Measuring farm tree diversity in recent coffee landscapes of Mount Kenya

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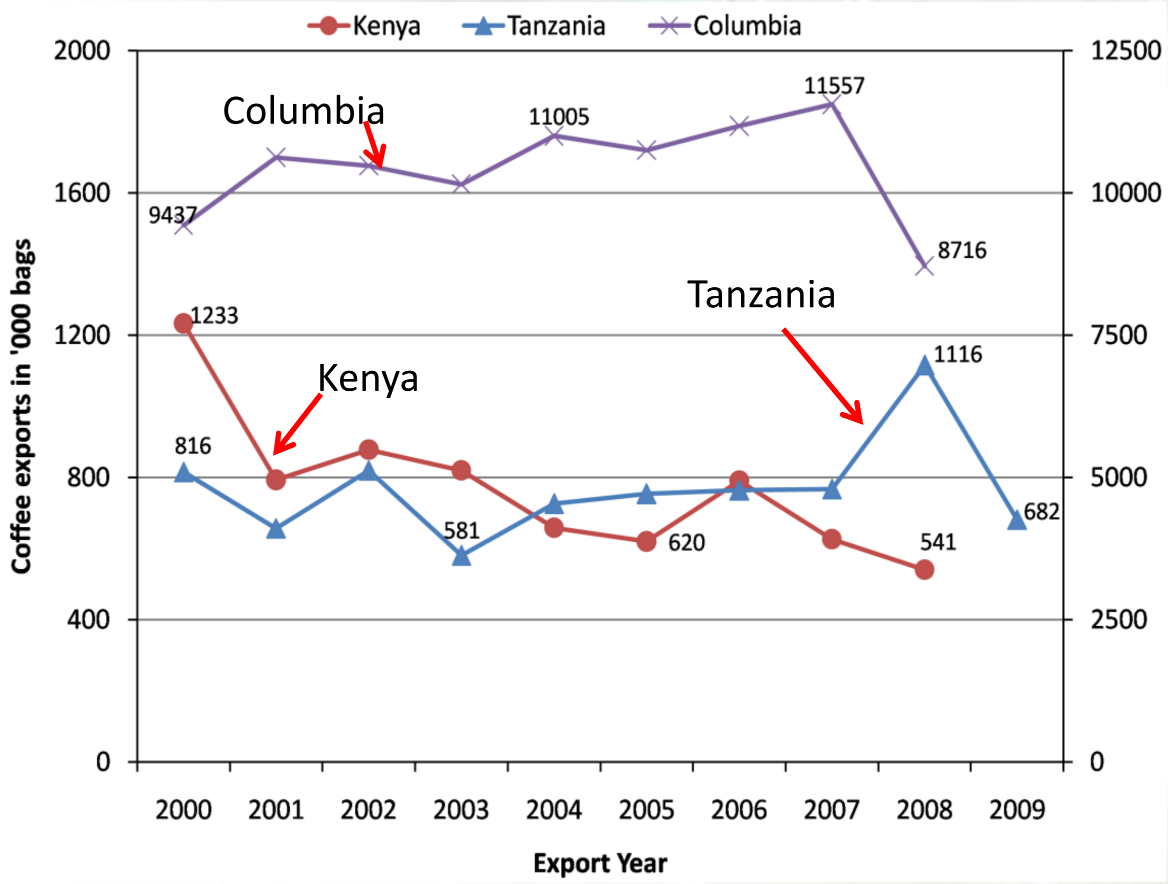
Evolution of Kenya's smallholder coffee

- **Kenya's smallholder coffee growing begun at independence**
- **Coffee growing areas gazetted to ensure quality and quantity of produce (Akiyama, 1987).**
- **By 1952, 3,000 acres under coffee**
- **Presently about 120,000 Ha under smallholder coffee**
- **Production trends: 43,778 metric tonnes (1963); 140,000 metric tonnes (1987/88) and stagnated ca. 50,000 (since 2000)**
- **Supply increases in the world coffee market in 90's. In 2001, price of arabica dropped to <60 cents a pound from >$2 a pound (ICO, 2005).**
- **Market liberalization exposed smallholders to higher price risks**
- **Uncertain market and loss of coffee productivity have affected living standards, incomes, food security in coffee growing areas**
- **Coffee farmers are diversifying investment from coffee**

Kenya's coffee exports fell by over 50% between 2000 and September, 2010; world market share declined from 3.1% in 1986 to 0.6% by 2006 (ICO, 2010).

Source: ICO statistics, 2010



Columbian mild coffee exports by: Columbia, Kenya and Tanzania

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Do coffee agro-forests provide livelihood and landscapes resilience?

- **Coffee agroforestry- integrating diverse tree species in coffee farming landscapes**
- **Trees products to diversify, diet & stabilize farmer incomes & contribute ecological services e.g. soil protection, nutrient cycling, water retention and carbon capture (Chazdon et al., 2009)**
- **Farmers benefit culturally by maintaining biological diversity that ensure productivity (Lengkeek et al. 2005)**
- **Genetic diversity helps farmers to manage their inputs in more efficient ways - e.g. a mix of fast growing and slow growing timber grown for different markets; fruit species with different fruiting phenology contribute to HH food security (Dawson et al., 2009)**
- **Shaded coffee as opposed to sun coffee- recognized as a more sustainable production approach (Mas and Diestch, 2004). Coffee systems are reservoirs of indigenous tree species (Perfecto et al., 2005).**
- **Coffee shaded with any density of *Cordia alliodora* has better benefit-cost ratio than un-shaded estates although yields were lower (Peeters, 2003)**
- **Shade coffee certification offer farmer premiums to enhance biodiversity maintenance.**

Research challenges and opportunities

- Protected reserves role on biodiversity conservation is hinged on the quality of the landscape matrix around these reserves (Bhagwat et al., 2008)
- Farming systems challenges: irregular production, fluctuating input and output prices and impact of agriculture on the environment (Le Gal et al. 2011)
- Impact of converting natural forests to different agroforestry systems have not studied for many agricultural landscapes (Fitzerbert et al., 2008; Asase and Tetteh, 2010)
- We don't know the status tree diversity in smallholder coffee farms
- Characterizing farm tree demographics helps to identify shortcomings that underlie tree based systems e.g. viability of trees for genetic resource supply and conservation
- Not clear the extent to which farmers are willing to conserve tree diversity given resource constraints e.g. land (Lengkeek & Carsan, 2004)

Study objectives

- To investigate agroforestry tree species richness and abundances on smallholder coffee farms showing differences in coffee production behaviour such *as increasing, decreasing* or *constan*t yield trends
- To determine tree diversity assemblages maintained under different coffee agro-ecological zones around Mount Kenya

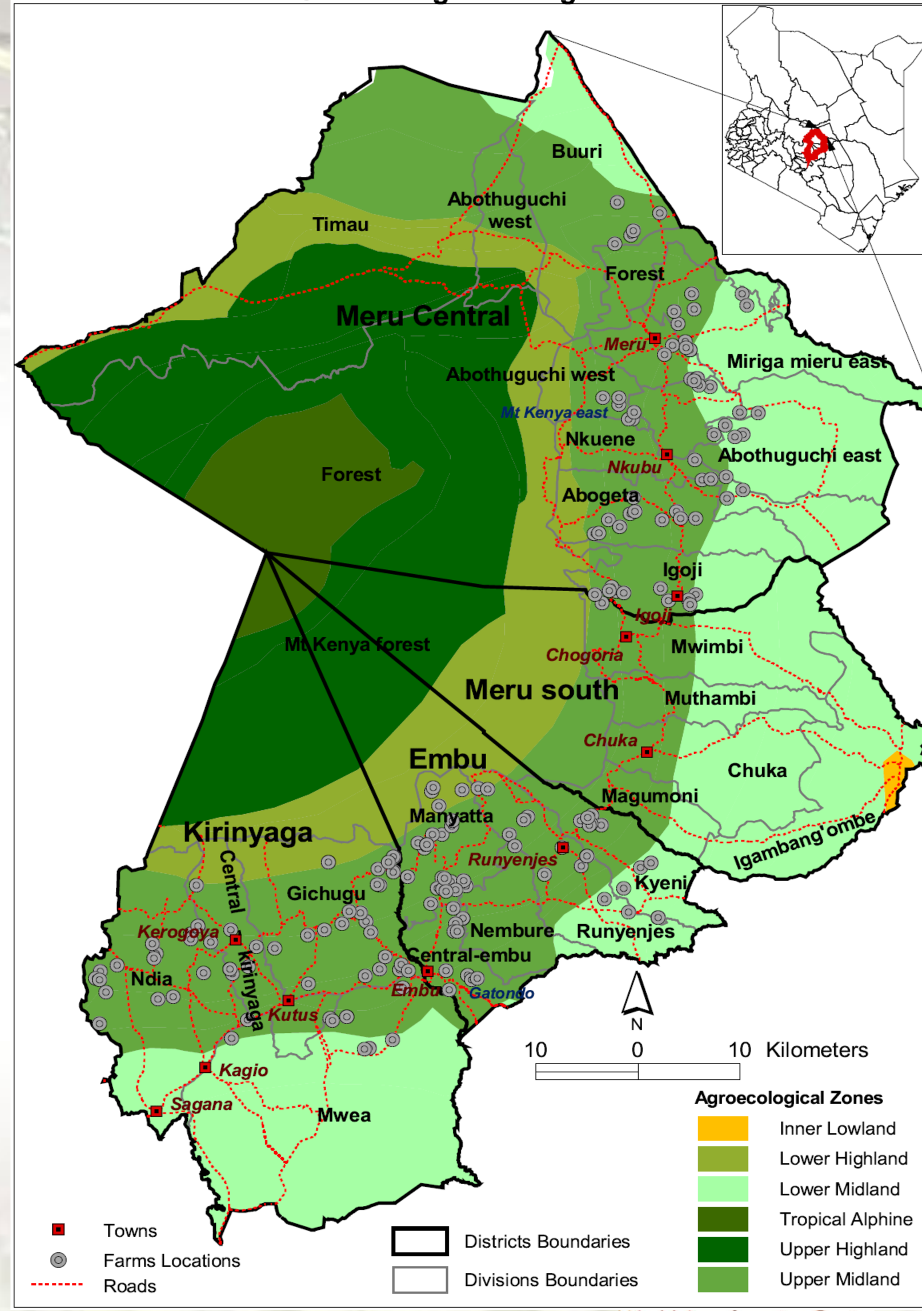
Hypothesis:

H_0 :Farms with decreasing coffee production (cherry yields) support higher levels of tree abundances and richness on farm

H_1 :Farms with increasing coffee production (cherry yields) have decreased tree abundances and richness on farm

Research Methods

- Cross-sectional survey in three coffee districts of Mt Kenya (Meru , Embu & Kirinyaga)
- The zones are comparable on coffee and other crops production practices and largely representative of smallholder coffee systems in Kenya
- The regions have strong farmer organization by cooperatives and societies



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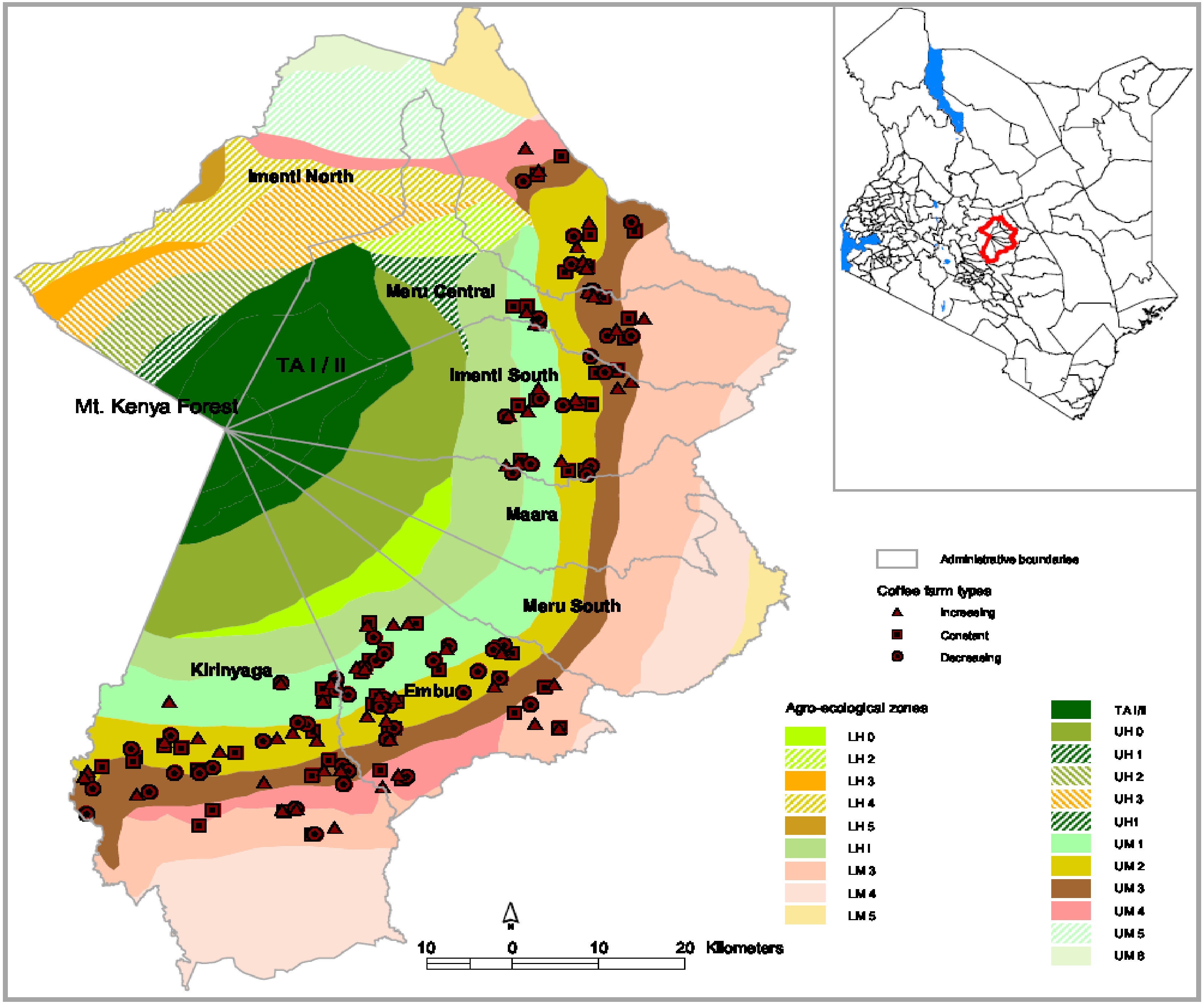
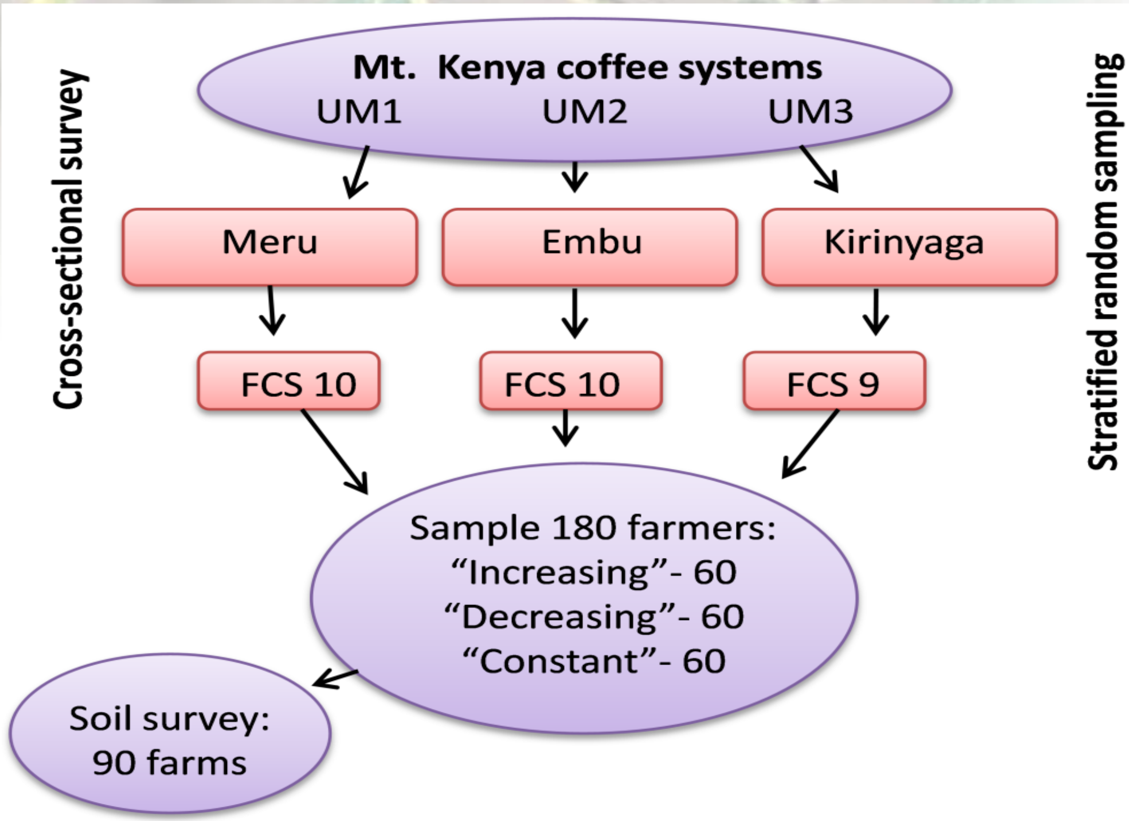

Imenti North
Meru Central
TA I / II
Mt. Kenya Forest
Imenti South
Maara
Meru South
Kirinyaga
Embu
Administrative boundaries
Coffee farm types
Increasing
Constant
Decreasing
Agro-ecological zones
LH 0
LH 2
LH 3
LH 4
LH 5
LH I
LM 3
LM 4
LM 5
TA I/II
UH 0
UH 1
UH 2
UH 3
UH1
UM 1
UM 2
UM 3
UM 4
UM 5
UM 6
10
0
10
20
Kilometers

Farms sampling strategy



Farm types	Mean cherry yield rate (kg yr $^{-1}$)	Mean No. of coffee bushes
Increasing	2101 (s.d =1380)	727 (s.d = 652)
Constant	1032 (s.d = 907)	465 (s.d = 410)
Decreasing	688 (s.d =709)	444 (s.d = 368)
ANOVA	P < 0.001	P = 0.003

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Field methods

- Ground-based methods used to record tree species presence on coffee farms
- Trees defined as all woody perennials growing to >1.5 m tall, including exotics (Beentje, 1994; Brown, 1997).
- All trees ≥5 cm DBH measured
- Local/common names of trees recorded from local farmer consultations
- Trees identified to species level according to Beentje (1994) or Maundu and Tengnäs (2005).

Tree diversity analysis

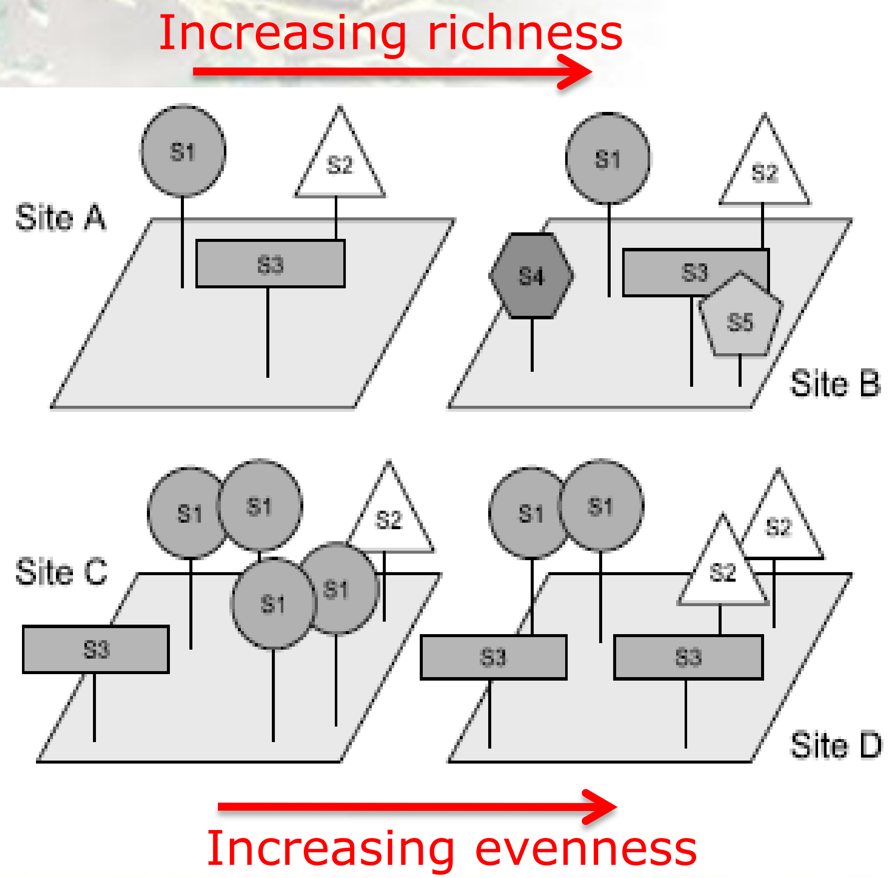
- **Diversity refers to the number of species that can be differentiated, and to the proportions (or relative abundances) of the number of trees in each species.**

  - diversity refers to both richness and evenness

- Diversity indices, species accumulation and rank abundance curves used to compare species richness and evenness

- Rènyi diversity used to rank tree communities from low to high diversity (Legendre & Legendre, 1998)

- Poisson regressions used to relate tree richness , abundance to cherry production level (trend)



Source: Kindt and Coe (2005)

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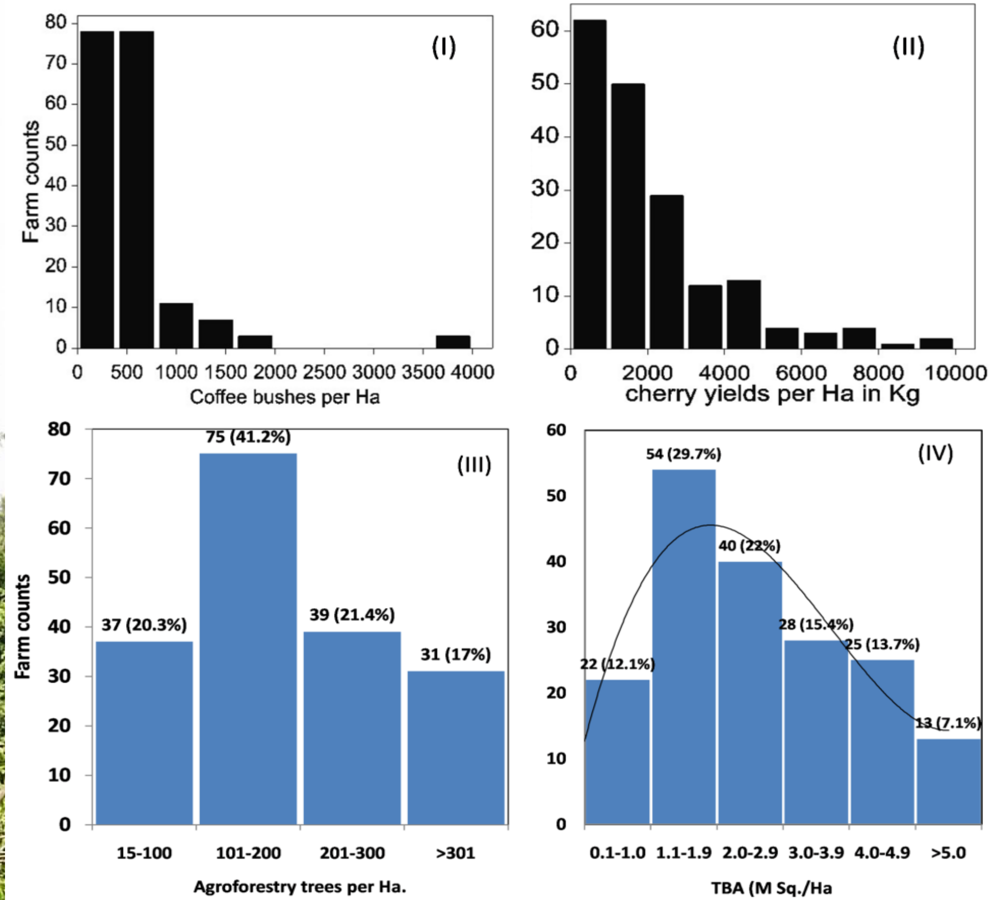
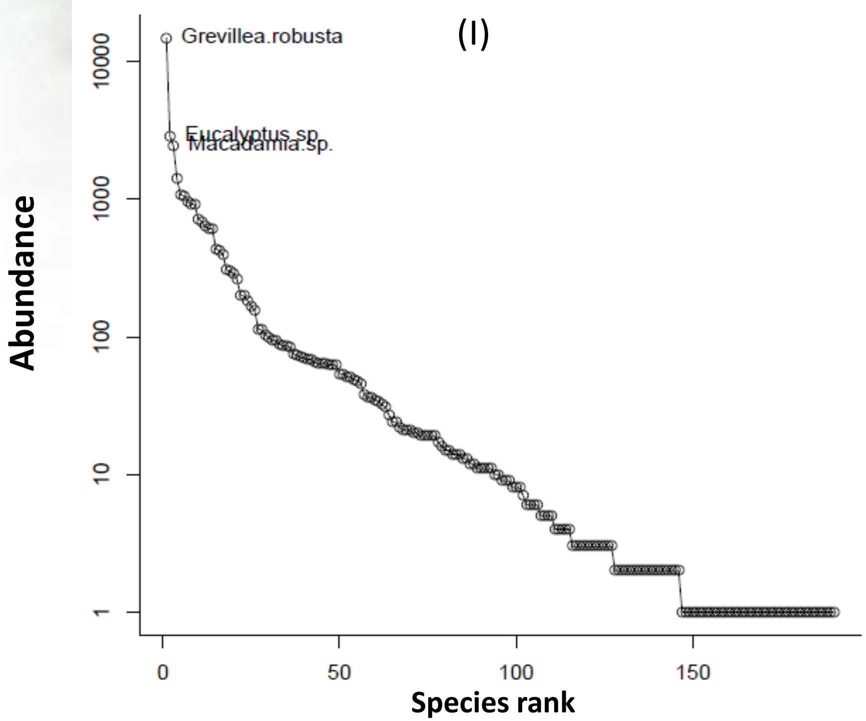
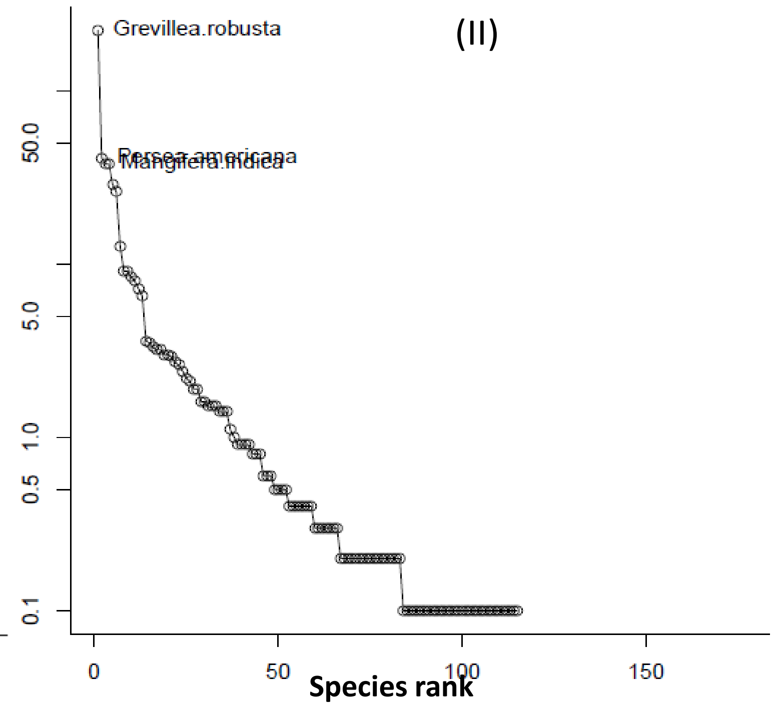
Results



- **75% (156) farms cultivate 250-750 bushes ha^{-1}**
- **61%(110) produce 1000-2000 kg cherry ha^{-1} yr^{-1}**
- **41% (75) farms, tree density : 100-200 trees ha^{-1}**
- **51% (54) farms: TBA class of 1.1-2.9 m^{2} ha^{-1}**
- **Average tree volume : 36.31 (31.1-41.5) m^{3} ha^{-1}**

Tree abundance and basal area distribution (excluding coffee)

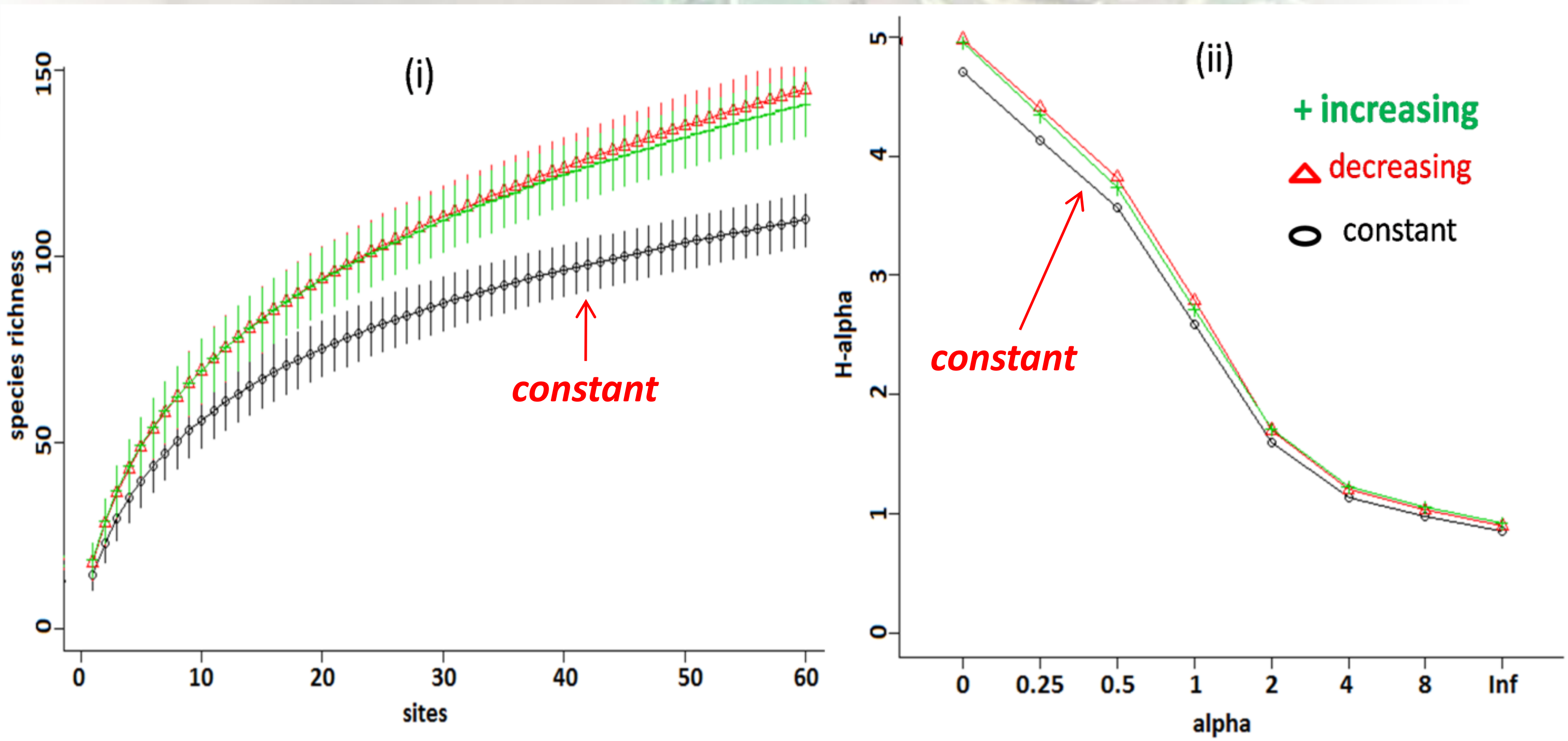




Rank abundance by tree counts (Relative density)			
Rank	Species	Abundance	Proportion (%)
1	*Grevillea robusta*	14923	41
2	*Eucalyptus sp.*	2877	7.9
3	*Macadamia sp.*	2445	6.7
4	*Mangifera indica*	1402	3.9
5	*Cordia africana**	1086	3
6	*Carica papaya*	1059	2.9
7	*P. americana*	969	2.7
8	*Catha edulis**	921	2.5
9	*C. lusitanica*	920	2.5
10	*B. micrantha**	722	2

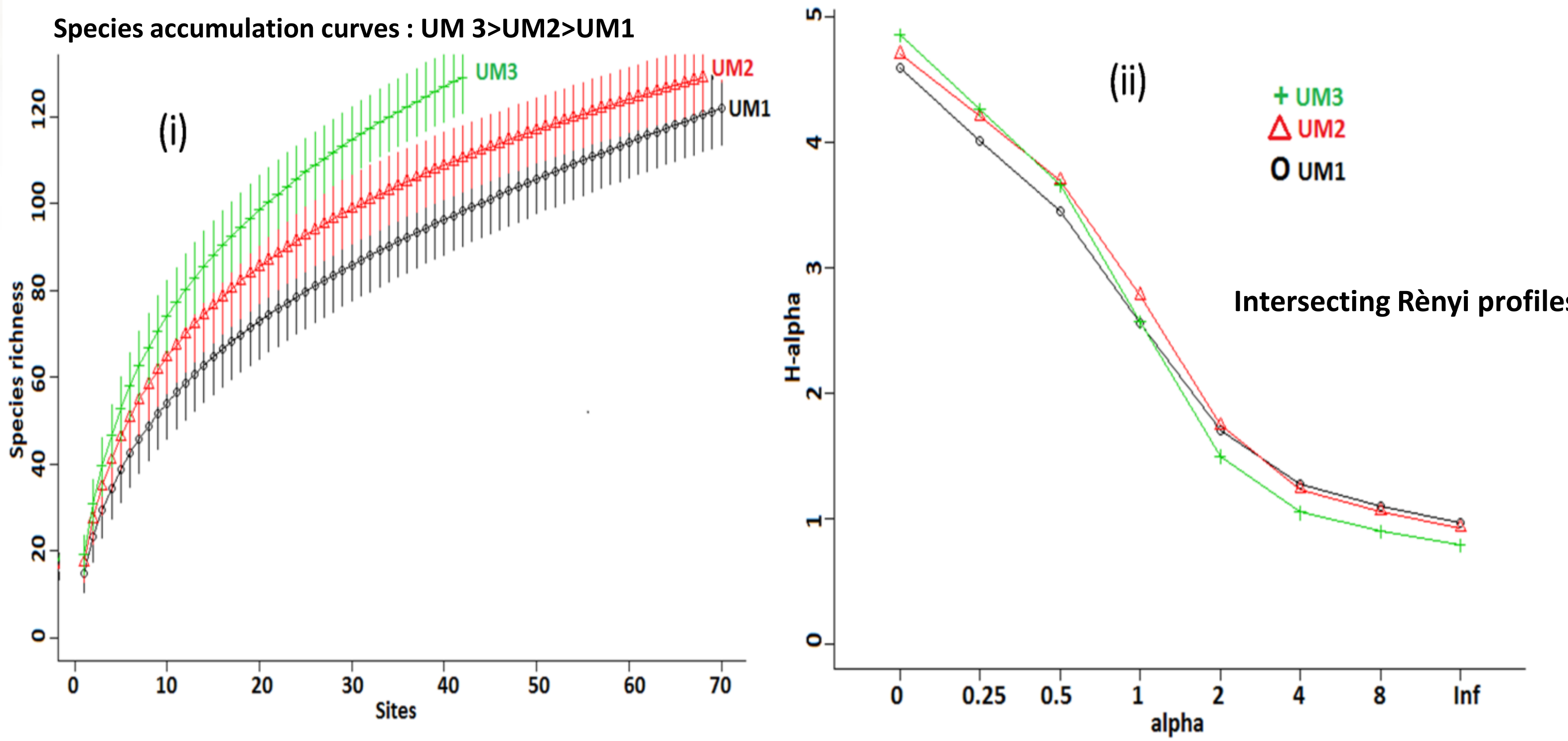
Rank abundance by tree basal area (relative dominance)			
Rank	Species	Total basal area (m^2)	Proportion (%)
1	*Grevillea robusta*	223.3	41.9
2	*P. americana*	40.9	7.7
3	*Mangifera indica*	37.7	7.1
4	*Cordia africana**	37.5	7.1
5	*Eucalyptus sp.*	28.8	5.4
6	*Macadamia sp.*	26	4.9
7	*C. macrostachyus**	12.7	2.4
8	*B. micrantha**	9.1	1.7
9	*C. lusitanica*	9.1	1.7
10	*Vitex keniensis**	8.4	1.6

Species accumulation curves (i) and Rènyi diversity profiles (ii) by farm typology



Farm category (n)	Farm size Ha. (s.d)	Total richness (mean)	Total abundance (mean)	Shannon index	Inverse –Simpson index
Constant (60)	1.18 (1.2)	**110 (14.4)**	**10,079 (168)**	**2.59**	**4.93**
Decreasing (60)	1.12 (0.9)	**145 (17.9)**	**11,149 (186)**	**2.79**	**5.49**
Increasing (60)	1.37 (0.9)	**141 (18.4)**	**14,592 (243)**	**2.72**	**5.51**
All farms (180)	**1.22 (1.0)**	**190 (16.9)**	**35,820 (199)**	**2.76**	**5.4**

Tree diversity analysis by coffee agro-ecological zones



AEZ	Species richness (H_0)	Shannon index (H_1)	Inverse Simpson (H_2)	Proportion (%) of most dominant species (H_∞)
UM1 (n=70)	98	2.56	4.23	0.38
UM2 (n=68)	110	2.78	4.17	0.40
UM3 (n=42)	129	2.57	5.69	0.46
All farms (n=180)	190	2.76	5.40	0.41

Results

Poisson GLM (with log link) showed farm categories (based on cherry produce) were significantly different in terms of richness (P <.001; Chi Pr = 0.005) and abundance (P <.001; Chi Pr < 0.001)

- Treating constant farms as reference, analysis showed that the cherry increasing farms were significantly different from the constant farms (P = 0.001); however farms that are on decreasing trend were not significantly different from the constant ones (P = 0.161).
- Tree abundance were significantly different between categories (P <.001; Chi Pr < 0.001). Effects of increased and decreased cherry production are different from the constant ones (P <.001).
  - Tree richness and abundance significantly different by AEZ (P< 0.001)
  - Strong evidence that UM3 tree density is different from those in UM1. Abundance in UM2 is however not significantly different from UM1 (P = 0.593)

Conclusions

- The marginal coffee zone (UM3) on average has higher species richness but is also most uneven; main coffee zone (UM2) do not contain significantly different species from the UM1 and UM3 indicating prevalence of species sharing

- The 'coffee *increasing* and *decreasing* farms' have higher species richness and abundance than the stagnated ones. Results imply that farms getting out of coffee farming reduce tree diversity as they probably open up for food crop activities and coffee land is fragmented

- Tree diversity is un-even among the surveyed farm tree population; the ten most highly ranked species are mainly exotics. But there are also displacement of some exotics e.g. avocado, and indigenous species e.g. Cordia, Vitex and Croton)

- Low densities of indigenous species on farm pose a challenge to genetic resources provisioning within coffee farming landscapes -implications on tree reproductive ecology. Tree domestication activities should promote planting of indigenous trees that benefit smallholders e.g. for coffee shading, timber and ensure connectivity at the landscape level.