LANDSCAPE ECOLOGY IN MEXICO:

EVOLUTION, RESEARCH, EDUCATION AND FUTURE (SELECTED THEORETICAL AND META-SCIENTIFIC ASPECTS)

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ABSTRACT

*Context:*The impulse to write this contribution was the effort of co-authors to bring the European landscape ecologist closer to the development, research & didactic approaches and possible future development of landscape ecology in Mexico from the theoretical, metascientific and applied point of view.

Purpose: The purpose of the metascientific approach, in this case meta-landscape ecological approach, is to increase the degree of generalization of existing empirical-methodological, theoretical-application and didactic knowledge and results of landscape-ecological research, so that generally valid landscapeecological regularities and principles can be determined The aim was to acquire new generalizing and holistic qualities and perspectives in the field of landscape ecology in Mexico at this level.

Methods: The two-step methodical procedure was elaborated, using metascientifically oriented landscape ecological and ecological Mexican literature, complemented by our studies and personal experience.

Results: In this way, new knowledge, representing the added value and meaning of landscape ecologicalevolution, research, education and future development in Mexico was gained. It will serve also to Mexican landscap ecologists.

Conclusiones: Mexican landscape ecology, lying at the intersection of European and American landscape ecology, can be described as integrative, idiographic-nomothetic at the spatial level of the landscape in the contact zone of European and American research approaches and principles.

Keywords: landscape ecology, evolution, research, education, metascientific approach, future development, Mexico

INTRODUCTION

The impulse to write this contribution was the effort of co-authors to bring the European landscape ecological public closer to the development, research- and didactic approaches and future development of landscape ecology in Mexico from the theoretical and meta-scientific point of view. The meta-scientifically-oriented original landscape ecological and ecological

Mexican studies with long-time empirical, application and theoretical-meta-scientific knowledge and experience of the co-authors of this paper, allowed to outline briefly the main feature of development, research, education and possible future of landscape ecology in Mexico.

MATERIAL AND METHODS

Material

Key and supportive-complementary meta-analytically oriented Mexican studies

Key meta-analytically oriented Mexican study (MAS) for the metascientific evaluation and interpretation of main features of evolution, research, education and the possible future of landscape ecology in Mexico, is "La Ecología en México: retos y perspectivas" (Ecology in Mexico: challenges and perspectives) (Martínez-Ramos *et al.* Eds. 2017, (MAS1)), published in Revista Mexicana de Biodiversidad Volume 88, Supplement 1, 2017. In this extensive publication main subdisciplines of Mexico's ecology are systematically analyzed at different hierarchical levels (molecular ecology, evolutionary ecology, ecosystem ecology, macro-ecology and landscape ecology) from the empirical-methodical and application point of wiev. The most important study for our analysis was „ La ecología del paisaje en México: logros, desafíos y oportunidades en las ciencias biológicas" (Landscape ecology in Mexico: achievements, challenges and opportunities in biological sciences) (Arroyo-Rodríguez *et al.* 2017, (MAS2). The metascientific position and importance of landscape ecology in Mexico is complemented by other ecological disciplines such as „La macroecología en México: historia, avances y perspectivas" (Macroecology in Mexico: history, progress and perspectives) (Rodríguez *et al.*, 2017, (MAS3), „Ecología de la restauración en México: estado actual y perspectivas" (Restoration ecology in Mexico: state of the art and perspectives) (López-Barrera *et al*., 2017 (MAS4)), „La conservación en México: exploración de logros, retos y perspectivas desde la ecología terrestre" (Conservation in Mexico: exploring achievements, challenges and perspectives from terrestrial ecology) (List, *et al*., 2017, (MAS5)), „Análisis y perspectivas del estudio de los ecosistemas terrestres de México: dinámica hidrológica y flujos de nitrógeno y fósforo". (Analysis and perspectives of the study of terrestrial ecosystems in Mexico: hydrological dynamics and fluxes of nitrogen and phosphorus) (Martinez-Yrizar *et al*., 2017 (MAS6)), „Ciencia para la sustentabilidad: investigación, educación y procesos participativos" (Sustainability science: research, education and participative processes) (Casas *et al*., 2017, (MAS7)), „Resiliencia, vulnerabilidad y sustentabilidad de sistemas socioecológicos en México" (Resilience, vulnerability and sustainability of socioecological systems in Mexico) (Balvanera, 2017, (MAS8)), „Ecología, tecnología e innovación para la sustentabilidad: retos y perspectivas en México" (Ecology, technology and innovation towards sustainability: challenges and perspectives in Mexico) (Gavito *et al*., 2017, (MAS9)), „La restauración ecológica en México: una disciplina emergente en un país deteriorado" (Ecological restoration in Mexico: An emerging discipline in a deteriorated country) (Calva-Soto & Pavón, 2017, (MAS10)) „La Ecología Evolutiva del Desarrollo en México" (The evolutionary ecology of development in Mexico,(Álvarez-Buylla, 2017, (MAS11)), „The evolution of ecology in Mexico: facing challenges and preparing for the future" (Martínez *et al*., 2006 (MAS12)), and „Applying Ecology in the Third World: The Case of Mexico" (Castillo & Toledo, 2000 (MAS13)). As supportive and complementary empirically-methodically oriented Mexican papers (EMP), we considered, „Los estudios de paisaje y su importancia en México, 1970-2010" (Landscape studies and their importance in Mexico, 1970-2010) (Urquijo & Bocco, 2011, (EMP1)), „La geografía física y el ordenamiento ecológico del territorio:

Experiencias en México“ (Bocco *et al*., 2005 (EMP2)), „La investigación ecológica a largo plazo (LTER) y su proyección en México“ (Burgos *et al*., 2007 (EMP3)), „Multiple successional pathways in human-modified tropical landscapes: New insights from forest succession, forest fragmentation and landscape ecology research (Arroyo-Rodríguez *et al*., 2017 (EMP4)), „Patrones y tasas de cambio de uso de suelo en México“ (Velázquez *et al*., 2003 (EMP5)), „A landscape perspective on biodiversity conservation: the case of Central Mexico“ (Velázquez *et al*., 2003 (EMP6)) and „Una mirada al conocimiento de los ecosistemas de México“ (Balvanera *et al*., 2016 (EMP7)).

Theoretical-meta-scientific and applied studies, publications of co-authors

The following theoretical-metascientifically and applied oriented landscape ecological and geographical papers dealing with landscapes and landscape ecology in Mexico (TMA) served as important complementary source of information: sustainable development (TMA1) (Kremsa, 2021; 2004b; 1999g; 1999i; 1997c), landscape ecology in theory and practice (TMA2) (Kremsa, 2004b), hierarchical organization of landscapes in Mexico (TMA3) (Kremsa, 2000; 2000b; 1990e), landscape scale (TMA4) (Kremsa 2001c; 2001d; 2000e), landscape mapping (TMA5) (Kremsa & Varela, 2000; Lipsky & Kremsa, 1994), landscape monitoring (TMA6) (Kremsa, 2002g; 2001b; 2001c; 1995), landscape information system (TMA7) (Kremsa, 1999h; 1996; 1995; 1993), landscape processes (TMA8) (Kremsa, 1999c; 1991), landscape diversity (TMA9) (Kremsa, 2002d; 2002e; 2002f), landscape ecological stability (TMA10) (Kremsa, 1999f), landscape history (TMA11) (Kremsa 2003p; 1995), landscape futurology (scenarios, prognosis) (TMA12) (Kremsa, 2003p; 2001f; 1999a; 1999d), rural landscapes (TMA13) (Kremsa, 2021; 2002g; 2001f; 2000d; 1999a; 1999g; 1999i), mountain landscapes (TMA14) (Kremsa, 2002a; 2000a; 2000c; 1999h; 1998), coastal landscapes (TMA15) (Kremsa, 2004a; 2003c; 2003d; 2003e; 2003f; 2002b; 2002h), forested landscapes (TMA16) (Kremsa, 2001a; 2000c; 2000e), landscape desasters (TMA17) (Kremsa, 2003g; 2003h; 2003i; 2003j; 2002f), land use (1997a; 1997b; 1997d), remote sensing for landscape ecology (TMA18) (Kremsa, 1995; 1993), GIS for landscape ecology (TMA19) (Kremsa, 2003k; 1995; 1993), landscape ecology as scientific basis for sutainable tourism, and ecotourism (TMA20) (Kremsa, 2004a; 2003a; 2003b; 2003l; 2003m; 2003n; 2002c) and landscape ecological plan for the development of the Mexican Basin (TMA21) (Žigrai & Borja, 1981; Borja & Žigrai, 1982; Žigrai, 2001; 2003; 2012; 2020). We have presented the meta-synthesis “Meta-Landscape Ecology Approach to Determine the Nature of Mexican Landscape Ecology (Selected Meta-Scientific Aspects)“ (Kremsa & Žigrai, 2021).

Methods

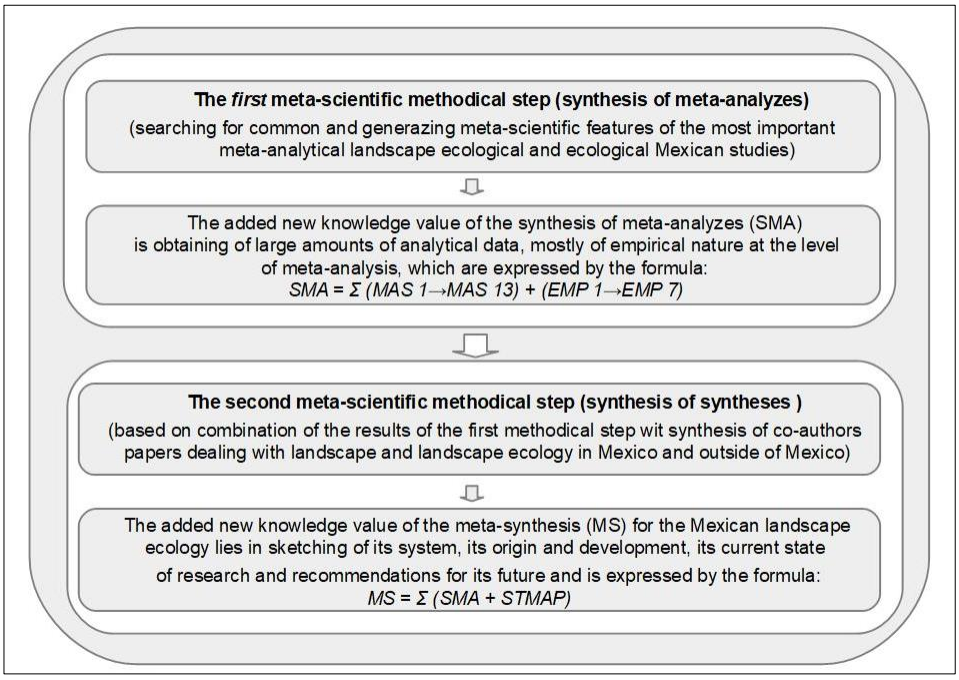
The metascientific landscape ecological approach with two-step methodical procedure was elaborated, using metaanalytically oriented landscape ecological and ecological Mexican studies, complemented by our theoretical-metascientifically and applied oriented landscape ecological and geographical papers dealing with landscapes and landscape ecology in Mexico. This allowed us to outline the main features of development, research, education and possible future development of landscape ecology in Mexico. The aim of the first metascientific methodical step is *synthesis of meta-analyzes* (analysis of analyzes). This means searching for common and generalizing metascientific features of the most important original metaanalytical landscape ecological and ecological Mexican studies with large amounts of analytical data, mostly of empirical nature at the level of meta-analysis. The meta-analysis produced an overview of data, to determine the breadth of its spectrum, as well

as the strength of their common time-spatial links. This increased their informative power and the possibility of mutual comparison. The added new knowledge value of the synthesis of meta-analyzes (SMA) for the Mexican landscape ecology is expressed by formula:

$$SMA=\Sigma(MAS1\rightarrow MAS13)+(EMP1\rightarrow EMP7)$$

where the (MAS) represent the key meta-analytically oriented Mexican studies and (EMP) represent supportive and complementary empirically-methodically oriented Mexican papers. The mission of the second methodical step is meta-synthesis (synthesis of syntheses) based on combination of the results of the first methodical step (synthesis of meta-analyzes, SMA) with synthesis of experiences and results of theoretical-metascientifically and applied oriented landscape ecological and geographical papers of co-authors dealing with landscapes and landscape ecology in Mexico and outside of Mexico (STMAP = Σ (TMAP 1→TMAP 21). The landscape ecological meta-synthesis represent generalized holistic virtual process and reflection in temporal-spatial contextuality, complexity and integrity. It allows a brief outline of the development, nature, research directions and education system of Mexican landscape ecology, as well as its position and possibilities for cooperation in the context of other countries dealing with landscape ecological issues. The added new knowledge value of the meta-synthesis for the Mexican landscape ecology lies in sketching of its system, its origin and development, its current state of research and recommendations for its future development.This added new knowledge value of the meta-synthesis (MS) consists of synthesis of meta-analyzes (SMA) and synthesis of (STMAP) and is expressed by the formula: MS = Σ (SMA+ STMAP). The two-step methodical procedure for compiling this paper is schematically shown in Fig. 1.

Fig. 1: Scheme of meta-scientific landscape ecological approach whith two-step methodical procedure



RESULTS AND DISCUSSION

System of landscape ecology in Mexico

All scientific disciplines, not excluding landscape ecology, create an internal system, consisting of certain information flow-related elements. These elements of the system of landscape ecology include the origin, development, nature, concept, object, approach, subject, goal, contribution and future of landscape ecological research. This system is important for understanding Mexican landscape ecology as a scientific discipline with its history, achieved empirical-methodical, applied-didactic and theoretical-methodological results, as well as its socio-scientific significance, management and possible future development. The obtained knowledge in this paper is the result of metascientific interpretation and synthesis of individual Mexican original studies, as well as our long-term empiricalmethodical, application-didactic and theoretical-metascientific experience. Based on these new results we outlined the recommendations for future development of the landscape ecological empirical research and methodical approaches, education of landscape ecology, application possibilities of landscape ecology and theoretical and metascientific issues of landscape ecology in Mexico, as well as cooperation of Mexican landscape ecology with selected countries dealing with landscape ecological issues. We have elaborated the metasynthetical study "Meta-Landscape Ecology Approach to Determine the Nature of Mexican Landscape Ecology (Selected Meta-Scientific Aspects)" (Kremsa & Žigrai, 2021).

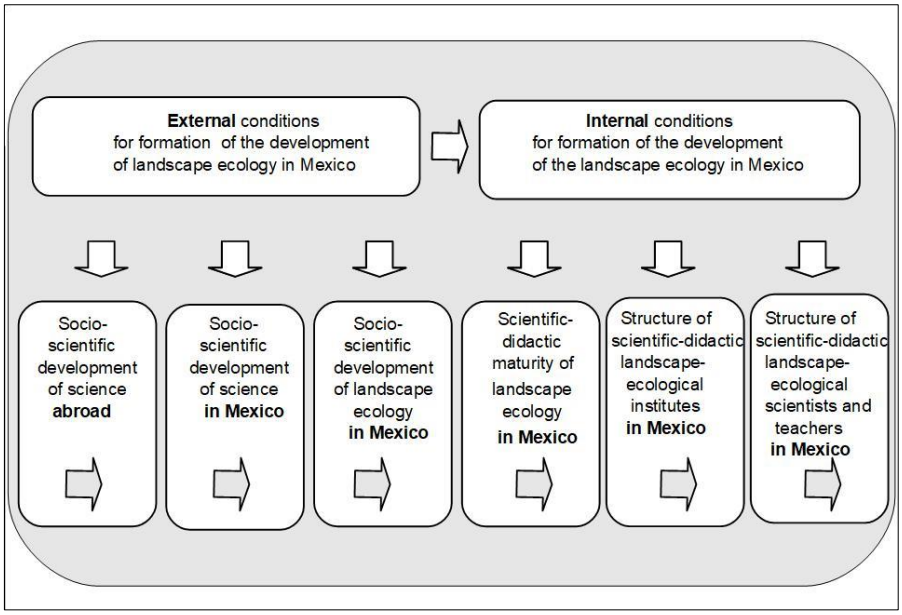
Origin and development of landscape ecology in Mexico

External and internal metascientific conditions

The emergence and evolution of landscape ecology in Mexico must be understood in the natural, socio-scientific and spatio-temporal context of development of ecology in America, Latin America and Ibero-America at the intersection of American (especially USA, Canada, Argentina, Chile, etc) and European (especially Spain) landscape ecology. Mexican landscape ecology as an ecological subdiscipline originated from ecology itself. Ecology in Mexico began to develop from the middle of the last century and has made relevant contributions to the conservation of biodiversity. Origin and development of landscape ecology in Mexico depended largely also on selected metascientific conditions, which schematically shown in Fig. 2.

The development of landscape ecology in Mexico was influenced by external as well as internal conditions. The main external condition was the socio-scientific development of science abroad, which created an external framework for the socio-scientific development of science in Mexico, specially for landscape ecology. The most important internal condition for the development of landscape ecology in Mexico was primarily a scientific-didactic maturity of landscape ecology. This reflected the results of the scientific level of institutions and their staff dealing with the issue and nature of landscape ecology.

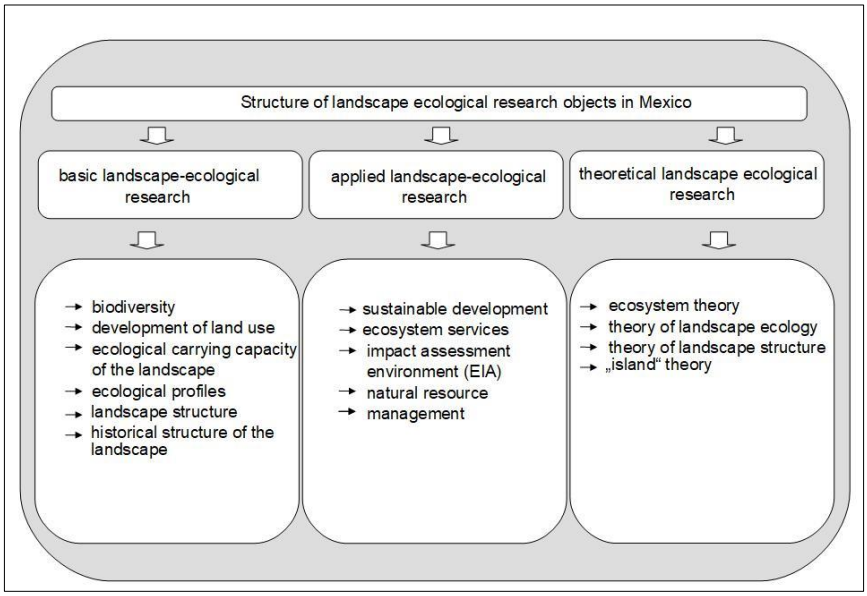
Fig. 2: Scheme of selected selected meta-scientific conditions influencing the development of landscape ecology in Mexico



The structure of landscape ecological research in Mexico

Based on a search of Mexican landscape ecological literature and our personal experince, it is possible to roughly derive, among other things, the structure of landscape ecological research itself, which is schematically shown in Fig. 3.

Fig. 3: Scheme of the structure of landscape ecological research objects in Mexico

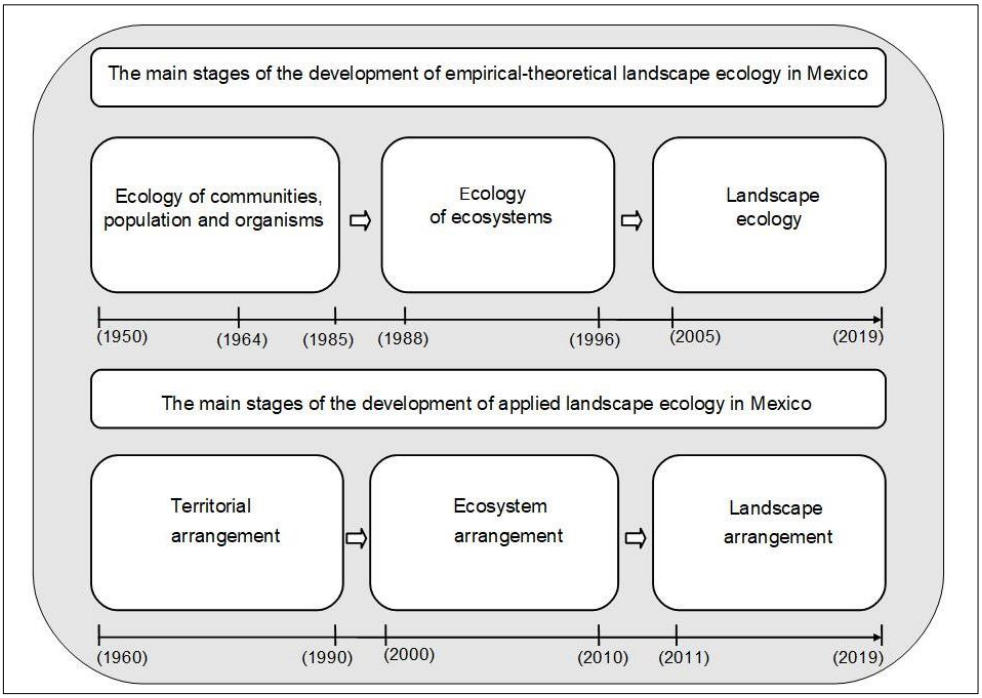


Basic landscape ecological research is focused mainly on biodiversity, development of land use, ecological carrying capacity and ecological profiles. Applied landscape ecological research focuses mainly on the issue of sustainable development, ecosystem services, impact assessment environment and natural resource management. The object of theoretical landscape ecological research was mainly ecosystem theory, theory of landscape ecology, theory of landscape structure and „island" theory. It follows from the content of the sketched structure of the Mexican landscape ecology that, she based on the original ecology, which influenced the empirical-methodical, theoretical-metascientifical, applied and didactic nature of landscape ecological research in Mexico.

Development of empirical-theoretical and applied landscape ecology in Mexico

The main stages of the development of empirical-theoretical and applied landscape ecology in Mexico are schematically shown in Fig. 4.

Fig. 4: The main stages of the development of empirical-theoretical and applied landscape ecology in Mexico



The overall development of landscape ecology in Mexico can be roughly divided into the following three main developmental empirical-theoretical and application stages: → within the development of *empirical-theoretical landscape ecology*: development of research on ecology of communities, population and organisms) (1st stage in the years 1950 - 1985), subsequent development of research in *ecology of ecosystems* (2nd stage in 1986 - 1996) as well as development of landscape ecology research (3rd stage in 2005 – 2019) and → within the development of *applied landscape ecology*: development of research of spatial arrangement of territory (1st stage in 1960 - 1990), subsequent development of research of

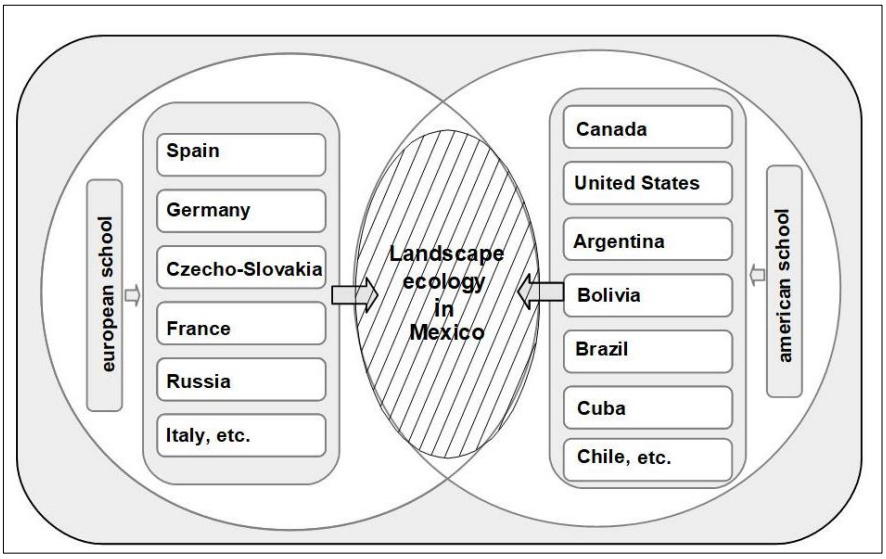
spatial arrangement of ecosystems (2nd stage in years 2000 - 2010), as well as development of research of spatial arrangement of landscapes (3 stage in the years 2011 – 2020).

Of course, there are no sharp boundaries between these three developmental stages of empirical-theoretical and applied landscape ecology, because their main research directions intersect, older ones fade away and newer ones begin to develop. Therefore, it is necessary to understand the overall development of landscape ecology and its nature in Mexico in the space-time contextuality, complexity and integrity.

International position of Mexican landscape ecology

During the development of landscape ecology, among other things, there was a gradual expansion of its research object and subject. This circumstance caused the gradual crystallization of the two main world directions of the development of landscape ecology, represented by the European and North American directions. These research directions ultimately influenced the development and character of landscape ecology with its research objects and approaches in Mexico. The Mexican landscape ecology is situated at the intersection of European and American landscape ecology. It can be described as integrative, idiographic-nomothetic at the spatial level of the landscape in the contact zone of European and American research approaches and principles, which is schematically illustrated in the second approach in Fig. 5.

Fig. 5: The position of the Mexican landscape ecology and the influence of the European and American landscape ecological schools



Looking at this scheme, we can see that Mexican landscape ecology has been influenced by both the European and American landscape ecology schools with its individual research approaches and directions. These contributed directly or indirectly to the development of landscape ecology in Mexico at the empirical-methodical and theoretical-application level.

The European school of landscape ecology

The European landscape ecological approach has contributed both at the topical ecologicalecosystem level and at the choric geographical and landscape level:

→ to the close connection of the geobotanical and ecosystem research approach and the application of its research to landscape ecological plans and projects. This research direction contributed from a meta- scientific point of view to the development of a bio-ecologically oriented narrower landscape ecology focused on ecosystem research at landscape level; (Wagening Eco-Planning Research Direction (Nassauer & Opdam, 2008; Zonneveld, 1990; Jongman (Ed.), 2004));

→ to phytocenological research, as a basis for the study of the landscape biocomplex within the basic and applied landscape ecological research necessary for the elaboration of ecological profiles. This research direction contributes to the development of empirics and methodic of a more narrowly understood landscape ecology, ie. „bio-ecological", whose main research object is ecosystems at landscape level. (Montpellier Direction of Bio-Ecological Landscape Research (Godron *et al.*, 1968));

→ to develop the natural potential of the landscape, based primarily on the analysis of soil potentials, relief and land use, as a basis for interpretation and evaluation of the abiocomplex as part of the overall landscape ecological complex serving for basic integrated landscape ecological research, methodics and theories of „geo-ecological" type of landscape ecology. (Leipzig School of Geo-Ecological Landscape Research (Haase, 1974; 1996);

→ to the spatial-geosystemic and holistic understanding of the landscape, presented in the learning about the landscape, dealing with landscape organization from its naturalistic aspect. This influences to some extent the meta-scientific character of the „geographical" landscape ecology. (Moscow-St. Petersburg School of Geography (Preobrazhensky, 1983; Isachenko, 2006; Armand, 1975));

→ to theoretical-methodical, spatial-functional interconnection and approach to the research of landscape ecology, lying on their intersection. This research direction marked the philosophy of landscape ecology in Central Europe, which is also reflected in its metascientific current understanding of both „ecological" and „geographical", landscape ecology, as well as in its narrower and broader sense. (Basel Geo- and Ecosystem Research Direction (Leser, 1997));

→ to the conceptual link between basic and applied research, and model for the development of the structure of the landscape plan representing one of the most important forms of applied landscape ecological research in Central Europe. This research direction has been a great contribution to the development of a broader understanding of landscape ecology, looking at the relationship between the natural features of the landscape and human society. (Hanoverian-Bad Godesberg School of Landscape Planning and Conservation and Care (Buchwald & Engelhardt, 1968));

→ to the Czechoslovak direct contribution in Mexico – it was realized by elaborating of landscape ecological plan for the development of the Mexican Basin at UNAM in Mexico City in 1981 (Žigrai & Borja 1981; Borja & Žigrai, 1982), by presenting theoretical problems of landscape science and landscape synthesis (Drdoš, 1965;1983) during his lectures at UNAM in Mexico City in 1990/1991, as well as long term research and lectures in Mexico (Kremsa, 1990-2019) on extensive issues such as hierarchical organization of landscapes in Mexico (Kremsa, 1990) landscape processes (Kremsa, 1991), sustainable development (Kremsa, 1991), landscape ecological stability (Kremsa, 1991), landscape ecology as a scientific basis for sutainable tourism and ecotourism (Kremsa, 2003), remote sensing for landscape ecology (Kremsa, 1993) and GIS for landscape ecology in Mexico (Kremsa, 1995), land use (Kremsa, 1997) and landscape ecology in theory and practice (Kremsa, 2004), etc.

The American School of Landscape Ecology

The American landscape ecological approach has contributed both at the topical ecological ecosystem level and at the choric geographical and landscape level:

→ to develop basic analytical-bioecological and nomothetic-merological oriented landscape ecological research;

→ to master inductive mathematical-statistical procedures and model methods of landscape ecological research;

→ to develop the principles and procedures of bio-ecological landscape ecology focused on the research of preserved natural ecosystems at the landscape level in mostly larger North American areas, as well as

→ to carry out landscape ecological research in smaller areas on more detailed cartographic scales.

It should be noted that the influence of the American School of Ecology and Landscape Ecology on the development of ecology and landscape ecology in Mexico was manifested mainly due to Mexico's neighboring position with the USA. Mexican students and young scientists had the opportunity to get acquainted with and master the ecological and landscape ecological research directions, procedures and approaches at the leading American ecological institutions.

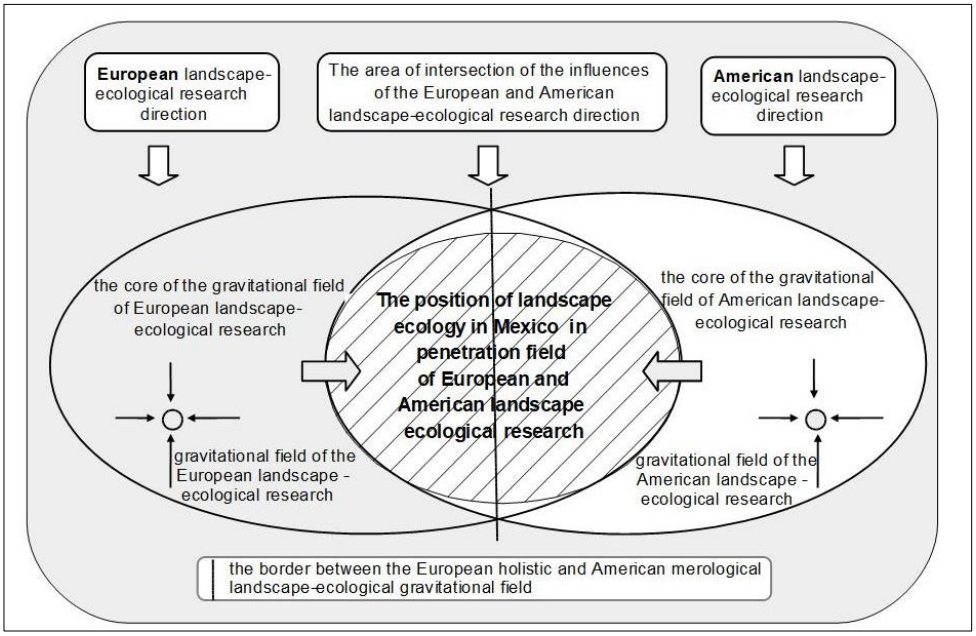
From the above brief characteristics of the European and North American research direction of landscape ecology, we can se, that there are also problems with the effort to create a unified landscape ecology, which would include these two empirical-methodical, theoretical-metascientific and applied research objects, approaches and goals. Nevertheless, these two different research directions of landscape ecology are not mutually exclusive, but on the contrary complement each other appropriately and thus at the same time enrich each other. The European landscape ecological research direction provides the North American direction with a certain holistic-application framework that emphasizes the socio-scientific significance and position of landscape ecology in North America.

On the other hand, North American landscape ecological research will strengthen the nomothetic character of European landscape ecology using mathematical-statistical and modeling methods, which will, among other things, strengthen its position among other scientific disciplines. The mutual benefits resulting from the nature of both directions of development of landscape ecology are likely to lead to their future convergence as one of the prerequisites for a unified landscape ecology.

In this way, Mexican landscape ecology, lying at the intersection of European and American landscape ecology, can be described as integrative, idiographic-nomothetic at the spatial level of the landscape in the contact zone of European and American research approaches and principles, which is schematically illustrated in the second approach in Fig. 6.

Although Mexican landscape ecology lies at the intersection of geographical and ecological entities, structures, processes and approaches, it is more ecological than geographical in nature. This corresponds to its research object dealing with landscape ecological processes and the spatial structure of a set of ecosystems especially at the topical level.

Fig. 6: The position of landscape ecology in Mexico in penetration field of the influences of European and American landscape ecological research diretions



The „ecological“ landscape ecology is represented by bio-ecological, empirical, theoretical-methodical and applied research approaches and aspects. Typical features of „ecological“ landscape ecology is its merological and nomothetical scientific nature. The function of „ecological“ landscape ecology lies in strengthening the efficiency of basic ecological research, in strengthening the authenticity of landscape ecology, in strengthening the exactness of the landscape ecology as a whole and in strengthening complementarity with „geographical“ landscape ecology.

The „geographical“ landscape ecology is relatively less developed in contrast to the predominant „ecological“ landscape ecology in Mexico, thanks to the strong influence of the American ecology with a dominant mathematical-statistical approach to ecosystem research, mainly at the topical level. This circumstance is due to a certain isolation of the geographically oriented landscape ecology, which has strong roots in Europe. The „geographical“ landscape ecology is represented by geo-ecological, empirical, theoretical-methodical and applied research approaches and aspects. The research object of landscape ecology is oriented on landscape ecological processes and the spatial structure of a set of ecosystems at the landscape level in a human-landscape relationship.Typical features of „geographical“ landscape ecology is its holistical and transdisciplinary scientific nature. The function of „geographical“ landscape ecology lies in enhancing the effectiveness of applied landscape ecological research, in strengthening the participation of landscape ecologystrengthening the contextuality of landscape ecology and in strengthening complementarity with „ecological“ landscape ecology

Current state of landscape ecological research in Mexico

The meta-analytical studies by Arroyo-Rodríguez *et al*. (2017) and Martínez-Yrízar *et al*. (2017) and our own experience and meta-analysis of current state of landscape ecological and ecosystem ecological research in Mexico allowed the synthesis of following main achieved results of a metascientific landscape ecological interpretation:

→ The largest cluster of all especially empirical-territorial landscape ecological studies across Mexico was found in the Federal District alone, due to the high concentration of scientific and didactic institutions with great research potential. On the other hand, it is only 5 % of the theoretical-conceptual, resp. model studies, which indicates less interest in this focus of scientific work;

→ Research in the field of ecosystem ecology, with a functional approach to terrestrial ecosystems in Mexico, formally began in the early 1980s with quantitative studies, mainly on primary productivity and nutrient cycles in tropical and temperate forests;

→ The research spectrum of especially plant ecosystems corresponds very well to the structure of landscape types of Mexico;

→ The analysis of the spectrum of landscape ecological research objects shows that the study of the impact of changes in spatial heterogeneity of landscape elements on biological diversity prevails. It is one of the central themes of landscape ecology with a balanced share of its geographical and ecological entities, structures and processes;

→ A high proportion of studies investigating the impact of land use change on the nature of ecosystems is characteristic for a broader understanding of landscape ecology with a greater share of human-geographical entities, structures and processes;

→ *Ecosystem ecology*, representing a type of ecological, more narrowly understood, landscape ecology, focuses its attention on the functional processes of the ecosystem at different time and space scales, by analyzing its stores, balances and flows of water, energy and nutrients. The increased application of ecosystem ecology is also a manifestation of its significant impact on the Mexican landscape ecology;

→ In Mexico were focused two up to date major research topics of ecosystem ecology and landscape ecology on hydrological dynamics and nitrogen and phosphorous fluxes of ecosystems and terrestrial landscapes. This circumstance points, inter alia, to the need for close cooperation between the geographical and ecological types of landscape ecology;

→ The incorporation of more sophisticated methodologies (stable isotopes, remote sensing, «Eddy Covariance» towers) and the work in national networks have allowed strengthening ecosystem research in Mexico;

→ The importance of ecosystem research in Mexico in the context of ecosystem ecology is also emphasized by its highly sophisticated methodology;

→ Spatial (landscape) aspect of landscape ecology is reflected in its geographical part in research of ecological succession, regeneration and restoration in a landscape context;

→ Detailed short-term field ecological research at the lowest spatial level is often without a landscape context. This information deficit is caused by a smaller representation of geographical landscape ecology, the knowledge of which is necessary for the correct decisionmaking process on water management, protection of critical habitats for the provision ofenvironmental services, conservation and management of ecosystems and landscapes;

→ There is still no coordinated, targeted plan for landscape ecological research at the level of the United Mexican States and probably not at the level of individual states. The research is carried out by experts from other fields;

→ The dimension of the environmental problems facing Mexico new challenges to ecologists and landscape ecologists, whose research wishes to contribute to the conservation of biodiversity;

→ The information generated by landscape ecology studies focused on conservation represents one of the main tools for decision-making management and conservation of landscapes biodiverity and geobiodiversity in Mexico and

→ In Mexico, a megadiverse country, it is crucial to increase the resources allocated to the training of professors and researchers in the field of landscape ecology and to strengthen the institutions that carry out education and research in landscape ecology.

Recommendations for future development of landscape ecology in Mexico

Meta-scientific issues of landscape ecology in Mexico

→ It is necessary to determine the authenticity and identity of Mexican landscape ecology by taking into account the specific natural, social-historical and scientific conditions of Mexico;

→ Focus on the selection of the main objective criteria and conditions of authenticity and identity of Mexican landscape ecology: 1) preserving the inseparability of geographical entities from ecological entities, 2) preserving the scope of landscape ecological trinity (ie the ecological process, structure and scale of the landscape), as well as 3) maintaining a balanced relationship between the object and the subject of landscape ecological research. This is a prerequisite for understanding the internal logic of the development of Mexican landscape ecology in its spatio-temporal and natural-social contextuality, complexity and integrity;

→ Strengthen the so far insignificant geographical (ie. spatial-polycentric-geosystem -holistic) principle and research approach to landscape ecology and thus to alleviate the imbalance between the geographical and ecological part of Mexican landscape ecology. This means strengthening geographically oriented landscape ecology at the choric landscape level in addition to bio-ecological research at the topical level;

→ Maintain a qualitative and quantitative balance between theory and practice of landscape ecology, as well as between basic and applied landscape ecological research, which is one of the main conditions for future development of landscape ecology in Mexico;

→ Research into meta-landscape ecology will need to be explored, taking into account its general nature. This will make it easier to understand the ever-increasing natural and social complexity of ecological-environmental and socioeconomic problems in the Mexican landscape;

→ Necessary condition for outlining the potential future development of landscape ecology research trends in Mexico is a metascientific synthesis and a generalization of its hitherto evolution together with accumulated empirical-methodical, theoretical-application and didactic landscape ecological knowledge and experience;

→It will be necessary to realize that the ecological-geographical duality of landscape ecology, together with its current position at the top of the choric hierarchical chain of ecological disciplines, also represents a great potential for Mexican landscape ecology to cooperate with other ecological disciplines in landscape research on empirical-methodical, theoretical-metascientific and application levels;

→ Also, it will be necessary to realize that landscape ecology can play a central role in the collaboration of several scientific disciplines dealing with landscape research in Mexico because of its penetrating and integrating ecological-geographical character;

→ It should be stressed that the main condition for the manifestation of the social relevance of landscape ecology in Mexico is its acceptance by a wide range of the population as a necessary and useful scientific discipline, which constitutes the essence of the landscape ecological awareness of society. This awareness consists in understanding the spatio-temporal and ecological-relationship nature-social complexity, contextuality and integrity in the landscape;

→ It should be noted that the considerable potential ability to apply the results of the basic landscape ecological research for the needs of practice in addressing current and future issues of the use, transformation and protection of the landscape in Mexico arises from the internal entity of landscape ecology at the interface of geographical-spatial and ecological-relationship sciences;

→Support the cooperation, coordination and participation of a number of scientific disciplines including landscape ecology, dealing with spatial planning in tackling increasingly complex ecological-environmental and social problems, as well as conflicts concentrating in the Mexican landscape;

→ It should be borne in mind that in the future, landscape ecological planning in Mexico must draw theoretically and methodologically mainly from landscape, environmental and spatial planning. In addition to landscape ecology, it should be based on other scientific disciplines such as geography, urbanism and environmental sciences;

→ To enhance the ability of landscape ecology as a scientific discipline to communicate and cooperate with socio-political decision-makers and citizens' initiatives to transform the results of their basic and applied research for its needs. The key moment is obviously here ability and necessity of transfer of landscape ecological relationship-ecological a spatial-holistic scientific thinking and language in a sectoral way thinking and speech of politicaladministrative and legislative staff focus and

→ Support the motivation of landscape ecologists to apply basic results of landscape ecological research in practice and in the pedagogical process. This will also help to strengthen the landscape ecological awareness of the society, as well as to strengthen research of the scientific-managerial-marketing character of landscape ecology focused on the organization of landscape ecological activities and building a marketing image and trademark of landscape ecology, and

→To foster interaction not only between colleagues in Landscape Ecology or Ecology, but between colleagues from different disciplines, in order to obtain a more holistic and integrative understanding of the impact that human activities have on landscapes and the environment.

Organizational level of landscape ecology in Mexico

→ The establishment of the Long-Term Ecological Research Network (Red Mex-LTER) was an important organizational measure for fragmented mexican landscape ecological research of the relationship between different ecosystems and different types of landscape. It allowed the creation of a database platform for social-scientific decision-making and thus indirectly strengthening the position of a more widely understood landscape ecology;

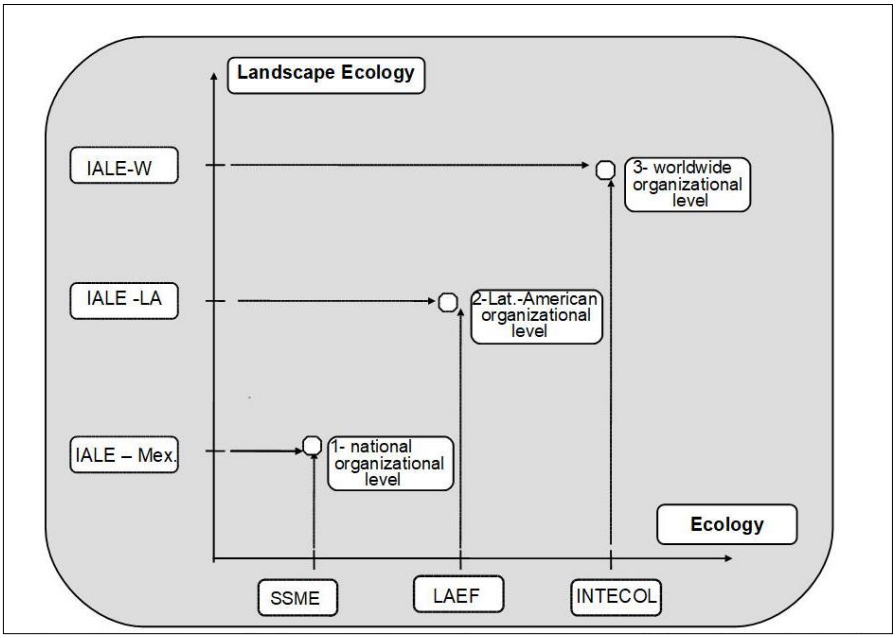
→ Mexico cooperates in landscape ecological research focused on the relationship between ecosystems and the landscape, with several countries, especially with Latin America, the USA, Canada and Spain. According to the publication results, UNAM has proven to be animportant cooperating Mexican partner. Despite the advances made by mexican landscape ecology, there are still important knowledge gaps and methodological and conceptual limitations. This circumstance weakens even more effective cooperation between Mexico and other countries in the field of landscape ecological research and

→ „Landscape ecological sciencing“ is meta-scientifically oriented sciencing, which is understood as a science related activities and processes.Its content include, inter alia, 1) establishing and interconnecting landscape ecological institutions, 2) organizing landscape ecological events, 3) drawing up landscape ecological projects, 4) securing financial resources, 5) publishing landscape ecological periodicals and 6) presenting landscape ecological studies and work. In the case of Mexican landscape ecology, landscape ecological sciencing should focus primarily on elaboration of the „National Program of Landscape Ecology. Science, Research, Teaching and Application“, etc.

International and national collaboration between landscape ecology and ecology in Mexico

The outline of the possible future cooperation between ecology and landscape ecology as its branch, at the organizational three-degrees level, from the Mexican point of view, is schematically, shown in Fig. 7. The following proposed measures result from this scheme:

Fig. 7: Scheme of cooperation between landscape ecology and ecology organizations at the national, Latin-American and global levels



At the *national* level, specifically between the Mexican Association for Landscape Ecology (IALE-M) and the Scientific Society of Mexican Ecology (SSME)

→ Cooperation between Mexican landscape ecology and ecology is possible especially within the working groups of theoretical landscape ecology and general and theoretical ecology, which is, among other things, one of the basic preconditions for the development of both scientific disciplines. This cooperation should be reflected in particular in the intensified joint publication of the results of landscape ecological and ecological research in the scientific journal „Ecología del Paisaje“. Both societies would benefit from this cooperation at the empirical-methodical, theoretical-meta-scientifical and application level. Landscape

ecology provides for the ecology of landscape-spatial contextuality of ecological structures, phenomena and processes and vice versa ecology fills the landscape with landscape components, plots, corridors and matrices necessary ecological content for basic and applied landscape ecological research at the local and regional level in Mexico and

→ To establish of the IALE-Mexico chapter. We think that a detailed review of Mexican literature, among other things, shows sufficient research-didactic geographical and ecological potential to establish this IALE group, which would contribute considerably to, among other things, the visibility of Mexican landscape ecology within the global context of landscape ecology;

At the *Latin American* level between the Latin American Association of Landscape Ecology (LA-IALE) and the Latin American Ecological Federation (LA-EF).

Latin American associations of landscape ecology and ecology cover and organize cooperation with their Latin American national, resp. regional associations.

→ For more effective cooperation and joint research, it would be necessary to set up their individual working groups for the development of theoretical and meta-scientific aspects of landscape ecology, which are very important for outlining other paradigms of its development;

→ The joint research platform of these associations should be, among other things, research into spatial-functional aspects of Latin American ecosystems, both to determine their landscape ecological potential needed to provide individual ecosystem services, and to develop one of the necessary landscape ecological materials for example, for implementation of the Latin American landscape agreement;

→This cooperation would, on the one hand, present the landscape ecological scientific profile of individual states at the regional level of the lower order, as well as the supra-regional (ie higher regional order) representing the common nature of Latin America's landscape ecology in terms of unity based on diversity individual Latin American countries. landscape ecological empirical knowledge, methodological approaches and theoretical knowledge of individual Latin American countries would complement, enrich and stimulate each other. It would also increase the overall scientific and research potential of landscape ecology. The creation of IALE-Latin-America would create a very influential IALE member with a strong professional background, which could translate into worldwide scientific research and publishing activities as well as presentations at international events and

→ Closer scientific-pedagogical and organizational cooperation between Latin American countries could be enhanced by disseminating and penetrating scientific information and knowledge through the traditions, diffusion, adaptation, innovation and migration of individual landscape science schools and directions generated in the relevant scientific institutions. Position. tasks and and collaboration of Mexican landscape ecology at the Latin American level consists primarily in providing empirical, methodological and theoretical experience and knowledge of Mexican landscape ecology and ecology gained from long-term contacts with American landscape ecology and ecology for the needs of Latin American Association of Landscape Ecology (LA-IALE) and the Latin American Ecological Federation (LA-EF).

At the *worldwide* level between the International Association of Landscape Ecology (IALE) and the International Association of Ecology (INTECOL).

The common research platform of the above-mentioned international associations, among others, should probably be the study of spatially-functional aspects of ecosystems and their

interrelationships at the planetary level, with the planet Earth being understood as one large ecosystem.

→ This needs to be explored across its local, regional and continental ecosystems across their choric scales and boundaries, which seem to „dissolve". This issue is to be addressed by the newly formed planetary, resp. global ecology. The contribution of IALE and INTECOL to global basic and applied landscape ecological and ecological research should lie in the close cooperation of their national and regional institutions, respectively chapters on tackling global climate change, biodiversity and bioproduction and

→ From the metascientific point of view, this means a more intensive exchange of landscape ecological and ecological meta-data and cooperation in their evaluation at the level of analysis and synthesis, as well as their implementation at the application level. Here, planetary ecology at the highest choric level of can be based on the already achieved empirical-methodical, theoretical-metascienitifically and applied knowledge and experience of ecology located at lower spatial levels, from landscape ecology to autecology. The position and role of the Mexican Landscape Ecology and Ecology as part of the Latin American Association of Landscape Ecology (LA-IALE) at the worldwide level between the International Association of Landscape Ecology (IALE) and the International Association of Ecology (INTECOL) is to transfer the empirical, methodological and applied landscape ecological and ecological knowledge with very high landscape and biological diversity of Mexico. In this way, Mexican landscape ecology and ecology will contribute to solving planet-wide ecological-environmental problems in terms of maintaining sustainable development.

Theoretical-and meta-landscape ecology in Mexico

→ The importance of theory for the existence and development of each scientific discipline is generally acknowledged, which is twice as true for Mexican landscape ecology as a relatively young cross-sectional and integrative scientific discipline with a lack of maturity and considerable variation in its concept, character, structure and definition, as well as research objects and approaches;

→ Without intensive and permanent elaboration of theoretical questions of landscape ecology it is not possible to ensure the progress of landscape ecology in Mexico as a whole.

→ This statement stems from the fact that theoretical landscape ecology represents the highest generalizing and abstract level of basic and applied landscape ecological knowledge in terms of terminology, empirical data, research methods and individual theories. At the same time, theoretical landscape ecology is part of scientific theory as a partial discipline of philosophy. (closer Žigrai, 2010);

→ The synthesis of acquired rich empirical-methodical and application knowledge at the local and regional level shows that the foundations of theoretical landscape ecology in Mexico have not been formulated yet, which would allow to draw some generalizations and regularities of landscape ecological research. These are important in order to explain the entities, phenomena, structure and processes of landscape ecology in their temporal-spatial contextuality, complexity and integrity, as well as to guide its basic, methodical and applied landscape ecological research. (closer Žigrai, 2016);

→ Nevertheless, it is possible to find out from the excerption of Mexican landscape ecological studies certain links and relationships between individual ecosystems at different taxonomic levels and thus to deduce certain recurring regularities.

→ A meta-scientific analysis of the most important landscape ecological and ecological Mexican literature and the rich empirical-methodical and applied knowledge gained from it

at the local and regional level shows that it will be necessary to generalize and formulate the foundations of theoretical landscape ecology. The creation of regularity is a generalization of empirical, methodical and applied knowledge of landscape research within the scientific basis of landscape ecology;

→ Within its meta-scientific superstructure, the focus of the research object of the theory of landscape ecology as a meta-cientific subdiscipline lies in outlining the regularities of development, structure, prognosis and system of theoretical knowledge about landscape ecology as a scientific discipline;

→ The theory of landscape ecology represents the highest generalizing and abstract level of basic and applied scientific knowledge about landscape ecology in the form of terminological concepts, empirical data, research methods and individual theories;

→ The theory of landscape ecology is part of scientific theory as a partial discipline of philosophy. The need to pay intensive attention to the future research of landscape theory underlines its importance, which lies primarily in the fact that it protects the authenticity and identity of landscape ecology, as well as from its absorption by other sciences with a stronger theoretical basis. In addition, it supports the coherence of the landscape ecology and its integrity, as well as the contact between its base and the meta-scientific superstructure and

→ Last but not least, the importance of the theory of landscape ecology lies in the fact that it increases the efficiency of landscape ecology and cheapens its basic and applied research. The elaboration of the theory of landscape ecology is very demanding for a holistic-integrative and abstract way of thinking, as well as for intra-, inter- and transdisciplinary cooperation of several intersecting disciplines, especially ecology and geography. Only in this way is it possible to understand the theoretical issues of landscape ecology in its spatio-temporal and natural-social complexity. This consideration also shows, inter alia, that one of the main conditions for the future development of landscape ecology in Mexico is the intensive cooperation of landscape ecologists, ecologists and geographers in the framework of basic, applied and theoretical research.

→ The metascientific analysis of the most important landscape ecological and ecological Mexican literature and its rich empirical-methodical and application knowledge obtained at the local and regional level shows that:

→ It will be necessary to generalize and formulate the basics of theoretical landscape ecology. Its main research object, as mentioned above, is the creation of regularity, resp. by generalization of empirical, methodical and application knowledge of landscape research within the scientific basis of landscape ecology;

→It should be noted that within the framework of its metascientific superstructure, the focus of the research object of landscape ecology theory as a meta-subdiscipline lies in outlining regularities, resp. principles of development, structure, forecast and system of theoretical knowledge about landscape ecology as a scientific discipline;

→ The theory of landscape ecology represents the highest generalizing and abstract level of basic and applied scientific knowledge of landscape ecology in the form of terminological concepts, empirical data, research methods and individual theories;

→ At the same time, the theory of landscape ecology is part of scientific theory as a partial discipline of philosophy. The need to devote intensive research into theory of landscape ecology in the future underscores its importance, in particular by protecting the authenticity and identity of landscape ecology, as well as from being its absorbed by other sciences with a stronger theoretical base;

→ In addition, it promotes the coherence and integrity of landscape ecology, as well as the contact between its base and metascientific superstructure;

→ The importance of landscape ecology lies in the fact that it increases the effectiveness of landscape ecology and makes its basic and applied research cheaper;

→ The elaboration of the theory of landscape ecology is very demanding for a holistic integrative and abstract way of thinking, as well as for intra-, inter- and trans-disciplinary cooperation of several penetrating disciplines, especially ecology and geography. Only in this way is it possible to understand the theoretical issue of landscape ecology in its spatiotemporal and natural-social complexity and

→ It also implies that one of the main conditions for the future development of landscape ecology in Mexico is the intensive cooperation of landscape ecologists, ecologists and geographers in the framework of basic, applied and theoretical research.

Empirical Landscape Ecology in Mexico

→ Research into the impact of landscape structure on biodiversity will need to extend this taxonomic and functional group to the level of the region and the country as a whole, taking into account the evolution of its use. From the meta-scientific point of view, this means strengthening the spatial-holistic character of the „geographical" landscape ecology;

→ Evaluate the effect of the matrix on maintaining the diversity of individual plots areas in order to increase landscape ecological functionality, this means strengthening the spatialholistic character of the „geographical" landscape ecology too;

→Strengthen the current field landscape ecological research in such cartographic scales that depict the landscape and its ecological structure in a broader spatial context. The ecological approach needs to be enriched with a spatial-holistic-polycentric view;

→ Carry out additional research with a greater number of heterogeneity of landscapes and ecosystems, as well as the complex biogeographic history of the Mexican territory. This means strengthening the cooperation of landscape ecology with other scientific disciplines and especially with biogeography and historical geography;

→ Attention needs to be paid to the importance and quality of water as a natural resource from a biological, ecological and social point of view, especially in relation to land use change. This requires more intensive cooperation of landscape ecology with other sciences such as ecology, biology and human geography;

→ The long-term monitoring program for research on the models and processes of terrestrial ecosystems in Mexico, in particular ecosystem ecology, needs to be strengthened to support addressing current ecological and environmental challenges associated with accelerated ecosystem change at national and global levels and

→ Ensure permanent standardization of individual methodical approaches within the field of ecosystem research as a part of ecologically oriented landscape ecological research. This will ensure time-spatial comparability of research results in different types of Mexican countries.

Education of Landscape Ecology in Mexico

→ In Mexico there are no specialized academic programs in LE, but there are multiple opportunities for studying this discipline;

→ There are at least 73 graduate degrees in biological sciences and 36 in earth sciences in the National Register of Quality Graduate Conacyt, in which students could carry out research related to LE. For example, both the Colegio de la Frontera Sur (ECOSUR) and the Centro de Investigación Científica de Yucatán A.C. (CICY) offer postgraduate courses entitled „Landscape Ecology";

→ At the Institute of Ecology A.C. (INECOL) the postgraduate course offers the «Spatial analysis applied to landscape ecology» course and

→ In the postgraduate courses of the National Autonomous University of Mexico (UNAM) there is a wide range of courses related to LE. For example, the Center for Research in Environmental Geography (CIGA) offers a master's program in Geography (Field of Knowledge in Integrated Landscape Management) and courses in „Ecogeography", „Landscape Geography" and „Landscape Assessment Methods", while the Institute for Ecosystem and Sustainability Research (IIES) offers the course „Ecology of fragmented tropical forests". These examples show different options and approaches for the training of human resources in LE, which will contribute strongly to the development of this discipline in Mexico. Although it seems at first glance taking into account the data from the above-cited literature that in Mexico there is a multiple opportunity in Mexico to study landscape ecology in the life sciences or earth sciences, it is not a full field of study or subject of landscape ecology but only mostly postgraduate courses. At the same time, these courses are not a separate subject of landscape ecology, but are usually part of other didactic subjects, such as environmental geography, ecogeography, landscape geography, methods of landscape evaluation and ecology of tropical forest. This situation constitutes an internal and external disadvantage for landscape ecology in relation to other subjects. The internal disadvantage lies in the lack of a link between landscape ecology as a scientific discipline and landscape ecology as a teaching subject. and

→ Landscape ecology as a scientific discipline creates and determines the scientific landscape ecological background and authenticity of landscape ecology as a teaching subject. On the other hand, landscape ecology as a teaching subject enriches the didactic knowledge and skills of landscape ecology with the theoretical-, metascientific and empirical-applied part of landscape ecology. The external disadvantage of landscape ecology lies in its weaker position as an equivalent teaching subject with other subjects, which could lead to its merging and thus disappearing with other subjects. Based on many years of experience during the scientific-research, didactic and application activities of the co-author of this article in Mexico the following didactic landscape ecological measures in Mexico are proposed:

→ to deepen the didactic profile of landscape ecology through more intensive information exchange between landscape ecology as a scientific discipline and landscape ecology as a teaching subjec;

→ to intensify the theoretical-methodical and empirical-application experience university didactic ecology and geography for the development of didactic landscape ecology as an ecological subdiscipline;

→ to elaborate a nationwide textbook of landscape ecology, which would represent a synthesis of the current state of its empirical-methodological, theoretical-meta-scientific, didactic and application state. The authors of this unifying textbook should be the leading landscape ecologists, ecologists and geographers from each of the relevant Mexican academic departments dealing with the above-mentioned landscape ecological issues;

→ Grants for graduate studies in landscape ecology;

→ Training in how to engage in transdisciplinary, interinstitutional and international research and

→ Focus on problem solving, communication skills for environmental education, and raising societal awareness. In addition, it should be noted that the focus and profiling of landscape ecology courses are primarily based on the content and scope of the authors of classical textbooks of landscape ecology, such as (Forman & Godron, 1986, and translations of books into Spanish, such as Naveh & Lieberman, 2001), whose main research object is

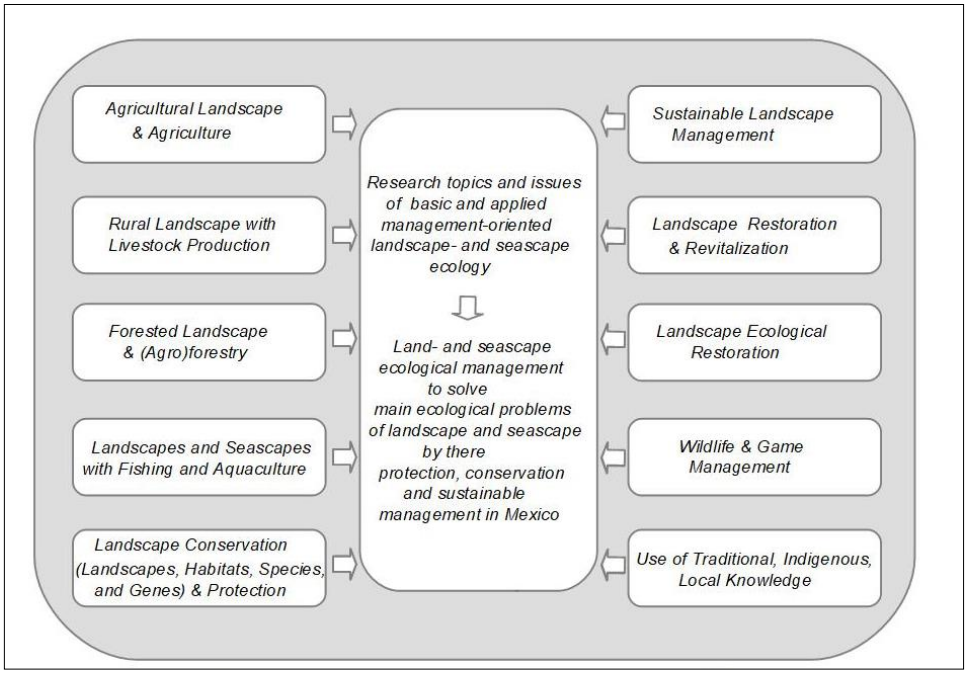
a country with its genesis, structure, processes, properties and scale from an ecological-geographical aspect. There are very few meta-scientific aspects that deal with landscape ecology as a scientific discipline, e.g. with its history, philosophy, internal and external character, unity, authenticity, identity, as well as position and cooperation with other scientific disciplines.

Applied Landscape Ecology in Mexico

Research topics of applied landscape ecology to solve main ecological problems of landscape by its protection, conservations and sustainable management in Mexico

Based on many years of experience during the applied research, and application activities of the co-author of this article in Mexico, the following applied landscape ecological management in Mexico are highlighted and schematically shown in Fig. 8:

Fig. 8: Landscape and seascape ecological management in Mexico



→ within *Agricultural Landscape* & Agriculture: landscape ecologically oriented intensification of agriculture in rainfed areas and reconversion of irrigated ones; Landscapeagroecological techniques (terracing, green manure, etc.), Efficient management of energy, soil, and water; Use of advanced technologies (remote sensing, GIS, etc.) for agrilutural landscape management and land-use planning on a rural community scale;

→ within *Rural Landscape* with Livestock Production: Ecological Intensification of cattle raising by integrated LE management of animals, soil, and plants; Agro-silvo-pastoral system with diverse forage (Prevention of deforestation); Water management in the landscape and efficient use of water;

→ within *Forested Landscape* & (Agro)forestry: Sustainable polyspecific agroforests (coffee, cocoa, home gardens); landscape ecological management of secondary forests;

Valuation of environmental services of forests; Sustainable harvesting of timber and nontimber products;

→ within *Landscapes and Seascapes* with Fishing and aquaculture: Sustainable use of freshwater landscapes and marine seascapes and species; Ecological fishing techniques; Ecologically sound aquaculture farms; Sustainable management of freswater and coastal landscapes and marine seascapes; Protection of mangroves, coral reefs, etc;

→ within *Landscape Conservation* (landscapes, habitats, species, and genes) & Protection: Landscape -ecological management plans for protected areas: landscape ecological management plans for protected areas; Ecological management of populations of threatened species; In situ conservation of local germplasm;

→ within *Sustainable Landscape Management*: landscape ecological evaluation and management of landscapes; Household and community-scale agrosilvo-pastoral systems; Use of advanced technologies for landscape management and land-use planning at community, microregional and regional levels;

→ within *Landscape Restoration & Revitalization*: Rehabilitation of natural and managed landscapes; Reforestation of landscapes with native local and regional species; Rehabilitation of freshwater and coastal landcapes and marine seascapes; Reintroduction of endangered or rare species into landscapes;

→ within landscape Ecological restoration: Rehabilitation of natural and managed landscapes; Reforestation of landscapes with native local and regional species; Rehabilitation of freshwater and coastal landcapes and marine seascapes; Reintroduction of endangered or rare species into landscapes;

→ within *Wildlife & Game Management*: Sustainable management of species and preservation of their habitats and

→ within *Use of traditional, indigenous, local knowledge*: Rescue of indigenous ecological knowledge; Use of traditional techniques (green manure, artisan irrigation, terracing, vegetational manipulation); Use of varieties of plants and animals under indigenous management; Use of traditional knowledge of landscape in indigenous communities. The above-mentioned approaches of landscape ecological management in Mexico represent a set or system of activities, which are mainly focused on agricultural, forestry, urban and sea landscapes. At the same time, these individual activities complement and support each other. Because this is a complex issue, it is necessary to formulate the principles of science dealing with landscape management from an ecological aspect. One of the tasks of this science will be to connect basic landscape ecological research with the needs of applied landscape ecological research focused on landscape management.

State Institutions responsible for research and protection of Environment and Natural Resources in Mexico

Main state institutions responsible for the environment are: The Ministry of Environment and Natural Resources - SEMARNAT, The Ministry of Agrarian, Land, and Urban Development - SEDATU, The Ministry of Agriculture and Rural Development -SADER , The Federal Attorney for Environmental Protection - PROFEPA and National Institute of Ecology and Climate Change - INECC), as well as National Commission for the Knowledge and Use of Biodiversity - CONABIO, National Forestry Commission - CONAFOR, National Commission of Natural Protected Areas - CONANP and National Water Commission – CONAGUA. The legal basis for the application of the results of landscape ecology research in practice is provided by General law of ecologial balance and environmental protection (1988), Federal Law of Environmental Responsibility (2013), etc., as well as official mexican regulations and rules. The main global environmental problems (deforestation, soil

erosion, loss of biodiversity, water depletion, species exploitation, etc.) in Mexico are continuing to increase at alarming rates. Mexican ecologists are confronted with a system that values the generation of new scientific knowledge over its social use. Because the economic benefits obtained from SNI constitute a significant portion of the salaries of Mexican researchers, these scientists tend tofocus on producing scientific papers rather than on communicating useful information to non-scientific sectors or participating in other practical activities. Three main research institutions have an applied orientation: Colegio de la Frontera Sur (Ecosur), Instituto Mananthin de Ecologia y Conservacion de la Biodiversidad (IMECBio) e Instituto de Ecologia y Alimentos (lEA). Research is focused on terrestrial ecosystems and landscapes. Marine and aquatic ecosystems need more research projects. Most applied projects focused on conservation, forestry and agriculture. on livestock production, which is a major cause of deforestation and land-use change in the tropical lowlands of Mexico. Only few projects were related to restoration ecology.

Applied landscape ecological measures in Mexico

Based on many years of experience during the scientific research, didactic and application activities of the co-authors of this article and taking into account the above research topics of applied landscape ecology to solve main ecological problems of landscape protection, conservations and sustainable landscape management in Mexico the following applied landscape ecological measures in Mexico are proposed:

→ Federal, state and private funding agencies should expand support for applied interdisciplinary, multidisciplinary and transdisciplinary research and education centers, projects, education;

→ Federal, state and private finding agencies should devote a portion of their resources to support potentially transformative research, including opportunities at the intersection of the geography and ecolog/life sciences, as well as other disciplines;

→Federal, state and private funding agencies should enhance the ability of more than one researcher to serve as principal investigator (PI) on applied research projects;

→ Develop mechanisms to ensure effective collaboration and cooperation among federal, state and private & non-governmental agencies that support applied (landscape) ecological research;

→ Funding agencies should also provide expanded support for experienced investigators to receive training in a new field (sabbatical fellowships, grants, etc.);

→ To close the gap between scientific research and environmental problems in Mexico

→ To improve governmental policy on applied (landscape ecological) science;

→To incorporate trained landscape ecologists into federal and state agencies;

→ To support solution oriented applied ecology, not only problem oriented pure ecology;

→ To develope landscape ecological planning and management methods;

→ To generate applied landscape ecological knowledge in interaction with society;

→ To transfer landscape ecological knowledge from theory to practice;

→ To establish Mexican network of applied (landscape) ecology to improve the collaboration;

→ To make more efficient and constant communication between scientists, local social sectors and decision makers;

→ Grants for scientists communicating useful information to nonscientific sector or participating in other practical activities;

→ Promote research with a social impact;

→ Change the system of academic rewards to emphasize the importance of applied research;

→ Increase the number of LE investigators supported by the SNI in ecological institutions;

→Develop landscape ecological information system;

→ Include ethnoecological research and use native knowledge;

→ Integrate basic and applied research with landscape and resource management

→ Investigate and undestrand, how scientific institutions and researchers perceive the social and economic actors in landscape & natural resources management;

→ Conduct research in conjunction with the actors involved in the management of landscapes & natural resources (producers, government agencies, NGO, international agencies, etc.);

→ Develope new methods with advanced technologies, to solve problems in agriculture, forestry, fisheries, wildlife management, biodiversity conservation, resource extraction, etc;

→ Landscape ecologists should be more involved in decisions related to the management and conservation of landscape & natural resources;

→ Applied landscape (agro)ecology institutions and researchers must recognize the importance of small-scale, community-based producers and promote the effective, practical use of new scientific knowledge in the field;

→ Focus applied research on community-based systems of landscape & natural resource management and production (ejidos and indigenous communities): agriculture, forestry, fishery;

→ Plan (agro)ecological research according to the information demand, cultural background and production problems of rural producers;

→ Retain LE scientists, while continuing to foster international collaborations;

→ Employment opportunities for young scientists (landscape ecology) in Mexico;

→ To integrate Landscape Science with other sources of information: Landscape Management is an ecological, social, economic, cultural, and political phenomenon;

→ Mechanisms to link the work of social organizations (both governmental and nongovernmental) with academic institutions linking academic work with the regional social sectors;

→ Facilitate public access to the information and expertise of research institutions;

→ To encourage the formation of networks of people and institutions for a common purpose and

→ Transform scientific findings to meet the needs of different sectors (i.e., recreating the information to make it understandable and usable for lay audiences).

The scientific-pedagogical further development of Mexican landscape ecology

Every scientific discipline, including Mexican landscape ecology, needs to ensure certain structure and conditions for its further development. The structure of the future development of Mexican landscape ecology should be based on a continuous-accumulation, Innovation-application, theoretical-meta-scientific and pedagogical-didactic pillars.

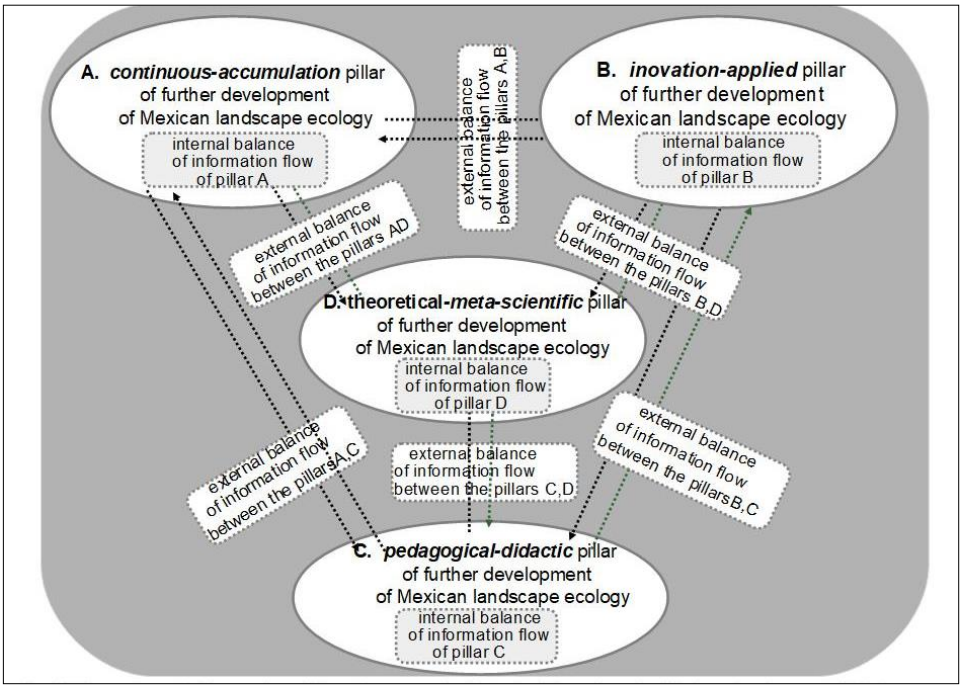
The content of *the continuity-accumulation pillar* should be the effort to continue the use empirical-methodical and application-didactic landscape-ecological knowledge acquired so far, experience and skills. These are the result of a long process effects of temporal properties and especially temporal accumulation potential, temporal inertia and time continuity.These properties allow the transfer of acquired knowledge, skills and competences for future generations by gathering considerable information forces.

The content of *the innovation-application pillar* should be the effort to respond to new ones in time social paradigms and research landscape ecological directions and thus help to address current issues and topics natural and social problems,

The content of *the theoretical-metascientifical pillar* should be the effort to deal with the most important issues such as the unity and authenticity of landscape ecology, landscape ecological contextuality, complexity and integrity, the relationship between basic and applied landscape ecological research, theoretical and metascientific principles of landscape ecology, its sustainable development, as well as the conditions for maintaining the scientific and pedagogical development of landscape ecology.

The pedagogical-didactic pillar should be based on the already rich didactic-pedagogical knowledge and understanding of landscape ecology, acquired in the past and specified in previous part of this paper, as well as supplemented by new and planned topics and activities in the development of the teaching process. The system of pillars and conditions for preserving the scientific-pedagogical further development of Mexican landscape ecology is schematically shown in Fig. 9.

Fig. 9: The system of pillars and conditions for preserving the scientific-pedagogical further development of Mexican landcape ecology



From a metascientific point of view, these include, among other things, maintaining the internal balance information flows within the continuum-accumulation, innovation-application, pedagogical-didactic and theoretical-metascientific relevant pillars. It is also necessary to maintain an external balance of information flows between the individual pillars. At the same time, the theoretical-metascientific pillar has a key position in maintaining the stability and cohesion of the system of these pillars.

CONCLUSIONS

A metascientific analysis and synthesis of the most important landscape ecological and ecological Mexican literature and the rich empirical-methodical and applied knowledge gained from it at the local and regional level together with many years of experience during the scientific-research, didactic and application activities of the co-authors of this article can be stated that in Mexico:

→ Origin and development of landscape ecology in Mexico must be understood in the natural, socio-scientific and spatio-temporal context of development of ecology in America, Latin America and Ibero-America;

→ Mexican landscape ecology, lying at the intersection of European and American landscape ecology, can be described as integrative, idiographic-nomothetic at the spatial level of the landscape in the contact zone of European and American research approaches and principles;

→ Mexican landscape ecology based on the original Mexican ecology, which influenced the empirical-methodical, theoretical-metascientifical, applied and didactic nature of landscape ecological research in Mexico;

→ Mexican basic landscape ecological research is focused mainly on biodiversity, development of land use, ecological carrying capacity and ecological profiles;

→ Mexican applied landscape ecological research focuses mainly on the issue of sustainable development, ecosystem services, impact assessment environment and natural resource management;

→ Mexican theoretical landscape ecological research is focused mainly on ecosystem theory, theory of landscape ecology, theory of landscape structure and „island“ theory;

→ Without intensive and permanent elaboration of theoretical questions of landscape ecology it is not possible to ensure the progress of landscape ecology in Mexico as a whole;

→ Research into meta-landscape ecology will need to be explored, taking into account its general nature. This will make it easier to understand the ever-increasing natural and social complexity of ecological-environmental and socioeconomic problems in the Mexican landscape;

→ There are no specialized academic programs in landscape ecology in Mexico, but there are multiple opportunities for studying this discipline;

→ In Mexico it is crucial to increase the resources allocated to the training of professors and researchers in the field of landscape ecology and to strengthen the institutions that carry out education and research in landscape ecology;

→ Maintain a qualitative and quantitative balance between theory and practice of landscape ecology, as well as between basic and applied landscape ecological research, which is one of the main conditions for future development of landscape ecology in Mexico;

→ Applied (landscape) ecology was used mainly for Ordenamiento ecológico, Biodiversity conservation, Sustainable development, Ecosystem services, Ecological zoning, Impacts on the environment Natural resorces management, Regional planning, Environmental planning, landscape ecological planning, etc;

→ It also implies that one of the main conditions for the future development of landscape ecology in Mexico is the intensive cooperation of landscape ecologists, ecologists and geographers in the framework of basic, applied and theoretical research;

→ Necessary condition for outlining the potential future development of landscape ecology research trends in Mexico is a metascientific synthesis and a generalization of its hitherto evolution together with accumulated empirical-methodical, theoretical-application and didactic landscape ecological knowledge and experience and

→ From the Mexican point of view is very important to outline the possible future cooperation between ecology and landscape ecology as its branch at the organizational national, Latin American and worldwide level.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

RESUMEN

ECOLOGÍA DEL PAISAJE EN MÉXICO:
EVOLUCIÓN, INVESTIGACIÓN, EDUCACIÓN Y FUTURO
(ASPECTOS SELECCIONADOS TEORICOS y METACIENTÍFICOS)

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Propósito: El impulso para escribir esta contribución fue el esfuerzo de los coautores por acercar a los ecólogos de paisaje de Europa a la evolución, enfoques de investigación y didáctica y al posible desarrollo futuro de ecología del paisaje en México, desde el punto de vista teórico, metacientífico y aplicado. Fue un proceso de pensamiento de compilación y generalización según su objeto de investigación, enfoque y sujeto, que representan elementos del sistema metacientífico de la ecología del paisaje mexicano. El objetivo era adquirir nuevas cualidades y perspectivas generalizadoras y holísticas en el campo de la ecología del paisaje en México a nivel metacientífico.

Métodos: Para los estudios y evalución de la evolución de ecología del paisaje en México hemos utilizado el análisis metacientífico y la síntesis metacientífica de ecología del paisaje. Se elaboró el procedimiento metódico de dos pasos: el análisis metacientífico de ecología del paisaje y la síntesis metacientífica de ecología del paisaje, utilizando estudios mexicanos del ecología y ecología del paisaje, meta-científicamente orientados, complementados con nuestros estudios meta-científicos y nuestra experiencia personal en México.

Resultados: El análisis metacientífico y la síntesis metacientífica aportaron nuevos conocimientos, que representan el valor agregado y el significado de la evolución metacientífica de ecología del paisaje en México. La ecología del paisaje mexicana, situada en la intersección de la ecología del paisaje europea y americana, puede describirse como integrador, idiográfico-nomotético en el nivel espacial del paisaje en la zona de contacto de los enfoques y principios de investigación europeos y americanos.

Palabras clave: meta-ecología del paisaje, ecología del paisaje, evolución, investigación, educación, síntesis metacintífica, desarrollo futuro, México.

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