Introduction

Agroforestry systems have a complex canopy structure difficult to scale up from field measurements only. The time course of coffee LAI has been characterized previously using MODIS and field measurements (Taugourdeau et al., 2014).

Coffee understory is located under a tree stratum of variable density, size and phenology (e.g. leaf area index dynamics, different species).

This tree stratum plays an important role in the light environment and microclimate of the understory, and ultimately impacts the production of coffee fruit. Paradoxes very high spatial resolution satellite images allow to characterize these systems in terms of tree coverage and leaf area indices at appropriate spatial scale (from root to plant), and at different dates.

Site characteristics:
- Coffee based agroforestry system, Turrialba volcano, Costa Rica (9°58'19"N,63°43'46"W), 1km²
- Tropical humid climate
- Coffea arabica L. var Catuna
- Erythrina poepigiana O.F. Cook is used as shade tree. Broadleaf deciduous tree that totally deblooms during February-March

Available images:

- Date of acquisition: 2009-09-20
- Data product (source, date, size, format, number of bands, spatial resolution, spectral range):
  - MODIS
  - USGS

Part I: tree detection and crown diameter

AUTOMATIC on images
- VHRS image treatment to create a 50 cm B&W image with enhanced contrast between tree crowns and background:
  - Pan-sharpening (OTB) → Conversion to reflectance → Geo-referencing (QGIS) → textures and vegetation indices calculation (OTB)
- Crown discs detection with Hough circles method
- Smoothing/deconvolution filters for each tree size range
- Tree correspondence between images dates
- MANUAL on images
  - Photointerpretation: discs positionned on the image
  - Tree correspondence between images dates
- Field MEASUREMENTS
  - Stratification by crown size and field measurement of 40 tree crowns diameters from horizontal digital photos (with scale, 4 azimuths per tree)

Fig. 01: Tree crown Automatic (A) Manual (M) delimitation comparison by zone (Z)

Part II: tree height

AUTOMATIC on images
- Tree positions and crown diameters used together with sun/satellite geometry to place a transect along sun direction
- PAN profile is extracted along the transect for each tree
- Shadow length is estimated from thresholds of the PAN transect, and used to compute tree height, using geometry
- MANUAL on images
  - Tree height is estimated from allometric relationship with tree crown diameter
- Field MEASUREMENTS
  - Field measurements of 40 trees heights from horizontal digital photos (with scale, 4 azimuths per tree)

Part III: tree leaf area

AUTOMATIC on images
- Average NDVI within crown is extracted for each tree, only fully included pixels are averaged
- Locally calibrated Leaf area index vs. NDVI relationship is used to compute the tree LAI
- Tree leaf area is obtained from average LAI times the disc surface
- MANUAL on images
  - 3 years time-course of leaf area volumetric density on 5 trees is used for all other trees
- Field MEASUREMENTS
  - Field measurements of 40 trees leaf area from LAI2000

Conclusions and perspectives

- Detection of shade trees is highly dependent on date of acquisition and phenological cycle: for instance images acquired in February or March show less contrast between shade tree and coffee strata than images acquired in December
- Tree height estimations using a single allometric relationship between tree crown diameter and tree height is more precise than using the shadow-length method but requires a field calibration
- Shadow-length method remains attractive when no field data are available
- The relationship between tree LAI and NDVI on image pixels is satisfactory to estimate shade tree leaf area for every image. On the contrary, leaf area volumetric density is less efficient because of inter-tree variability in phenology
- A consistent evolution of the shade tree characteristics was found confirming an increase of tree sizes since 2000. This evolution is different between zones
- Such time-series analysis of the evolution of the structure of shade trees can be input into a light interception and photosynthesis model (Charbonnier et al. 2013)