Unmixing the patterns within big data: discriminating forest in French Guiana using modis time-series

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Unmixing the patterns within big data: Discriminating forests in French Guiana using the MODIS time-series

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I. Introduction

Despite the availability of 40+ years of remotely sensed satellite data, from multiple sources (e.g. Landsat, MODIS, SPOT), and multiple types of sensors (e.g. optical, radar, thermal), tropical forests are still poorly understood in terms of their composition and functioning. This is particularly true for French Guiana, the sparsely populated and highly forested French overseas Department which comprises the French segment of the biologically diverse Guiana Shield ecoregion (see **Figure 1**).

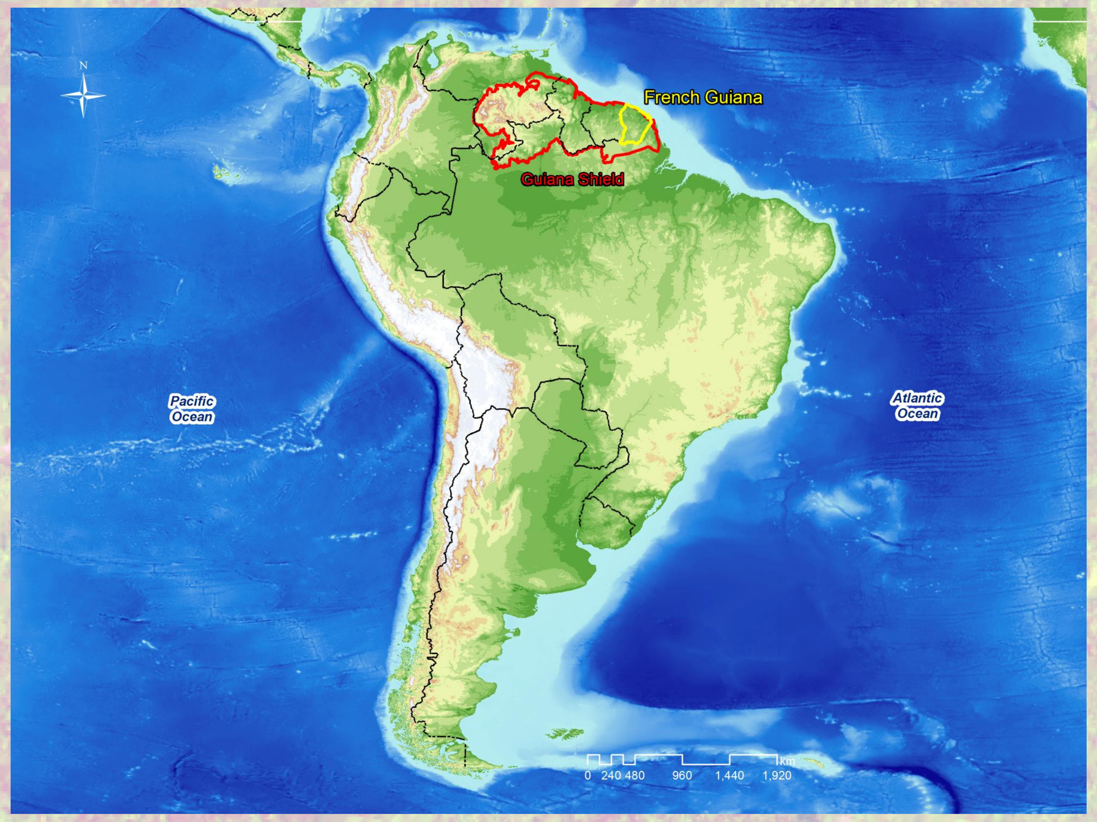

Figure 1: Location of French Guiana and the Guiana Shield Ecoregion

While French Guiana's forests have been mapped under successive global land cover assessment initiatives such as the Global Land Cover Characterization (GLCC), Global Land Cover 2000 (GLC2000), and GlobCover 2009, among others, French Guiana's forests are repeatedly depicted as one large 'green carpet,' despite evidence from the ground that French Guiana possesses a range of diverse forest ecosystems. In 2011, the need to go beyond the 'green carpet' effect led researchers to publish a new map of French Guiana's "forest landscape types" which was based on data from the Vegetation instrument onboard the SPOT-4 satellite, and differentiating the 'green carpet' into five main groups of forest [3].

Given the increasing availability of multitemporal remotely sensed data, the overall objective of this study was to examine the extent to which forest types in French Guiana could be discriminated via unmixing of multitemporal, multispectral reflectance data.

II. Methods

This study utilizes data from the 15-year archive of MODIS, particularly data which has been adjusted for the bi-directional reflectance distribution function (BRDF), and normalized to nadir viewing angle (i.e. the MCD43A4 product). In terms of the adjustment for BRDF, the MCD43A4 data utilized is derived from observations from MODIS Terra and MODIS Aqua, and models reflectance based on the local 'solar noon' (i.e. when the sun is at its highest point in the sky), with the solar azimuth being normalized. Use of reflectance data for the solar noon in theory should minimize intra-canopy shadowing. Reflectance data at 463m resolution were acquired for the MODIS reference tile h12v08 (covering much of eastern Guyana, all of Suriname and French Guiana, and parts of Brazil), for the period 18 Feb. 2000 - 17 Feb. 2015, representing 180 months of data. Data (originally 16-day averages) were grouped into their respective months, and the quality flag data contained within the MCD43A2 dataset were utilized to extract only reflectance data which had undergone full BRDF inversion. Monthly composites were then generated from the 180 months of data, producing 12 monthly averages (**Figure 2**).

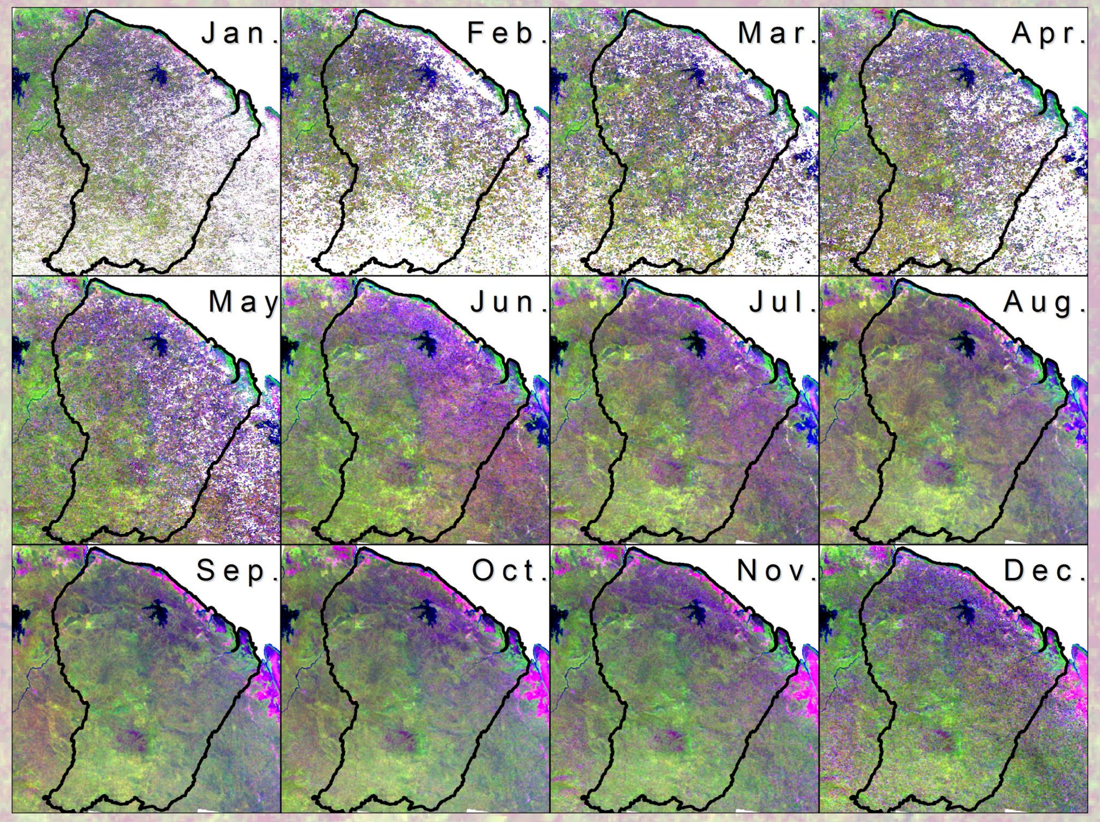

Figure 2: Monthly MOD43A4 reflectance composites for French Guiana

Instead of using a traditional classification, the data were instead analyzed using spectral mixture analysis (SMA), using the CLASlite processing system, which contains a standardized library of endmembers for mapping fractional cover of: (i) bare substrate, (ii) photosynthetic vegetation (PV), and (iii) non-photosynthetic vegetation (NPV) [1] [2]. Following the generation of fractional cover estimates of bare substrate, PV, and NPV for each month, the data were further processed to generate minimum-mean-maximum composites using a subset of 6 months of data (July-December). This was done because of substantial cloud cover during the January to June period, corresponding mainly with French Guiana's wet season.

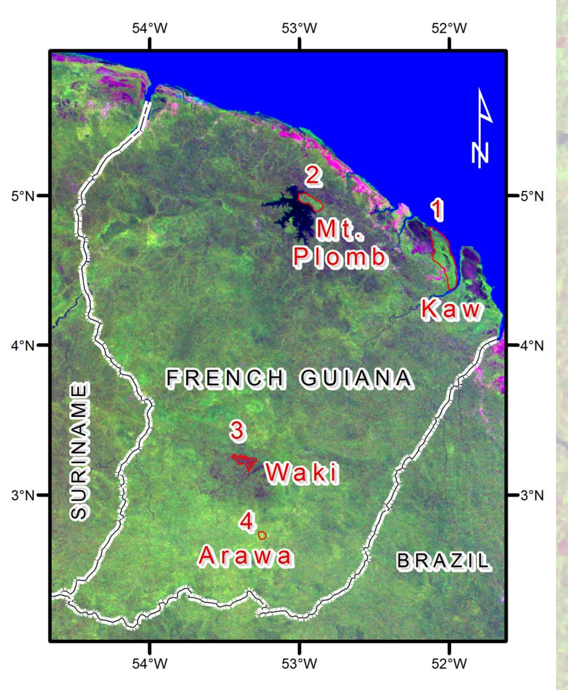

Figure 3: Location of the 4 pilot sites (overlain on mean September reflectance data from MODIS)

Additionally, where the minimum-mean-maximum composites provided illustrations of how the 3 endmembers 'behave' over a 6-month period, based on contrasts visible in those composites, 4 smaller sites were selected in order to assess how forest structure and composition can be inferred from the unmixing results. Based on the full 12 months of SMA results, 'curves' for the mean intra-annual trends in the endmembers were then generated for the 4 sites (shown in **Figure 3**).

III. Results

Minimum-mean-maximum composites for reflectance of bare soil, NPV, and PV are displayed in **Figures 4-5**, which reveal French Guiana's forests as being less than uniform in their reflectance of these endmembers. In the bare substrate composite, dark areas depict forests with consistently low exposure of bare soil and substrate over the 6 months composited (e.g. the forests covering the northern 2/3 of the territory and a patch of forest in the south).

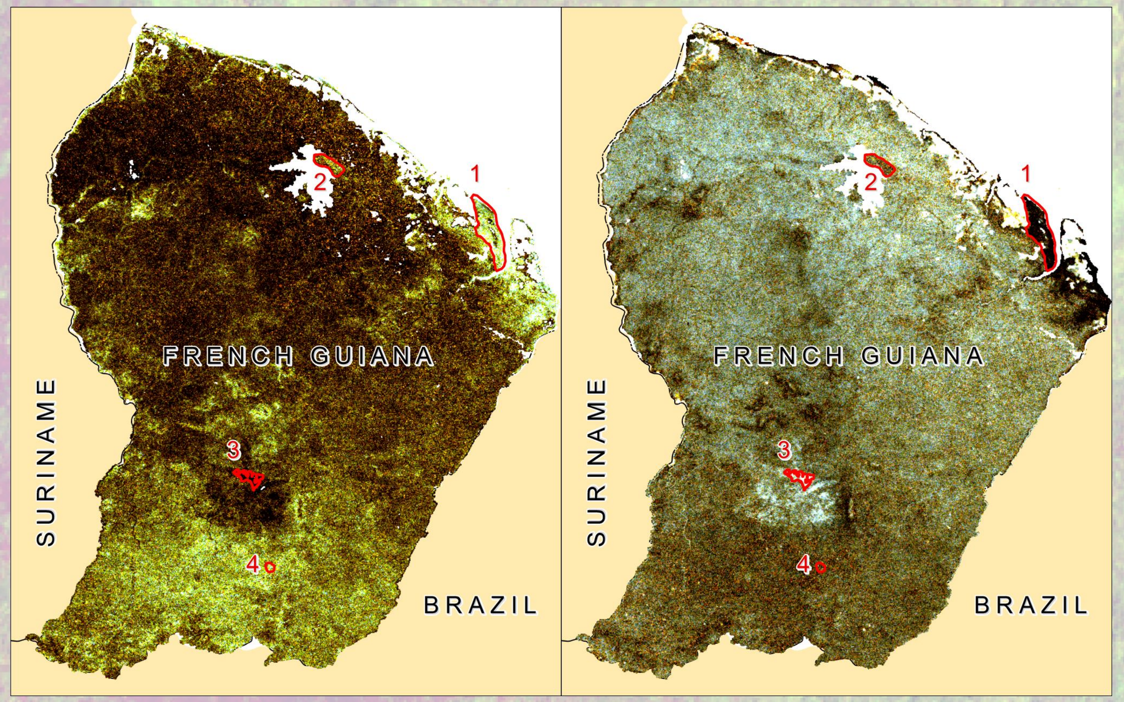

Figure 4: Minimum-mean-maximum composite of bare substrate (left) and NPV reflectance (right)

Bright areas depict areas with consistently moderate to high exposure of substrate (e.g. some of the coastal forest, some of the southern forest, and some forests near the eastern and western borders), while areas in between in color depict areas where such exposure is not consistent over the 6 months. In contrast, the NPV composite provides another layer of information in illustrating how the exposure of woody vegetation changes over time. Bright areas such as the patch of forest in the south of the territory (e.g. site 3) show forests with consistently high NPV fractions, while dark areas (e.g. the coastal forests in the northeast) essentially highlight forests with consistently low exposure of woody vegetation.

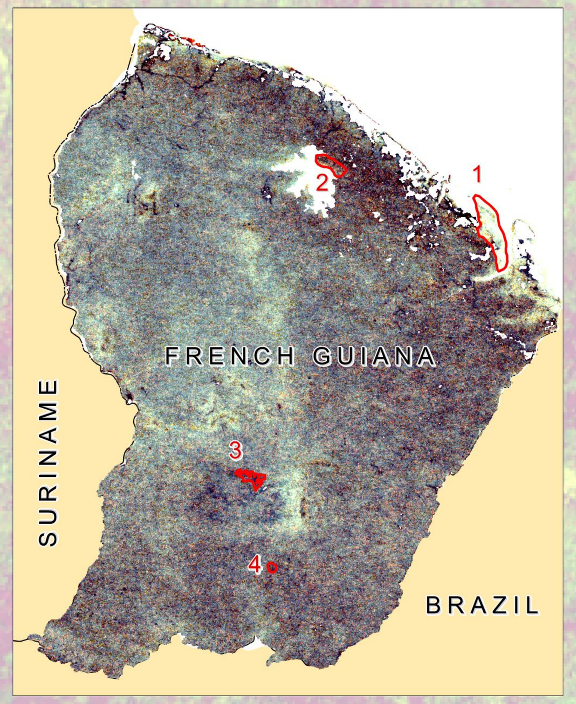

Figure 5: Minimum-mean-maximum composite of PV reflectance

Beyond being able to utilize the composites as visual cues for forest composition and structure, assessing the trends at the 4 pilot sites is also illustrative. **Figures 6**, for instance, illustrate the intra-annual variation in the bare substrate fraction at those 4 sites. It can be observed that each site displays its own distinctive trend in terms of bare substrate fractional cover, and this is largely also true for the NPV and PV fractions, as well (**Figures 7-8**).

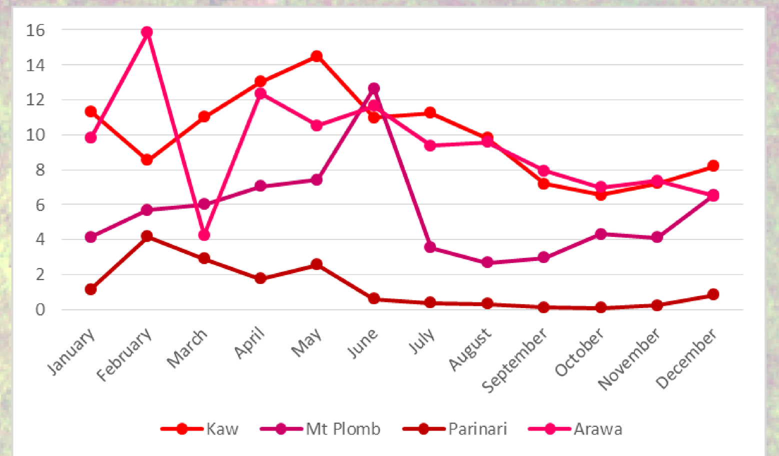

Figure 6: Intra-annual variation in the bare substrate fraction, at the 4 pilot sites

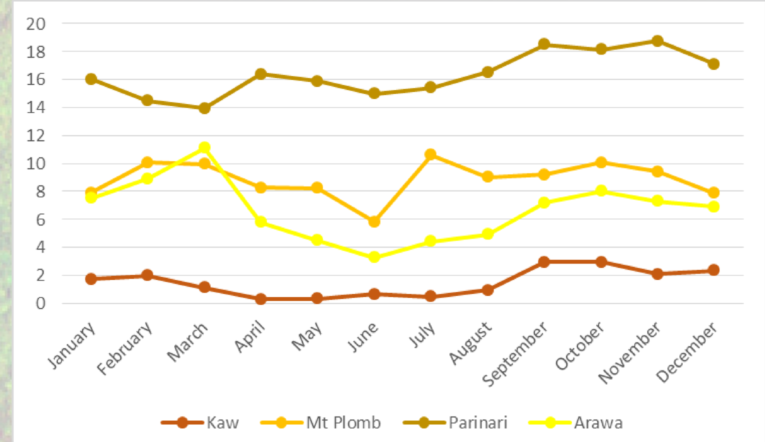

Figure 7: Intra-annual variation in the NPV fraction, at the 4 pilot sites

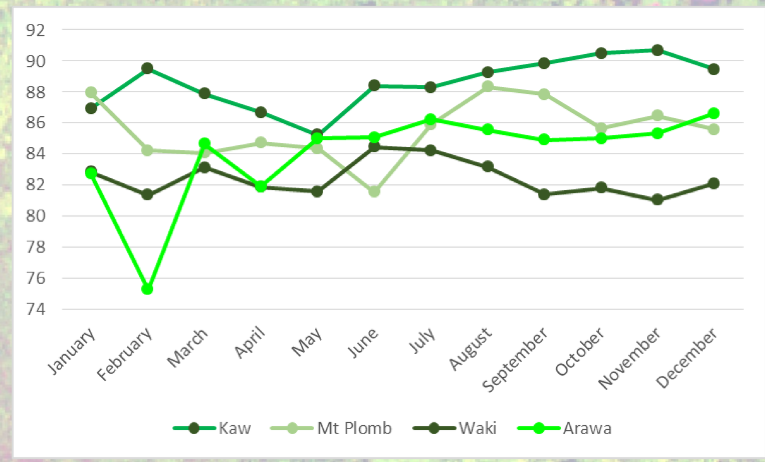

Figure 8: Intra-annual variation in the PV fraction, at the 4 pilot sites

IV. Future research

Future research is planned along the following lines:

- Time-series analysis of the 180 months of MCD43A4 data
- Forest cover classification based on SMA results
- Comparison with SMA of Landsat reflectance
- Comparison / validation with available field data

V. Selected bibliography

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