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USE OF MODIS AND SPOT VEGETATION TIME-SERIES DATA FOR MONITORING PHENOLOGICAL VARIATION IN TROPICAL FOREST ECOSYSTEMS IN WESTERN AFRICA AND THE GUIANA SHIELD

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1. INTRODUCTION

The advent, in the early 1970s, of earth observation satellites with multispectral sensors brought about the development of vegetation indices which simplified the complex spectral data collected by those sensors into basic information about vegetation condition. Where the first EO satellites [of the Landsat series] were only able to revisit areas of the earth on the order of twice per month, twenty years on, sensors were developed possessing a much higher temporal resolution than their predecessor instruments [2]. In that vein, MODIS (on the Aqua and Terra satellites), and Vegetation* (on the SPOT-4 satellite) constitute examples of multispectral sensors with high temporal resolution - able to image the same parts of the globe on a near-daily basis (* the Vegetation sensor is now defunct).

The fruit of that effort has been that both sensors have yielded over 15 years to date of global observations, with Vegetation's archive spanning December 1998 through April 2014, and MODIS' archive beginning in February 2000 and continuing to present day. From the large volumes of data collected – the epitome of 'big data' – a range of vegetation indices have been extracted from the multispectral data collected by both MODIS and Vegetation, allowing for monitoring of changes of vegetation in even the most remote parts of the world. This paper thus examines the utility of data from both sensors in assessing canopy-level phenological variation in forests in both western Africa and the Guiana Shield. The main objectives of this study are to utilize vegetation indices to assess variation in top-of-canopy greenness in the forests western Africa and the Guiana shield, and to compare how such regions differ in these estimates of greenness.

2. METHODS

In terms of this study's specific geographic domain, that domain includes two areas lying on the same latitude, and spanning 10 degrees by 10 degrees, and corresponding to tiles h12v08 and h19v08 in MODIS' reference system. One of the reasons for choosing both as study areas was due to their lying on the same latitude and hence being subject to similar solar illumination conditions (though at different times). The tile

covering a part of western / central Africa includes parts of Cameroon, the Central African Republic, Gabon, and Nigeria, while the tile over South America covers most of the Guiana Shield, including all of French Guiana and Suriname, and parts of Brazil, and Guyana.

Across both sensors, 5 vegetation indices were utilized, as follows. Data derived from SPOT-4's Vegetation sensor were obtained from Europe's Copernicus Global Land Service portal, and included the following variables, hereafter referred to as 'vegetation indices': (i) fraction of absorbed photosynthetically active radiation (FAPAR), (ii) fraction of green vegetation cover (FCOVER), (ii) leaf area index, and (iv) normalized difference vegetation index. The Vegetation data used covered the period December 1998 through April 2014. Data from the MODIS sensors on the Terra and Aqua satellites were obtained from NASA's Reverb ECHO platform, and included FAPAR and LAI (MCD15A2 product), which were obtained directly, while enhanced vegetation index (EVI) and NDVI were derived from MODIS nadir BRDF-adjusted reflectance data obtained from Reverb ECHO (MCD43B4 product). EVI and NDVI were derived from MODIS using standard formulas, and the use of BRDF-adjusted products allowed comparison with BRDF-adjusted datasets from Vegetation. The MODIS data used covered the period February 2000-2015. The existence of overlapping products (i.e. FAPAR, LAI, NDVI) allows for the assessment of how MODIS and Vegetation respectively visualize top-of-canopy phenological patterns.

Since this paper focuses on forests, non-forest areas were masked out, using a forest mask generated from the European Space Agency's 2009 GlobCover product. Although both the MODIS and Vegetation data used were of a comparable $1km^2$ spatial resolution, due to the large volume of data from the 15+ years of observations, data were temporally composited by generating averages (means) for each month, derived from the respective time-series for each product. The approach of compositing years of observations is similar to that employed in [4] and [6]. Mathematical means were then extracted from the monthly composites of each of the 5 vegetation indices utilized. Beyond intra-region comparisons of vegetation indices, a comparison of trends in the vegetation indices between the two regions studied was also performed.

3. RESULTS

Figures 1-2 below demonstrate the intra-annual trends of the vegetation indices, across the Guiana Shield and western Africa, respectively. Where this data provides an idea of when forest canopies are at their greenest, in the case of the Guiana Shield, it can see that the various vegetation indices illustrate fairly similar patterns in how forest canopy greenness changes across the year. EVI, FAPAR, and LAI from MODIS all indicate peaks in greenness during September, while FAPAR, FCOVER, LAI, and NDVI from Vegetation, and NDVI from MODIS, all indicate peak greenness during October, with both September and October pertaining to the dry season. Most of the indices also indicate greenness to be at its lowest during the April-May timeframe. While western Africa is on the same latitude as the Guiana Shield, the patterns in greenness

are fairly distinct, in that the majority of the vegetation indices show peaks in greenness in both the May-June and September-October timeframes. The second peak corresponds to that region's peak in the rainy season.

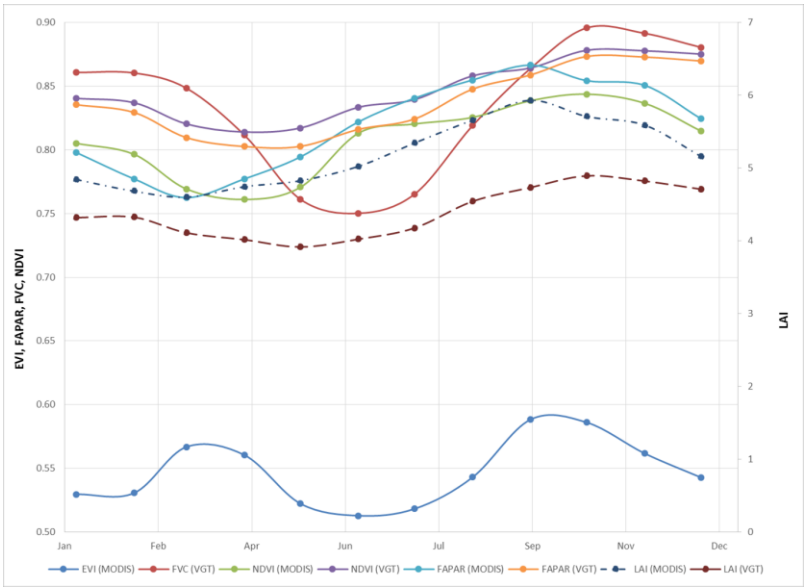

Figure 1: Comparison of intra-annual trends in vegetation indices across the forests of French Guiana

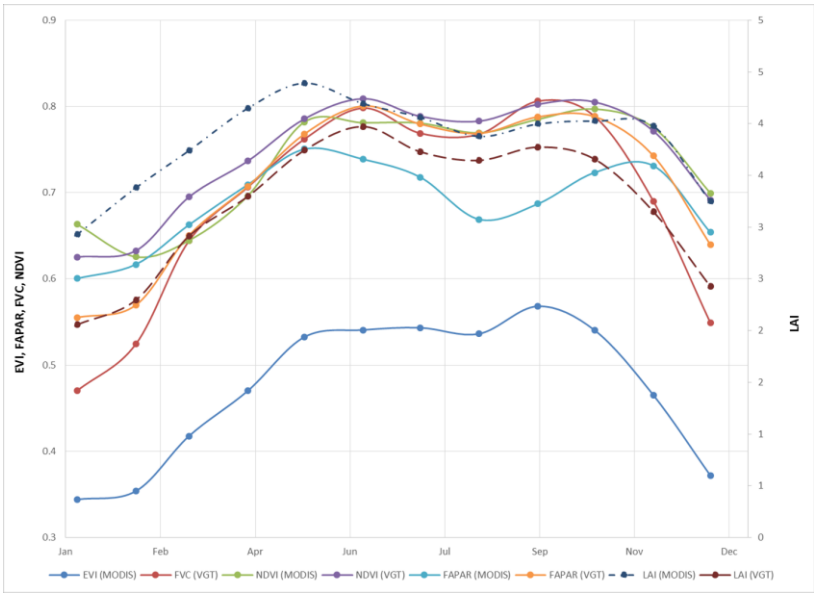

Figure 2: Comparison of intra-annual trends in vegetation indices across the forests of western Africa

Comparison of the vegetation indices for each area also illustrates discrepancies between the estimates from MODIS and Vegetation. For the Guiana Shield, average monthly FAPAR estimate was, overall, 2.2% lower in MODIS than in Vegetation, while LAI estimates from MODIS were 18.2% higher than those from Vegetation. NDVI estimates from MODIS were, overall, 4.5% lower than those from Vegetation. For western Africa, FAPAR estimates from MODIS were 2.7% lower than those from Vegetation, while LAI

estimates from MODIS were 21.4% higher than those of Vegetation, and NDVI estimates from MODIS were 1.3% lower than those of Vegetation.

4. DISCUSSION

In terms of this study's findings, comparison of the vegetation indices of both MODIS and Vegetation shows slight differences in the behavior of both sets of products, in terms of magnitude, and phase. Those small differences notwithstanding, for the most part those indices appeared to behave consistently, across the study's geographic domain, which covers two large forested landscapes in two continents. In other words, multitemporal vegetation index data from two distinct multispectral satellite sensors show similar patterns in terms of the estimates of canopy-level greenness. Another finding of note is that at least 3 of the 5 vegetation indices studied, namely FAPAR, FCOVER, and NDVI, are similar in magnitude and in temporal trends. EVI, whose formulation includes a correction for "canopy background signal," is markedly distinct in magnitude from the 3 aforementioned indices, although the temporal trend displayed is similar.

While the next phase of this study involves linkages with ongoing projects examining, in the field, phenological patterns in central African forests, the observations over the Guiana Shield are in accordance with phenological patterns identified through field studies [1] [5]. Furthermore, where previous studies have called into question the utility of vegetation indices in light of artefacts caused by varying illumination, where both study sites are on the same latitude, both sites are thus subject to the same illumination regimes [3]. If the variation observed in vegetation indices were merely artefacts of illumination, one would expect that both sites would display similar trends in estimated canopy greenness, and this has been clearly demonstrated to not be the case. It can thus be surmised that the various satellite-derived products are indeed detecting real changes in greenness, though what drives such changes in greenness still needs to be evaluated.

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