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REVIEW ARTICLE

Eighty-year review of the evolution of landscape ecology: from a spatial planning perspective

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Abstract

Context Sustainable spatial development requires the establishment of a balance between rational land use and the protection of nature, ecosystems and biodiversity on various spatial levels and temporal horizons. The integration of landscape ecology and spatial development planning can help overcome the complex problems of managing landscapes and natural resources and increase the chances of reaching sustainable spatial development.

Objectives The main goal of this research is to provide insight into the development of landscape ecology from the spatial planning perspective.

Methods A chronological systematization and categorization were made of relevant papers, authors and events that are important for an understanding of the discipline's development. An analysis of their content and interrelationships in the integral chronological overview enabled the identification of landscape ecology's developmental periods.

Results Research resulted in the elaboration of an integral chronological overview of the scholarly and professional communities' key activities and achievements, making it possible to monitor the development of theory, key developmental concepts and their corresponding methodological procedures, methods and techniques. The overview enabled the identification of (a) types of "arenas" for professional dialogue, (b) key authors and works, (c) relationships among components within the same, but also between different, categories of components of the chronological overview, and on the basis of all this (d) the establishment of developmental periods. Five developmental periods of the discipline have been established: (1) Landscape Ecology Foundation Period 1939–1979, (2) Landscape Ecology Establishment Period 1980–1987, (3) Landscape Ecology Solidification Period 1988–1991, (4) Period of Retrospection and New Articulation 1992–2005, and (5) Period of Stable Development 2006- present.

Conclusions Research indicated continued development of the theoretical–methodological framework of landscape ecology and its links with spatial planning through the constant reexamination of existing perspectives and the establishment of new ones. The numerous conceptual frameworks selected in the paper unequivocally illustrate a strong conditionality between landscape ecology and spatial planning.

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However, the systematization of written sources revealed that few papers present a review or perspectives with regard to the link with spatial planning, which is why this research has become an important basis for future research in a form of a curriculum for initial research on the relationship between landscape ecology and spatial planning.

Keywords Landscape ecology · Chronological overview · Spatial planning perspective · Landscape planning · Research methodology

Introduction

The second half of the twentieth century was characterized by accelerated and drastic changes in the developmental context on the global and local level, and the appearance of numerous complex, primarily social and ecological problems. This spurred their research, but also the search for socially and ecologically responsible concepts and instruments to manage sustainable planning and development. If sustainable planning aspires to "link knowledge about sustainability with actions to achieve it", landscape planning enables spatial development decisions to be grounded on better understanding the relationship between "different land uses, ecosystems and biotopes at different scales, and over time" (Ahern 2005a).

Starting in the 1970s, protecting the environment, nature, biodiversity and landscapes became the backbone of several different ecological and environmental planning and management models, and the instruments, such as Ecological Planning (McHarg 1969), Landscape Planning (Fabos 1985), Environmental Management Planning (Takeuchi and Lee 1989), Rural Planning (Golley and Bellot 1999), Sustainable Land Planning (Botequilha Leitão and Ahern, 2002), Integrated Planning (Healey 1998; Moulaert et al. 2007) etc. Regardless of the differences in theoretical precepts and methodologies, their common denominator was their alignment with the values and principles of key development documents devoted to conserving and protecting nature, environment and landscapes adopted by relevant international organizations, in particular the United Nations (UN 1972, 1987, 1992, 1996, 2002, 2015; UN Habitat 2016), asnd the European Union (EU 1985, 2001, 2013). According to these documents, planning sustainable spatial development is an arrangement between human-dominated land use and the protection of nature, landscapes, ecosystems and biodiversity, in accordance with the needs and identity of the community on various spatial levels and temporal horizons.

The central research question became how to provide a composite balance between urban, periurban and rural regions and landscapes, and how to coordinate social, cultural and economic development with demands to conserve nature. In this sense, Landscape ecology is recognized as an important linking discipline in researching the relationship between planning and managing spatial development and ecological processes. Owing to the common perspective focused on nature and people shared by landscape ecology and spatial development, the important potential of their integrated actions was recognized and led to changes in traditional approaches to environmental planning. In this sense, spatial planning, land management and conservation are the primary arena of applied landscape ecology.

One of the oldest planning models initiated by the complex problem of managing landscapes and natural resources is Landscape-Ecological Planning (LANDEP) (Ruzicka and Miklos 1979, 1982a, b, 1990). The importance of developing and launching LANDEP is particularly highlighted in *Agenda 21*, where this integral spatial planning approach is acknowledged as being crucial to the management of landscapes and natural resources (UN 1992: chapter 10.7).

LANDEP integrates ecological processes, landscapes and spatial planning and is based on the theory of landscape ecology. It ensues from the understanding that such an integration makes it possible to overcome developmental problems due to the traditional sector approach to spatial planning, and its application can increase the chances of reaching sustainable spatial (and overall) development. The reason for undertaking the research is the insufficient number of papers that provide a synthesized overview of the development of landscape ecology, emphasizing its importance in spatial planning activities. The paper is written from the position of the urbanist, architect and planner, intending to be some sort of curriculum for initial research on the relationship between landscape ecology and spatial planning. A

paper written from the perspective of an ecologist would also substantially complement this study of the landscape ecology evolution and open up a number of new questions, conclusions, and contributions for future research. Research was spurred from the recognition that a large number of review or historically-based papers exist on the development of landscape ecology (Neef 1982; Quinby 1988; Schreiber 1990; Forman 1990; Leser and Rodd 1991; Wu 2007; Antrop 2007; Wiens et al. 2007; Gustafson 2011; Wu 2012, 2017; Risser and Iverson 2013; McIntyre et al. 2013; Forman 2015; Wu 2017), and papers oriented toward the perspective of integrating landscape ecology and spatial planning (Schreiber 1977; Vink 1983; Steinitz 1990; Thorne and Huang 1991; Ahern 1999; Antrop 2001; Breuste et al. 2008; Albert et al. 2014), but only one paper (Hersperger 1994) provides a literature review of its application in spatial planning. Hersperger (1994) summarizes the characteristics and concepts of landscape ecology and the existing approaches of its application for planning establishing a cross-section of the discipline's development up to the time the manuscript was written. In this sense, this paper aims to establish a new overview of the development of landscape ecology from the spatial planning perspective in contemporary times, in which associations and networks of experts formed in the field of landscape ecology and various types of meetings held are chronologically systematized and analyzed in addition to reviewing published sources.

The first year of the research coincides with the work of German geographer Troll (1939) who first articulated the term landscape ecology. Since 2019-year marks landscape ecology's 80th anniversary, now is a timely moment for an overview of its development.

This paper consists of three parts. The first part presents the research methodology. The second part provides a review of selected key components important to defining the chronological overview. The third part establishes their interrelationships and five developmental periods:

- Landscape Ecology Foundation Period 1939–1979,
- Landscape Ecology Establishment Period 1980–1987,
- Landscape Ecology Solidification Period 1988–1991,
- Period of Retrospection and New Articulation 1992–2005, and
- Period of Stable Development 2006-present.

Research methodology

The main goal of this research is to provide insight into the development of landscape ecology from the spatial planning perspective. We aimed to present an integral chronological overview of the key activities and achievements of scholarly and professional communities, making it possible to follow the development of theory, concepts and their corresponding methodologies. Compiling the overview was motivated by the following research questions:

- In which types of "arena for professional dialogue" did communication between the scholarly and professional communities take place and develop? What results were achieved?
- What are the key sources and in which scholarly fields are these sources located?
- What can be used to establish the extent of their impact on the professional community?
- Which authors made the most important contribution to the articulation and development of the discipline?
- Can developmental periods be identified in relation to their prevailing concepts?

A chronological overview was generated based on information from four types of relevant sources, primarily in English, that were published from 1939 to 2019:

- Scholarly articles in highly rated international journals and in journal special issues or thematic chapters,
- Scholarly and professional books,
- Proceedings from professional, scholarly and scientific events, and
- All the issues of the International Association for Landscape Ecology (IALE) Bulletin.

Research was carried out in four interconnected research phases. In the first phase information was collected on: (a) research networks and associations, their activities and organized conferences, and (b) published papers in international journals, scholarly and

professional books, and proceedings. In the second phase a critical analysis was made of selected source content. Their comparative analysis verified information and established the chronological order of when publications came out and events took place (conferences, seminars, meetings, etc.), and the ideas, theories and concepts they dealt with. In the third phase, a final selection was made of the chronological overview's most important components that provided the best insight into the development of the discipline, and interrelations between different types of activities by theoreticians and practitioners of the discipline (publishing, organizing meetings and founding associations) that were important to an understanding of its development from the spatial planning perspective. The basic criteria for selecting relevant written sources were the following types of research: (a) reviews that considered the development of landscape ecology from the historical viewpoint or established a cross-section of previous development with regard to relevant events, and (b) papers that introduce new perspectives or discuss new theoretical or methodological approaches that are complementary to spatial planning issues. Using these criteria, a total of 242 relevant written sources were selected, including all the issues of the IALE Bulletin. Relevant written sources include:

- Papers in reference journals: 71 + 55 papers in special issues,
- Special issues or thematic chapters in reference journals: 10,
- Scholarly and professional books: 45,
- Thematic chapters in scholarly and professional books: 27,
- Conference proceedings: 6,
- Conference papers: 27.

A parallel analysis was made of (a) IALE activities including 26 active IALE regional chapters, (b) the activities of IALE working groups, two of them particularly important from the spatial planning perspective—*Landscape Planning* and *Historical Landscape Ecology*, and (c) 93 different types of events. In the fourth phase developmental periods were identified in relation to prevailing concepts and some regularities were determined in the discipline's development.

Chronological overview components: preliminary research results

Hereinafter the paper will give an overview of components that were important for the development of landscape ecology from the spatial planning perspective. The components are given chronologically according to the following categories:

- Published sources:
  - o Scholarly and professional journals referenced in the international citation base Journal Citation Report and Web of Science,
  - o Scholarly and professional books by referential authors in the field and proceedings from scholarly conferences organized by landscape ecology associations,
- Associations and networks of experts formed in the field of landscape ecology, and
- Various types of meetings held.

The paper will present what its authors consider most relevant. Relevancy was determined by analysis and comparative analysis of the content of a large number of published papers.

Published sources

Scholarly and professional books

The final selection included 42 scholarly and professional books and six proceedings from scholarly and professional conferences organized by landscape ecology associations. The basic criteria for book selection were editions whose thematic framework established new theoretical or methodological insight or presented a review or critical survey of landscape ecology's previous development. In addition to these papers, the overview included 16 agendas, conventions, declarations or strategies of importance to the development of landscape ecology, and were articulated by relevant international organizations.

Scholarly and professional journals

The final selection included 21 globally relevant scholarly journals whose topics cover landscape ecology, and from them 127 articles were singled out for the needs of this paper. The basic criterion for

journal selection was its influence expressed as an SCImago Journal Rank (SJR) indicator. Articles were selected based on two types of contributions (a) review articles, and (b) perspectives. Selected journals were categorized into several scholarly fields, the leading ones being ecology, environmental science and geography. For the needs of this paper, 69, or more than half (54.33%) of the total number of selected articles came from *Landscape Ecology*, 32 articles came from *Landscape and Urban Planning*, while from one to three articles were chosen from other journals (Table 1). This analysis indicates the leading position of *Landscape Ecology* in the development of the theoretical, methodological and conceptual framework of landscape ecology and its application in the field of spatial planning. On the other hand, *Landscape and Urban Planning* with its series of special issues on landscape ecology has contributed to the development of debates on the application of landscape-ecological studies in the spatial planning process.

Within the scope of the total number of selected written sources, authors Forman and Wu have the most, 13. They are followed by authors Wiens with 12 papers, Naveh with 11, Turner and Opdam with 9, Ruzicka with 6 and all others with 5 or less papers.

Professional associations and networks

National and international associations and networks of professionals from various backgrounds have been especially important for the development of landscape ecology in the theoretical and practical sense. They make it possible to establish ongoing dialogue between their members, to discuss and validate values and ideas, and thereby ensure the profession's development. In this sense, it is important to single out the foundation and activities of the first organization of landscape ecologists, the *Netherlands Society for Landscape Ecology,* founded in 1972 that later grew into the *Working Community for Landscape Research* (WLO) as the regional chapter of IALE in Holland. In this paper we monitor most consistently the activities of the globally largest and most influential International Association for Landscape Ecology (IALE) founded in 1982. In its further development IALE founded 26 regional chapters and the following are most active in organizing various types of meetings: (a) US-IALE Regional Chapter, founded in 1986 and expanded its activities to North America-IALE in 2019, (b) IALE-Europe founded in 2009 and (c) IALE United Kingdom founded in 1992. The activities of various thematic working groups within IALE have made a special contribution to scholarly-research work in the field of landscape ecology, and two are of particular importance in linking landscape ecology and spatial planning: (a) *Landscape Planning*—initiated in 2015 with the goal of providing a forum for continued debate toward linking landscape planning science and practice to the benefit of humankind and nature, and (b) *Historical Landscape Ecology*—also initiated in 2015 with the goal of providing a forum to exchange ideas on the historical background of landscape ecology in relation to new challenges, current questions and the further development of theories and methods. Two institutes also hold important positions in contemporary landscape ecology research: (a) *Institute of Landscape Ecology Münster* with its leading research group *Applied Landscape Ecology and Ecological Planning*, and (b) *Institute of Landscape Ecology* with many years of experience within the Slovak Academy of Sciences (SAS).

Events held

A separate category of components used to monitor the development of landscape ecology as a discipline consists of various types of meetings devoted to landscape ecology. We consider them particularly important since they enable a review of various types of research by a large number of professionals coming from a variety of developmental contexts, but also because such meetings are an important basis for establishing networks of people, organizations and institutions. Some of these meetings resulted in proceedings, some joint conclusions as manifestos of the discipline, but there were also public events that enabled the broader public to be included and promoted topics outside of professional circles (exhibitions, competitions, events, etc.). The overview singles out 93 relevant meetings, as follows:

- 20 symposiums, the leading being *International symposia on problems of landscape ecological research* (ISPLER) held in 1967 in Czechoslovakia (in Slovakia as of 1994), organized by the Slovak Academy of Sciences (SAS),

Table 1 List of referenced journals whose thematic framework includes the field of landscape ecology with the number of articles in the final selection of sources

Journal name	First published	Scholarly field (according to SJR)	SJR 2019 (Scimago Journal & Country Rank)	No. of issues per year	No. of relevant articles chosen
Science	1880	Arts and Humanities, History and Philosophy of Science, Multidisciplinary	13.11	48	1
Geographische Zeitschrift (Geographical Journal)	1885	Earth and Planetary Sciences, Earth-Surface Processes, Social Sciences, Geography, Planning and Development	0.23	4	1
Fennia, International Journal of Geography	1889	Agricultural and Biological Sciences, Forestry, Environmental Science, Ecology, Social Sciences, Geography, Planning and Development	0.4	2	1
Angewandte Botanik *(Journal of Applied Botany and Food Quality since 2003)*	1902	Agricultural and Biological Sciences, Food Science, Plant Science	0.34	1	1
Ecology	1920	Agricultural and Biological Sciences, Ecology, Evolution, Behavior and Systematics	2.51	12	1
Universitas: an interdisciplinary journal for the sciences and humanities	1956	Arts and Humanities, Philosophy	–	12	1
BioScience	1951	Agricultural and Biological Sciences	2.54	6	3
Advances in Ecological Research	1962	Agricultural and Biological Sciences, Ecology, Evolution, Behavior and Systematics, Environmental Science	0.13	2	1
Landscape Research	1968	Environmental Science, Management, Monitoring, Policy and Law, Nature and Landscape Conservation, Social Sciences, Geography, Planning and Development	0.59	4	2
Geoforum	1970	Social Sciences, Sociology and Political Science	1.62	6	1
Annual Review of Ecology Evolution and Systematics	1970	Agricultural and Biological Sciences Ecology, Evolution, Behavior and Systematics, Environmental Science	7.88	1	2
Landscape Planning *(Landscape and Urban Planning since 1986)*	1974–1986	Environmental Science, Ecology Management, Monitoring, Policy and Law, Nature and Landscape Conservation	–	4	1
Landscape Journal	1982	Environmental Science, Nature and Landscape Conservation	0.14	2	1
Ekológia (Bratislava)—International Journal for Ecological Problems of the Biosphere *(by 1989 Ekológia (ČSSR), by 1992 Ekológia (ČSFR))*	1982	Environmental Science, Ecology	0.28	4	3
Journal of Planning Literature	1985	Social Sciences, Geography, Planning and Development	1.41	1	1

Table 1 continued

Journal name	First published	Scholarly field (according to SJR)	SJR 2019 (Scimago Journal & Country Rank)	No. of issues per year	No. of relevant articles chosen
Landscape and Urban Planning	1986	Environmental Science, Ecology Management, Monitoring, Policy and Law, Nature and Landscape Conservation	1.74	20	32
Ecological Research	1986	Agricultural and Biological Sciences, Ecology, Evolution, Behavior and Systematics	0.65	6	2
Landscape Ecology	1987	Environmental Science, Ecology, Nature and Landscape Conservation, Social Sciences, Geography, Planning and Development	1.6	12	69
Frontiers in Ecology and the Environment	2003	Agricultural and Biological Sciences. Ecology, Evolution, Behavior and Systematics, Environmental Science	4.16	10	1
Journal of Land Use Science	2006	Earth and Planetary Sciences, Earth-Surface Processes, Environmental Science, Management, Monitoring, Policy and Law, Social Sciences, Geography, Planning and Development	0.83	6	1
Cities and the Environment	2008	–	–	1–2	1

- 22 conferences, including the leading annual thematic conference organized by IALE UK and conferences organized by IALE Europe every 4 years,
- 10 congresses organized by IALE,
- 31 annual meetings with different thematic frameworks organized by US-IALE,
- 4 workshops, the most important being *Allerton Park Workshop* held in 1983 that helped establish landscape ecology's theoretical and methodological apparatus, and two thematic workshops *Landscape Architecture/design* and *Landscape Ecology and Environmental Planning* held within the *1st International Congress in Landscape Ecology* in Veldhoven,
- 3 seminars, the most important being: *Methodology in landscape ecological research and planning* in Roskilde held in 1984 and *Connectivity in landscape ecology* in Münster held in 1987, and
- 3 gatherings in the form of training courses or forums.

A synthesized table with a chronological overview of the components from all four of the categories used to generate conclusions on the phases in the discipline's development is given as a supplementary file published online along with an article, while the references and publications listed within the manuscript are only exemplary for these development periods.

Chronological reading of landscape ecology development from the spatial planning perspective

Based on their final selection, overview components were chronologically systematized and categorized. Monitoring the changes resulted in five developmental periods:

- Landscape Ecology Foundation Period 1939–1979: Articulation of the discipline and establishing relations with spatial planning,

- Landscape Ecology Establishment Period 1980–1987: Synthesis and strengthening within the scholarly and professional community,
- Landscape Ecology Solidification Period 1988–1991: Expanding territorial reach and empowering discourse by introducing new topics and research findings,
- Period of Retrospection and New Articulation 1992–2005: Reexamining concepts, opening new perspectives and bridging the gap between science and practice, and
- Period of Stable Development 2006-present: Symbiosis of ecological and social mechanisms for sustainable landscape planning and development.

Landscape ecology foundation period 1939–1979: articulation of the discipline and establishing relations with spatial planning

The period from 1939–1979 can be considered the articulation of the discipline in which its conceptual apparatus was established, and the theoretical and methodological framework was set for landscape research, protection and planning. An association of landscape ecologists was formed, various communication and dialogue modalities were established within the discipline, and the basic methodological models and techniques of landscape research were established.

Carl Troll is at the origin of landscape ecology as a scholarly discipline. His book *Luftbildforschung und Landeskundige Forschung: Erdkundliches Wissen* (Troll 1939) inaugurated the discipline by introducing the concept of *landscape ecology*, a discipline that connects geography to an ecological perspective of space and thereby enables spatial models to be interpreted from the viewpoint of and in accordance with ecological concepts. At the very beginning, landscape ecology developed as a socially oriented discipline dealing with issues concerning the role of humans in the landscape, and the spatial levels of landscape relevant for the perception and practical application of established concepts (Naveh and Lieberman 1994). In addition to Troll, another German geographer, Ernest Neef, is widely recognized for his fundamental contributions to the theory of landscape ecology during the foundation period. It is particularly important to single out his widely influential book *Die theoretischen Grundlagen der Landschaftslehre*. The starting point of Neef's (1967) approach is based on the theory of geographical scale ranges explained as the arrangement of nature areas, and the theory of the smallest landscape ecological spatial units, the physiotope and the ecotope.

The first examples of integrating landscape ecology into spatial development planning took place in Czechoslovakia, where landscape ecology studies were the basis for planning optimal land use on the regional level. As of 1967, landscape research and the development of landscape ecology planning methodology took place in the *Institute of Landscape Ecology* of the Slovak Academy of Sciences in Bratislava. M. Ruzicka was in charge of research and was the key author contributing to the articulation of the discipline in relation to spatial planning. He was the first to articulate Landscape-ecological Planning (LANDEP) as a complex system of activities and research methods from various disciplines (ecology, biology, geography, spatial planning, etc.) that enabled landscape evaluation, and optimized landscape protection and development planning (Ruzicka and Miklos 1979, 1982a, b). During this period, also in Slovakia, there were five *International symposia on problems of landscape ecological research* (ISPLER) that were very important for discussing and validating the theoretical, conceptual and practical aspects of landscape ecology as a discipline, but also for disseminating knowledge to the professional as well as political and broader community in the context of socialist goverment.

A significant tipping point in the introduction of an ecologically sound approach to the planning and design of communities was established in the now widely known book *Design With Nature* (McHarg 1969). McHarg pioneered the concept of ecological planning which is based on three key directions: (1) a multidisciplinary approach to provide holistic design strategies, (2) a problem-based approach in line with a wide range of scales, and (3) a quantitative approach to measuring landscape performativity.

During this period, in 1972, the first organization of landscape ecologists was founded, the *Netherlands Society for Landscape Ecology*, which can be connected to the ISPLER symposiums that helped establish relations and a network of people and institutions involved in a similar topic. The main goal of this first community of landscape ecologists in the world was

"to acquire knowledge about the structure and function of landscapes, and to develop methods to implement landscape ecology in urban and regional planning, conserving nature and managing the human environment" (Jongman 1983: p. 5).

During this period connections were also established between spatial development planning and landscape ecology. A key contributions were made by (1) Van der Poel (1976) who pointed out the importance of linking (a) nature research and the principles of conserving landsacpes, and (b) spatial planning activities, but also on the need for landscape planning, and (2) Zonneveld (1979) who developed the conceptual framework of land classification as the basis for land evaluation, which in turn is the basis for land use planning and management.

Landscape ecology establishment period 1980–1987: synthesis and strengthening within the scholarly and professional community

The period from 1980 to 1987 can be considered a synthesis phase in which landscape ecology placed itself firmly in the scholarly community, strengthened the ecological prespective in researching landscape variability and developed the planning perspective of landscape ecology. Numerous topics opened up including the most important relationship between function and spatial patterns, the temporal perspective of landscape planning, and the hierarchy and scale of studies.

This period is characterized by the intensification of all types of professional activities. At the beginning of this period, in 1982, the International Association of Landscape Ecology (IALE) was founded in the city of Piešťany in Czechoslovakia and the host of the founding symposium was M. Ruzicka. At the founding symposium, Zonneveld (1982), the First President of IALE, noted that landscape ecology should further develop toward a holistic approach. Zonneveld was the most important catalyst, both in strengthening landscape ecology in the scholarly and professional community, and in enhancing the integration of North American landscape-ecological approaches with previously established land-use planning approaches.

The first important interaction between European and North American landscape ecology theoreticians took place in 1981, when five American ecologists participated in the First International Congress on Landscape Ecology organized by the Dutch Community of Landscape Ecologists (WLO) in the city of Veldhoven. The conference had a series of important lectures, research posters were exhibited and workshops were held (Tjallingii and de Veer 1982).

That same year, the widely-read article *Patches and structural components for a landscape ecology* was published in *BioScience* journal. Forman and Godron (1981) established a fundamental hypothesis in understanding "landscapes as ecological units with structure and function which are composed primarily of patches in a matrix". The structural characteristics of the corridor and landscape connectivity are positioned as initial concepts for understanding ecological structure and function (Forman 1983a, b) and as a fundamental ecological characteristic of landscape pattern (Merriam 1984). In the future development of landscape-ecological studies, as well as in the contemporary state of landscape ecology science, the *patch-corridor-matrix* has been established as the most widely used paradigm (Forman 1995b).

In 1983, the research network was further strengthened when IALE launched a bulletin. The main goal of this bulletin was to inform the scholarly community and the public about the association's work and research by publishing (1) reports from conferences, various meetings, workshops, etc., (2) information about current research, and (3) reviews. The introduction to the first issue of the IALE Bulletin stressed the link between landscape ecology and planning, and an openness for cooperation between landscape ecologists, planners, designers and landscape architects.

That same year, 25 ecologists took part in the Allerton Park Workshop held in Allerton, Illinois, USA, in order to discuss the nature and future of landscape ecology. The report on this workshop entitled "Landscape Ecology: directions and approaches" by Risser et al. (1984) made a significant contribution to the development of landscape ecology as an autonomous scholarly discipline, since it enabled the European and American research perspectives to overlap. In the report, landscape ecology is defined as a discipline involved in the "development and dynamics of spatial heterogeneity, interactions and exchanges across heterogeneous landscapes, the influences of spatial heterogeneity on biotic and abiotic processes, and management of spatial heterogeneity" (Risser et al. 1984: p. 7). The reference points of this discipline definition can be recognized in the modern

theory of landscape ecology. The participants in the Allerton Park Workshop singled out several important conceptual directions for development and research: (1) landscape in the anthropocentric perspective, (2) spatial heterogeneity, (3) flows or redistribution among internal ecological units and landscape components, and (4) human actions as deliberate processes in landscapes. The main questions were directed toward the heterogeneity of landscapes and improving landscape ecology through the management of natural resources. The workshop's particular contribution included methods to measure heterogeneity and approaches to data collection (Risser et al. 1984).

In October 1984, IALE initiated another modality of professional communication and dialogue—the first in a series of seminars was organized entitled "Methodology in landscape ecology research and planning". The same year Naveh and Lieberman published the book "Landscape Ecology: Theory and Application" in which they established "a new paradigm toward human ecosystematology and landscape ecology" (1984: p. 73). The authors had a dual view of landscape ecology—as a basic science and as the philosophy of planning land use; in their opinion, landscape ecology concerns not only the aesthetic characteristics of landscapes but is also a means to protect nature and its integral planning.

The turning point of landscape ecology establishment took place at the Symposium on Landscape Ecology organized by the IALE held during the 4th Congress of Ecology, at Syracuse, New York in August 1986. The agenda of this meeting consisted of seven keynote lectures by leading authors who rounded up a number of central conceptual frameworks in landscape ecology:

- I.S. Zonneveld, Chairman of the symposium: Introduction,
- R.T.T. Forman (USA): Shapes and flows in a landscape,
- P.G. Risser (USA): Landscape pattern and the distribution of materials, nutrients, and energy,
- M.G. Merriam (Canada): The study of ecological processes in farmland mosaics,
- P.F.M. Opdam and W.B. Harms (NL): Biogeographical impacts of changing the ecological infrastructure of the Dutch landscape,
- W. Haber (FRG): Using landscape ecology in planning and management, and
- M. Ruzicka (CSSR): Basic premises in landscape ecological planning.

Three basic characteristics of the landscape were focused in the further methodological and theoretical development of landscape ecology primarily through the influence of Forman and Godron (1986) and their book *Landscape Ecology*: (1) Structure: Study of spatial relations between landscape elements, (2) Function: Study of interactions between landscape properties, and (3) Changes: Study of changes in the structure and function of ecological mosaics over time. This book was the first to set out an array of basic concepts and principles of landscape ecology persisting to today, including the central ecological mosaic framework. The introduction of the land mosaic concept by Opdam and colleagues has also made a significant contribution in the early 1980s through pioneering large-scale, long-term and multidimensional analysis of the Dutch agricultural landscapes.

In 1987, the position of landscape ecology in the scholarly community was boosted by the launching of the journal *Landscape Ecology* by IALE. In the first editorial, founder and first editor-in-chief Frank B. Golley noted the rise in the number of ecological investigations and stressed the interdisciplinary and transdisciplinary nature of landscape ecology (Golley 1987). He confirmed the views of his predecessors that landscape ecology is founded on the research and description of relationhips between nature and spatial patterns (Forman and Godron 1986) on different spatial levels (Troll 1939), and that decision making in planning must be committed to protecting landscapes and the environment (Ruzicka and Miklos 1982a, b).

Landscape ecology solidification period 1988–1991: expanding territorial reach and empowering discourse by introducing new topics and research findings

The previous period of establishing landscape ecology and strengthening it in the scholarly and professional community had a strong impact globally. A holistic approach to landscape planning and management was broadly applied first in Czechoslovakia (Ruzicka and Miklos 1982a, b), in present-day Slovenia, and in Germany (Haber 1990), Denmark (Brandt and Agger 1984) and the Netherlands (Van der Maarel 1982). Landscape ecology studies later spread to other

countries, drawing on the initial research in Europe and integrating their orientation into ecological studies (Risser et al. 1984; Forman and Godron 1986; Turner 1989; Forman 1995a). In North America the specifically expressed view noted a strong connection with traditional ecology. The focus was on studying the impact of spatial patterns on ecological processes while, unlike the European perspective, humans were often disregarded or considered a social-economic factor of the landscape (Wu 2012).

In the transition from the period of development to solidification of the discipline, the opening of an Australian perspective holds a special place. The development of an Australian landscape ecology approach was led by Saunders and Hobbs (Saunders et al. 1987; Saunders and Hobbs 1991) both of whom were later honored by IALE as Distinguished Landscape Ecologists. This perspective is specific to the practical foundation of seeking to address land management policy issues.

Below we will single out authors, topics and research findings we consider central for the development of landscape ecology that also illustrate this phase of the descipline's solidification:

- Toth (1988) proposes a new soft paradigm to analyze landscapes and territories focused on analyzing function and then the spatial dimension and structure (Toth 1988: p. 193). He singles out the following topics for future research: (a) the degree of mutual adaptation between users and their surroundings, and (b) how to create sites, orientation and hierarchy in relation to site users.
- The Delcourts insist on the temporal dimension of studying landscapes (Delcourt and Delcourt 1988). They were the first to define time as the quaternary dimension of landscape and described temporal–spatial scale as an organizational paradigm in landscape ecology (1988: p. 25).
- Turner (1989) analyzes the relationship between landscape patterns and their effect on ecological processes. She defines landscape "as a spatially heterogenous area" and singles out the development and dynamics of spatial heterogeneity in natural areas, interaction and exchange through heterogenous landscapes, the impact of spatial heterogeneity on biotic and abiotic processes, and managing spatially heterogenous landscapes as key topics for future research (Turner 1989: p. 173).
- Research on the relationship between landscape components—spatial patterns and ecological processes—was continued by Wiens and Milne (1989). They consider that landscape ecology will only develop a powerful conceptual and theoretical basis if a uiniversal scale is found that is suitable for all disciplines participating in its articulation. For these reasons they advocate "researching microlandscapes that have the potential to serve as a model of larger-scale landscape systems".
- Zonneveld (1989) also advocates researching landscapes through a series of smaller samples and singles out land unit as part of a broader landscape system, in accordance with the assumption that a landscape "can be considered as a system and is composed of hierarchical wholes" (Zonneveld 1989: p. 68). He feels this approach is: (1) a central concept in landscape ecology, (2) a mapping tool, and (3) a means to convey knowledge about landscapes through evaluation.

The book *Changing Landscapes: An Ecological Perspective* (Zonneveld and Forman 1990) opened up a new understanding of landscape ecology in relation to current theories such as sustainable development and landscape ecology management. The authors of individual chapters began the reexamation of previously established concepts and opened up new topics, which would be an introduction to the discipline's next period of development:

- Zonneveld (1990) singles out three perspectives when studying landscapes: the visual aspect, chronological aspect and landscape as an ecosystem.
- Forman (1990) notes the importance of the concept of sustainable development and establishing a relationship between society and the activities of the community, and the ecological integrity of a landscape. He describes landscape as "a mosaic of local ecosystems that contain humans and their activitites (Forman 1990: p. 261) and singles out scale, spatial patterns and patch dynamics as three key components of spatial ecological theory.
- Ruzicka and Miklos (1990), continued to be involved in landscape planning, protection and development based on the ecological nature of landscapes.

- Haber (1990) introduces the concept of protecting the ecological values of landscapes and their strategic management. He feels that planning and management can lead to: (1) the identification, reduction and/or mitigation of impacts on the environment and landscapes, (2) maintaining and improving ecotopes and ecological diversity, and (3) the protection of rare and sensitives groups of ecosystems.

One of the more important publications in this period is *Quantitative methods in landscape ecology: the analysis and interpretation of landscape heterogeneity* whose editors Turner and Gardner (1991) opened discussion on innovative quantitative research methods and their practical application. Also in this period was a special issue of the journal *Landscape and Urban Planning* with the topic *Landscape Ecology* from September 1991 in which landscape ecology is linked to current planning and design concepts. We would particularly single out Golley and Bellot (1991) who consider that the plan, as a landscape ecological hypothesis, is a field experiment from which landscape ecologists and planners can acquire new knowledge, and Hall (1991) who stresses the importance of the planning perspective and proposes functionalism as a concept that makes it possible to link planning, landscape and social ecologies.

Period of retrospection and new articulation 1992–2005: reexamining concepts, opening new perspectives and bridging the gap between science and practice

The period from 1992 to 2005 can be conditionally considered a phase in which the already numerous developmental concepts and approaches were reexamined, discussed, compared and evaluated along with the scope of the methodological patterns, and the adequacy of applied models and techniques. This period was opened with the Earth Summit (UN Conference on Environment and Development) in Rio de Janeiro in 1992, that resulted in *Agenda 21*, which noted the importance of the LANDEP model. Especially important for the "new articulation" of landscape ecology and understanding this period was adoption of the *European Landscape Convention* by the Council of Europe in 2000 in Florence that focused on the importance of landscape protection, management and planning, and triggered international discussion on landscapes (Council of Europe 2000). The same year an international ecological network of protected areas was formed in Europe, Natura 2000, founded with the mission of conserving biodiversity and ecosystems and the strategic planning of green infrastructures and natural areas (EU 2013). *The Johannesburg Declaration on Sustainable Development* (UN Nations 2002) also stressed the importance of protecting natural resources and their implication for economic and social development.

A series of thematic books came out in this period that can be divided into five categories. Following are those we consider important books that:

- Present the development of integrative tools and methods, the development of education and training, searching for ways to apply concepts and open up new perspectives: *Land Ecology: An Introduction to Landscape Ecology as a Base for Land Evaluation, Land Management and Conservation* (Zonneveld 1995), *Land mosaics: the ecology of landscapes and regions* (Forman 1995b) which updates previous observations in the field of landscape ecology (Forman and Godron 1986; Forman 1990), *Landscape Ecological Analysis: Issues and Applications* (Klopatek and Gardner 1999), *Landscape ecology in theory and practice: pattern and process* (Turner et al. 2001), *Learning Landscape Ecology: A Practical Guide to Concepts and Techniques* (Gergel and Turner 2002),
- Link European and North American perspectives in formal literature since the mid-1980s (Naveh and Lieberman 1984; Forman and Godron 1986): *Principles and methods in landscape ecology* (Farina 1998), *Landscape Ecology in Action* (Farina 2000), *Landscape Ecology: concepts, methods, and applications* (Burel and Baudry 1999, 2003), *Landscape Ecology: A Widening Foundation* (Ingegnoli 2002),
- Present a cross-section of the discipline's state or review it through discussions on theories and concepts and sum up the previous approaches: *Issues in landscape ecology* (Wiens and Moss 1999) and the expanded book *Issues and perspectives in landscape ecology* (Wiens and Moss 2005). In the context of the planning perspective, the sixth chapter should be singled out and the work of Ahern (2005b) who researched the relationship

between landscape ecology and landscape architecture and concluded that the integration of these two fields was a three-stage evolutive process: (1) articulation of the basic theory and principles as a framework for research and practical applications, (2) opening dialogue on spatial levels, processes and interactions between humans and landscapes, and (3) reciprocal integration—landscape ecology's theoretical framework informs design, and design principles and process inform and expand landscape ecology's theoretical framework. There are also important contributions on the topics of conservation planning at the landscape scale (Margules 2005) and landscape ecology in land-use planning (Jongman 2005).

- Develop the transdisciplinary nature of landscape ecology: *Placing Nature: Culture and landscape ecology* (Nassauer 1997), and
- Provide the planning perspective: *Landscape Ecology Principles in Landscape Architecture and Land-Use Planning* (Dramstad et al. 1996).

In August 2000, a new special issue of the journal *Landscape and Urban Planning* with the topic of *Holistic landscape ecology in action* problematized the holistic approach in landscape ecology and gave it predecedance over traditional approaches (Palang et al. 2000a; Naveh 2000; Li 2000). A series of original scholarly articles deliberate the importance of the holistic approach in studying landscapes and the results are given of the workshop on holistic landscape ecology held at the 5th IALE World Congress in Colorado in 1998. Particularly important are the papers on the application of the holistic perspective in planning, using and managing regional development (Bastian 2000; Palang et al. 2000b; Makhzoumi 2000).

The goal of the US-IALE Annual Meeting held in 2001 with the topic *Pattern, Process, Scale, & Hierarchy: Interactions in Human-Dominated and Natural Landscapes* was to identify key questions and define the goals of future research in the twenty-first century. Wu and Hobbs (2002) give an overview of the most important conclusions from this event and single out six key questions: (1) interdisciplinarity or transdisciplinarity, (2) the integration of basic research and applications, (3) conceptual and theoretical development, (4) education and training, (5) international scholarly communication and cooperation, and (6) informing and communicating with the public and decision makers.

Bearing in mind the planning perspective used for analysis in this paper, we additionally feel that the following research is relevant for this period:

- Botequilha Leitão and Ahern (2002) make the following recommendations for landscape planning: (1) define the focus of activities, (2) analyze in a participatory process, (3) base the diagnosis on the most important recognized characteristics, (4) create a prognosis based on alternative plans and evaluations through a second phase of participatory process, and (5) articulate a synthesis based on an implementation plan and correct it continuously when monitoring implementation.
- In order to link spatial pattern studies and ecological processes in spatial planning, Opdam et al. (2002) propose the use of: (1) empirical case studies, (2) value modelling studies, (3) studies modelling guidelines and standards, and (4) multidisciplinary design and evaluation tools (Opdam et al. 2002: p. 767).

The transition from retrospective period to stable development is characterized by a series of experimentally based research and development of such approaches in landscape studies. The pioneers of new approaches to studying urban ecosystems are Felson and Pickett (2005) who point out "designed experiments" as a mechanism for taking advantage of the area of overlap between ecologists and urban designers. This approach has opened new directions for the conception, testing and implementation of new, experimentally based methodologies and conceptual frameworks of landscape ecology in relation to spatial planning and design.

Period of stable development 2006-present: symbiosis of ecological and social mechanisms for sustainable landscape planning and development

From 2006 to present, a new understanding of and approach to landscape ecology planning has been in operation. In this period debates were initiated regarding landscape ecology and the science of sustainability along with recognizing that the application of landscape-ecological concepts and methods has the potential to help the sustainable planning,

management and conservation of landscapes. The most important characteristic of the period is the unmistakable orientation toward sustainable landscape development along with searching for methodological forms, methods and techniques to realize it, through a series of investigations that stress the link with sustainability (Haines-Young 2000; Wu 2006, 2008, 2010, 2013b; Naveh 2007a; Musacchio 2009c; Antrop et al. 2013; Opdam et al. 2018). Preliminary research in this period is found in a new special issue of *Landscape and Urban Planning* with the topic *Landscapes and sustainability* from March 2006 (Potschin and Haines-Young 2006; Antrop 2006).

A series of thematic books came out in this period that can be divided into five categories. Following are those we consider important books that:

- Develop methodological instructions and applications in landscape ecology: *Scaling and Uncertainty Analysis in Ecology Methods and Applications* (Wu et al. 2006), *Learning Landscape Ecology A Practical Guide to Concepts and Techniques* (Gergel and Turner 2017), and *Essentials of Landscape Ecology* (With 2019);
- Present a cross-section of the discipline's state or review it through discussions on theories and concepts, the development of integrative tools and methods, the development of education and training, searching for ways to apply concepts and open up new perspectives: *From Landscape Research to Landscape Planning: Aspects of Integration, Education and Application* (Tress et al. 2006) and *Key topics in landscape ecology* (Wu and Hobbs 2007);
- Develop the transdisciplinary nature of landscape ecology: *Transdisciplinary Challenges in Landscape Ecology and Restoration Ecology—An Anthology* (Naveh 2007b), *Landscape Ecology for Sustainable Environment and Culture* (Fu and Jones 2013);
- Provide a historical perspective: *Foundation Papers in Landscape Ecology* (Wiens et al. 2007) and *History of Landscape Ecology in the United States* (Barrett et al. 2015); and
- Provide a planning perspective: *Landscape-ecological Planning LANDEP* (Špinerová and Miklós 2019).

In addition to the mentioned books, it is especially important to highlight Forman's (2008) book *Urban Regions: Ecology and Planning Beyond the City,* which expands the existing knowledge framework of urban regions by highlighting (1) major spatial arrangements with nature, environmental challenges and socio-cultural connections, and (2) planning approaches, trends, paradigms and key themes on the urban regional scale. This book also opens scholarly discussion on linking the urban ecology, physical and socioeconomic components of metropolitan areas toward the symbiosis of ecological and social mechanisms for sustainable landscape planning and development. In this sense, it is particularly important to single out the following studies:

- Pickett and Cadenasso (2008) open a discussion about linking the ecological and built components of urban mosaics in order to create an open cycle of ecological design;
- Wu (2008) propose three broad urban ecological approaches: ecology in cities, the ecology of cities as socioeconomic structures, and the ecology of cities as ecosystems, referring to the intensive growth trends of cities and urban areas based on the degree of focus on biological ecology, along with conceptual and methodological frameworks,
- Niemelä et al. (2011) explore ecological patterns and processes in the urban environment as well as the question of integrating ecology with social issues, opening a discussion of the application of urban ecology in land use planning;

The 7th IALE World Conference held in Wageningen in 2007 focused on the relationship between landscape ecology and sustainability. Along the lines of these Congress conclusions, a special issue of *Landscape Ecology* came out in October 2009 dedicated to the ecology and culture of landscape sustainability. Editor Musacchio (2009a) notes that its goal was to point out the need for a holistic integration of research and practice in the field of landscape ecology. Article authors introduce new conceptual terms of reference in the field of studying landscape sustainability: the six Es of landscape sustainability (Musacchio 2009b), landscape services as a link between landscape ecology and sustainable development (Termorshuizen and Opdam 2009) and landscape ecology as the basis of sustainable conservation (Wiens 2009).

Research that is also relevant for this period was carried out by Nassauer and Opdam (2008) who propose to include design, as a field that links scientific

research and practical applications, in the study of landscape patterns and processes. In this contect, design is defined as the intentional change of landscape patterns for the sake of the sustainable development of ecosystems and satisfaction of social needs (Nassauer and Opdam 2008). In the same spirit, Steiner (2011) indicates the possibility of a systhesis between science and ecological design, while Nassauer (2012), observing global trends in urbanization and the development of cities, proposes the introduction of a landscape-ecological urbanism synthesis.

A special issue of *Landscape Ecology* came out in October 2010 entitled *Landscape ecology as an integrated science for sustainability in a changing world* and was inspired by the symposium *Landscape ecology: An integrated science for sustainability in a changing world* held in 2009 as part of the 10th International Congress of Ecology (INTECOL) organized by the International Associaaton for Ecology in Brisbane, Australia. The editors of this issue, Pearson and McAlpine (2010), selected papers from four continents that included a variety of conceptual, theoretical and methodological frameworks dealing with the sustainable development of landscapes.

In line with the interest in urban sustainability in the context of landscape ecology, Ahern's (2010, 2013) research on urban sustainability and resilience toward integrating ecology with urban planning and design also holds a special place. The author proposes five strategies for enhancing interdisciplinary discourse on urban sustainability and resilience including (Ahern 2012): (1) biodiversity, (2) building urban ecological networks and managing connectivity, (3) planning and design for multifunctionality, (4) building redundancy and practicing modularization, and (5) practicing adaptive design to implement "safe-to-fail" design experiments.

Tying in with the previous special issues of *Landscape Ecology* that dealt with the concept of sustainability (Musacchio 2009b; Pearson and McAlpine 2010), a new special issue entitled *Key Concepts and Research Priorities for Landscape Sustainability* presented different theoretical, empirical approaches to landscape sustainability (Musacchio 2013). Particularly important are the papers on the expanding the landscape-ecological paradigm to design science (Jones et al. 2013; Swaffield 2013; Ahern 2013; Standish et al. 2013).

We would note in particular the importance and contribution of Wu (2013b: p. 999) whose paper explains the key definitions and concept of sustainability on the one hand, and landscape sustainability on the other, and proposes a framework to develop the science of landscape sustainability whose subject of research is "the capacity of a landscape to consistently provide long-term, landscape-specific ecosystem services essential for maintaining and improving human well-being".

Inspired by the results of the *5th Forum of Landscape Sustainability Science* held in August 2017 in Peking, organized by the Center for Human-Environment System Sustainability (CHESS), Beijing Normal University (BNU), Beijing, China Committee of Sustainable Resource Utilization and Disaster Reduction (CSRUDR) and the China Society of Natural Resources, Opdam et al. single out the key challenges and topics relevant for landscape sustainability that define "an interface between landscape ecology and sustainability science" (2018: p. 6). This article is also some sort of cross-section of the situation for future research and the development of theoretical, methodological and conceptual answers to achieve landscape sustainability: (1) integrating ecological and social mechanisms, (2) connecting landscape ecology to governance science, (3) linking scale levels in decision making, (4) incorporating design in landscape ecology to create solutions, and (5) bridging the gap between science and practice (Opdam et al. 2018). They point out the need to strengthen cooperation and the exchange of theories, methods and concepts between the field of landscape ecology on the one hand, and the the fields of spatial planning and urban design on the other, in order to achieve practical solutions based on landscape sustainability.

Concluding remarks

Research questions have been raised on several levels through: (1) studying the *context*, (2) recognizing basic *concepts*, and (3) defining *content* for future activities. The basic goal guiding this research was to present the development of the theory of landscape ecology from the planning perspective systematically and chronologically, pointing out the importance of synchronized research in these two fields and their symbiosis in theory as well as practice. Research

resulted in a chronological overview of the development of landscape ecology from the planning perspective through the selection of relevant written sources, the identification of important professional associations and networks, and various types of meetings that were held. A comprehensive timeline of presented components with respect to the discipline's noted developmental periods is given as supplementary material to this paper.

Monitoring changes led to pinpointing five periods of the discipline's development from the planning perspective. Those periods and most relevant references within them are presented on Table 2.

Our research has shown continued development of the theoretical–methodological framework of landscape ecology and its link to spatial planning through the constant reexamination of existing perspectives and establishing new ones. The numerous conceptual frameworks selected in the paper unequivocally illustrate the strong interconnection between landscape ecology and spatial planning. However, based on the systematization of written sources, it was noted that a small number of papers provide a review or perspectives regarding links to planning, thus the present research has become an important basis for future research. In this sense, future research can develop through a more detailed discussion of individual components analyzed in this paper through individual discussion of the documented periods.

Thus a theoretical–methodological framework has been established to integrate landscape ecology, as an important criterion, in the process of spatial planning, thereby highlighting spatial planning as a key arena for the application of landscape ecology. The importance of further strengthening this link has been recognized in some of the basic goals and theories of current global documents and reports. Within the scope of *Agenda 2030* for sustainable development, 17 goals of sustainable development were formulated, including to "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" (United Nations 2015). The *New Urban Agenda* states the aspiration to develop cities that "protect, conserve, restore and promote their ecosystems, water, natural habitats and biodiversity, minimize their environmental impact, and change to sustainable consumption and production patterns" (United Nations 2017). According to the *World Cities Report 2016: Urbanization and Development—Emerging Futures* (UN Habitat 2016) the demand for natural resources in cities is expected to rise 40–50% by 2033, and the situation today in spatial and land use planning is considered critical for the conservation of natural goods and their rational management, but equally critical for the development of new theoretical–methodological spatial planning models.

A step forward in advancing future research is certainly the equal development of process- and problem-oriented dialogue between landscape ecologists and planners, so that landscape ecologists develop theories and methodologies that are applicable in spatial planning, while spatial planners use the research results of landscape ecologists as a foundation in the spatial planning process. In accordance with this, a key field of future research, which will necessarily establish a relation between spatial planning and landscape ecology, is climatically responsible development, i.e. the concept of disaster risk management and the spatial resilience that stems from it. In order to confront this currently most important development challenge, we need adaptive planning and design as arenas for the development of transdisciplinary action between planners, designers, stakeholders and decision makers in order to generate innovative practices and methods (Ahern 2013). A second perspective for future research is based on "necessity and feasibility of linking landscape/land system approaches through geodesign" (Wu 2019). A third perspective should focus on the development and implementation of different kinds of designed experiments and pilot projects for testing physical model options and development scenarios for environmental transformation. In order to encourage scholarly-research work examining the relationship between landscape ecology and spatial planning, there is a need to: (1) develop new research groups within existing professional networks, (2) develop educational programs within events or educational institutions, and (3) maintain continuity in publishing papers on this topic in leading reference journals.

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Table 2 Timeline with an overview of Landscape Ecology development periods and key references

Period	Foundation period	Establishment period	Solidification period	Retrospection and new articulation period	Stable development period
	Articulation of the discipline and establishing relations with spatial planning	Synthesis and strengthening within the scholarly and professional community	Expanding territorial reach and empowering discourse by introducing new topics and research findings	Reexamining concepts, opening new perspectives and bridging the gap between science and practice	Symbiosis of ecological and social mechanisms for sustainable landscape planning and development
Year	1939–1979	1980–1987	1988–1991	1992–2005	2006–
Key authors	Troll (1939, 1950, 1971) Neef (1967) McHarg (1969) Van der Poel (1976) Zonneveld (1979) Schreiber (1977) Ruzicka and Miklos (1979, 1982a, b)	Forman and Godron (1981, 1986) Van der Maarel (1982) Forman (1983a, b) Vink (1983) Naveh and Lieberman (1984) Risser et al. (1984) Merriam (1984) Brandt and Agger (1984) Fabos (1985) Golley (1987) Saunders et al. (1987)	Toth (1988) Delcourt and Delcourt (1988) Quinby (1988) Turner (1989) Wiens and Milne (1989) Zonneveld (1989) Zonneveld and Forman (1990) Haber (1990) Steinitz (1990) Saunders and Hobbs (1991) Turner and Gardner (1991) Golley and Bellot (1991) Thorne and Huang (1991) Hall (1991) Leser and Rodd (1991)	Farina (1998) Naveh and Lieberman (1994) Forman (1995a, b) Zonneveld (1995) Dramstad et al. (1996) Nassauer (1997) Ahern (1999, 2005a, b) Burel and Baudry (1999, 2003) Wiens and Moss (1999, 2005) Klopatek and Gardner (1999) Golley and Bellot (1999) Naveh (2000) Turner et al. (2001) Antrop (2001) Wu and Hobbs (2002) Botequilha Leitão and Ahern (2002) Ingegnoli (2002) Opdam et al. (2002) Felson and Pickett (2005)	Wu (2006, 2008, 2010, 2013a, b, 2019) Tress et al. (2006) Antrop (2006) Potschin and Haines-Young (2006) Wu and Hobbs (2007) Naveh (2007a, b) Forman (2008) Pickett and Cadenasso (2008) Nassauer and Opdam (2008) Breuste et al. (2008) Musacchio (2009a, 2013) Wiens (2009) Termorshuizen and Opdam (2009) Ahern (2010, 2012) Pearson and McAlpine (2010) Niemelä et al. (2011) Steiner (2011) Nassauer (2012) Fu and Jones (2013) Risser and Iverson (2013) Albert et al. (2014) Opdam et al. (2018) Špinerová and Miklós (2019)

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