VEGETATION DYNAMICS

Understanding ecosystem structure and function requires familiarity with the techniques, knowledge and concepts of the three disciplines of plant physiology, remote sensing and modelling. This is the first textbook to provide the fundamentals of these three domains in a single volume. It applies cross-disciplinary insights to multiple case studies in vegetation and landscape science. A key feature of these case studies is an examination of relationships among climate, vegetation structure and vegetation function, to address fundamental research questions. This book is for advanced students and researchers who need to understand and apply knowledge from the disciplines of plant physiology, remote sensing and modelling. It allows readers to integrate and synthesise knowledge to produce a holistic understanding of the structure, function and behaviour of forests, woodlands and grasslands.

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A Synthesis of Plant Ecophysiology, Remote Sensing and Modelling

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Preface

"Classical" plant physiology is the study of physiological processes of individual plants of a single species growing in pots in glasshouses, growth cabinets and controlled-environment chambers. Single-factor experiments are frequently used to manipulate one variable (e.g. water supply, temperature) in order to establish the response of individual processes (e.g. transpiration rate, phloem loading) or whole plants (e.g. growth rate) to that variable. It has been an immensely powerful science, contributing to increased food productivity and crop genetic selection for many decades.

Ecophysiology takes knowledge gained from plant physiological studies and applies them to plants growing "in the wild", in real landscapes. This adds several layers of complexity arising from (a) large spatial and temporal variations in multiple variables (e.g. rainfall, temperature, solar radiation); (b) the interactions amongst multiple variables; and (c) complexities arising from the fact that landscapes are composed of multiple species. Although manipulative experiments can be undertaken in ecophysiology (e.g. rainfall exclusion, and rainfall redistribution troughs), the majority of ecophysiological studies do not manipulate environmental variables. Rather, they allow natural seasonal and inter-annual variation to impact on the structure and function of natural vegetation and measure the response of individual leaves, plants (trees, grasses, etc.) and canopies and use statistical inferences and models to analyse these responses.

Modelling of plant function can similarly be undertaken at small (leaves; xylem function), intermediate (trees, canopies) and large scales (stands, regions, sub-continental, global) across a range of temporal scales (typically hours to centuries). These models incorporate plant physiological and ecophysiological data (e.g. light response curves of leaves, eddy covariance tower flux data) to model the function (e.g. gross primary productivity [GPP], net primary productivity [NPP], evapotranspiration [ET]) of landscapes and biomes.

Remote sensing (RS) uses air-borne and satellite platforms for remote surveillance of land and vegetation surfaces (e.g. reflectance of solar radiation across multiple wavebands, land surface temperature). Using these remotely sensed data, plant structural attributes (e.g. LAI) and functional attributes (e.g. NPP, ET) can be calculated. As is the case for modelling, RS as a discipline is increasingly using physiological

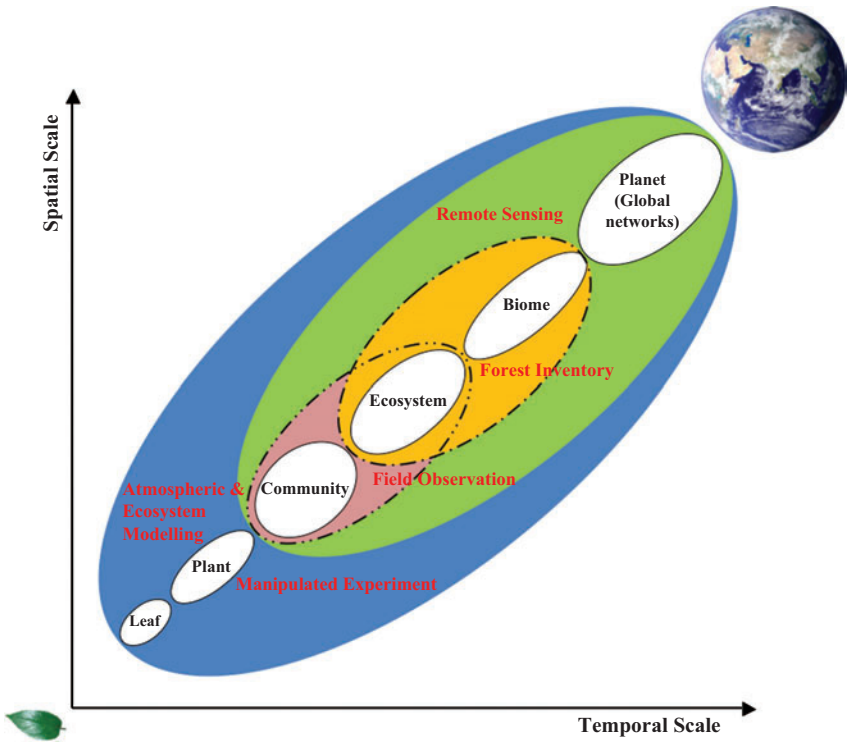

Figure I.1. A simplified conceptual representation of the different spatial and temporal scales of organisation (and study) encompassed in this textbook. Plant physiological and ecophysiological observations are mostly confined to cellular, leaf, whole plant, community and ecosystem spatial scales; most observations are made at sub-annual temporal scales and few observations have been made for longer than 15 years. In contrast, modelling can be undertaken from leaf-to-global-scales at almost any required temporal scale. Remote sensing is generally applied at community-to-global spatial scales and with weekly-to-decadal temporal scales.

and ecophysiological (e.g. canopy conductance, canopy gas fluxes, LAI) data to validate/test/compare remotely sensed estimates of landscape processes and vegetation structure. Figure I.1 provides a simplified representation of these three disciplines and their overlap.

Aims of This Book

The first aim of this book is to provide a relatively simple guide to some key aspects of plant physiology and plant ecophysiology, as they relate to the functional behaviour of natural landscapes, with particular emphasis on carbon (C) and water fluxes. This section should be of most value to those who are experienced modellers and remote sensing practitioners who need to increase their knowledge of plant physiology and ecophysiology. The focus on physiology pertaining to C and water fluxes is deliberate because these fluxes are two of the principal vegetation functions that drive

all downstream aspects of landscape function (e.g. catchment water balance, productivity, biogeochemical cycling). The second and third aims are to provide similar introductions to the disciplines of remote sensing (RS) and modelling of vegetation structure and function. It is likely that ecophysiologists will, at some point in their career, need to include aspects of these two disciplines in their work; similarly, modellers will increasingly use RS data in conjunction with ecophysiological information whilst RS practitioners increasingly need the ability to develop and apply models and incorporate/understand ecophysiological data in relation to the insights generated through remote sensing.

Thus, the final aim of this book is to provide some level of integration of the three disciplines. It is our contention that a full understanding of landscape function requires integration across these disciplines. We hope that this text may facilitate that integration.

Structure of the Content of the Book

The book has four sections. Section One contains the basic plant physiology and ecophysiology required to examine landscape carbon and water fluxes. The second section provides an overview of the techniques available in remote sensing, including consideration of the physical principles of remote sensing and the different platforms available to examine landscape structure and function. The third section provides descriptions of the basic modelling of vegetation and landscape processes across multiple scales. The final section contains seven case studies where data from ecophysiological, modelling and RS studies are presented and combined to provide a richer and deeper understanding of landscape structure and function. These case studies include (1) Carbon and water fluxes of five contrasting biomes (boreal forests, arid and semi-arid grasslands, tropical montane forests, Amazonian forest, savannas); (2) groundwater-dependent ecosystems; (3) and global drought and forest mortality.

We hope you enjoy the read.