Lithuanian Forest Tree Successional Categorisation

Subjects: Plant Sciences

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Developing forest harvesting regimes that mimic natural forest dynamics requires knowledge on typical species behaviors and how they respond to environmental conditions. Species regeneration and survival after disturbance depends on a species' life history traits. The four types of ecologically invariant life-history trajectories of species turnover are a core component to evaluate if the development of the forest community is progressing towards the restoration of the climatic climax.

life history species turnover disturbance generalists disturbance specialists

succession generalists succession specialists climatic climax forest dynamics

gap colonizers gap competitors forest colonizers forest competitors

1. Introduction

Forests are complex systems of interacting organisms; to manage them for tree species composition and production we need thorough knowledge of the variety of tree species' life histories and how they interact. Within the hemi-boreal forest climatic zone there are three main forest disturbance regimes that host a variety of successional characteristics: (i) stand succession (large or stand replacing disturbance such as severe fire, windthrows, or current clear felling), (ii) cohort dynamics (related to partial disturbances of a stand such as a low intensity ground fire or forest thinning), and (iii) gap dynamics (such as small patch or a fallen tree) [1]. Succession is a sequential shift of patterns and processes in terms of the relative abundance of dominant species [2]. The succession of forest stands and patches largely determines the extent to which forest communities are able to cope with changes in environmental conditions and forest loss due to natural disturbances or human activity [3][4][5][6]. Forest disturbances trigger successional events that lead to climatically determined end communities or climatic climax, generally regarded as a position of stability in the development of vegetation [7][8][9].

The first definition of climax was described by Clements [10] as the ability of species composition to remains stable for more than one tree generation (i.e., the tree species replace themselves) in the absence of disturbance other than tree deaths due to old age. Thus, a forest that can regenerate naturally with the same composition over time can qualify as natural climax. In reality, however, the difference between a successional forest and a climax forest is subjective, as a forest ecosystem is dynamic, where succession is a continual process [11]. Although Clements' [10] dynamic ecology concept is still valid [12], it does not represent the boundless factors impacting ecological succession. For example, the role and importance of both biotic and abiotic factors in predicting species distributions remains unclear [13][14][15][16][17]. Therefore, no clear conclusion can be drawn as to the successional position of tree species [10]. The probability of species survival and succession after disturbance depends on a species' genetic profile to deal with a variety of environmental characteristics [18]. In other words, a tree's life history traits define its position along its successional pathway that includes functional strategies for reproduction or resource capture [19].

The fundamental principle underlying the theory of invariance is that the laws of nature always have the same form for all observers [20]. This implies that all the elements of any developing living system interact, and thus all elements are ecologically equivalent, as the essence of ecological law and processes lies in invariance by which a living system following a disturbance returns to its stable state [21][22]. From a wildlife perspective, each organism, population, and community have different environmental scales in both time and space [23], and individual species may impact another species' life history traits [24][25]. Thus, there are different perceptions about the interactions among species (that otherwise can survive virtually the same for millions of years), which proceed towards the ecological equivalence of climatically determined end communities [26]. Primary forests exist in a delicate but stable climax with all other components of the ecosystem; not one component can change without compensating changes in the others. For example, harvesting or thinning a forest stand will inevitably be followed by changes in the soil profile, vegetation, and life occurrence [9]. Generally, the dynamics of forest communities can be controlled by a set of ecologically invariant life-history traits of tree species turnovers [9][27][28][29][30]. Therefore, a variety of tree species' life histories and how they are integrated into the forest system need to be summarized as a continuum of ecologically invariant life-history trajectories of species turnover [11].

The natural tendency of forest succession is towards climatic climax, whereas the succession of forests after human activity (e.g., fire, grazing, and soil deterioration due to over-cultivation) can result in adaptation of biotic climaxes [9]. Therefore, forest restoration that aids the recovery of forest structure, ecological functioning, and biodiversity towards those typical of a climax forest by the re-instatement of ecological processes is needed [31]. From an organism-centered perspective, developing forest management and exploitation regimes that mimic the natural conditions as closely as possible requires the determination of the degree to which typical species behaviors are responsible for the emergence of climatic climax [32][33][34][35][36][37].

2. Successional Categorization of Forest Tree Species in Lithuania

Lithuania (62,000 km^2) is situated in the hemi-boreal climatic zone (i.e., the transitional zone from temperate to boreal forests) and is affected by the humid marine climate of the Baltic Sea [38]. The natural potential forest cover of Lithuania is predominantly composed of five main forest types: (i) hemi-boreal spruce forest with mixed broadleaved trees (55%), (ii) mixed oak–hornbeam forests (22%), (iii) boreal and hemi-boreal pine forests with partial broadleaved trees (18%), (iv) lime-pedunculate oak forests (4%), and (v) species-poor oak and mixed oak forests (1%) [39]. Thus, the natural climatic climax of the region for tree species consisted of Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* L.) Karst), birch (*Betula pendula* Roth and *B. pubescens* Ehrh), alder

(*Alnus glutinosa* L. Gaertn. and *A. incana* L. Moench), English oak (*Quercus robur* L.), small-leaved lime (*Tilia cordata* Mill.), and European hornbeam (*Carpinus betulus* L.) [40]. Currently approximately 33% of Lithuania is forested with Scots pine, Norway spruce, and birch forming the dominating forest stand types [41]. The full range of hemi-boreal forest species found in Lithuania and their life history dynamics can be found in Table 1.

Table 1. A simplified framework for the life history dynamics for hemi-boreal tree species in Lithuania.

Tree species	Life history traits						
	Dominant Stand Proportion [41]	**Soil Moisture** A [42][43]	**Soil Fertility** B [42][43]	**Shade Tolerance**	**Hardiness** C [44]	**Life Expectancy** [43] **(Harvesting age)**[45]	**Successional Strategy**
Dominant Forest Tree Species							
Scots pine (*Pinus sylvestris* L.)	34.6%	1–3 and 5	1–3 and 5	Intolerant	9	300–400 (110)	Disturbance generalist
Norway spruce (*Picea abies* L. Karst)	20.9%	3–4	3–4	Intermediate	7	200–300 (71)	Succession generalist
Silver birch (*Betula pendula* Roth)	22.0%	2–5	2–4	Intolerant	9–10	150 (61)	Disturbance generalist
Black alder (*Alnus	7.6%	4–5	3–4	Intermediate	7	180–200 (61)	Disturbance generalist

glutinosa L. Gaertn)							
Grey alder (*Alnus incana* L. Moench)	5.9%	2–5	3–4	Intermediate	9	50–70 (31)	Disturbance generalist
Eurasian aspen (*Populus tremula*)	4.6%	3–4	3–4	Intolerant	9	80–100 (41)	Disturbance generalist
English oak (*Quercus robur* L.)	2.2%	3–4	3–4	Intolerant	6–7	500–600 (121)	Disturbance specialist
European ash (*Fraxinus excelsior* L.)	0.9%	3–5	4–5	Intermediate	7–8	> 300 (101)	Succession specialist
Other Secondary Native Forest Species							
Small-leaved lime (*Tilia cordata* Mill.)	0.4%	3	3–4	Intermediate	7	500–600 (61)	Succession specialist
Downy birch (*Betula*	0.4%	3–5	2–5	Intolerant	9	100[D]	Disturbance generalist

pubescens Ehrh)							
European hornbeam (*Carpinus betulus* L.)	0.2%	3	3–4	Tolerant	5	200–300 (61)	Disturbance generalist
Norway maple (*Acer platanoides* L.)	0.2%	3–4	3–5	Tolerant	8	150–300 (101)	Disturbance specialist
White willow (*Salix alba* L.)	<0.2%	4	4–5	Intolerant	8	>100 (31)	Disturbance generalist
Bird cherry *(Prunus padus L.)*	<0.2%	4–5	3–5	Intermediate	9	150[D]	Disturbance specialist
Crack willow (*Salix fragilis* L)	<0.2%	4	4–5	Intolerant	8	75 (31)	Disturbance generalist
Field elm (*Ulmus minor* Mill.)	<0.2%	2–4	4	Intermediate	5	300 (101)	Succession specialist
European white elm	<0.2%	3–4	3–4	Tolerant	6–7	250–300 (101)	Succession specialist

(*Ulmus laevis* Pall.)							
Wych elm (*Ulmus. glabra* Huds.)	<0.2%	3–4	4–5	Tolerant	6	300 (101)	Succession specialist
Wild apple (*Malus sylvestris* L. Mill.)	<0.2%	4–5	3–5	Intolerant	8	300[D]	Disturbance specialist
Wild pear (*Pyrus pyraster* L. Burgsd.)	<0.2%	3–4	3–4	Intermediate	6	200–300[D]	Disturbance specialist
Introduced Species							
European beech (*Fagus sylvatica* L.)	<0.2%	3 [38]	3–4	Tolerant	5	500 (101)	Succession generalist
Sessile oak (*Quercus petraea* Matt. Liebl.)	<0.2%	3	2–3	Intermediate	6–7	500–600[D]	Disturbance specialist
Large-leaved lime (*Tilia*	<0.2%	3–4	4–5	Intermediate	7	500–600[D]	Succession specialist

doi:10.1016/j.biocon.2012.05.001.

4. Aubry, C.; DeVine, W.; Shoal, R.; Bower, A.; Miller, J.; Maggiulli, N. Climate Change and Forest Biodiversity: A Vulnerability Assessment and Action Plan for National Forests in Western Washington; USDA Forest Service: Pacific Northwest Region, Portland, OR, USA, 2011; p. 308.

platyphyllos Scop.)							
Wild cherry (*Prunus avium* L.)	<0.02%	3–4	3–4	Tolerant	8	100[D]	Disturbance generalist

[A] Soil moisture is rated on 1–5 scale: 1 = dry and 5 = very wet. [B] Soil fertility is rated on a 1–5 scale: 1 = infertile and 5 = very fertile. [C] Hardiness refers to the ability of tree to tolerate the cold: 0 = intolerant, 0 °C, and 10 = most tolerant, down to −40 °C [44]. [D] Harvest age was not defined.

3. Conclusion

Each hemi-boreal forest tree species can be represented by one of the four types of ecologically invariant life-history trajectories of species turnover: disturbance generalists, disturbance specialists, succession generalists, succession specialists. Here, we touch on their importance of these four types of life-history strategy of gap colonizers, gap competitors, forest colonizers, and forest competitors, their absence and presence in the community, and how they could be used as a core component to evaluate if the development of the community is progressing towards the restoration of the climatic climax. However, further research in needed to develop the concept of forest succession. This could be undertaken through the inclusion of other biotic components, such as, ground vegetation, wildlife and microorganisms, and their impacts on forest succession as an ecosystem. In closing, we suggest that forests should be managed to maintain environmental conditions that support their natural variety and the sequence of tree species' life histories.

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Berlin/Heidelberg, Germany; New York, NY, USA, 1974, doi:10.1007/978-3-642-65517-3.

8. Whittaker, R.H. A consideration of climax theory: The climax as a population and pattern. Ecol. Monogr. 1953, 23, 41–78, doi:10.2307/1943519.
9. Richards, P.W. The Tropical Rain Forest: An Ecological Study; Cambridge University Press: New York, NY, USA, 1952.
10. Clements, F.E. Nature and structure of the climax. J. Ecol. 1936, 24, 252–284.
11. Raimundas Petrokas; Virgilijus Baliuckas; Michael Manton; Successional Categorization of European Hemi-Boreal Forest Tree Species. *Plants* **2020**, *9*, 1381, 10.3390/plants9101381.
12. Frelich, L.E. Forest Dynamics and Disturbance Regimes: Studies from Temperate Evergreen-Deciduous Forests; Cambridge Studies in Ecology Series; Cambridge University Press: Cambridge, UK, 2002; p. 266.
13. Lewis, J.S.; Farnsworth, M.L.; Burdett, C.L.; Theobald, D.M.; Gray, M.; Miller, R.S. Biotic and abiotic factors predicting the global distribution and population density of an invasive large mammal. Sci. Rep. 2017, 7, 44152, doi:10.1038/srep44152.
14. Eliot, C.H. The Legend of Order and Chaos. In Philosophy of Ecology; DeLaplante, K., Brown, B., Peacock, K.A., Eds.; Elsevier: Waltham, MA, USA, 2011; pp. 49–107.
15. Eliot, C.H. Method and metaphysics in Clements's and Gleason's ecological explanations. Stud. Hist. Philos. Sci. C 2007, 38, 85–109.
16. Hagen, J.B. An Entangled Bank: The Origins of Ecosystem Ecology; Rutgers University Press: New Brunswick, NJ, USA, 1992.
17. Hagen, J.B. Organism and Environment: Frederic Clements's Vision of a Unified Physiological Ecology. In The American Development of Biology; Rainger, R., Benson, K.R., Maienschein, J., Eds.; University of Pennsylvania Press: Philadelphia, PA, USA, 1988; pp. 257–280.
18. Borman, M.M.; Pyke, D.A. Successional Theory and the Desired Plant Community Approach. Rangelands 1994, 16, 82–84.
19. Bazzaz, F.A. Plants in Changing Environments: Linking Physiological, Population, and Community Ecology; Cambridge University Press: Cambridge, UK, 1996.

20. Rusbult, C. Einstein’s Theory of Relativity is a Theory of Invariance-Constancy. 2007. Available online: https://www.asa3.org/ASA/education/views/invariance.htm (accessed on 27 October 2019).
21. Kazansky, A.B. Agential anticipation in the central nervous system. In Anticipation. In Learning from the Past; Nadin, M., Ed.; Cognitive Systems Monographs 25; Springer International Publishing: Cham, Switzerland, 2015; pp. 101–112.
22. Li, B.-L. Fractal geometry applications in description and analysis of patch patterns and patch dynamics. Ecol. Model. 2000, 132, 33–50.
23. Gergle, S.E., Turner, M.G. Learning Landscape Ecology: A Practice Guide to Concepts and Techniques; Springer: New York, NY, USA, 2001.
24. Angelstam, P.; Manton, M.; Pedersen, S.; Elbakidze, M. Disrupted Trophic Interactions Affect Recruitment of Boreal Deciduous and Coniferous Trees in Northern Europe. Ecol. Appl. 2017, 27, 1108–1123.
25. Edenius, L., Bergman, M., Ericsson, G.; Danell, K. The role of moose as a disturbance factor in managed boreal forests. Silva Fenn. 2002 36, 57–67.
26. Gleason, H.A. The structure and development of the plant association. Bull. Torrey Bot. Club 1917, 44, 463–481.
27. Petrokas, R.; Baliuckas, V. Self-sustaining forest. Appl. Ecol. Environ. Res. 2017, 15, 409–426.
28. Wendt, H.; Didier, G.; Combrexelle, S.; Abry, P. Multivariate Hadamard self-similarity: Testing fractal connectivity. Phys. D: Nonlinear Phenom. 2017, 356–357, 1–36.
29. Combrexelle, S.; Wendt, H.; Didier, G.; Abry, P. Multivariate scale-free dynamics: Testing fractal connectivity. In Proceedings of the 42nd IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), New Orleans, LA, USA, 5–9 March 2017; pp. 3984–3988.
30. Sun, J.; Southworth, J. Remote sensing-based fractal analysis and scale dependence associated with forest fragmentation in an Amazon tri-national frontier. Remote. Sens. 2013, 5, 454–472, doi:10.3390/rs5020454.
31. Elliott, S.D.; Blakesley, D.; Hardwick, K. Restoring Tropical Forests: A Practical Guide; Royal Botanic Gardens: Kew, UK, 2013; p. 344.
32. Gorshkov, V.G.; Makarieva, A.M. Biotic Regulation Overview. 2001–2019. Available online: https://www.bioticregulation.ru/life/life2.php (accessed on 5 August 2020).
33. Chazdon, R.L. Second Growth: The Promise of Tropical Forest Regeneration in an Age of Deforestation; University of Chicago Press: Chicago, IL, USA, 2014.

34. Erickson, V.; Aubry, C.; Berrang, P.; Blush, T.; Bower, A.; Crane, B.; DeSpain, T.; Gwaze, D.; Hamlin, J.; Horning, M.; et al. Genetic Resource Management and Climate Change: Genetic Options for Adapting National Forests to Climate Change; USDA Forest Service: Washington, DC, USA, 2012; p. 19.
35. Swenson, N.G.; Anglada-Cordero, P.; Barone, J.A. Deterministic tropical tree community turnover: Evidence from patterns of functional beta diversity along an elevational gradient. Proc. R. Soc. B Biol. Sci. 2011, 278, 877–884.
36. Gorshkov, V.G.; Makarieva, A.M.; Gorshkov, V.V. Revising the fundamentals of ecological knowledge: The biota-environment interaction. Ecol. Complex. 2004, 1, 17–36, doi:10.1016/j.ecocom.2003.09.002.
37. Petrere, M., Jr.; Giordano, L.C.; De Marco, P., Jr. Empirical diversity indices applied to forest communities in different successional stages. Braz. J. Biol. 2004, 64, 841–851.
38. Godvod, K.; Brazaitis, G.; Bačkaitis, J.; Kulbokas, G. The development and growth of larch stands in Lithuania. J. For. Sci. 2018, 64, 199–206.
39. Bohn, U.; Neuhäusl, R.; Gollub, G.; Hettwer, C.; Neuhäuslová, Z.; Raus, T.; Schluter, H.; Weber, H. Karte Der Natürlichen Vegetation Europas/Map of the Natural Vegetation of Europe. Maßstab/Scale 1: 2 500 000; Bundesamt für Naturschutz/Federal Agency for Nature Conservation, Bonn, Germany, 2003.
40. Smirnova, O.V.; Bobrovsky, M.V.; Khanina, L.G.; Braslavskaya, T.Y.; Starodubtseva, E.A.; Evstigneev, O.I.; Korotkov, V.N.; Smirnov, V.E.; Ivanova, N.V. Nemoral Forests. In European Russian Forests; Smirnova, O.V., Bobrovsky, M.V., Khanina, L.G., Eds.; Plant and Vegetation 15; Springer: Dordrecht, The Netherlands, 2017; p. 461, doi:10.1007/978-94-024-1172-0_5.
41. State Forest Service. Lithuanian Statistical Yearbook of Forestry 2017; Lutute: Vilnius, Lithuania, 2017.
42. Karazija, S. Types of Lithuanian Forest; Mokslas, Vilnius, Lithuania, 1988. (In Lithuanian)
43. Navasaitis, M.; Ozolinčius, R.; Smaliukas, D.; Balevičienė, J. Dendroflora of Lithuania; Lututė: Kaunas, Lithuania, 2003. (In Lithuanian)
44. More, D., White, J. Cassell's Trees of Britain and Northern Europe; Cassell: London, UK, 2003.
45. Lithuanian Republic. Republic of Lithuania Order on the Approval of Forestry Rules; Lithuanian Ministry of the Environment, Vilnius, Lithuania, 2010.