



LANDSCAPE EVOLUTION

LANDFORMS,
ECOSYSTEMS, AND SOILS

JONATHAN D. PHILLIPS

LANDSCAPE EVOLUTION

This file contains only the table of contents & preface.

The book can be obtained via:

<https://www.elsevier.com/books/landscape-evolution/phillips/978-0-12-821725-2>

This page intentionally left blank

Cover art by Petr Mores

LANDSCAPE EVOLUTION

Landforms, Ecosystems, and
Soils

JONATHAN D. PHILLIPS



Elsevier
Radarweg 29, PO Box 211, 1000 AE Amsterdam, Netherlands
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, United Kingdom
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States

Copyright © 2021 Elsevier Inc. All rights reserved.

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Details on how to seek permission, further information about the Publisher's permissions policies and our arrangements with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: www.elsevier.com/permissions.

This book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein).

Notices

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

Library of Congress Cataloging-in-Publication Data

A catalog record for this book is available from the Library of Congress

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library

ISBN: 978-0-12-821725-2

For information on all Elsevier publications visit our website
at <https://www.elsevier.com/books-and-journals>

Publisher: Candice Janco
Acquisitions Editor: Megan Ashdown
Editorial Project Manager: Hilary Carr
Production Project Manager: Debasish Ghosh
Cover Designer: Mark Rogers

Typeset by TNQ Technologies



Contents

Preface	ix
Chapter 1 An integrated approach to landscape evolution	1
Introduction	1
Key concepts	10
Background: evolutionary pathways in landscapes	15
Comparison and contrast: integrated approach to landscape evolution versus traditional approaches	25
References	28
Chapter 2 Earth surface systems as supraorganisms	37
Introduction: supraorganisms	37
State factor model	46
Ecosystem evolution	57
The upshot.....	60
References	61
Chapter 3 Observing landscape evolution.....	69
Introduction	69
Methods and approaches	70
Indicators	81
References	90
Chapter 4 It depends on the scale: scale contingency in landscape evolution	97
Overview of scale issues	97
Scale (in)dependence.....	100
Hierarchies and the vanishing point	103
Time—real and realized	110

Scale contingency	112
References	113
Chapter 5 Historical contingency in landscape evolution	117
Memory, inheritance, and legacies	117
Succession and state transitions	123
Canalization	124
Extinction and reinforcement of evolutionary pathways	125
Maturation	132
Divergence and convergence	132
Evolutionary pathways and historical trajectories	135
Summary	147
References	149
Chapter 6 Attractors and goal functions in landscape evolution	159
Introduction	159
Deterministic, single-outcome systems	164
Multiple path, multiple outcome concepts	171
Plasticity, degrees of freedom, and constraints	176
Goal functions and emergence	178
Multiple causality	186
Circular reasoning	187
Consilience?	190
References	193
Chapter 7 Thresholds, tipping points, and instability	201
Introduction	201
Thresholds in the landscape sciences	208
Lessons from the past	214
Mode switches and meta-thresholds	215

Example: a hierarchy of thresholds	218
Conclusions	221
References	222
Chapter 8 Selection and landscape evolution	227
Introduction	227
Ecosystem selection	232
Abiotic selection	233
Preferential flow.....	237
Efficiency selection	240
Selection is <i>local</i>	246
Why aren't landscapes always becoming more efficient?	249
Occam's selection.....	252
Example: Inner Bluegrass, Kentucky	254
References	261
Chapter 9 The perfect landscape	269
The perfect storm	269
The perfect landscape	271
Triangles, badasses, and axioms	273
Evolutionary creativity	280
Evolution of landscape diversity.....	291
Conclusions	295
References	295
Chapter 10 Landscape evolution and environmental change	301
Landscape evolution lessons	301
Transformational, reciprocal, emergent evolution: TREE	304
A churning urn of burning funk	306

Landscape evolution stories	307
Lower Sabine River	308
Trees and surface drainage in the Šumava Mountains	322
The last word	334
References	335
Index	339

Preface

Sometimes it is a useful thought experiment, or a convenient model assumption, to imagine a landscape as an isotropic plane, with some process acting unequally upon it. The featureless landscape then develops features as the inequalities manifest themselves. Literal or figurative peaks and pits, ridges and valleys, and so on emerge.

Now imagine the landscape with multiple processes acting unequally upon it, each creating its own (literal or figurative) topography. Sometimes these processes may be more or less independent; in other cases, they may reinforce or offset each other, and mutually influence each other in various other ways. Then, imagine that each of these processes also influences other aspects of the surface, such as, say, color, texture, and opacity. In each of these respects, the phenomena acting on our thought-experimental surface also may be independent, offsetting, or mutually reinforcing. What a complex, difficult to interpret or predict surface emerges!

But we are not done with our experiment. Figure that the initial surface was not isotropic—like unicorns and mermaids, isotropic surfaces in nature are imaginary! And figure that the hypothetical surface is just one layer in a volume, influenced by the layers above and below, which are comparably complicated.

The abstraction in the first paragraph, or something close to it, is the way we have traditionally looked at landscape evolution, at least partly due to the necessity of isolating and simplifying so as to try and make sense of a very complex phenomenon. Each additional “now imagine” or “figure that” brings us closer to the way actual landscapes evolve.

This is the view of landscape evolution that I am trying to present here, in all its glorious complexity—though I naturally fell short of even identifying all the glorious complexity, much less explaining it. But even so, I know what story I want to try to tell. But how to tell it?

Henry David Thoreau wrote: “Every man will be a poet if he can; otherwise a philosopher or man of science. This proves the superiority of the poet. Every poet has trembled on the verge of science.”

This is a science book. I wish that I could make it more of a book that is also art, literature, or poetry. Those are ways of experiencing and understanding Earth systems and landscapes and their changes that are complementary to science, and would do a better job of conveying why I—and many of my fellow scientists—devote ourselves to the study of Earth systems. I would like to think that I am a scientist with the soul of a poet. Alas, I am only a scientist who wishes he had the soul of a poet. I have tried to season the book with a bit of imagination, humor, and introspection, but my working vocabulary and communication skills are those of the scientist, not the novelist or the poet.

All of this is not so much to tamp down expectations of entertainment, or to prepare the reader for the cold, hard facts of science, the resolute acknowledgment of uncertainty, and the convoluted chains of explanation, interpretation, and speculation that follow. Rather, it is because I wish I could translate, or at least embed, the cold, the hard, the resolute, and the convoluted in some appreciation of the wonder and joy that accompanies them. Many people feel that science, representing nature via mathematics, statistics, data, diagrams, etc., dulls its appreciation. And sadly, I guess it does for many. But for me—and again, for many if not most of my professional peers—it has the opposite effect. For us, science causes wonder and joy to blossom into awe, astonishment, and delight—notwithstanding the pain and despair that sometimes comes with knowing what we humans are doing to our planet.

Arthur C. Clarke wrote that “any sufficiently advanced technology is indistinguishable from magic.” Riffing on that theme, I once gave a talk proclaiming “any sufficiently improbable event is indistinguishable from the miraculous.” Some definitions of “miracle” invoke the divine or supernatural, but I have in mind the definition as: “an extremely outstanding or unusual event, thing, or accomplishment.” The point is that due to the inescapable, irreducible role of geographical and historical contingency in Earth surface systems, all such systems (landscapes, ecosystems, soils, etc.) are unique in some respects (formal arguments along these lines are summarized in [Chapter 9](#)). Thus, the probability of existence of any given state of any given system at a given point in time is infinitesimally low. This exceedingly low probability makes nearly any landscape in some senses extremely outstanding and unusual, and thus a miracle.

Another take on miracles is from Alan Moore’s *Watchmen*: “In each human coupling, a thousand million sperm vie for a single egg. Multiply those odds by countless generations, against the

odds of your ancestors being alive, meeting, siring this precise son; that exact daughter...until your mother loves a man ...and of that union, of the thousand million children competing for fertilization, it was you, only you...(it's) like turning air to gold... a thermodynamic miracle.”

Earth surface systems (mountains, watersheds, forests, sink-holes, or whatever) have certain commonalities and are in part governed by principles that apply everywhere and always. But each also embodies the particular combination of environmental factors of a given location and a unique sequence of events. Like the contingencies affecting whether two people meet and reproduce, going back generation after generation, landscapes are affected by uncountable contingencies—events that did or did not happen; the occurrence and timing of meteor impacts, fires, floods, storms, earthquakes, bison herds, insect swarms, lightning strikes, droughts, landslides, gully erosion, dust deposition, human impacts, etc., etc., etc., over thousands to billions of years.

Knowing people is not just about knowing human biology, physiology, medicine, anthropology, psychology, sociology, and so on. It is about knowing individuals. The same goes for landscapes. Place matters, and history matters, and truly understanding one of them, like understanding a person, requires dealing with them one-on-one. That's the kind of approach to geosciences—integrating laws, place, and history—reflected in this book.

From James Still's novel, *River of Earth*: “These hills are jist dirt waves, washing through eternity. My brethren, they hain't a valley so low but what it will rise agin. They hain't a hill standing so proud but hit'll sink to the low ground o' sorrow. Oh, my children, where air we going on this mighty river of earth, a-borning, begetting, and a-dying — the living and the dead riding the waters? Where air it sweeping us? ...”

When we think about the science of landscape evolution, we often, and for obvious and good reasons, think in terms of “how did it get to be this way?” or “how will it change in the future?” These are perfectly natural things to be curious about, and perfectly good starting points for thinking about landscape evolution. Those questions, logical as they may be, unconsciously (at least) privilege the present, as either the endpoint of history up to now or the starting point for things to come. To understand landscape evolution, we need to move past this to recognize that the state of a landscape now, however broadly “now” is defined, is just a momentary snapshot of constant

change—analogous to a still frame from an endless (from the human perspective) film. Or—to a River of Earth.

We know this. But we forget. Because now is what we can directly observe, and the recent past is what we can directly recall. We unavoidably emphasize it. Because we sometimes want to change things from the way they are now or correct historical mistakes, we often valorize some “before” condition, real or imagined, as the way things ought to be. And that “before” condition—preindustrial, presprawl, precolonial, etc.—may indeed be better by some criteria. But when we seek to restore it, we need to recognize that the way it was (or seems to have been) is not necessarily the way it would be now absent industry, sprawl, human population expansion, or whatever. There exists no single particular “right” or optimal way for landscape to be; that “before” state cannot be viewed as what was intended to be there for all time.

The constant, pervasive change represented by the flow of the River of Earth not only has no particular predestination but also no particular pathway. And what happens within an Earth surface system today effects its path tomorrow. The past and present intertwine and melt into the future. Earth and its systems are always becoming. Evolution is contingent, path dependent, and ongoing.

There is no destination; only a journey with many possibilities.

Thoreau again: “The most distinct and beautiful statement of any truth (in science) must take at last the mathematical form.”

An accomplished cook or a great musician might well thrive on improvisation; making on-the-fly adjustments and decisions. However, if they want to communicate their creative process to someone who was not in the room while they did it, they must also produce some sort of durable record—a recipe, a recording, and musical charts. That is why, though I recognize and even promote the virtues of nonstandardized approaches, I am dealing with formalisms.

Dictionary definitions of *formalism* are generally something along the lines of “rigorous or excessive adherence to prescribed forms.” By its own definition, of course, “excessive” is not a good thing. But “rigorous,” to a scientist, is. Prescribed forms, in this context, refer to mathematical, logical, and graphical representations. Note that I do not advocate communication only via formalisms, but that formalisms should accompany presentations in other forms (most commonly prose or narrative in my case).

Why are formalisms important? First, they provide an additional, crucial level of testability and falsifiability. Can the facts, evidence, data, and the arguments and interpretations based on them be presented in some rigorous, prescribed form? Second, they are divorced (at least as much as anything human can be) from the cultural and social baggage that often inhibits cross-cultural communication. Mathematical notations, for instance, have universally agreed-upon meanings independent of politics, culture, and time (or at least less dependent). Third, formalisms at least mitigate language barriers. As I write, English has become the *lingua franca* of science, giving an unearned advantage to those of us for whom it is a first language. For others, some of my clever turns of phrase, cultural references, stylistic nuances, and metaphors may be less effective, or even useless. However, if I accompany those words with a good enough formal statement of my ideas, those ideas will still be accessible. Likewise, many people may be quite adroit, ingenious, and subtle in communicating in their native language, but much more limited in subsequent languages. Formalisms allow them to convey their ideas to monolingual louts such as myself.

So, this book contains some mathematics, some logical arguments, and some axiomatic deductions. Sorry. But not really.

So many people deserve thanks and acknowledgments for this book and the several decades of work leading up to it. So many ... and I hope they know it and feel it. But I will not try to list them, as the list would be so long, and my highly and increasingly fallible memory would surely omit some.

Instead I will acknowledge places—landscapes where I have had my conversations with Earth and been honored and delighted to help solve many mysteries, fail to solve many more, and encounter so even more yet to be solved.

I will start with the environments where I did much of the fieldwork in my career. These include the Inner Bluegrass karst region of central Kentucky and the Cumberland Plateau of eastern Kentucky, rivers of the Texas coastal plain (Sabine, Neches, Trinity, Brazos, Guadalupe, and San Antonio), and the Ouachita Mountains in southwestern Arkansas.

Then there are the places where I spent less time, but got out of my humid subtropical frame of reference and experienced much different landscapes, such as the old-growth forests of the Czech Republic, especially in the Sumava Mountains and the outer western Carpathians; the Sonoran Desert of Arizona; the

White Desert of the Egyptian Sahara; the tropics of northeastern Queensland, Australia; the North Island, New Zealand.

I should also acknowledge the woods and fields of various places in central and eastern North Carolina, where I spend a good bit of my formative years happily roaming and accidentally learning.

Two places deserve special recognition as my spiritual homes, so to speak. Big Walker Mountain and Hungry Mother State Park in southwestern Virginia is a place where I have always had family connections and have returned repeatedly over my entire life. There are parts of it where I could, and did, and still could, navigate the forest trails in complete darkness, for no other reason than that I could, and it was another way to experience that miraculous (because they all are!) landscape.

The other is the area in and around Croatan National Forest in eastern North Carolina. There I have lived on several different occasions and am returning to as I complete this book. There I have done professional fieldwork for many years. There my children were born, and my grandchildren play. There many hours have been spent traversing the terrain by kayak, canoe, rowboat, foot, and bicycle. There many hours have been spent sitting or lying idly (at least physically) on the forest floor, the riverbank, and the beach. So, thanks to the sand, the mud, and peat. Thanks to the cypress, the tupelo, the beech, the oak, the longleaf, and even, begrudgingly, the loblolly pine. Thanks to the alligator, the great blue heron, the osprey, the bald eagle, and the canine that leaves tracks on the river edge almost every night and might be a red wolf but is probably just a big coyote. Thanks to the ravine swamps, the drowned river valleys, the sand ridges, the marshes, the barrier islands (modern and paleo-), the dunes, and the pocosins.

Finally, thanks to you for at least making a stab at reading this book.

It's been fun.