# Tropical forest-transition landscapes: a portfolio for studying people, tree crops and agro-ecological change in context

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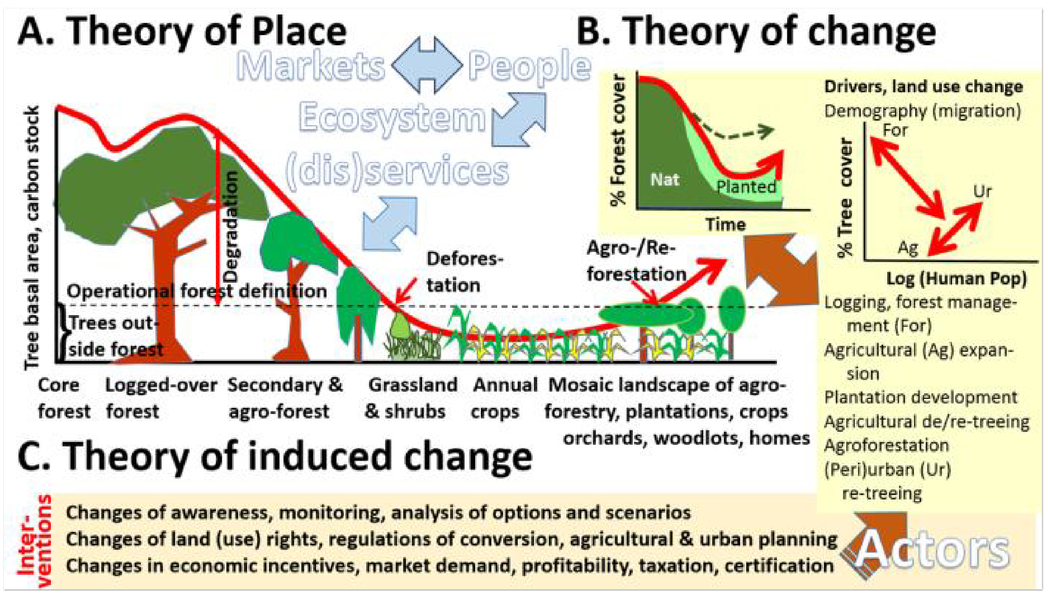
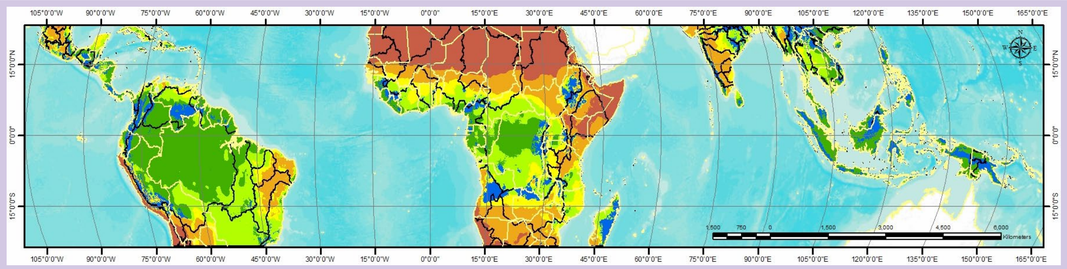
## Forest-transition theory as underlying Theory of Place, Theory of Change and Theory of Induced Change



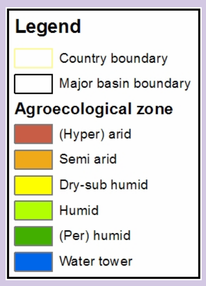

## Research questions

- Can the forest transition concept, in combination with climate and watershed data, be used for **a rigorous typology of situations**, in which any set of sampling sites can be compared to global prominence (frequency) of similar conditions?
- How do the **ASB, PEN and FTA-Sentinel landscape** portfolios perform in representativeness according to such a typology?
- How do theory of place and theory of change interact in **modifying the trajectory** of tree cover changes?

## 1 Agro-ecological zonation

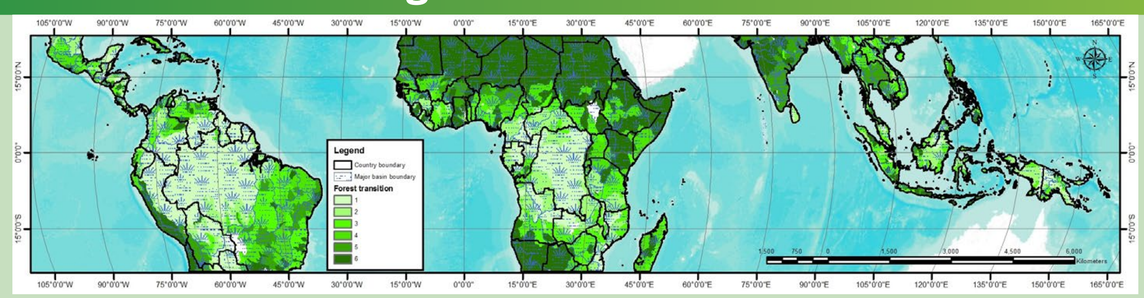


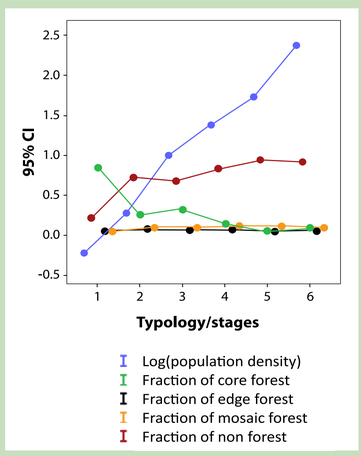
| Aridity-humidity index (rainfall/potential ET) | Agro-ecological zone |
|---|---|
| <0.2 | (Hyper) arid |
| 0.2–0.5 | Semi arid |
| 0.5–0.65 | Dry–sub humid |
| 0.65–1.0 | Humid or Water Tower if AE>2.77 |
| >1.0 | (Per) humid or Water Tower if AE>2.77 |

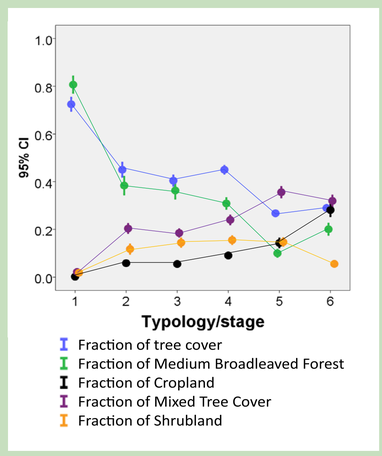



| Agro-ecological zone (indicative mean annual rainfall range) | Ecosystem services' issues related to dominant land uses; degradation (loss of services owing to loss of functions) | Recovery, restoration, agro-forestation | Target geography (sentinel landscapes: most have multiple zones) | Human population density: (min)–mean–(max) km$^{-2}$; forest % |
|---|---|---|---|---|
| Dryland<br>18% of tropical area; 3% of tropical population (8.5 km$^{-2}$); 0% of sentinel landscapes' area | Few high-value tree crops; overharvesting of trees for fuelwood; annual fires; overgrazing by livestock; wind erosion; irrigated agricultural islands of functioning sub-humidity with risks of salinization | Specific attention to migratory circuits and routes for wildlife and pastoralists | Not a target for FTA research: dryland agroforestry and sparse tree cover are researched elsewhere | No sentinel landscapes |
| Semi-arid 17% of tropics; 17% of people (54.87 km$^{-2}$); 21% of sentinel landscapes' area<br>Dry sub-humid 10% of area; 11% of people (62.3 km$^{-2}$); 20% of sentinel landscapes' area | Location-specific opportunities for tree-based participation in global markets; overharvesting of commercial timber and within urban reach for charcoal; land clearing for crop production; annual fires; local climate effects of tree-cover change | Controlled use of remaining forests, legalization of fuelwood trade as basis for investment; recognition of meso-climatic effects of tree cover in 'parklands' | **West African Savannah** (Ghana, Togo, Burkina Faso, Mali)<br>**East African Miombo** (Zambia, Malawi, Mozambique) | (1)–35–(1758) 0% forest (at >50% cover)<br>(0)–23– (4727) 14% forest |
| Water towers 11% of area; 15% of people (74.25 km$^{-2}$); 15% of sentinel landscapes' area | Expansion of highland crops and vegetables; coffee, tea, cacao; overharvesting of commercial timber; highly vulnerable biodiversity (endemic); changes in local climate; modified water flows; erosion/sedimentation; loss of soil C and nutrients | Recognition of specific hydrological functions, including attention to riparian zones as key to buffering, and ecological connectivity; incentives need to match downstream (including urban) interests | **Nile-Congo Water Towers** (Uganda, Kenya)<br>**South Asian Water Tower** (Western Ghats in India) | (0)–152– (17,025) 14%<br>(118)- 213– (1360) 43% |
| Humid forest 19% of tropics; 22% of people (59.44 km$^{-2}$) 19% of SL area | Convertible to coffee, tea, cacao, rubber, bananas, oil palm, pasture. Overharvesting of commercial timber; connectivity loss ecological corridors; changes in local climate; soil compaction; erosion/ sedimentation; loss of soil C and nutrients | Shift from monocultural tree crops to diversified agroforestry; restoration of degraded pastures; spatially explicit forest restoration for biological corridors; changes in land tenure may be needed | **Mekong** (China, Lao PDR, Viet Nam, Thailand)<br>**Central America** (Nicaragua, Honduras) | (7)–69–(301) 67%<br>(0)–74 –(6929) 63% |
| (Per-) humid lowland forest 25% of tropics; 32% of people (69.07 km$^{-2}$); 25% of sentinel landscapes' area | Convertible to oil palm, rubber, pulp and paper plantations. Logging along rivers and major roads; overharvesting of commercial timber; high biodiversity loss; erosion/ sedimentation; loss of soil C and nutrients; peatland issues | Opportunities for domestication and increased use of resources may require changes of rules for market access; changes in land tenure may precede ecological recovery | **West Amazon** (Peru, Paraguay, Brazil)<br>**Central African humid tropics** (Cameroon, Republic of the Congo, Democratic Republic of the Congo)<br>**Insular Southeast Asia** (Sumatra and Borneo in Indonesia) | (0)–3–(229) 92%<br>(1)–59–(5622) 82%<br>(0)–43–(8705) 58%, 73% |

## 2 Forest transition stage at sub-basin level



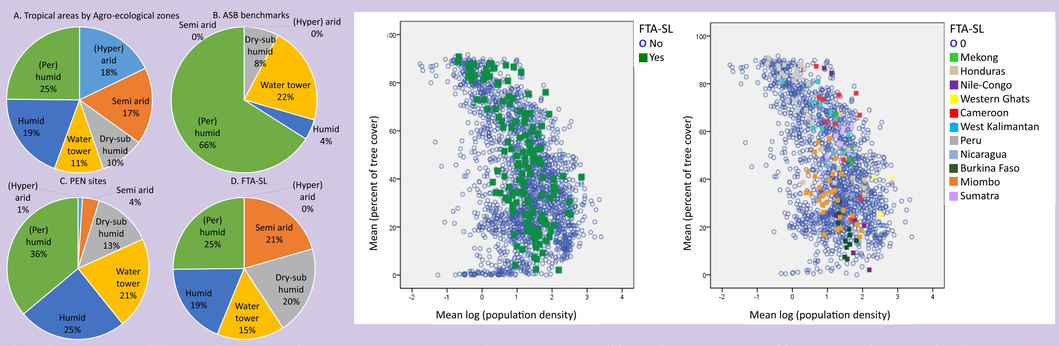




- The fraction of medium broadleaved forest and fraction of tree cover decreases almost monotonically from stage 1 to 5 and increase again from stage 5 to 6
- The fraction of mixed tree cover follows exactly the opposite trend, suggesting an inflection point at stage 5
- The fraction of cropland consistently increases and the fraction of shrubland is low at both ends and plateauing at stages 2 to 5.

- The forest transition typology (stages) shows that population density is monotonously increasing from early to later stages;
- As population density increases, the fraction of core forest decreases, while the fraction of non-forest increases
- The initial increase in shrubland can imply logging as driver of deforestation and/or non-permanent land uses that leave degraded forest behind
- The reduction of shrubland in later stages implies that (planted) tree cover catches up with deforestation, while further expansion of agriculture gets shifted to such lands rather than the remaining forest

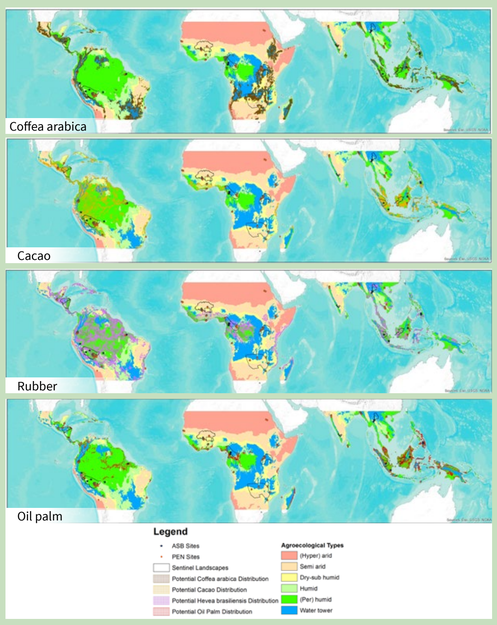
## 3 Tests of representativeness




- ASB sites were biased towards active humid forest margin areas;
- PEN sites, to a lesser extent are also biased towards humid tropics areas:
- FTA-SL, except for the (Hyper)arid areas, are very well representing the variations in the tropics

- FTA-SL as a set of landscapes well cover the variations of population density x % tree cover in the tropics;
- Spatial autocorrelation tend to be strong with sub-basins within each SL form clusters within the scatterplot;
- There are some overlapping clusters but as a set the complementarity is strong

## 4 Tree crops: existing and potential areas




- The similar areas of commodities are compared to the actual harvested areas taken from FAO statistics for cacao, rubber and oil palm, and from Bunn et al. (2015) for *Coffea Arabica*
- Climate change will involve shifts in the geographic boundaries for all tree crops, but future expansion is still most likely within the areas indicated here.
- Coffee (arabica) is associated with the water tower zone with relatively high human population density
- Oil palm is restricted to the (per)humid zone, which it shares with rubber and cacao

## Conclusions

- ASB and PEN sites were biased towards active humid forest margin settings and early stages of forest transition respectively;
- FTA provides a 5% sample of area, 8% of people, 9% of tree cover and 10-12% of potential tree crop presence across the tropics, with quantified biases across zones, transition stages and HDI;
- In the 'water tower' configuration (strong coffee presence) relatively high population density coincides with high biodiversity and contested ecosystem services;
- The FTA portfolio can be cautiously used for quantified confidence intervals on global trends in trade-off and synergy phases of the tropical forest transition.

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