



Universiteit
Leiden
The Netherlands

Satellite remote sensing of plant functional diversity

Hauser, L.T.

Citation

Hauser, L. T. (2022, June 22). *Satellite remote sensing of plant functional diversity*. Retrieved from <https://hdl.handle.net/1887/3348489>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/3348489>

Note: To cite this publication please use the final published version (if applicable).

Satellite Remote Sensing of Plant Functional Diversity

Leon T. Hauser

© Leon T. Hauser (2022)

Satellite Remote Sensing of Plant Functional Diversity

PhD Thesis at Leiden University, The Netherlands

The research described in this thesis was conducted at the Institute of Environmental Sciences (CML), Leiden University, the Netherlands. All rights reserved. No parts of this publication may be reproduced in any form without the written consent of the copyright owner.

ISBN: 9789051918878

Cover: Elke E.M. Hauser

Layout: Leon T. Hauser

Printing: UFB - Grafisch - Leiden University

Satellite Remote Sensing of Plant Functional Diversity

Proefschrift

ter verkrijging van
de graad van doctor aan de Universiteit Leiden,
op gezag van rector magnificus prof.dr.ir. H. Bijl,
volgens besluit van het college voor promoties
te verdedigen op woensdag 22 Juni 2022
klokke 10.00 uur

door

Leon T. Hauser

geboren te Subiaco (WA), Australië

Promotor: Prof.dr. P.M. van Bodegom

Co-promotores: Prof.dr. N.A. Soudzilovskaia

Dr.ir. J. Timmermans

Promotiecommissie: Prof.dr. J.C. Biesmeijer

Prof.dr.ing. J.W. Erisman

Prof.dr. A.K. Skidmore (Universiteit Twente)

Dr. A.K. Schweiger (University of Zurich)

Prof.dr. M. Baratchi

To Wil, Otto, and Elke

“The most striking feature of earth is the existence of life.

The most striking feature of life is its diversity”

David Tilman (2000)

Table of Contents

Chapter 1.:	General introduction	10
1.1.	On the importance of monitoring biodiversity.....	10
1.2.	What is biodiversity?	10
1.3.	The promise of remote sensing	11
1.3.1.	Need for quantitative monitoring of large-scale biodiversity dynamics	11
1.3.2.	The potential of optical remote sensing of vegetation	12
1.3.3.	Translating spectra to plant diversity concepts	13
1.4.	Challenges in linking ecological and remote sensing concepts of biodiversity.....	16
1.4.1.	The next frontier: satellite remote sensing of plant biodiversity.....	16
1.4.2.	Disparities in the concept of scale in ecology and remote sensing	18
1.4.3.	Training and validation	19
1.5.	Research aims	20
Chapter 2.:	Explaining discrepancies between spectral and in-situ plant diversity in multispectral satellite earth observation	23
2.1.	Introduction.....	24
2.2.	Methodology	26
2.2.1.	Study area	26
2.2.2.	Data collection	28
2.2.2.1.	Field data collection	28
2.2.2.2.	Leaf biochemical traits.....	28
2.2.2.3.	Sentinel-2 surface reflectance	29
2.2.3.	Data analysis	29
2.2.3.1.	Diversity metrics	29
2.2.3.2.	Simulating spectral diversity through radiative transfer models.....	30
2.2.3.3.	Statistical analysis.....	31
2.3.	Results.....	32
2.3.1.	Assessing links and discrepancies between spectra and in-situ traits through RTM simulations	32
2.3.2.	Trait-, Taxonomic and Spectral diversity relationships in empirical data	34
2.3.3.	Multivariate constituents of spectral diversity through linear mixed-effect models	35
2.4.	Discussion.....	36
2.4.1.	Leaf and canopy simulations show large differences in relation to empirical observations	36
2.4.2.	Vegetation cover is dominant in spectral diversity signal	37
2.4.3.	Spectral Variability Hypothesis works for taxonomic diversity, the underlying mechanism remains unexplained	38
2.4.4.	Absence of leaf trait diversity in spectral diversity signal	39
2.4.5.	Expanding spectral diversity applications.....	39
2.5.	Conclusions.....	40

Chapter 3.: Towards scalable estimation of plant functional diversity from Sentinel-2 imagery: in-situ validation in a heterogeneous (semi-)natural landscape	42
3.1. Introduction	43
3.2. Methods	45
3.2.1. Study area	45
3.2.2. Field measured plant traits	46
3.2.3. Remotely sensed plant traits	47
3.2.3.1. Sentinel-2 data	47
3.2.3.2. Radiative transfer model inversion	47
3.2.3.2.1. Look-up Table (LUT)-based inversion	48
3.2.3.2.2. Sentinel Application Platform Biophysical processor	49
3.2.3.2.3. PROSAIL-D/Support Vector Regression hybrid approach	49
3.2.4. Functional and taxonomic diversity estimations	50
3.2.5. Statistical analysis	51
3.3. Results	52
3.3.1. Trait estimates	52
3.3.2. Functional diversity estimates	57
3.4. Discussion	58
3.4.1. Estimating canopy and leaf traits	58
3.4.2. Estimating multivariate functional diversity	60
3.4.3. Ecological implications	61
3.5. Conclusions	63
Chapter 4.: Linking land use and plant functional diversity patterns in Sabah, Borneo, through large-scale spatially continuous Sentinel-2 inference	64
4.1. Introduction	65
4.2. Methods	67
4.2.1. Study area	67
4.2.2. Retrieval of functional traits	67
4.2.3. Estimating functional diversity	68
4.2.4. Land use data	69
4.2.5. Data analysis	69
4.3. Results	70
4.3.1. From mapping spatially explicit spectral trait indicators to functional diversity estimates	70
4.3.2. Land use patterns of plant functional diversity	72
4.4. Discussion	73
4.4.1. Functional diversity retrieval	73
4.4.2. Land use gradient as qualitative assessment	74
4.4.3. Outlook	76
4.5. Conclusion	76
Chapter 5.: Sizing up the scale dependence of satellite-based plant diversity estimates: Functional diversity-area relationships observed through Sentinel-2 over the Bornean rainforest-plantation matrix	78

5.1.	Introduction.....	79
5.2.	Methods	82
5.2.1.	Study area	82
5.2.2.	Datasets.....	82
5.2.3.	Functional diversity	84
5.2.4.	Scaling of plots	85
5.2.5.	Data analysis	86
5.3.	Results.....	87
5.3.1.	FAR against null-model predictions	87
5.3.2.	FAR across land use types	88
5.3.3.	The scale dependency of environmental predictors	89
5.4.	Discussion.....	89
5.4.1.	Comparison against field and airborne studies	90
5.4.2.	Passive sampling hypothesis.....	91
5.4.3.	Trait convergence.....	92
5.4.4.	Environmental drivers.....	93
5.4.5.	Alpha and beta diversity components	93
5.4.6.	Recommendations.....	94
5.4.7.	Limitations.....	95
5.5.	Conclusions.....	95
Chapter 6.:	General discussion	97
6.1.	Lessons learned.....	98
6.1.1.	Disentangling spectral diversity.....	98
6.1.2.	Physics-based estimation of functional diversity.....	100
6.1.3.	Validation of satellite remotely sensed plant diversity	103
6.1.4.	Large-scale spatially continuous application	104
6.2.	Considerations of scale dimensions	105
6.2.1.	Spatial scale and resolution.....	105
6.2.2.	Spectral resolution	108
6.2.3.	Temporal dimension	109
6.3.	Future outlook.....	110
6.4.	Conclusions.....	113
Chapter 7.:	Supplementary Materials	115
Chapter 8.:	References	146
I.	Summary	176
II.	Samenvatting	178
III.	Acknowledgements	180
IV.	Curriculum Vitae	182
V.	Publications	183