



Universiteit
Leiden
The Netherlands

Geometry of vegetation patterns: understanding patterns in dryland ecosystems and beyond

Jaïbi, O.

Citation

Jaïbi, O. (2021, November 24). *Geometry of vegetation patterns: understanding patterns in dryland ecosystems and beyond*. Retrieved from <https://hdl.handle.net/1887/3243448>

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/1887/3243448>

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

Geometry of Vegetation Patterns

*Understanding patterns in dryland ecosystems and
beyond*

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 24 november 2021
klokke 15.00 uur

door

Olfa Jaïbi

Promotor:

Prof.dr. Arjen Doelman

Universiteit Leiden

Copromotor:

Dr. Martina Chirilus-Bruckner

Universiteit Leiden

Promotiecommissie:

Prof.dr. Frank van der Duijn Schouten

Leiden University

Prof.dr. Roeland Merks

Leiden University

Prof.dr. Ehud Meron

Ben-Gurion University

Prof.dr. Vivi Rottschäfer

Leiden University

Prof.dr. Peter van Heijster

Wageningen University

© Olfa Jaïbi, 2021.

Print: Groenprint.

Front Cover: Cover design by Bram Bergs.

To Dikkie and Patat.

To those who still don't have access to education.

Contents

1	Introduction	1
1	Ecological background	4
1.1	Ecological context	5
1.2	Ecosystem models studied	7
1.3	Ecosystem dynamics	9
2	Mathematical concepts	10
2.1	Reaction-diffusion equations, orbits and patterns	10
2.2	Geometric singular perturbation theory	17
3	The onset of patterns	20
4	Content of thesis	24
4.1	Multistability of striped vegetation patterns	24
4.2	Existence of (novel) localized vegetation patterns in a generalized ecosystem model	25
	Appendices	29
	1.A Turing bifurcation on sloped terrains	29
2	Multi-stability of model and real dryland ecosystems through spa- tial self-organization	31
1	Introduction	32
2	Theory	34
2.1	Model description	34
2.2	Theoretical outcomes	34
2.3	Testable predictions	37
3	Data acquisition & processing	38
4	Results	39
5	Discussion	40
	Appendices	43
2.A	Dimensional extended-Klausmeier	43
2.B	Description of study sites	43
2.C	Data sets	44
2.C.1	Topographical data	44
2.C.2	Biomass measurements	45
2.C.3	Optical data	45

2.D	Data processing	46
2.D.1	Spectral analysis, direction of anisotropy and wavelength	46
2.D.2	Pattern classification	48
2.D.3	Cross-spectral analysis and migration speed	48
2.D.4	Assessment of uncertainty in calculations of slope gradient and aspect from topographical data	49
2.D.5	Assessment of uncertainty in estimation of pattern frequency from optical imagery	50
3	The existence of localized vegetation patterns in a systematically reduced model for dryland vegetation	55
1	Introduction	56
2	Set-up of the existence problem	62
2.1	The fast reduced problem	62
2.2	The slow reduced limit problems	64
2.3	Critical points and homogeneous background states	68
2.4	The slow flows of the $\varepsilon \neq 0$ system	70
3	Localized front patterns	75
3.1	$W^u(P^0) \cap W^s(\mathcal{M}_\varepsilon^+)$ and its touch down points on $\mathcal{M}_\varepsilon^+$	76
3.2	Traveling 1-front patterns – primary orbits	77
3.3	Traveling 1-front patterns by the perturbed integrable flow on $\mathcal{M}_\varepsilon^+$	81
3.4	Stationary 1-front patterns	86
3.5	Stationary homoclinic 2-front patterns: vegetation spots and gaps	89
3.6	Spatially periodic multi-front patterns	96
4	Simulations and discussion	100
4.1	Simulations	100
4.2	Discussion	106
	Appendices	111
3.A	Derivation of the model equations in one spatial dimension	111
3.B	The derivation of the scaled model	112
3.C	Lemma 2.6 and the Bogdanov-Takens bifurcation scenario	113
4	Outlook	115
	Bibliography	121
	Samenvatting	135
	Curriculum Vitae	139