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EDITORIAL

Forty milestones in landscape ecology: commemorating the 40th anniversary of the Allerton Park workshop

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Science advances nonlinearly, characterized by phases of rapid growth with breakthroughs and periods of steady development with only incremental progress. Landscape ecology exemplifies this pattern: initially proposed as a distinct field 85 years ago, it developed steadily in Europe for about 40 years before experiencing swift global expansion in the 1980s. Today, landscape ecology is a well-established field of study worldwide. One of the key catalysts for its burgeoning development in the 1980s was the Landscape Ecology Workshop held in Allerton Park, Illinois, USA, during April 25–27, 1983 (also known as the Allerton Park workshop). The workshop has had profound influences on the development of landscape ecology by helping create a new paradigm centered on spatial heterogeneity, scale, and interdisciplinarity. The workshop report (Risser et al. 1984) has been cited about 700 times as per Google Scholar. A discipline that fails to honor its past may diminish its capacity to envision the future. Thus, *Landscape Ecology*, the flagship journal of the International Association for Landscape Ecology (IALE), has published several invited articles to reflect on the significance of the workshop, both historically and in shaping future directions (Risser 1995; Wiens 2008; Risser and Iverson 2013; Wu 2013a; Foody 2023; Forman 2023; Frazier 2024; Pearson 2024). In celebration of the 40th anniversary of the Allerton Park workshop, we have selected 40 key milestones and the 40 most cited articles to commemorate the enduring impact and legacy of this pivotal event.

Forty key milestones in landscape ecology

Defining and selecting key milestones

A milestone literally means "a milepost made of stone" or broadly "an important point in progress or development" (https://www.merriam-webster.com/). Here, we define milestones as groundbreaking or exceptionally influential events in the development of landscape ecology. These milestones can be either significant publications or historic meetings. For publications, we focus on new theories/perspectives, new methods/approaches, and exemplary case studies, all of which are directly related to the core topics of landscape ecology. To quantify "extraordinary influence", we adopt the minimum number of citations that a "citation classic" must have (i.e., 400), according to Eugene Garfield, the founder of ISI (now Clarivate Analytics) and a pioneer in bibliometrics and scientometrics (Garfield 1993). To put this in perspective, Van Noorden et al. (2014) showed that, based on Thomson Reuter's Web of Science (now Clarivate Analytics, covering natural and social sciences as well as humanities), only about 0.026% of published articles from 1900 to 2014 had more than 1,000 citations. Based on the same database, Pendlebury (2020) reported that only 0.17% of the journal articles and proceedings papers between 1970 and 2020 were cited more than 500 times, and this percentage dropped precipitously to 0.04% for those cited more than 1,000 times. For meetings, we evaluate them more subjectively by examining whether they have substantially shaped the direction or increased the global influence of the field. Being the first meeting on a continent alone does not necessarily make it a milestone.

Based on the above criteria and after a painstaking process, we selected 40 milestones out of hundreds of candidates (Table 1). The selection process was difficult because of the subjectivity and ambiguity in the criteria. However, relying solely on metrics would not be accurate or fair. Although the milestones on the list are all important contributions to landscape ecology in certain ways, we acknowledge that our biases in academic training, research interests, and even cultural backgrounds certainly influenced the selection of these milestones. To provide a more comprehensive account of the field's history, we supplement the primary list of 40 milestones with an additional set of 50 notable events (Table S1). In the following, we highlight some of the milestones, with comments on each milestone included in the tables.

The first 40 years of landscape ecology

Landscape ecology, coined by Carl Troll (1939), emerged as a regionally-focused research field that combined the pattern-oriented geographical approach, inspired by aerial photography, with the process-oriented functional approach embodied in the term "ecosystem" coined by ArthurTansley (1935).[1] The term "biogeocenosis" was developed by the

[1] Although biogeochemistry is now considered a key component of ecosystem ecology, the term "biogeochemistry" had been coined by a Russian geochemist (Vernadsky 1926) nine years before the term "ecosystem" appeared for the first time.

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Table 1 Forty Milestones in landscape ecology

Chrono-logical Order	Time	Event	Notes on milestones	Google Scholar Cites (7/3/2023)	Cites/Year
1	1939	Troll, C. 1939. Luftbildplan und ökologische Bodenforschung. Pages 241–298. Zeitschrift der Gesellschaft für Erdkunde, Berlin	Carl Troll (1939) coined the term, landscape ecology (landschaftsökologie), and defined it in 1968 as "the study of the main complex causal relationships between the life communities and their environment … expressed regionally in a definite distribution pattern (landscape mosaic, landscape pattern) and in a natural regionalization at various orders of magnitude"	670	8.0
2	1947	Watt, A. S. 1947. Pattern and process in the plant community. Journal of Ecology 35:1–22	Alex S. Watt (1947) conceptualized plant communities as dynamic patch mosaics, in which spatial pattern and ecological processes are related. This seminal paper has had far-reaching impacts in ecology, particularly in areas of disturbance ecology and patch dynamics	3410	44.9
3	1967	MacArthur, R. H., and E. O. Wilson. 1967. The Theory of Island Biogeography. Princeton University Press, Princeton	The MacArthur-Wilson theory was a primary inspiration for the initial development of the North American landscape ecology, and remains quite influential in modern landscape ecology, albeit often only heuristically. Metapopulation theory and patch dynamics are also conceptually linked to the theory of island biogeography	26,981	481.8
4	1967	Neef, E. 1967. Die theoretischen Grundlagen der Landschaftslehre. Haack, Gotha, Germany	This German book has often been regarded as the first textbook on landscape ecology. The book has a geographical emphasis, with key terms such as geographical scale ranges, the smallest landscape ecological spatial units, and ecotope	489	8.7
5	1969	Levins, R. 1969. Some demographic and genetic consequences of environmental heterogeneity for biological control. Bulletin of the Entomological Society of America 15:237–240	Richard Levins (1969) developed the first metapopulation model (the Levins model or the patch-occupancy model). One year later he coined the term "metapopulation" and defined it as "a population of populations which go extinct locally and recolonize" in a book chapter, entitled "Some Mathematical Problems in Biology" (Levins 1970)	4,610	85.4
6	1974	Levin, S. A., and R. T. Paine. 1974. Disturbance, patch formation and community structure. Proceedings of the National Academy of Sciences (USA) 71:2744–2747	Simon A. Levin and Robert Paine (1974) developed the theory of patch dynamics, with a mathematical model that predicted the effects of disturbances on community structure, dynamics, and stability by relating landscape pattern to local population processes. An important follow-up study was published by the same authors was published seven years later, empirically demonstrating how the theory of patch dynamics can help understand community dynamics in a rapidly changing landscape (Paine and Levin 1981)	1254	25.6

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Table 1 (continued)

Chronological Order	Time	Event	Notes on milestones	Google Scholar Cites (7/3/2023)	Cites/Year
7	1979	Bormann, F. H., and G. E. Likens. 1979. Pattern and Process in a Forested Ecosystem: Disturbance, Development and the Steady State Based on the Hubbard Brook Ecosystem Study. Springer-Verlag, New York	This book presented the shifting mosaic steady state model in detail to link the spatial pattern and ecosystem processes of a forested watershed. It was enormously influential in shaping the ecological thinking of forest ecosystems	4309	97.9
8	1981	The first international conference on landscape ecology	This conference held in the Netherlands was a watershed moment which brought together most of the pioneering landscape ecologists in Europe and North America for the first time. It was the beginning of the golden age of landscape ecology. The conference produced a proceedings which was published in the following year (Tjallingii, S. P., and A. A. de Veer, eds. 1982. Perspectives in Landscape Ecology. Proceedings of the International Congress of the Netherlands Society of Landscape Ecology, Veldhoven, The Netherlands, April 6–11, 1981. Pudoc, Wageningen)	N/A	
9	1981	Forman, R. T. T., and M. Godron. 1981. Patches and structural components for a landscape ecology. Bioscience 31:733–740	Richard Forman and Michel Godron proposed the patch-corridor-matrix model as a new paradigm and a spatial language for contemporary landscape ecology. Two years before that, in the edited book, "Pine Barrens: Ecosystem and Landscape" (1979), Forman already proposed the landscape mosaic framework for studying population and ecosystem processes in heterogeneous landscapes composed of multiple ecosystems	1,409	33.5
10	1982	The establishment of the International Association for Landscape Ecology (IALE)	This historic event took place at the 6th International Symposium on Problems of Landscape Ecological Research, Pestany, Czechoslovak Socialist Republic (CSSR), October 29, 1982, hosted by Milan Ruzicka, a pioneering landscape ecologist in CSSR who served as Vice President of IALE and a member of the first editorial board of Landscape Ecology. Isaak S. Zonneveld from the Netherlands was elected the inaugural president	N/A	

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Table 1 (continued)

Chronological Order	Time	Event	Notes on milestones	Google Scholar Cites (7/3/2023)	Cites/Year
11	1983	The Allerton Park workshop on landscape ecology	This was the first landscape ecology meeting on the American continent, which was organized by Paul Risser, James Karr, and Richard Forman with supported from NSF Ecology Program. It was participated by 25 people (23 from the US, one from Canada, and one from France). The workshop produced a report: Risser, P. G., J. R. Karr, and R. T. T. Forman. 1984. Landscape Ecology: Directions and Approaches. Illinois Natural History Survey Special Publ. 2, Champaign	703	17.6
12	1984	Naveh, Z., and A. S. Lieberman. 1984. Landscape Ecology: Theory and Application. Springer-Verlag, New York	This was the first English textbook on landscape ecology that had a global influence, emphasizing a holistic landscape ecology perspective based on the Total Human Ecosystem concept (THE). The key ideas of landscape as THE were presented two years before: Naveh Z (1982) Landscape ecology as an emerging branch of human ecosystem science. Advances in Ecological Research 12:189–237	2,588	66.4
13	1985	Pickett, S. T. A., and P. S. White, editors. 1985. The Ecology of Natural Disturbance and Patch Dynamics. Academic Press, Orlando	This edited book, with contributions from a number of leading ecologists, included both conceptual and empirical studies of disturbance ecology, patch dynamics, and nonequilibrium dynamics of ecosystems. It has been one of the most influential ecology books published since the 1980s	6,068	159.7
14	1986	Forman, R. T. T., and M. Godron. 1986. Landscape Ecology. Wiley, New York	This was the first landscape ecology texbook in North America, which has had a wide-spread impact on the development of the field around the world. It is a fundational book of landscape ecology based on the patch-based paradigm	7000	189.2
15	1986	The establishment of the US Chapter of IALE (US-IALE) and its first annual symposium	This groundbreaking event was held at University of Georgia, Athens, USA, January 15–17, 1986, and the symposium theme was “The Role of Landscape Heterogeneity in the Spread of Disturbance” (See Turner 2015 for details). US-IALE, which became the North American Regional Chapter of the International Association for Landscape Ecology (IALE-NA) in 2019, has been a primary leader in the development of modern landscape ecology since its birth	N/A	

Table 1 (continued)

Chronological Order	Time	Event	Notes on milestones	Google Scholar Cites (7/3/2023)	Cites/Year
16	1986	O'Neill, R. V., D. L. DeAngelis, J. B. Waide, and T. F. H. Allen. 1986. A Hierarchical Concept of Ecosystems. Princeton University Press, Princeton	This was one of the two books published in the 1980s that had profoundly influenced ecological thinking in the United States and much of the western world during the 1980s and 1990s (the other one being Allen and Starr 1982). It provides a lucid introduction to (ecological) hierarchy theory that explains why and how ecological systems are hierarchically organized based on process rates. Landscapes are explicitly discussed, which is one of the reasons why it has had a pervasive and lasting impact on the development of modern landscape ecology	3256	88.0
17	1987	The launching of the journal, Landscape Ecology	The founding of the flagship journal of IALE was one of the most important milestones in the history of landscape ecology. The founding Editor-in-Chief Frank Golley and 18 editorial board members were all eminent landscape ecologists as well as distinguished ecoloigsts and geographers. They were from 10 countries (predominantly Europe and North America), including R. Forman, M. Gordon, W. Haber, S. Levin, Z. Naveh, P. Risser, C. Steinitz, and I. Zonneveld	N/A	
18	1987	Addicott, J. F., J. M. Aho, M. F. Antolin, D. K. Padilla, J. S. Richardson, and D. A. Soluk. 1987. Ecological neighborhoods: scaling environmental patterns. Oikos 49:340–346	This paper developed the concept of ecological neighborhood for scaling landscape heterogeneity based on organism movements in space and time. It has been a foundational paper for behavioral landscape ecology	996	27.7
19	1987	Gardner, R. H., B. T. Milne, M. G. Turner, and R. V. O'Neill. 1987. Neutral models for the analysis of broad-scale landscape pattern. Landscape Ecology 1:19–28	This was the first paper that introduced percolation theory into landscape ecology as a neutral model framework for analyzing landscape pattern and predict phase transitions. Neutral landscape models have been widely used in theoretical and empirical studies during the past decades, significantly advancing our understanding of the processes and consequences of landscape fragmentation and connectivity	1,048	29.1
20	1988	O'Neill, R. V., J. R. Krummel, R. H. Gardner, G. Sugihara, B. Jackson, D. L. DeAngelis, B. T. Milne, M. G. Turner, B. Zygmunt, S. W. Christensen, V. H. Dale, and R. L. Graham. 1988. Indices of landscape pattern. Landscape Ecology 1:153–162	This paper introduced three of the most commonly used landscape metrics (Dominance Index, Contagion Index, and Fractal Dimension), with application examples. It has been the most cited paper published in Landscape Ecology since 1987	2413	68.9

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Table 1 (continued)

Chronological Order	Time	Event	Notes on milestones	Google Scholar Cites (7/3/2023)	Cites/Year
21	1989	Legendre, P., and M.-J. Fortin. 1989. Spatial pattern and ecological analysis. Vegetatio 80:107–138	This is one of the earliest and most influential papers that introduce spatial statistical methods into the analysis of (often autocorrelated) ecological and environmental data, including Moran's I, Mantel test, trend surface analysis, semi-variograms, and Kriging. A landmark book on spatial statistics for ecologists was published 16 years later: Fortin, M.-J., and M. R. T. Dale. 2005. Spatial Analysis: A Guide for Ecologists. Cambridge University Press, Cambridge (the 2nd edition was published in 2014)	3057	89.9
22	1989	Wiens, J. A. 1989. Spatial scaling in ecology. Functional Ecology 3:385–397	This has been one of the most influential papers on spatial scaling in ecology, articulating several key concepts and their relationships (e.g., grain, extent, scale domains, scale dependence, and scale discontinuity)	6,316	185.8
23	1989	Turner, M. G. 1989. Landscape ecology: The effect of pattern on process. Annual Review of Ecology, Evolution, and Systematics 20:171–197	This extremely influential review paper highlighted one of the most prominent themes of landscape ecology in North America—effects of spatial heterogeneity (often created by disturbances) on ecological processes	5,059	148.8
24	1991	Turner, M. G., and R. H. Gardner. 1991. Quantitative Methods in Landscape Ecology: The Analysis and Interpretation of Landscape Heterogeneity. Springer-Verlag, New York	This was the first book devoted solely on quantitative methods in landscape ecology, focusing primarily on landscape pattern analysis and simulation modeling	1,544	48.3
25	1992	Levin, S. A. 1992. The problem of pattern and scale in ecology. Ecology 73:1943–1967	This has been the most influential paper on the issue of scale and scaling in ecolog, which is a key research topic in modern landscape ecology	9380	302.6
26	1994	Andren, H. 1994. Effects of habitat fragmentation on birds and mammals in landscape with different proportions of suitable habitat: a review. Oikos 71:355–366	Habitat fragmentation implies a loss of habitat, reduced patch size and an increasing distance between patches, but also an increase of new habitat. In these landscapes, habitat fragmentation is primarily habitat loss. However, in landscapes with highly fragmented habitat, patch size and isolation will complement the effect of habitat loss and the loss of species or decline in population size will be greater than expected from habitat loss alone	4402	151.8
27	1995	Forman, R. T. T. 1995. Land Mosaics: The Ecology of Landscapes and Regions. Cambridge University Press, Cambridge	This has been the most comprehensive and influential foundational book that presents the patch-based paradigm of modern landscape ecology	9162	327.2

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Table 1 (continued)

Chronological Order	Time	Event	Notes on milestones	Google Scholar Cites (7/3/2023)	Cites/Year
28	1995	McGarigal, K., and B. J. Marks. 1995. FRAGSTATS: Spatial Pattern Analysis Program for Quantifying Landscape Structure. Gen. Tech. Rep. PNW-GTR-351. USDA-Forest Service, Portland	This most widely used landscape pattern analysis software has greatly popularized the use of landscape metrics worldwide	5,393	192.6
29	1995	Riitters, K. H., R. V. O'Neill, C. T. Hunsaker, J. D. Wickham, D. H. Yankee, S. P. Timmins, K. B. Jones, and B. L. Jackson. 1995. A factor analysis of landscape pattern and structure metrics. Landscape Ecology 10:23–39	This paper provided the first comprehensive analysis of correlations and redundancy among landscape pattern metrics	1,829	65.3
30	1995	Wu, J., and O. L. Loucks. 1995. From balance of nature to hierarchical patch dynamics: A paradigm shift in ecology. Quarterly Review of Biology 70:439–466	This paper critiques the equilibrium paradigm in ecology and proposes a spatially explicit pattern-process-scale framework by integrating patch dynamics and hierarchy theory in a landscape context. It advocates that landscape ecology is not only a field of study, but also represents a new paradigm that applies to the science and practice of ecological systems across scales	1725	61.6
31	1996	Roth, N. E., J. D. Allan, and D. L. Erickson. 1996. Landscape influences on stream biotic integrity assessed at multiple spatial scales. Landscape Ecology 11:141–156	This was one of the early and most influential studies that examined how land use and land cover affected the biological integrity of steams on multiple spatial scales, using a landscape approach (with Habitat Index and Index of Biological Integrity). It has been one of the most cited papers in Landscape Ecology since 1987. Other influential papers on riverine landscape ecology include: Allan et al. 1997 (cited 1437 times), Ward et al. 2002 (cited 1390 times), Wiens 2002 (cited 1194 times), and Allan (2004; cited 4532 times)	1152	42.7
32	2001	Turner, M. G., R. H. Gardner, and R. V. O'Neill. 2001. Landscape Ecology in Theory and Practice: Pattern and Process. Springer-Verlag, New York	This has been one of the most influential landscape ecology textbooks for the past two decades, which focuses on the effects of landscape pattern on population processes, ecosystem dynamics, and spread of disturbances. The second edition was published in 2015	4,826	219.4
33	2002	Forman, R. T. T., D. Sperling, J. A. Bissonette, A. P. Clevenger, C. D. Cutshall, V. H. Dale, L. Fahrig, R. France, C. R. Goldman, K. Heanue, J. A. Jones, F. J. Swanson, T. Turrentine, and T. C. Winter, editors. 2002. Road Ecology: Science and Solutions. Island Press, Washington, D.C	This was the first book on road ecology that emerged from landscape ecology but focused on the structure, function, and ecological influences of roads	3,278	156.1

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Table 1 (continued)

Chronological Order	Time	Event	Notes on milestones	Google Scholar Cites (7/3/2023)	Cites/Year
34	2003	Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. Annual Review of Ecology, Evolution, and Systematics 34:487–515	This has been one of the most influential publications on habitat fragmentation and biodiversity, advocating that habitat loss and fragmentation per se must be explicitly distinguished in assessing their effects on biodiversity	9,919	496.0
35	2003	Manel, S., M. K. Schwartz, G. Luikart, and P. Taberlet. 2003. Landscape genetics: combining landscape ecology and population genetics. Trends in Ecology and Evolution 18:189–197	This was the seminal paper that defined a new field of study: landscape genetics, which stimulated a flurry of research activities within landscape ecology and molecular ecology	2,961	148.1
36	2005	Antrop, M. 2005. Why landscapes of the past are important for the future. Landscape and Urban Planning 70:21–34	This influential paper analyzed the pattern and driving forces of European landscapes from a historical perspective, and discussed the importance of the diversity and identity of cultural landscapes	2343	130.2
37	2008	Nassauer, J. I., and P. Opdam. 2008. Design in science: extending the landscape ecology paradigm. Landscape Ecology 23:633–644	This was a groundbreaking paper that proposed a pattern-process-design paradigm for landscape ecology	635	42.3
38	2009	Termorshuizen, J. W., and P. Opdam. 2009. Landscape services as a bridge between landscape ecology and sustainable development. Landscape Ecology 24:1037–1052	This was one of the earliest and most influential papers on landscape services, a concept that makes the ecosystem services concept more relevant to landscape planning/design and landscape sustainability	855	61.1
39	2011	Pijanowski, B., A. Farina, S. Gage, S. Dumyahn, and B. Krause. 2011. What is soundscape ecology? An introduction and overview of an emerging new science. Landscape Ecology 26:1213–1232	This is the first special issue on soundscape ecology that integrates the concepts and principles of landscape ecology with acoustic ecology, bioacoustics, and urban environmental acoustics	837	69.8
40	2013	Wu, J. 2013. Landscape sustainability science: ecosystem services and human well-being in changing landscapes. Landscape Ecology 28:999–1023	This paper coined the term, "landscape sustainability science", and defined what it is with a conceptual framework. This paper has become the second most cited paper published in Landscape Ecology since its inception in 1987. A sequel was published 8 years later: Wu, J. 2021. Landscape sustainability science (II): core questions and key approaches. Landscape Ecology 36:2453–2485	1,552	155.2

Russian geobotanist Vladimir N. Sukachev through a series of publications during the 1940s, and has often been regarded as equivalent to "ecosystem" (Dronin and Francis 2019). However, Troll (1971) considered biogeocenosis to be "obviously identical with" landscape ecology. During the 1920s-1940s, multiple efforts led by prominent geophysical and biological scientists in Europe and the former USSR aimed to achieve a similar goal: understanding and managing the landscape in its totality by integrating the living organisms with their geophysical environment—the agglomeration of botany, zoology, hydrology, pedology, geomorphology, geochemistry, meteorology, climatology, silviculture, and land management.

In 1968, Troll defined landscape ecology as "the study of the main complex causal relationships between the life communities and their environment …… expressed regionally in a definite distribution pattern (landscape mosaic, landscape pattern)" (Troll 1971). This initial definition of landscape ecology clearly resembled Tansley's (1935) definition of ecosystem. However, the emphasis in Troll's definition on the regionally expressed landscape mosaic of multiple ecosystems gave landscape ecology a distinctive feature. In 1967, the German geographer Ernst Neef, who is sometimes considered a founder of landscape ecology along with Carl Troll, published the first textbook on landscape ecology (Neef 1967). The book (in German) had a geographical emphasis, with key terms such as geographical scale ranges, the smallest landscape ecological spatial units, and ecotope. Interestingly, the classic paper on plant communities as patch mosaics by Alex S. Watt (1947), which had a profound influence on patch dynamics and disturbance ecology in North America during the 1970s and 1980s, had no detectable impact on the early development of landscape ecology in Europe.

For the first 40 years, the development of landscape ecology took place primarily in Germany, the rest of Central Europe, and the former USSR, with related but distinct efforts led by prominent geographers and ecologists. A substantial amount of pioneering interdisciplinary landscape (and geoecological) research was accomplished during this period, which has been well documented in several reviews (e.g., Naveh 1982; Bastian and Steinhardt 2002; Dronin and Francis 2019; Frolova 2019). Landscape ecology not only originated in Europe, but also developed a strong interdisciplinary vision in its early decades, integrating biology, ecology, geography, land appraisal/management, and landscape planning/design holistically in a regionally expressed landscape mosaic. This salient theme of early European landscape ecological studies—often described as being "transdisciplinary" and "holistic"—seems more relevant today than ever, as sustainability is the greatest challenge of our time.

However, for some 40 years since Troll (1939), the field developed rather slowly, and the research activities were confined mainly to Central Europe. One motivation for the Allerton Park workshop was the observation that the field was going through "a conceptual bottleneck" with multiple definitions and ideas that had "never been coalesced, organized, and confronted rigorously to produce a theoretically sound basis for understanding landscape-scale interactions" (Risser et al. 1984). The workshop was intended to help advance the field by exploring and identifying a coherent set of relevant theories, questions, and approaches.

The golden age of landscape ecology

The period from the 1980s to the 1990s marked the golden age of landscape ecology. During the late 1970s and early 1980s, a new and different version of landscape ecology was developed independently in North America, characterized by the patch-corridor-matrix (PCM) model (Forman 1979, 1981, 1983; Forman and Godron 1981, 1986). The PCM model focuses on the structure, function, and dynamics of landscape elements (i.e., patches, corridors, and matrix), and provides a "spatial language" for ecologists, geographers, and managers/planners to communicate and collaborate. The first international conference on landscape ecology, held in the Netherlands in 1981, provided the first ever opportunity for European and North American landscape ecologists to exchange their ideas in person (Forman 2015). In 1982, the International Association for Landscape Ecology (IALE) was established through a joint effort by landscape ecologists from both sides of the North Atlantic.

While Carl Troll (1939), inspired by aerial photography and the concept of ecosystem, merged geography and ecology to give rise to landscape ecology, MacArthur and Wilson (1967), in their search for the underlying processes of the species-area relationship,

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integrated ecology with geography to develop the theory of island biogeography (IBT). With pervasive influences on biogeography, ecology, and evolutionary biology in general (Losos and Ricklefs 2010; Whittaker et al. 2017), the IBT played an instrumental role in shaping the conceptual foundation of landscape ecology in North America. Several key models and theories, such as the PCM model, metapopulation theory (Levins 1969, 1970), and patch dynamics (Levin and Paine 1974; Pickett and White 1985), were inspired by and conceptually related to the IBT. Spatial patchiness in terrestrial landscapes is ubiquitous, often created and maintained by natural and anthropogenic disturbances that lead to nonequilibrium ecological dynamics. This "patchiness-disturbance" perspective, often traced back to the early work of Watt (1947) on vegetation mosaic, became increasingly dominant in ecological thinking in North America in the 1970s and 1980s (Levin and Paine 1974; Whittaker and Levin 1977; Pickett and Thompson 1978; Paine and Levin 1981; Pickett and White 1985).

The 1983 Allerton Park workshop, the first meeting on landscape ecology in North America, brought together the previously mentioned concepts, theories, and methods, and explicitly established spatial heterogeneity as the central theme of landscape ecology, catalyzing a surge of studies on the pattern-process-scale relations. The core questions proposed at the workshop have stimulated and shaped the development of landscape ecology worldwide ever since, and they remain relevant today (Turner et al. 2001; Wiens 2008; Wu 2017; With 2019; Forman 2023; Pearson 2024). The establishment of the US Chapter of IALE (US-IALE; now IALE-NA) and its inaugural symposium in 1986 marked a watershed moment, ushering in a new and transformative era for landscape ecology. A year later, the flagship journal of IALE, *Landscape Ecology*, was launched, which played a critical role in publishing some of the most original and creative ideas in landscape ecology (see Barrett et al. 2015; Wu 2017). With these developments, new kinds of landscape ecologists joined the field, with interests in population ecology, behavioral ecology, and disturbance ecology in heterogeneous landscapes.

New ideas, theories, and quantitative methods proliferated from the late 1980s through the 1990s, significantly advancing and reshaping the field during this dynamic period. Concepts like spatial heterogeneity, pattern analysis, disturbance, patch dynamics, pattern-process relationships, scale, hierarchy, neutral landscape models, fractals, and habitat fragmentation soon became buzzwords in landscape ecology (e.g., Gardner et al. 1987; Turner 1987; Turner and Gardner 1991; Forman 1995a, b; Wu and Loucks 1995; Farina 1998). All of these topics were centered on spatial heterogeneity—its causes, processes, and consequences. The interplay between pattern, process, and scale quickly emerged as the dominant paradigm, shaping the trajectory of the field. The rapid development of landscape ecology was also boosted by the availability of remote sensing data, computers, and GIS (Iverson et al. 1989; Haines-Young et al. 1993; Iverson 2007; Foody 2023). The launch of the Landsat satellite in 1972, along with other technological breakthroughs in remote sensing, GIS, and GPS, revolutionized geographic and environmental sciences and played a pivotal role in advancing landscape ecology during this time period. These technological advances allowed for the rapid development of landscape metrics and other spatial analysis/modeling methods (O'Neill et al. 1988; Legendre and Fortin 1989; Turner and Gardner 1991; McGarigal and Marks 1995; Gustafson 1998), which were a key characteristic of modern landscape ecology.

Two seminal books on hierarchy theory—Allen and Starr (1982) and O'Neill et al. (1986)—had a major influence on the development of landscape ecology during the 1980s and 1990s, particularly in advancing the understanding of spatial scaling of landscape patterns and processes. Several seminal papers on scale and scaling by landscape ecologists followed, with pervasive influences across ecology, geography, and other related fields (e.g., Delcourt and Delcourt 1988; Turner et al. 1989; Wiens 1989; Levin 1992). By integrating hierarchy theory and patch dynamics through a multiscale, spatially explicit framework, the hierarchical patch dynamics paradigm (Wu and Loucks 1995) links several ecological theories together, including Watt's (1947) early conceptualization of plant communities as patch mosaics, patch dynamics (Levin and Paine 1974; Pickett and White 1985; Wu and Levin 1994), the shifting mosaic steady state model (Bormann and Likens 1979), and land mosaics (Forman 1995a). Landscape ecology also became "wetter" by focusing more on "waterscapes". The emergence of riverscape ecology, in particular, revolutionized traditional approaches to studying rivers by emphasizing the importance of spatial heterogeneity and connectivity in rivers and their surrounding landscapes (Roth et al. 1996; Allan et al. 1997; Ward et al. 2002; Allan 2004). The landmark publication "Land Mosaics: The Ecology of Landscapes and Regions" by Forman (1995a) remains the most-cited book in landscape ecology.

This golden era was a time of rejuvenation and revolution (in the sense of a paradigm shift), which resulted in what can be called, "modern" or "contemporary" landscape ecology. This updated and expanded version of landscape ecology had a stronger ecological foundation, and helped to free landscape ecology from the confines of being perceived solely as an "applied science" by many earlier landscape ecologists. It opened up new opportunities for theoretical and experimental explorations of the causes, processes, and consequences of spatial heterogeneity. Within a decade, landscape ecology found its way to Australia, China, and other parts of the world (Ludwig et al. 1997; Cao et al. 2002; Fu and Lü 2006). By the 1990s, landscape ecology emerged as one of the most exciting and dynamic disciplines in both ecology and geography in North America and Europe. It emerged as a leading field in spatial pattern analysis and scaling within and beyond ecological and geographical sciences (Gibson et al. 1998; Wu et al. 2006; Frazier et al. 2023).

A pluralistic field both diversifying and converging

Since the beginning of the twenty-first century, landscape ecology has continued to strengthen its scientific foundation that hinges on the relationship between spatial heterogeneity and ecological processes. Modern landscape ecology is not just a field of study; it also represents a new ecological-geosocial paradigm that views the world through a multiscale pattern-process lens. A number of new research frameworks and directions have emerged, delving into specific landscape types and thematic issues. Textbooks and monographs have mushroomed, each recognizing spatial heterogeneity as a central theme, but offering distinct perspectives on the scope and main topics of the field (e.g., Farina 1998, 2022; Turner et al. 2001; Burel and Baudry 2003; Wiens and Moss 2005; Wu and Hobbs 2007; Turner and Gardner 2015; With 2019). With its historical roots in geography, ecology, and other disciplines, landscape ecology has always been inherently interdisciplinary and pluralistic. Therefore, the concurrent trends of diversification and convergence within the field are not surprising, nor do they signal an "identity crisis". This dual process is a characteristic of a rapidly evolving interdisciplinary field, where diverse perspectives enhance understanding while convergence fosters coherence and actionable insights.

Interfacing with other well-established disciplines, landscape ecology has several new subfields that are still rapidly developing. Urban landscape ecology has been one of the most active area of research across ecological and geographical sciences in recent decades (Jenerette and Wu 2001; Luck and Wu 2002; Jenerette et al. 2007; Buyantuyev et al. 2010; Fernandez and Wu 2016; Muderere et al. 2018). Road ecology emerged in the early 2000s (Forman et al. 2002), focusing on the ecological impacts of roads and transportation networks—particularly on issues such as roadkill, habitat fragmentation, and species invasions. Landscape ecology's principles, such as patch-corridor-matrix model and landscape connectivity, are foundational to road ecology. Landscape genetics integrates landscape ecology principles with population genetics, focusing on the effects of landscape heterogeneity on genetic flows and biodiversity (Manel et al. 2003). This integration has allowed for a more nuanced understanding of how spatial patterns affect species survival and adaptation in fragmented landscapes. Related to metapopulations and patch dynamics, the concepts of meta-communities (Leibold et al. 2004) and meta-ecosystems (Loreau et al. 2003) were developed, aiming to understand how spatial heterogeneity affects community organization and ecosystem processes. Combining principles of bioacoustics and landscape ecology led to the development of soundscape ecology which aims to understand how the landscape of biological, geophysical, and anthropogenic sounds—the soundscape—influence and are influenced by the communication, behavior, and distribution of species, as well as how soundscape pattern reflects the function and health of ecosystems (Pijanowski et al. 2011).

Landscape epidemiology, as a concept first published by the Russian parasitologist Evgeny N. Pavlovsky (1966), reemerged as a vibrant field of study in the 2000s as a result of the interactions between landscape ecology and (spatial) epidemiology, both of which were boosted by GIS, remote sensing, and advanced spatial analysis methods (Kitron 1998;

Ostfeld et al. 2005). This revitalized field focuses on the impacts of landscape and environmental heterogeneity, including land-use changes, habitat alterations, and climate variability, on the distribution and dynamics of vector-borne diseases. This interdisciplinary approach helps in predicting disease outbreaks and designing effective intervention strategies by explicitly recognizing the critical role of landscape structure in shaping ecological interactions that influence health outcomes. In addition, "seascape ecology" has become firmly established, which combines marine science and landscape ecology to understand the causes and ecological consequences of spatial patterning in seas and oceans (Pittman et al. 2011, Pittman 2018). Conceptually, this line of research can trace back to, among others, the earlier marine studies of patch dynamics (e.g., Levin 1978; Steele 1978, 1989).

Since the early 2000s, landscape ecology has become increasingly integrative and holistic, evidenced by the surge of interests in highly inter- and transdisciplinary topics. For example, landscape ecological principles and methods have been increasingly integrated in landscape design/planning to create more resilient and sustainable landscapes (Botequilha Leitao and Ahern 2002; Nassauer and Opdam 2008; Ahern 2013; Hersperger et al. 2021). Several influential publications have emphasized the importance of historical landscape changes and driving forces for understanding and planning sustainable landscapes (Bürgi et al. 2004; Antrop 2005; Milovanovic et al. 2020). Studies of landscape effects on ecosystem services have mushroomed in recent decades, leading to the emergence of the "landscape services" concept, which emphasizes the services provided by both individual ecosystems and their interactions in a landscape (Termorshuizen and Opdam 2009; Turner et al. 2013; Bastian et al. 2014; Bürgi et al. 2015; Plieninger et al. 2019). Landscape services is "an extremely apt bridging concept that links landscape pattern, ecosystem services, aesthetics, values, and decision making" (Wu 2013b), which is also closely related to landscape multifunctionality (Lovell and Taylor 2013; Mastrangelo et al. 2014; Sturck and Verburg 2017; Lavorel et al. 2022), landscape resilience (Cumming 2011; Cumming et al. 2013; Arnaiz-Schmitz et al. 2023), and landscape sustainability (Potschin and Haines-Young 2006, 2013; Wu 2006, 2013b, 2021; Naveh 2007; Musacchio 2009, 2013; Opdam et al. 2018). Landscape multifunctionality is a necessary but insufficient condition for both landscape resilience and sustainability; similarly, landscape resilience is essential for sustainability but does not guarantee it (Wu 2021).

In the past two decades, landscape ecology has also expanded rapidly around the world, evidenced by several impactful international events and by the changing landscape of scientific publications in the field (see the next section). Since its establishment in 1982, IALE has held 11 world congresses (once every four years). Five took place in Europe: Roskilde, Denmark in 1983; Münster, Germany in 1987; Toulouse, France in 1995; Wageningen, the Netherlands in 2007; and Milan, Italy in 2019. Three were held in North America: Ottawa, Canada in 1991; Snowmass, Colorado, USA in 1999; and Portland, Oregon, USA in 2007. Thus, eight out of the 11 world congresses have been held in Europe and North America. The other three were held in Darwin, Australia in 2003 (the 6th); Beijing, China in 2011 (the 8th); and Nairobi, Kenya in 2023 (the 11th), respectively. The 12th is scheduled to take place in Valparaiso, Chile in 2027 (the first in South America). These events clearly demonstrate that landscape ecology has become a truly global science. As the field expands scientifically and geographically, landscape ecology is becoming more prominent in addressing global issues, including biodiversity conservation, climate change mitigation and adaptation, and many of the 17 Sustainable Development Goals (Wu 2017, 2021; Gilman and Wu 2023; Frazier 2024). These recent developments highlight the growing influences of landscape ecology and its role in shaping sustainable landscapes across diverse regions worldwide.

Forty most-cited papers in landscape ecology

Landscape ecological studies have proliferated since the onset of the golden era in the early 1980s. Based on the Web of Science (WoS) database, Wu (2017) reported that the number of articles published in *Landscape Ecology* and the number of articles containing the terms "landscape" and "ecolog*" in their titles, abstracts, or keywords across all other outlets combined, both increased exponentially from 1987 to 2016. Using a more extensive database, Scopus,

Journal : Medium 10980	Article No : 2000	Pages : 22	MS Code : 2000	Dispatch : 18-11-2024

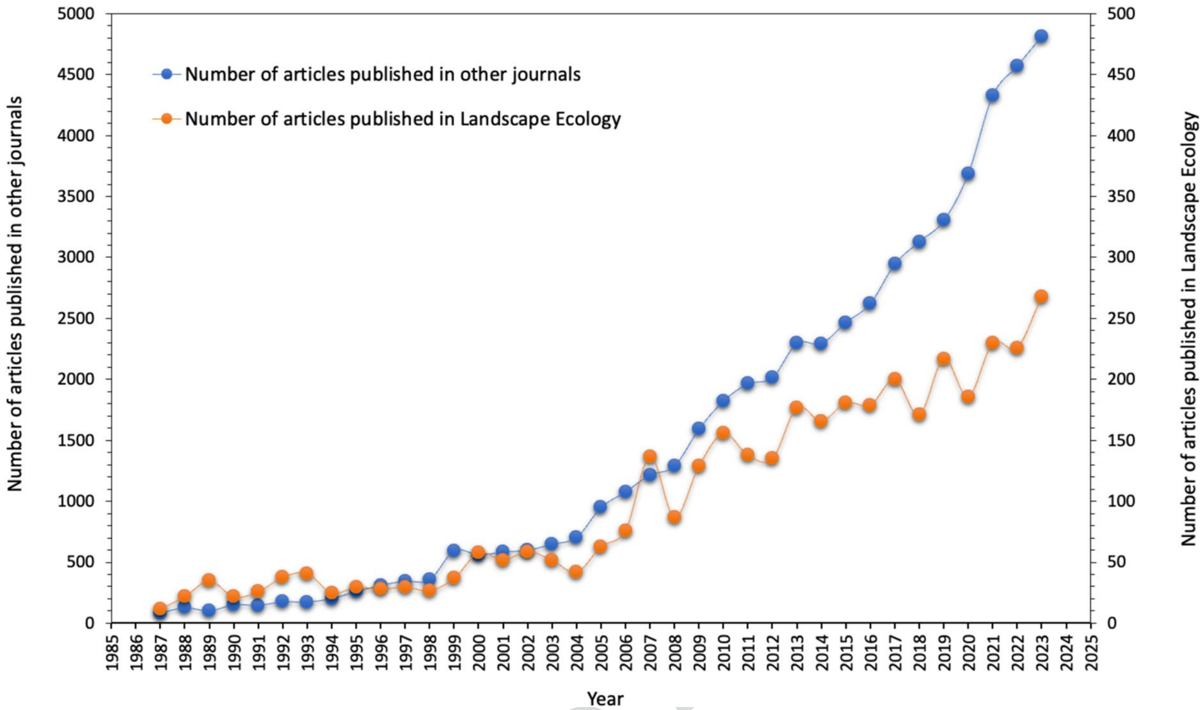


Fig. 1 The number of articles published in the journal, Landscape Ecology (in red) and the number of landscape ecology-relevant articles published in other journals (i.e., those whose titles, abstracts, or keywords contained the words "landscape" and "ecolog*"), based on Scopus (https://www.scopus.com; accessed in June 2024)

we show here that this increasing trend has continued beyond 2016, with articles from all other sources exhibiting an even faster acceleration rate (Fig. 1). The top 10 countries with the most publications between 1987 and 2023 are: USA, China, UK, Australia, Canada, Germany, France, Spain, Brazil, and Italy (Fig. 2). USA has been the largest contributor to the literature in landscape ecology, leading China by a ratio of 2.3 to 1 in total contributions. However, China's annual output became the second highest around 2005, soared rapidly since then, and nearly caught up with the US by 2023 (Fig. 2). For articles published in *Landscape Ecology*, the dominance of the US is even more apparent, and the major contributing countries are similar to those across all other publication outlets, though in a slightly different order (Fig. 3). Given the history of modern landscape ecology discussed above, this is somewhat expected.

Landscape ecological research has increasingly been published in a variety of well-established mainstream journals associated with professional societies. However, in recent years, a number of journals from publishers like MDPI and PLOS, which pour out thousands of articles per year per journal, have further boosted the number of landscape ecology-related articles. The current scientific publishing landscape is unprecedentedly muddy and chaotic.[2] The flagship journal of a scientific society, by definition, is the most reliable barometer of a discipline's development. So, here we list the top 40 most cited papers from the IALE's flagship journal—*Landscape Ecology* from 1987 to 2023 (Table 2). Previously, Wu (2013a) reported the top 20 most cited papers during 1987–2012, and Wu (2017) listed the top 30 most cited papers during 1987–2016. Comparing this top 40 list with the other two lists can help us better understand the dynamics of the most appealing topics and the most influential papers in this field since the Allerton Park workshop.

[2] A recent report by the InterAcademy Partnership (2022) discussed some widespread concerns with scientific publishing today and recommended a series of measures to address malpractices (https://www.interacademies.org/publication/predatory-practices-report-English).

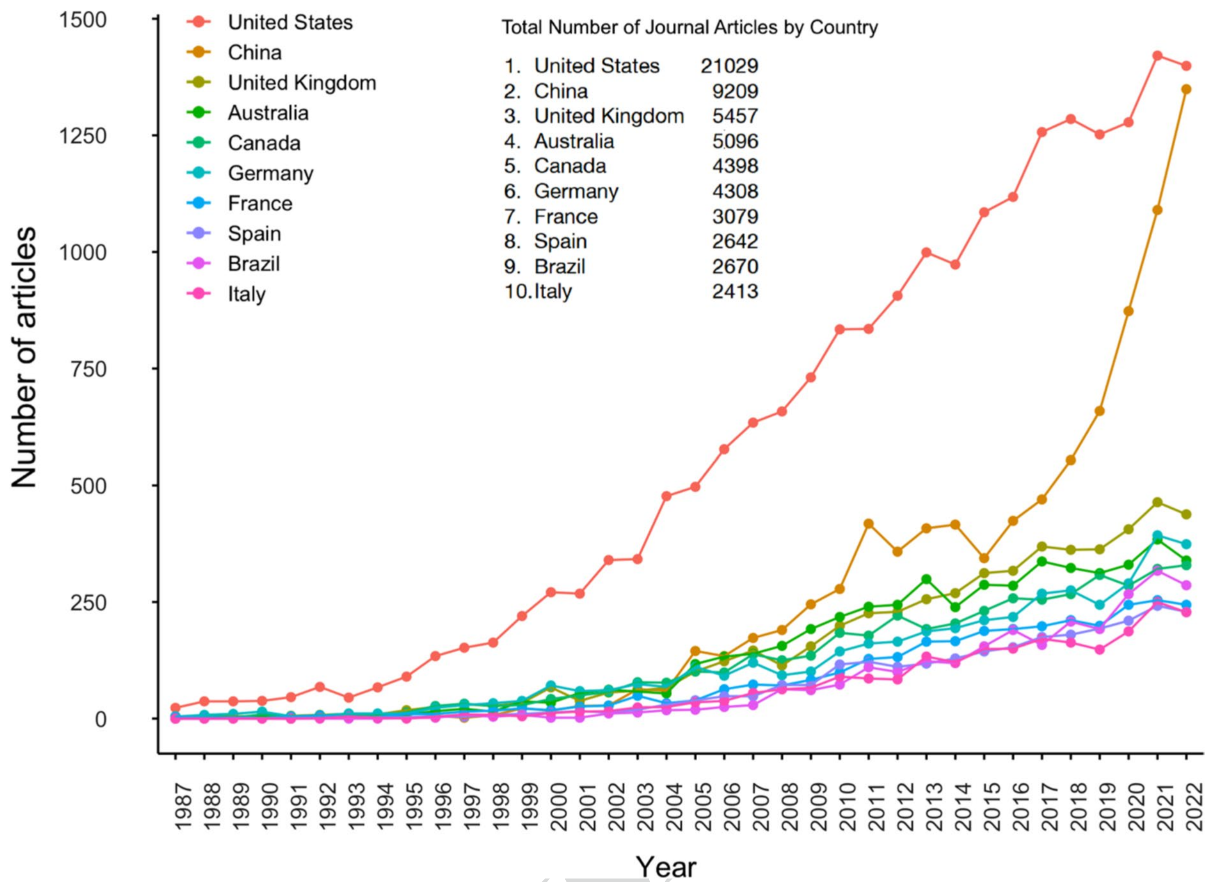
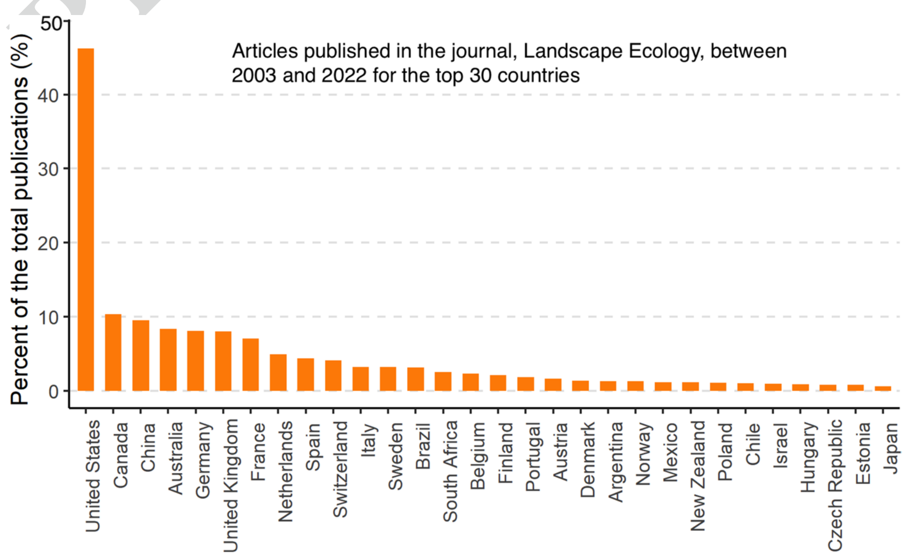


Fig. 2 Top 10 countries with most published landscape ecology-related articles (as per author affiliations) during 1987–2022 based on Scopus (https://www.scopus.com; accessed in June 2023). Landscape ecology-relevant articles refer to those that contained both the words "landscape" and "ecolog*" in their titles, abstract, or keywords

Fig. 3 Top 30 countries that had the most articles published in the journal, Landscape Ecology, between 2002 and 2022, based on Scopus (https://www.scopus.com; accessed in June 2023)



Journal : **Medium 10980**	Article No : **2000**	Pages : **22**	MS Code : **2000**	Dispatch : **18-11-2024**

Table 2 The forty most-cited articles published in Landscape Ecology, the flagship journal of the International Association for Landscape Ecology (IALE), based on data from Scopus (https://www.scopus.com; accessed on June 22, 2024)

Authors	Year	Article title	# Cites
O'Neill R.; Krummel J.; Gardner R.; Sugihara G.; Jackson B.; DeAngelis D.; Milne B.; Turner M.; Zygmunt B.; Christensen S.; Dale V.; Graham R	1988	Indices of landscape pattern	1271
Wu J	2013	Landscape sustainability science: Ecosystem services and human well-being in changing landscapes	1033
Riitters K.; O'Neill R.; Hunsaker C.; Wickham J.; Yankee D.; Timmins S.; Jones K.; Jackson B	1995	A factor analysis of landscape pattern and structure metrics	1007
Wu J	2004	Effects of changing scale on landscape pattern analysis: Scaling relations	906
Luck M.; Wu J	2002	A gradient analysis of urban landscape pattern: A case study from the Phoenix metropolitan region, Arizona, USA	802
Turner M.; O'Neill R.; Gardner R.; Milne B	1989	Effects of changing spatial scale on the analysis of landscape pattern	796
Jaeger J.A.G	2000	Landscape division, splitting index, and effective mesh size: New measures of landscape fragmentation	772
Mitsch W.; Bernal B.; Nahlik A.; Mander Ü.; Zhang L.; Anderson C.; Jørgensen S.; Brix H	2013	Wetlands, carbon, and climate change	751
Zeller K.; McGarigal K.; Whiteley A	2012	Estimating landscape resistance to movement: A review	720
Gobster P.; Nassauer J.; Daniel T.; Fry G	2007	The shared landscape: What does aesthetics have to do with ecology?	718
Forman R.T.T	1995	Some general principles of landscape and regional ecology	708
Li H.; Wu J	2004	Use and misuse of landscape indices	662
Roth N.E.; David Allan J.; Erickson D.L	1996	Landscape influences on stream biotic integrity assessed at multiple spatial scales	652
Pascual-Hortal L.; Saura S	2006	Comparison and development of new graph-based landscape connectivity indices: Towards the priorization of habitat patches and corridors for conservation	650
Wu J.; Hobbs R	2002	Key issues and research priorities in landscape ecology: An idiosyncratic synthesis	645
Bürgi M.; Hersperger A.; Schneeberger N	2005	Driving forces of landscape change—Current and new directions	636
Buyantuyev A.; Wu J	2010	Urban heat islands and landscape heterogeneity: Linking spatiotemporal variations in surface temperatures to land-cover and socioeconomic patterns	634
Matthews R.; Gilbert N.; Roach A.; Polhill J.; Gotts N	2007	Agent-based land-use models: A review of applications	633
Franklin J.F.; Forman R.T.T	1987	Creating landscape patterns by forest cutting: Ecological consequences and principles	632
Verburg P.H.; Overmars K.P	2009	Combining top-down and bottom-up dynamics in land use modeling: Exploring the future of abandoned farmlands in Europe with the Dyna-CLUE model	629
Jelinski D.E.; Wu J	1996	The modifiable areal unit problem and implications for landscape ecology	614
Falcucci A.; Maiorano L.; Boitani L	2007	Changes in land-use/land-cover patterns in Italy and their implications for biodiversity conservation	601
Seto K.C.; Fragkias M	2005	Quantifying spatiotemporal patterns of urban land-use change in four cities of China with time series landscape metrics	573

Table 2 (continued)

Authors	Year	Article title	# Cites
Gardner R.; Milne B.; Turnei M.G.; O'Neill R	1987	Neutral models for the analysis of broad-scale landscape pattern	559
Hargis C.D.; Bissonette J.A.; David J.L	1998	The behavior of landscape metrics commonly used in the study of habitat fragmentation	521
Turner M.G	1990	Spatial and temporal analysis of landscape patterns	503
Termorshuizen J.W.; Opdam P	2009	Landscape services as a bridge between landscape ecology and sustainable development	482
Lovell S.T.; Taylor J.R	2013	Supplying urban ecosystem services through multifunctional green infrastructure in the United States	477
Wu J.; Shen W.; Sun W.; Tueller P.T	2002	Empirical patterns of the effects of changing scale on landscape metrics	469
Pijanowski B.; Farina A.; Gage S.; Dumyahn S.; Krause B	2011	What is soundscape ecology? An introduction and overview of an emerging new science	468
Turner M.G.; Romme W.H	1994	Landscape dynamics in crown fire ecosystems	461
Van Oost K.; Govers G.; Desmet P	2000	Evaluating the effects of changes in landscape structure on soil erosion by water and tillage	455
Baguette M.; Van Dyck H	2007	Landscape connectivity and animal behavior: Functional grain as a key determinant for dispersal	441
Ahern J	2013	Urban landscape sustainability and resilience: The promise and challenges of integrating ecology with urban planning and design	439
Connors J.P.; Galletti C.S.; Chow W.T.L	2013	Landscape configuration and urban heat island effects: Assessing the relationship between landscape characteristics and land surface temperature in Phoenix, Arizona	438
Vogt P.; Riitters K.H.; Estreguil C.; Kozak J.; Wade T.G.; Wickham J.D	2007	Mapping spatial patterns with morphological image processing	428
Plotnick R.E.; Gardner R.H.; O'Neill R.V	1993	Lacunarity indices as measures of landscape texture	420
McGarigal K.; Wan H.; Zeller K.; Timm B.; Cushman S	2016	Multi-scale habitat selection modeling: a review and outlook	407
Gustafson E.J.; Parker G.R	1992	Relationships between landcover proportion and indices of landscape spatial pattern	404
Kindlmann P.; Burel F	2008	Connectivity measures: A review	402

The list of top 40 most cited papers published in *Landscape Ecology* between 1987 and 2023 reveals several important trends and insights. Together, they reflect both some of the enduring core research themes and emerging key topics of modern landscape ecology (Forman 1995b; Wu and Hobbs 2002). First, several central themes have continued to attract much attention, such as landscape metrics (e.g., O'Neill et al. 1988; Gustafson and Parker 1992; Plotnick et al. 1993; Riitters et al. 1995; Li and Wu 2004), scale effects and scaling (e.g., Turner et al. 1989; Jelinski and Wu 1996; Wu et al. 2002; Wu 2004; McGarigal et al. 2016), fire disturbance (e.g., Turner and Romme 1994), and landscape connectivity and habitat fragmentation (Hargis et al. 1998; Jaeger 2000; Baguette and Van Dyck 2007; Kindlmann and Burel 2008; Zeller et al. 2012). This is not surprising because spatial heterogeneity is the cornerstone of modern landscape ecology. Heterogeneity begets patterns. Studying the ecology of landscapes requires quantifying heterogeneity through pattern analysis. Patterns affect processes, both of which are scale-dependent. As a result, scale effects occur, and scaling becomes necessary for understanding and predicting across landscapes. Fire disturbance and habitat fragmentation (or connectivity) are quintessential "landscape" phenomena that effectively illustrate how spatial patterns, ecological processes, and scale interact, thus consistently receiving substantial attention from landscape ecologists.

The list also highlights several emerging areas from recent decades. Research on urban landscapes has been growing more rapidly in both quantity and diversity than other types of landscapes, such as agricultural lands and natural areas. As a pluralistic science, landscape ecology has continued to integrate with other disciplines, creating new research frontiers in response to global environmental challenges. Specifically, the emerging areas include the quantification of the spatiotemporal patterns of urbanization (Luck and Wu 2002; Seto and Fragkias 2005), urban heat islands (Buyantuyev and Wu 2010; Connors et al. 2013), landscape services (Termorshuizen and Opdam 2009), landscape genetics (Zeller et al. 2012), soundscape ecology (Pijanowski et al. 2011), climate change mitigation (Connors et al. 2013; Mitsch et al. 2013), urban ecosystem services and green infrastructure planning (Ahern 2013; Lovell and Taylor 2013), and, currently a major focus, landscape sustainability and resilience (Cumming 2011; Ahern 2013; Wu 2013b). During the past two decades, the field has increasingly emphasized broadly interdisciplinary and transdisciplinary subjects, such as urban ecology, climate change, and landscape sustainability, which links landscape pattern, biodiversity, ecosystem function, ecosystem services, human wellbeing, and landscape planning and governance. This is not surprising, as landscape sustainability should be the ultimate goal of landscape ecological studies. Overall, the list of the forty most-cited papers in *Landscape Ecology* generally supports our selection of the forty milestones in the field presented above.

Concluding remarks

The Allerton Park workshop has played a pivotal role in advancing landscape ecology by introducing a new paradigm (Wiens 2008; Wu 2013a; Forman 2023; Pearson 2024). This paradigm integrates several ecological and geographical theories and perspectives—such as patch dynamics, disturbance ecology, island biogeography theory, landscape geography, and population and ecosystem ecology—to study the ecology of spatial heterogeneity, which remains a central theme in landscape ecology today. It also underscored the importance of spatial pattern analysis and modeling, particularly through remote sensing, GIS, and potentially AI-driven methods for pattern recognition and classification (Risser et al. 1984). Indeed, remote sensing and GIS are now indispensable tools for landscape ecologists, and AI and big data seem poised to transform landscape ecology and other related sciences in years to come (Hampton et al. 2013; Runting et al. 2020).

We observe that the significance of the Allerton Park workshop is not universally recognized. For example, several recent reviews of landscape ecology history by European authors do not even mention it (e.g., Bastian and Steinhardt 2002; Francis and Antrop 2021; Van Eetvelde and Aagaard Christensen 2023). On the other hand, early European contributions have often been underrepresented in publications by authors outside Europe. From the 40 milestones and most-cited papers presented here on this special occasion, it is evident that landscape ecology originated in Europe as a hybrid between geography and ecology in the 1930s. It developed slowly as a localized research area for about four decades, but with a strong holistic and geographic character.

The field burst into bloom globally in the 1980s and 1990s. During this golden era, geographically differentiated ideas began to coalesce, galvanized by new ecological theories, analytical methods, and digital technologies. As a result, landscape ecology became a globally recognized discipline. However, nothing grows forever. Since the turn of the century, landscape ecology has entered a phase of steady development. Interestingly, but not surprisingly, the transdisciplinarity and holistic thinking that characterized landscape ecology in its early stages have once again become central themes of the field today, with a more urgent and challenging goal—to maintain and design sustainable landscapes in the Anthropocene. This trend seems inevitable because sustainability has become the theme of our time, and because global sustainability cannot be achieved without first sustaining our landscapes.

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