CAP
	Palms	Fruit trees	Pasture	
pH	4,5 a ± 0,14	4,4 ab ± 0,08	4,5 a ± 0,11	4,3 b ± 0,1
C (%)	3,1 ± 0,9	2,8 ± 0,5	3,1 ± 0,7	3 ± 0,7
N (%)	0,2 ± 0,03	0,2 ± 0,03	0,21 ± 0,03	0,19 ± 0,02
P ($mg.kg^{-1}$)	58,2 a ± 26,5	68,8 a ± 41,4	54,9 a ± 27,4	23,5 b ± 10,6
K ($mg.kg^{-1}$)	147 ± 126	152 ± 140	151 ± 122	119 ± 122
Mn($mg.kg^{-1}$)	6,5 ± 2,1	7,1 ± 2,4	5,9 ± 1,8	4,5 ± 1

AFS = 12-13 year old



Soil CO_2 fluxes in different periods of the year, in a palm-based AFS (12 year old), second growth, old pasture, and mature forest (J. Queiroz 2004)

AFS = 12-13 year old



Soil CH4 fluxes in different periods of the year, in a palm-based AFS (12 year old), second growth, old pasture, and mature forest (J. Queiroz 2004)


SHAU LIN

Fruit cultivation – native species

Timber + Animal products

Food & Ecosystem Services

Rehabilitated productivity of degraded lands for diverse food and fiber systems

Terrestrial C Sequestration

Plant productivity enhanced to fix and sequester C and augment sinks for other GHGs

Terrestrial Biogeochemical Cycles

50-60 pages Booklet organized by a Master student receiving a 6-months CNPq scholarship (ongoing activity)

= One of the synthesis/review booklets to be produced within the next 6 months through CNPq scholarships (T & E aim) → language suitable for undergraduate students