Unraveling tree diversity

The forest in eastern Cape Breton, Nova Scotia

Olaf Thomas Bouman

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Disclaimer
This book is written for general audiences with an interest in trees and environmental education. The book examines the question of tree diversity at the conceptual level and discusses in detail data collected in the County of Cape Breton, Nova Scotia, Canada. Any factual errors in this book were entirely the author's fault. Readers are advised that author does not take any responsibility for any action a reader might take as result of reading this book.

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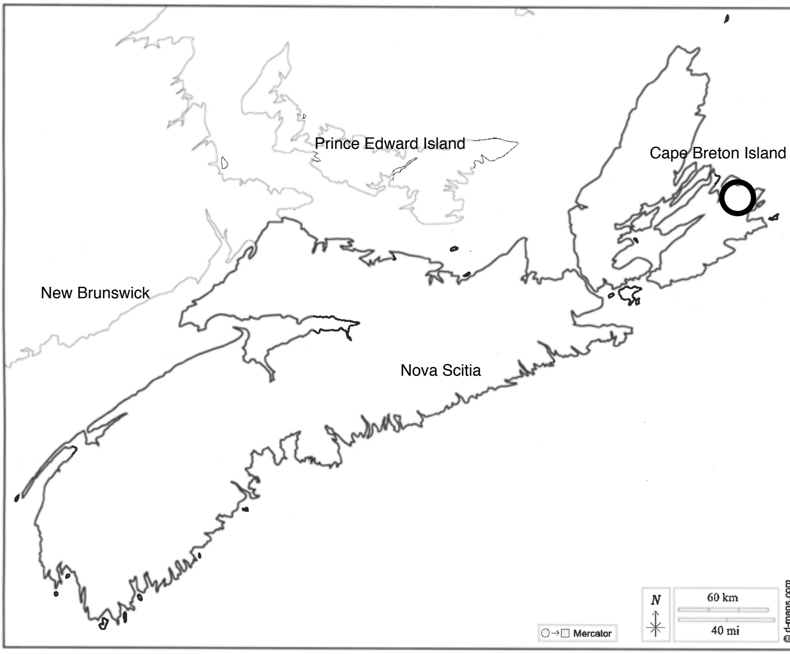
« Une œuvre d'art est un coin de la nature
vu à travers un tempérament. »
Emile Zola, 1866

Content



Map showing the Island of Cape Breton in the Province of Nova Scotia on Canada's east coast.
Note: The circle indicates the area where the author collected forest data for this book..
Source: https://d-maps.com/pays.php?num_pay=622&lang=en

Tree growing on rocky ground

Preface

In September 1999, I accepted a faculty position to teach in the Bachelor of Science program at Cape Breton University (CBU; University College of Cape Breton at the time of my appointment) in the County of Cape Breton, Nova Scotia. The appointment gave me the next twenty years to devote myself to two parallel strands of diversity research, in fields and in forests. Coincidentally, I arrived in Eastern Cape Breton twenty years after my registration at the Georg-August-University in Göttingen, Germany, to study forest science. I spent ten years in Göttingen to develop an environmental view of forests and their management. I became most concerned with the question: How does human agency by way of air pollution and plantation forestry affect the chemistry of soils and the mineral nutrition of Norway spruce? To answer this question, I used chemical analyses of numerous samples of plant and soil material and water. This was exciting scientific research producing data-intensive evidence to explore novel concepts of plant-environment interaction from which I drew inspiration throughout my ensuing research career.

An eye-opening lesson about the nutrition of forest trees came to me not in a chemical laboratory and not during endless hours in libraries and computer rooms but in the middle of a forest near my alma mater. There I spotted this big sandstone boulder completely barren only with slight cavities and fissures on the top. This micro habitat must have been sufficient for a spruce seed to germinate and grow to a full-size tree eventually developing roots that, like tentacles of an octopus, reached the soil below the boulder. Since then, I have seen the same amazing miracle performed by trees in many other places especially in naturally regenerating forests commonly found in Canada.

It was a generous stipend of the Deutscher Akademischer Austauschdienst (DAAD) that brought me first to Canada in 1989. The truly welcoming Canadian culture and an amazing English teacher from Barbados convinced me to return to Canada in 1991. In Canada, my research interest shifted gradually from growth and mineral nutrition of a single species to the question: How do different plants and trees cope with resource limitations in their environment? To take a good jump at this question, there could have hardly been for me a better region than the Province of Saskatchewan. I was fortunate to work first with experienced agricultural scientists in the dry climate of southwest Saskatchewan and then coordinate a comprehensive research program in the mid-boreal forest of northern Saskatchewan.

The question of coping for survival is intimately linked to a much bigger question: Does a mixture of different plants in grasslands or trees in forests, be it a difference in size or species, facilitate the survival of the grassland or forest as a whole in an environment characterized by resource limitations? The question led me ultimately to view a field or a forest as one big organism. In the Province of Nova Scotia, I caught a glimpse of the internal dynamics of each of those two big organisms. My research in the fields of the Agricultural College on Nova Scotia's mainland and in the forest on eastern Cape Breton Island made me discover significant diversity effects in the internal dynamics of fields and forests.

Knowledge of the geographic variation of plant and tree diversity has been and will continue to be a prerequisite to assess any long-term impacts of past, present and future human footprints on nature. With a clear geographic focus on eastern Cape Breton, this book is a contribution to special plant geography. But the book is much more than that: It serves as a template for much needed assessments of tree diversity in forest regions with a history of human-induced disturbances and transformations of nature such as agricultural settlement, acid rain, climate change, industrial wood exploitation, and the introduction of pathogens such as beech bark disease. The book is written from a scientific perspective for general audiences with an interest in forests, trees, and environmental education. However, a scientific perspective is never without temperament, never absolute truth. Therefore, my personal scientific perspective on tree diversity in eastern Cape Breton has to great extent been shaped by research opportunities that opened up through personal encounters with good and well-intended people in Canada.

At CBU, I was fortunate to work over the years with undergraduate students who were genuinely curious to explore the purpose of plant and tree diversity. I would like to extend sincere thanks to my students who endured my teaching and followed patiently my research protocols. A number of student research assistants diligently collected data for me in fields and forests regardless of pestering bugs and unpleasant weather conditions. My sincere thanks go to Peter S., Keith D., Joyce E., Clifford P., Shannon G., Nury D., Erik A., Napoleon B., Mark M., Lindsey H., Clayton D., Andrew M., Julie F., Jeff C., Kelly K., Meghan S., Bridget G., Jennifer M., Elizabeth J., Garrit O., Erika T., and Paul C. Special acknowledgement must go to Nadine Vaninetti, Anthony Mazzocca, Eileen Roach, Terri MacPherson, Jennifer Sylliboy, Christine Frisch, and Emily Bennett whose dedicated work efforts contributed to scientific manuscripts that stood up to rigorous peer review for publication in reputable journals. I am particularly grateful to Anthony Mazzocca who went on to collaborate with me and secured financial and in-kind support for my research in his professional capacity as the Watershed Coordinator at CBRM Water Utility responsible for the protection of public water supply areas.

As a forest scientist, I was grateful to my colleagues in the Department of Biology for electing me into their ranks during my tenure at CBU from September 1999 to April 2018. As can be expected for a young university, the Department grew and changed during my time but there was one constant pillar of advice and support at CBU in the person of Denise Forgeron. Denise instructed students in the labs for my botany and genetics courses. With her professional competence and sincere collegiality, Denise made it easy for me to develop positive and productive rapport with students which was very helpful to pursue my research agenda. I was also grateful that CBU Biology supported my applications for two one-year sabbatical leaves in 2006 and 2013. My sabbatical leaves were productive thanks to the collegiality of the members of the Pasture Biodiversity research team at the Nova Scotia Agricultural College, Dr. C. Conrad at Saint Mary's University, Dr. G. Larocque at the Canadian Forest Service, Peter Townsend at Nova Scotia Department of Natural Resources, B. Pardy and R. Duggan at Canadian Parks Service, and Dr. J. Kubiniok at Saarland University.

I shall always remain grateful to Hamish Kimmins and Volkmar Biederbeck. It was the textbook on forest ecology written by Hamish that aroused my interest in forest science in Canada. Hamish made me visit Canada for the first time in my life in 1989. At the University of British Columbia and in the evergreen rain forest on the Pacific coast, Hamish and his graduate students were incredibly generous and patient with me. Volkmar Biederbeck was the professional chance encounter of a lifetime for me. Volkmar contracted me as a research associate at the Agriculture Canada Research Station in Swift Current, Saskatchewan in 1991. As short a time span as it was, the Station was in many ways the best place I ever worked before and after. It was in Saskatchewan that my wife and I made up our mind to stay in Canada.

I would be remiss to not mention Ray Schachter with whom I have maintained a cordial personal friendship since my arrival in Canada more than thirty years ago. A couple of years ago, Ray invited me to join the informal seminar science plus. About eight times a year, Ray lines up exceptionally qualified presenters from a wide range of disciplines in the humanities, mathematics, science, and technology. The seminar was very helpful for me to write a non-fiction book on tree diversity for general audiences. I would also like

to thank Ray for reading the first chapter of my book and giving me much appreciated feedback.
Lastly, I owe much gratitude debt for the steadfast support of my wife Claudette and our two children Art and Leandra. Claudette has also become my author role model who has enjoyed the art of writing steadily with her unwavering Bajan grit since both of us retired in 2018. I always intended to write a book at the end of my research and teaching career. Claudette's trail blazing and her literary success left me eventually with no other choice but to buckle down and get started on writing this book. As children, Art and Leandra did not really know what I was doing during my many absences from home but they understood that my work was meant to be more than putting bread on the table. Son and daughter are now well on their way to serving in their chosen professions. For sure, they are not into forest science.
Publishing this book has been made possible by the Verlag Kessel of Remagen, Germany. I sincerely appreciated the diligence and expedience of Dr. N. Kessel who turned my manuscript into a fine presentable book.

Cole Habour, 15th June 2025
O. Thomas Bouman

A patchwork of hardwoods, mixed woods, and softwoods in historic agricultural settletment area of eastern Cape Breton

Chapter one: What about diversity?

Trained as a forest scientist at a reputable university in Europe I had seen a wide range of forest types across Canada and beyond, conducted research in agricultural fields, planted forests, and natural forests by the time I arrived in 1999 in the most northeastern county of the Province of Nova Scotia, Canada. Many years of working in the County of Cape Breton as a researcher and teacher, afforded me with opportunities to study trees not planted by men and women but by nature. During much of the same time span, my research in the wild was complemented by testing mixtures of herbaceous plants in controlled field trials at the Agricultural College in north-central Nova Scotia. Climate, soil, and human influences in my new research terrain stood in some contrast to previous research in Saskatchewan of the 1990s. There a checker board of wheat fields and fallow fields dominated the vegetation cover of the south and forests that of the north. Admittedly, the forest and human influences in Cape Breton stood in stark contrast to the forests I had researched in my native Germany of the 1980s and in Saskbush of the 1990s. Did the forest of Cape Breton lie somewhere midpoint on the environmental spectrum I had researched so far? Yes, I was up to discover a distinct type of forest and special trees.

It did not take long for me to find out that the predominantly forested landscape of Cape Breton was usually populated by trees hardly older than 100 years. In fact, the entire forest looked very much like patchwork resulting from a period of forest clearing for agriculture in the 19th century followed by abandonment of agriculture and industrial exploitation for wood in the 20th century. Why would anyone be interested in what wood cutters might refer to as scrap forest and conservation biologists as degraded secondary forest? Well, there was something that intrigued me about the forest apart from the few yet impressive old-growth remnants with large-diameter trees. The forest of eastern Cape Breton regenerated itself almost exclusively by force of nature and often as a mixture of tree species. These naturally generated tree species mixtures aroused my scientific curiosity. I wished to know what distinguished the growth of some of these tree species that looked different but grew in the same location. Does botanical classification of the form of flower, fruit, and foliage have any significance for the survival and growth in the long life of trees? What do mixtures of different forms mean for the functioning of tree species and the forest as a whole? Do the local species mixtures serve any natural purpose or even generate benefits that accrue from forest existence to human life? Let me backtrack a bit and report an incident that took me by surprise early in my science career.

We were on our way to a forest research site located in the Harz Mountains of central Germany. To get there fast, we first took our car on the *Autobahn*. One would think driving on a German *Autobahn* allows for traveling at a high speed. It usually does but not that morning in the mid 1980s. We were caught in a traffic jam, a long line of cars moving bumper to bumper at a snail's pace for at least half an hour.

Resigned to the limits of motorization beyond infrastructure capacity, we began to casually read the slogans written on bumper stickers which had become very popular in those days to raise awareness of environmental problems. Most messages were clear and straightforward such as “Atomic power – No thank you!” or “Save the forest” or “Stop acid rain”. In fact, the last slogan spoke directly to our own forest research concerned with the acidification of soils and how this process would affect the nutrition of single-species plantations of Norway spruce (*Picea abies*) under conditions of severe air pollution.

In the course of the industrial revolution, long-range trajectories of acidifying air pollutants (composed of nitrogen and sulfur) began to cross the boundaries of national territories in Europe and North America. In Europe, uncontrolled emissions of sulfur from the smoke stacks of highly industrialized regions in England contributed to the acidification of forested basins which led to a decline of salmon stocks in Scandinavian rivers. Similar environmental trajectories were discovered in North America. For example, maps show areas of high risk of freshwater acidification due to air pollution at low acid buffering capacity of lakes in Cape Breton County. The public Water Utility of the County draws water from large lakes for supplying many people with potable water.

A mono causal slogan like “Stop acid rain” on those bumper stickers expressed more deeply doubt and uncertainty among increasingly educated masses and a more populous intellectual bourgeoisie. The political establishment was accused of using the power monopoly of the secular state to abuse popular trust in the apparently infallible bulwark of science, technology, engineering and math (STEM). In the case of Acid Rain, STEM capacity was abused by the state to justify the construction of high smoke stacks that facilitated the transfer of atmospheric pollution from densely populated urban regions to largely depopulated rural (hence politically weak) regions without any regard for the health of nature’s woods and water bodies.

That morning in 1985 we were, however, taken a bit by surprise when we read a new and different kind of slogan on one of those bumper stickers. It proclaimed: “Species diversity means quality of life”. My colleague turned towards me and asked a simple yet puzzling question: “What does that mean?” Truthfully, science has not come up with an unambiguous answer to this question even to this day as I write this passage more than 35 years later. Key questions still need to be sorted out conceptually and certainly even more so in view of nature's realities.

In recent decades, numerous papers have been published on the subject of diversity including the diversity of trees in forests (arboreal diversity). Too many scientific publications on plant and tree diversity remain however, inconclusive and close with the truism that there is a need for more research. As a matter of fact, only a much smaller number of scientists have rigorously tested in controlled forest experiments straight-forward scientific hypotheses about tree diversity effects using species mixtures that also occur in naturally regenerated forests. There is a natural reason for this: Trees live much longer than humans and forests are much older than humanity. As opposed to agricultural 'plot experiments', tree diversity effects are usually explored by counting trees and using measurements of trees and forest conditions with far greater statistical noise due to factors that are difficult to control or simply unknown. It is not possible to measure exactly the casting of shade by one tree on its neighbor and of the upper on the lower crown within the same tree. In view of the much greater height of a forest canopy and the variation among individual tree crowns within a forest compared to crop fields and grasslands, the magnitude of error associated with shading and self-shading would appear to be far greater in forests than in fields. Another great unknown in tree diversity experiments are the spatial variation of depth, horizontal spread, and intensity of a tree's root system and the action of one tree's root system on that of a another tree.

The longevity of trees and forests continues to challenge a scientist's patience. Longevity should therefore heighten our caution in the assessment of tree diversity effects. Admittedly, a research career of devotion and humility is not the way to proceed for everyone. Some authors are tempted to turn to audacity proclaiming metaphorically the 'motherhood of trees', 'spirit of trees', or the 'secret life of trees'. As sobering as the caveat put by nature on forest research might sound, it has never subdued my enthusiasm to contemplate diversity and explore forests which I endeavor to convey to the reader in this book.

A philosophical dilemma

The term diversity in itself is a neutral one and not a measuring scale. Is an even composition better than only one species being abundant and dominant? Does the identity of any singular species in a floristically diverse forest matter for its overall productivity and resilience? Does the structural diversity matter that is created by individual trees of varying age, form, and size? That is not to say the question "what does tree diversity mean" is irrelevant! To the contrary, the question has evidently raised more questions than it provided answers which is what moves science forward.

Tree diversity is a question that has become more pressing since the natural forest cover on vast stretches of land has been transformed for the rationalization of agriculture and wood production in rural landscapes. Rationalization in this context refers to the economic concept of optimizing the input of capital, labor, and land. In practice, rationalization is all too often driven by investors' desire for rapid financial gains from short-term capital investments. In contrast, sustainable land use pursues the environmental goal of conserving the natural qualities of forests (including tree diversity) and the social goal of improving the quality of life for working folks and their off-spring hence inter-generational equity. Regrettably, the pursuit of high profits has often co-opted the notion of sustainable land use in the public realm.

Environmental pollution from urban industries and the capitalistic rationalization of rural land use at an unprecedented geographic and historical scale make for a daunting revelation of knowledge gaps in the assessment of tree diversity. For whatever it might be worth the puzzling slogan "Species diversity means quality of life" has injected new life into environmental sciences in general and forest science in particular. Ultimately, science nowadays more than ever deals with an immensely unsettling question: Do the environmental implications of undoubtedly enlightening reductionism in modern scientific research side-line or even compromise the discovery of a largely unknown "unity in diversity" purported in religions or traditional knowledge systems? Accordingly, two opposing (possibly antagonistic) views can be held about researching natural organisms.

A mechanistic (or material) view likens natural organisms to machines as opposed to the vitalistic (or immaterial) view. The latter view is founded on the truism that organisms can not be taken apart and reassembled like machines. Neither can organisms be created by mixing some substances in a high-tech laboratory let alone by the actions of alchemists and shamans. To this day, analytical limitations force scientists to conduct research on the assumption that natural organisms are machines as proposed by the 17th-century French philosopher Descartes during the 'birthing' of natural sciences in modern Europe's enlightenment era.

Chemical analyses of the ashes of a tree reveal the presence of the same chemical elements that can be found in the soil. The chemical element magnesium, for example, constitutes the central atom in the large organic chlorophyll molecule. Chlorophyll in turn enables plants to capture the energy of the sun. Magnesium just like potassium, calcium, and several other chemical elements, essential for plant growth, occur in the soil in inorganic form. The elements are derived from the weathering of the earth's mineral crust and dissolved in water. Once dissolved in water, and only there, can chemical elements of mineral origin be transformed into electrically charged ions and absorbed by plants. This mind-boggling knowledge has spurred vitalistic and teleological thinking among philosophers.

In spite of enormous detailed factual knowledge, we still do not dispose of any means in our scientific laboratories to determine what exactly injects life into organisms although we know that plants can not thrive without mineral elements. Indeed, we cannot, mechanically or otherwise, create living organisms such as trees. For all good intents and purposes we do not know of any universal design of the natural world. We do however know since the late 19th century that life is a temporal continuum running through the natural regeneration of organisms.

Microscopic observations of plant cells and their kernels (nuclei) during the formation of germ cells as sperm cells in male parts and as egg cells in female parts of flowers led to a profound conclusion by Strasburger – an immensely productive botanist in 19th century Germany. According to Strasburger, new cell nuclei can only arise from the division of other nuclei. This means that the nuclei of the male and female germ cells (and the heriditary elements found there-in), produced by a flower, stem from the division of nuclei of previous generations. The hereditary elements scientifically now known as chromosomes and genes and collectively referred to as the genome in living cells contain the information for chemical processes that reproduce the characteristic form and structure of a species generation after generation. A machine does not have the reproductive capacity of any natural organism.

The size and full chemical sequence of the genome has since 2010 been determined for some plant species including tree species. The number of known species' genomes is still a very small number compared to the species richness of the plant kingdom with an estimated number of more than 200,000 species. Knowing the size and sequence of the genome does however, not mean that the information in the genome has been decoded. Undoubtedly, important steps forward have been made while the specific functioning of the hereditary code, in its entirety, still remains far from being known. Scientists still wrestle immensely with the problem of finding out how the numerous segments of chemical sequences that constitute the hereditary code act and interact to make the predictable unfolding of the plant body and its functioning happen.

Knowing now the practically infinite size of the largely still secret meaning of the hereditary code and its life-giving potentiality, the philosopher-turned biologist Max Hartmann concluded in the mid 20th century from his discussion of the mechanism-vitalism-problem that we must contend with not knowing and perhaps will never know what injects life into an organism. That being said our still and perhaps ever so limited knowledge now enables scientists to modify the genomes of select tree species and release such genetically modified organisms into the natural world. Yet, this act might constitute biological contamination or biological enrichment in the absence of fully understanding the meaning of diversity. Prior experiences such as the scientific discovery and widespread adoption of synthetic nitrogen in agriculture have been a double-sided sword enormously beneficial to humanity but not without harm to the environment.

A question of purpose

Conceptually the slogan “Species diversity means quality of life” suggests that species diversity is useful and serves a purpose. This is nothing new! Philosophers of Greek Antiquity were already intrigued by the beauty, harmony, and regularity of form in celestial constellations and nature on earth. Modern scientists continue to seek for the purpose behind the variation of form that manifests itself in the existence of different organisms such as trees. Scientists also search for purpose behind the co-occurrence of different trees in the same place.

According to the textbook Philosophie by Friedlein (12th edition, 1968), a rational approach to the search for purpose in nature was proposed by the 18th century philosopher Kant at the University of Königsberg, Prussia. In his critique of *teleologische Urteilskraft* (purpose judgment), Kant recognized objective (meaning material) purpose in the relationship between natural things but he distinguished external from internal purpose. One might, for example, argue trees exist for the purpose of feeding giraffes. The animals feed indeed very much on leaves of Acacia trees in their natural habitat, the open woodlands of East Africa. However, serving the purpose of feeding giraffes only represents an external purpose of trees and may be a pure chance event. Acacia trees also exist in the absence of any giraffes in open woodlands of South America. Feeding small or large mammals does not serve the existence of Acacia trees. It is not within their inherent nature. In fact, fossil evidence indicates trees appeared on earth long time before large mammals like giraffes came into being. Thus, tree species have come to serve many external purposes in today’s nature by fulfilling a supportive function for other organisms in a variety of ways. One may only think of the yellow birch bark that provides nature with the material to construct hanging bird nests in the forks of tender tree branches.

Internal purpose as it reveals itself within natural organisms such as a tree’s development (ontogeny) suggests harmony, regularity, or even the embodiment of a developmental plan in nature. Tree leaves feed the roots with organic carbohydrates such as sugar while roots feed the leaves with mineral nutrients such as potassium. Leaves are the means for the roots of a tree to grow in size year after year but there would be no leaves without roots. In other words, the action in leaves and roots represent each a cause and effect within the whole organism of the tree. The two represent a functional unit in the life of a tree. We therefore need to look, in keeping with Kant's rational approach, at the whole organism to understand the inner purpose of its parts.

The tree is a good example that the idea of *das Ganze* (the whole) has encouraged philosophers, including Kant, to study the form and function of its parts. It should be noted though Kant's 18th century concept of the whole was rational and object-driven. A rational and object-driven concept for the study of the whole is not to be confused with the revival of subjective at times archaic and para scientific explanations of natural phenomena in the 20th century. Archaic views are occasionally misrepresented and referred to as 'holistic' world views. In other words, science must be separated from beliefs although the latter help to navigate life situations for which science cannot provide answers. Accordingly, Kant considers divinity to be a practical matter. This put the philosopher in convenient agreement with the protestant reformer Luther who proclaimed in the 16th century that the existence of divinity can only be justified by faith.

Nothing prevents us from suggesting that not only the abundance of microscopic cells in a tree but also the abundance of macroscopic trees in a forest form part of one big organism. Forests are often portrayed metaphorically as the earth's green lungs such as the Congo basin in Africa or the Amazon in South America. In fact, physical fusions of branches and roots (inosculations) among trees are known to occur. Scientifically, it seems however, still quite daring to suggest each species present in a forest is an essential part of the forest's inner purpose. The truth is we still know very little about the material significance of diversity among trees and the bearing of their differences on the material relationships among trees of different age, size, and species. Furthermore these differences might play out differently in different environments.

An individual scientist might be content to research with infinite patience some special features of tree diversity within a more or less narrow geographic scope. Such focused research experiences might well contribute more to the systematic advancement of forest science than any premature postulation of grand theories about natural