Direct and Indirect Estimation of Leaf Area Index, f_{APAR}, and Net Primary Production of Terrestrial Ecosystems

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A primary objective of the Earth Observing System (EOS) is to develop and validate algorithms to estimate leaf area index (L), fraction of absorbed photosynthetically active radiation (f_{APAR}), and net primary production (NPP) from remotely sensed products. These three products are important because they relate to or are components of the metabolism of the biosphere and can be determined for terrestrial ecosystems from satellite-borne sensors. The importance of these products in the EOS program necessitates the need to use standard methods to obtain accurate ground truth estimates of L, f_{APAR}, and NPP that are correlated to satellite-derived estimates. The objective of this article is to review direct and indirect methods used to estimate L, f_{APAR}, and NPP in terrestrial ecosystems. Direct estimates of L, biomass, and NPP can be obtained by harvesting individual plants, developing allometric equations, and applying these equations to all individuals in the stand. Using non-site-specific allometric equations to estimate L and foliage production can cause large errors because carbon allocation to foliage is influenced by numerous environmental and ecological factors. All of the optical instruments that indirectly estimate L actually estimate "effective" leaf area index (L_E) and underestimate L when foliage in the canopy is nonrandomly distributed (i.e., clumped). We discuss several methods, ranging from simple to complex in terms of data needs, that can be used to correct estimates of L when foliage is clumped. Direct estimates of above-ground and below-ground net primary production (NPP_A and NPP_B, respectively) are laborious, expensive and can only be carried out for small plots, yet there is a great need to obtain global estimates of NPP. Process models, driven by remotely sensed input parameters, are useful tools to examine the influence of global change on the metabolism of terrestrial ecosystems, but an incomplete understanding of carbon allocation continues to hamper development of more accurate NPP models. We summarize carbon allocation patterns for major terrestrial biomes and discuss emerging allocation patterns that can be incorporated into global NPP models. One common process model, light use efficiency or epsilon model, uses remotely sensed f_{APAR}, light use efficiency (LUE) and carbon allocation coefficients, and other meteorological data to estimates NPP. Such models require reliable estimates of LUE. We summarize the literature and provide LUE coefficients for the major biomes, being careful to correct for inconsistencies in radiation, dry matter and carbon allocation units.

INTRODUCTION

Humans have affected and continue to affect the Earth. For example, large areas have undergone land use change (e.g., deforestation, desertification), the chemical composition of gases in the atmosphere has been altered, surface water and aquifers have been contaminated, and atmospheric deposition of nitrogen and sulfur have begun to change the biogeochemical cycles in terrestrial and aquatic ecosystems. These changes are well documented (IPCC, 1995), but their effects on the sustainability of life are not fully understood. Mission to Planet Earth (MTPE), a NASA-initiated program that uses space-, ground-, and aircraft-based measurement systems, was founded to improve the understanding of the fundamental processes that define the Earth system

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