Estimating Canopy Water Content from Multispectral Satellite Imagery

by

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A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Environmental Science, Policy, and Management

in the

Graduate Division

of the

University of California, Berkeley

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Spring 2026

The dissertation of Priya N. Anand, titled Estimating Canopy Water Content from Multispectral Satellite Imagery, is approved:

Chair _____ Date _____

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University of California, Berkeley

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Abstract

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Canopy water content is a key indicator of vegetation drought stress, but ground measurement is slow and does not scale to large forested areas. This thesis develops and validates a method for estimating canopy water content from multispectral satellite imagery, using a combination of shortwave-infrared water absorption bands and a physically based radiative transfer model. We calibrate the model against three years of field measurements across a range of forest types and validate it on an independent held-out set of stands. The resulting estimates track ground-measured canopy water content closely during both wet and drought years, suggesting the method is suitable for regional-scale drought monitoring where ground sampling is impractical.

For my parents, who never once asked when I would finish.

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Acknowledgments

I thank my advisor and committee for their guidance, and the field crews who spent long summers collecting the canopy samples this work depends on. This research was supported by a graduate fellowship and a grant from the university's Institute for Environmental Science.

Chapter 1

Introduction

1.1 Motivation

Canopy water content (CWC) relates directly to plant water status and is one of the earliest indicators of drought stress, often changing before visible symptoms such as leaf browning appear. Ground-based measurement of CWC requires destructive sampling of leaf tissue, which limits monitoring to a small number of plots and makes it impossible to track change over large forested regions in real time (Ceccato et al., 2001).

Remote sensing offers a path to regional-scale monitoring. Several shortwave-infrared bands are sensitive to leaf water absorption features, and prior work has shown that vegetation indices built from these bands correlate with leaf-level water content under controlled conditions (Gao, 1996).

1.2 Contributions

This thesis makes the following contributions:

- A radiative transfer-based method for estimating canopy water content from multispectral imagery, calibrated against field data from three forest types.
- A three-year field validation dataset pairing satellite overpasses with destructive canopy sampling.
- An analysis of estimation accuracy during drought versus non-drought years.

1.3 Thesis Outline

Chapter 2 reviews prior remote sensing approaches to canopy water content estimation. Later chapters (omitted from this starter document) would present the calibration method, field validation, and results.

Chapter 2

Related Work

2.1 Spectral Indices for Water Content

The Normalized Difference Water Index and related shortwave-infrared indices have been widely used as proxies for vegetation water status (Gao, 1996), though their relationship to absolute canopy water content is indirect and depends on canopy structure.

2.2 Radiative Transfer Approaches

Physically based radiative transfer models such as PROSPECT relate leaf optical properties, including water content, to reflectance spectra, and have been coupled with canopy models to invert satellite reflectance for biophysical parameters (Ceccato et al., 2001).

2.3 Gap Addressed by This Thesis

Prior validation of these methods has generally used a single growing season. This thesis validates a radiative-transfer-based CWC estimate across three years spanning both average and drought conditions.

Bibliography

Ceccato, P. et al. (2001). "Detecting vegetation leaf water content using reflectance in the optical domain". In: *Remote Sensing of Environment* 77.1, pp. 22–33.

Gao, Bo-Cai (1996). "NDWI—A Normalized Difference Water Index for Remote Sensing of Vegetation Liquid Water From Space". In: *Remote Sensing of Environment* 58.3, pp. 257–266.