International Journal of Applied Geospatial Research
Volume 8 • Issue 1 • January-March 2017

Assessing Performance of Leaf Area Index in a Monitored Mountain Ecosystem on Mount Elgon-Uganda

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ABSTRACT

This study investigated the performance of leaf area index (LAI) and photosynthetically active radiation (PAR) in a mountain ecosystem. The authors hypothesized that significant spatial and temporal differences exist in LAI and PAR values in the Manafwa catchment on Mt. Elgon. This was accomplished through field measurements of actual LAI and PAR values of diverse vegetation types along a ~900m altitudinal gradient (1141–2029 masl) in the catchment. In-situ measurements were obtained from 841 micro-scale study plots in 28 sampling plots using high resolution LAI sensors. The findings showed a significant positive relationship exists between elevation and observed LAI ($r = 0.45$, $p = 0.01$). A regression model further shows that elevation and curvature of the landscape slope were highly significant ($p < 0.00002$) predictors of LAI. Finally, the authors detected significant spatial and temporal differences in LAI and PAR values in the study area. The study provides a critical basis for setting up long-term monitoring plans to understand mountain ecosystems and global climate change.

KEYWORDS

Leaf Area Index, Mount Elgon, Mountain Ecosystem, Photosynthetically Active Radiation, Spatial Sampling, Tropical Ecosyste

1. INTRODUCTION

1.1. Background to the Study

Leaf Area Index (LAI) and Photosynthetic Active Radiation (PAR) are important biophysical variables for quantifying phenological changes in ecosystems (Demarty et al. 2007; Tian et al. 2004). Understanding phenology changes at a landscape level, especially in a fragile mountain ecosystem, is critical because they offer new knowledge about spatial patterns and long-term trends. Yet there are persistent knowledge gaps and challenges in characterizing LAI and PAR performance in tropical mountain ecosystems. Some of these challenges are related to how we measure and constantly obtain reliable in situ LAI estimates in mountain ecosystems with a varied altitude, soil types, water availability, and diverse land management systems. Notwithstanding, the fact that obtaining in situ LAI/PAR measurements is a complicated task, modern instruments, such as the ACCUPAR LP-80 (Decagon Devices Inc.) have made it possible to continuously collect accurate field-based measurements of simultaneous below and above canopy. The techniques provide critical data for

DOI: 10.4018/IJAGR.2017010104

understanding spatial variability and phenological processes that can be used for vegetation analysis. PAR is an important detection index for vegetation cover and key parameter in ecosystem productivity, crop yield, and canopy cover models (Huemmrich & Goward, 1997; Lobell et al. 2003). In spite of the fact that research on application of in situ PAR measurement is limited (Yang et al. 2006), both LAI and PAR continue to be paramount models in assessing phenology.

The applications of empirical models have established the correlation among Normalized Difference Vegetation Index (NDVI), LAI, and PAR (Xavier and Vettorazzi 2004; Stenberg et al. 2004; Columbo et al. 2003). Xavier and Vettorazzi (2004) found that NDVI explained 54–74% of the variance in LAI values for the Ribeirão dos Marins watershed in Brazil with a mixed cover of sugarcane, pasture, riparian forests, eucalyptus and annual crops. Similarly, Gray and Song (2012) used IKONOS, Landsat, and MODIS images to model LAI over a forested area in North Carolina.

Nonetheless, empirical methods have some limitations like SVIs being affected by other factors like soil refection, sensor geometry, sun zenith angle among others. This may create circumstances where different NDVI values are observed for areas with similar LAI values (Xavier and Vettorazzi 2004). In addition, the relationships between SVIs and LAI are usually developed for a single point in time without a temporal dimension (Gray and Song 2012). This study will use MODIS NDVI time series covering 11 years to relate observed variation in LAI ranges to differences in land management as well as micro climatic changes in different seasons. The direct method for assessing LAR-PAR using ACCUPAR LP-80 will produce accurate in-situ measurements limiting the gaps in methods applied to phenology changes in a mountain ecosystem.

1.2. Rationale, Hypothesis, and Study Objectives

In East Africa, Pfeifer et al. (2012) reported LAI values of specific vegetation types of the Eastern Arc Mountains in South-west Kenya and Tanzania with spatial variation in the landscape. They showed that tropical montane and lowland forest had higher LAI-PAR than other areas within the study area. In addition, forests with higher precipitation had significantly higher LAI compared to all other forests. Nevertheless, there is still the need to carry out more systematic measurements of LAI at different altitudes for different cover types to ascertain whether the factor of elevation in combination with variables like precipitation and temperature can be reliably used as additional predictors of LAI (Pfeifer et al. 2012) for different cover types.

Although several studies have examined the spatial variation of LAI in diverse ecosystems (Xavier and Vettorazzi 2004; Jensen and Hardin, 2005; Peng et al. 2007; Gray and Song 2012), few studies have systematically studied the effect of altitude change on LAI in a tropical mountain ecosystem. Undoubtedly, critical baseline vegetation information is lacking. This study will fill this knowledge gap by assessing the impacts of anthropogenic activities on land use and vegetation cover types on Mt. Elgon ecosystem through the analysis of LAI patterns along an altitudinal gradient. In addition, the efficacy of identifying distinctive LAI zones from a moderate resolution NDVI time series will be assessed. The study provides long-term monitoring micro-scale study plots in the lower and upper catchments (Figure 1) to generate critical baseline vegetation information for the highly fragile mountain ecosystem in Manafwa catchment, Mt. Elgon, Uganda. We hypothesized that there were significant differences in spatial mean values of LAI values at different elevations, and land use land cover types within the catchment area. Three specific hypotheses were tested with the null hypothesis being no significant differences in the mean LAI estimates in diverse land cover types along ~ 900m altitudinal gradients. The tested hypotheses are summarized below:

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