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Estimation of Canopy Leaf Area Index of Tropical Rainforests of Sri Lanka from the Normalized Difference Vegetation Index along a Wide Altitudinal Gradient

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Abstract

The leaf area index (LAI) of a forest is a key determinant of its primary productivity. Estimation of LAI via remote sensing of forest canopies offers an alternative to direct measurement, which is difficult in tropical rainforests (TRFs). Our objectives were to determine the variation of LAI and Normalized Difference Vegetation Index (NDVI) of a range of TRFs of Sri Lanka across a wide altitudinal range (117-2,132 m above sea level) and develop a predictive model to estimate LAI from NDVI and canopy architectural properties. Ten permanent sampling plots (PSPs) of one hectare each were established in forest reserves of Kanneliya (117-174 m), Sinharaja-Pitadeniya (509-618 m), Sinharaja-Enasalwatte (1,042-1,065 m), Rilagala (1,668 m), Hakgala (1,804 m), Piduruthalagala (2,080 m) and Horton Plains (2,132 m). Canopy LAI and its architectural properties (i.e., Mean Leaf Angle (MLA) and leaf angle distribution) were computed by analysis of 'fish-eye' images obtained from September 2019 to July 2020, using hemispherical photography and HemiView software. Satellite images for March-April, 2020 were downloaded from Landsat 8 OLI/TIRS C2L1. NDVI (NDVI=λNIR-λRED/λNIR+λRED) was calculated from ENVI software, where λNIR and λRED are reflectances of near-infrared and red wavebands. ENVI software computed the maximum NDVI ($NDVI_{Max}$) and minimum NDVI ($NDVI_{Min}$) values among 30 m×30 m pixels within each PSP. Mean NDVI ($NDVI_{Mean}$) was computed by taking the mean of NDVI values of all pixels within a PSP. Canopy LAI ranged from 1.94 (Pidurutalagala) to 3.38 (Pitadeniya). The corresponding ranges for $NDVI_{Max}$, $NDVI_{Mean}$ and $NDVI_{Min}$ were 0.620-0.767, 0.594-0.764 and 0.429-0.747 respectively. Canopy LAI, $NDVI_{Max}$ and $NDVI_{Mean}$ showed significant (p<0.05) linear decreasing trends with increasing altitude. For every 1,000 m increase in altitude, LAI, $NDVI_{Max}$ and $NDVI_{Mean}$ decreased by 0.396 (Adjusted-R^2=0.407, AIC=-19.92), 0.066 (0.698,-66.72) and 0.058 (0.493,-61.27). In contrast, $NDVI_{Min}$ did not show a significant trend with altitude. Second-order polynomial functions showed greater explanatory power than the linear functions, in terms of adjusted-R^2 and AIC, in fitting the variation of LAI (Adj.-R^2=0.492, AIC=-20.77) and $NDVI_{Max}$ with altitude (0.755,-68.15). The estimated maximum LAI and $NDVI_{Max}$ were at 637 and 329 m above sea level respectively. From among a range of multiple linear regression models using different combinations of NDVI, canopy architectural properties and altitude, the following two models were selected for predicting LAI, based on their adj-R^2 and AIC values: LAI=1.269+[3.567.$NDVI_{Max}$]–[1.598.$NDVI_{Min}$]–[0.000215.Altitude] (Adj-R^2=0.544, AIC=-21.41); LAI=-0.673+[5.887.$NDVI_{Max}$]–[1.490.$NDVI_{Min}$]–[0.000452.MLA] (0.489, -20.27).

Keywords: Normalized Difference Vegetation Index, Leaf Area Index, Tropical rainforests, Altitude, Canopy architecture