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Jörg Löffler und Uta Steinhardt

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LANDSCAPE ECOLOGY

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Herausgegeben von
Editors

Jörg LÖFFLER & Uta STEINHARDT

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With 3 tables and 9 figures

Mit Beiträgen von
With articles by

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Uta Steinhardt, University of Applied Sciences, Eberswalde;
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Foreword

This volume of the *Colloquium Geographicum* is based on a conference meeting held in Bonn in February 2005. The aim was to summarise current research philosophies in German landscape ecology. We tried to ascertain if there are common approaches that might be used to develop visions for joint scientific activities in the future. Fundamentals and traditional approaches served as a basis for a discussion of current paradigms.

The articles presented in this issue shall stimulate further discussions about arising visions in landscape ecology based on fundamentals and paradigms of different disciplines. The editors wish to motivate those scientists and operators who focus on human-environment research to be critical of the status quo of landscape ecology.

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1 Fundamentals, Paradigms and Visions in Landscape Ecology

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1.1 Introduction

NEEF (1967) introduced a theoretical basis for the analysis of landscapes forming a geographical viewpoint. Neef also stressed the need for such a theory since landscape ecology in his opinion is a discipline "between the chair" of natural and social science and it will stick to this situation as long as landscape ecology adopt its theory from those sciences. Therefore, the design of a theory of landscape ecology is crucial and his "Theoretische Grundlagen der Landschaftslehre" (NEEF 1967) shall be a starting point from which a true landscape ecological theory is developed.

The *Landscape Ecology* by FORMAN & GODRON (1986) offers a way of understanding the structure, functioning, and dynamics of landscapes altered by disturbance, whether caused by humans or induced by natural forces. The theoretical assumption underlying this book – that all landscapes, from the wilderness to the central city and from the "natural" to the "developed", share a similar structural model – is an important one. The book outlines a powerful model – a spatial language for analysis – that enables one´s to look at the disturbed and undisturbed landscapes in a new way. It opens the possibility of taking a more comprehensive and synergistic view of a considerable amount of literature in ecology. The language of landscape ecology offers the possibility of a mediating role between natural scientists and designers of landscape.

In their book *Landscape Ecology, Theory and Application* NAVEH & LIEBERMAN (1994) regard landscape ecology not merely as a spatial ramification of population, community, and ecosystem ecology for the study of ecology of landscapes, but also as an innovative, dynamic, and integrative field of environmental study and action in its own right. The authors regard a landscape as a concrete, ordered whole of natural and human systems at different scales. To express this integration of natural and human systems, they introduce the term *total human ecosystem*. This book is a great movement to a broader transdisciplinary and holistic conception of landscape ecology, moving away from the narrower, bio-ecological, conceptual, and methodological framework, which has previously characterized much of landscape ecology stateside.

According to the "*Landschaftsökologie*" by FINKE (1994), landscape ecology aims at investigations concerning ecosystem coherences and their quantitative registration. In doing so the totality of all factors and agents shaping the landscape has to be included. Given that the field of activity of landscape ecologists involves the bio-, hydro-, pedo-, litho- and atmosphere, the landscape ecosystem is investigated by different departments and disciplines. Though the fundamental idea claims a holistic approach, the landscape ecosystem has to be subdivided into subsystems due to practical reasons. Landscape ecologists are required to demonstrate a stronger political dedication; they should no longer leave their results for implementation by policy makers without including their own valuable comments. For these purposes natural scientific facts have to be preprocessed by methods of social sciences and expertise.

In his "*Landschaftsökologie – Ansatz, Modelle, Methodik, Anwendung*", Leser (1997) considers landscape ecology as a special field between scientific disciplines and different fields of practical application. The development of landscape ecology in central Europe and especially in Germany is analysed, and fundamentals and definitions are discussed from the point of view of physical geography.

The textbook *Landscape ecology* by Turner et al. (2001) stands in the tradition of Forman & Gordon (1986) as well as Naveh & Lieberman (1994). The authors regard landscape as an area that is "spatially heterogeneous on at least one factor of interest". Thus, landscape may extend just over tens of meters rather than kilometres and can even be defined in an aquatic system. Landscape ecology is considered as an interdisciplinary science where human interactions with nature are included, naturally. But, landscape ecology is also regarded as a sub-discipline of ecology and an interdisciplinary area of research and application beyond ecology. The interaction between spatial patterns and ecosystem process, that is the causes and consequences of spatial heterogeneity of landscape, is emphasized, and so the quantification of patterns and process is presented comprehensive. Moreover, the importance of scales is stressed.

Development and Perspectives of Landscape Ecology (Bastian & Steinhardt 2002) is a comprehensive and cohesive expression of, and exposure to, German and European approaches to this science. The editors first review the short history of landscape ecology as a young transdisciplinary science dealing with the solution of environmental problems, and elaborate on disciplinary-to-meta-disciplinary approaches in landscape ecology. The book stress the need for a transdisciplinary system approach in science, saying that transdisciplinary landscape ecology has the ability to bridge gaps among disciplines on the one hand, and between science and society on the other. It therefore represents a post-modern science dealing with the complexity of the 21st century. In the perspective presented, this would be the end of linear and the beginning of non-linear system theory in landscape ecology.

The *Lehrbuch der Landschaftsökologie* by Steinhardt et al. (2005) was recently written by the Potsdam school around Heiner Barsch. The aim of the publication was to write a new textbook that would combine theories and practice within landscape ecology. It is mainly addressed to students and is based on the idea of linking the Anglo-American and central European philosophies.

Wiens & Moss (2005) recently published a collection of essays in their book *Issues and Perspectives in Landscape Ecology*. The essays provide an overview over the "rich tapestry of viewpoints and perspective that make landscape ecology at once a well-definied and yet also a frustratingly diverse discipline". According to Wiens & Moss (2005) the promise of landscape ecology lies in its integrative power and its demands to work with different disciplines. Landscape ecology is truly interdisciplinary, but landscape ecologists should be aware of the risk to splinter into sub-disciplines. Therefore, landscape ecology needs to become conceptually and operationally unified (Wiens & Moss 2005).

1.2 Is landscape self-organized?

Dr. Felix Müller (University of Kiel, Germany) used several project approaches to answer the question if landscape is self-organised. His contribution with a very thorough use of references is located „between the chairs“ and fulfills high theoretical claims at the same time. Based on the fact that landscape exists along a continuum of scales, the functionality of landscape systems can only be successful if both small-scaled processes, like the exchange of water at stomata or microbial activity in soils, and large-scaled processes, like global circulation, are considered.

The discussion of different theoretical concepts reveals that there is a problem of communication: Landscape ecologists create new terms like "Holon" (KOESTLER 1969, NAVEH & LIEBERMAN 1994), "Orientoren" (MÜLLER & FATH 1998), or "Econ" (LÖFFLER 2002), or they adopt terminology from other disciplines, like "health" from medicine. Many physical terms in particular find a metaphoric usage in landscape ecology, where they are not used for the solution of a problem of prediction but for communication. Of course, terms are created in science for the solution of a problem. In this context it seems legitimate to adopt existing terms from other disciplines in order to solve problems within one's own discipline. However, then one must cope with the question of which non-trivial predictions are produced with a metaphoric use of the terms. The abovementioned scale problem offers an exciting activity field in landscape ecology with regard to the investigation of spatio-temporal scenic phenomena. Until now, there is a lack of models that adequately describe the spatio-temporal dynamic of landscapes.

Regarding maps emerging from GIS-coupled modelling, one always needs to ask, on how much process-knowledge are these maps based? And on how much process-knowledge should these maps be based? How detailed do we need to work? A sufficiently exact process description is an inevitable prerequisite for the understanding of long-term landscape developments. Until now, the error probability of models is too large, so that, at best, only risk estimations are possible. With the involvement of detailed knowledge alone, no model improvement will be reached. This will be possible only if, at the same time, more knowledge about interactions becomes available and is integrated into such models. The method problem cannot be reduced to a data problem: simply attaining more area-wide basis data for larger spatial units brings no solution to the total problem. This becomes evident from many already existing "data-cemeteries". It is more important to provide necessary process data using indicators. Mineralization for instance is difficult to measure, but knowledge about, among others, the annual cycle of the water balance could enable conclusions to be drawn that would also be transferable to larger spatial scales. But here, a new problem arises: point data can only be transferred to spatial units if these units are characterized by the same environment. But the heterogeneity of landscapes is so distinct that the point-area transfer is seldom really justified. But how is scenic heterogeneity really comprehensible? At this point, one fails at measuring the immeasurable.

1.3 Driving forces in landscape ecology: past – present – future

Within the contribution of PD Dr. Felix Kienast (Swiss Federal Research Institute, Birmensdorf, Switzerland) landscape is regarded from an anthropocentric point of view, at which a sociological aspect is integrated right from the beginning. Authenticity of landscape must be seen as a decisive criterion for the esteem of landscapes. This leads to the question of how research programs concerned with scenic authenticity need to be designed and/or structured. Heterogeneity seems to be an important criterion and/or indicator of authenticity. This results in the need to antagonise the loss of heterogeneity, which accompanies actual globalization tendencies. In the context of the globalization trend, it becomes increasingly evident that driving forces of landscape development are to be sought in politics and socio-economics, i.e. in the development of the society. For instance human mobility is an image of economy, eventually. Thus, the development of landscape is not a phenomenon of natural science. Consequently, the "scientific optimization" of landscape (Koch et al. 1989, Grabaum 1996, Seppelt & Voinov 2002), as is often discussed, seems impossible. If the current condition of landscape is regarded as a result of a social and historic development, questions of the connection between heterogeneity and historic development arise: is the perception of landscape only possible based on the background of historic developments? Is every landscape a „charged landscape" – charged with historic information? Tradition is doubtless an essential aspect for scenic authenticity. However, scenic heterogeneity cannot be based solely on traditional knowledge; it needs to be promoted by new knowledge, as well. The receipt and the production of knowledge in the form of specialty competence becomes a key factor with regard to scenic authenticity and heterogeneity; otherwise, the forest dieback will soon be followed by a dieback of forest rangers. The positive evaluation of heterogeneous landscapes in human perception is both biologically (steppe theory: the cradle of humanity in the African savannah) and historically (image of a grown cultural landscape) motivated.

The quantification of ecological functions of a landscape using landscape metrics results in a very positive evaluation for several cultural-historical landscapes. On the contrary, landscapes changed by genetic engineering are monotonic and hence of much lower value. A reduction of the landscape towards landscape structure alone is inappropriate. For example a Disney-park has a heterogeneous structure and increases the diversity of cultural landscapes, but the effect on water- and matter-balance is homogenising. The determination of authenticity by heterogeneity and the synonymic use of authenticity, coherence and land scape character is not without controversy. This is obvious when the temporal variability of authenticity is queried. It is discussed in conjunction with nature conversation projects that aim to conserve cultural landscapes: Are traditional utilisations worth being maintained in museums, simply for their authenticity? For example, sheep-grazing is only practical with the support of subsidies. Recently, new loan programs have supported projects where old experiences are made again to stop the loss of competence. The latter is consistent with an increasing alienation - the counterpart to authenticity - of mankind to nature. The appreciation of nature is doubtless anthropocentristic and landscape can be explained by natural sciences alone. Hence, landscape dynamics have to be seen in the context of changes in societal values. In this meaning, landscape is an object, where systems of values merge. Authenticity is therefore a temporal variable, coupled to the current moral concepts of the society. An example: the straightening of the river Rhein by Tulla (1825) was an engineering feat in that time. The most fertile areas became secure of flooding and could be used for farming. Moreover, the navigability of the river was increased. Compared with the aims, it was a great success. But, if the negative consequences had been realised at that time, the project would have probably not been carried out in such a drastic way. There are more examples like this: The present water balance of Brandenburg that is characterised by a dramatic lowering of the ground water table is a result of decades, possibly centuries, of hydrological land improvement. This implies the need to be aware of the long term effects of landscape intrusion. Landscape ecology can fill such a niche for which no one has been responsible. Predictions are based exclusively on scientific understanding of processes. An understanding of processes based on history stays unconsidered, but is essential.

1.4 Landscape ecology – a scientific discipline or transdisciplinary platform for research and application?

Following Prof. Dr. Hartmut Leser (University of Basel, Switzerland) landscape ecology is a transdisciplinary scientific group that uses geoecological methods to analyse human-environment systems. There is an antagonism between geoecological-driven research and transdisciplinary needs. Hence, it is doubtful that a synthesis analysing a human-environment system can be done by a single person. It might be practical in small catchments, but as the investigated area becomes bigger it becomes unrealistic. The possibility of synthesis must not be a question of spatial extension, nor should this be a technical question. Landscape ecologists would claim, rather, that the challenge of syntheses is a question of a holistic understanding of landscape..

In principal, the cooperation of different disciplines is practised with regard to a certain problem. According to this, landscape ecology is an application-oriented discipline with landscape as its patient. Landscape ecology needs both an application orientation and fundamental research. The latter should be situated at universities, the former at universities of applied sciences. Scientific disciplines provide for the development of methods, both in the case of fundamental research and in application-orientated research for all kinds of scientific questions. This is confirmed by experiences done within the great research projects (Solling, Bornhoeved, etc.). These projects were not just based on natural sciences, and human ecology was so important to natural science that it was not conducted by human ecologists alone. Relevance for society is not only obtained by transdisciplinary problems - a *Science* paper could be relevant for society, even if not for several decades. Answers to the question of the self-image of the landscape ecologist range from "young Humboldt" to "measuring geo-ecologist". Moreover, the answer produces the other question if landscape ecologists are characterised by transdisciplinarity. Whether landscape needs its own scientific theory is answered positively, not only by Carl Troll, but also by Ernst Neefs "Theoretische Grundlagen der Landschaftslehre" (Neef 1967). The constant rethinking of this question is on the one hand the result of a poor transformation of this theory - that was founded by Neef and developed by

HAASE (1964, 1978) and RICHTER (1968) - into other disciplines. On the other hand, we forgot to read this theory in the right way. The challenge therefore is not to develop new theories, but to apply this existing theory and to improve upon such disadvantages as scales and hierarchies.

1.5 Landscape ecology: a scientific self-conception of research fields and objects

Within the frame of the SFB „Entwicklungskonzepte für periphere Regionen", PD Dr. Rainer Waldhardt (University of Gießen, Germany) pointed out that landscape ecology focuses on the interaction between species diversity and landscape structure of rural areas. The investigation of the interaction between diversity of wild bees and landscape structure is part of this SFB, but the question arises of whether to classify the study into a certain discipline. Is this project landscape or agro-ecology? Are there differences and similarities, respectfully? This article reaches the conclusion that „real" landscape ecology can only be done within a SFB. If the above mentioned animal ecology project is only background information for modelling *spatial ecology*, then zoologists are just required as servants to obtain the data within the SFB. Landscape ecological research should always have the standard to practise interdisciplinarity. This statement requires the analysis of abiotic factors that were not mentioned within this project. Spatial investigations of the water- and matter balance may serve as explanatory patterns of the distribution of wild bees and the phytodiversity. Within the project there was no coupling to abiotic factors, only to habitat types. The latter were used to extrapolate the species abundance to a great spatial extent and served as a basis for the modelling of species diversity. This is done methodologically by point measurements, a regionalisation based on GIS-techniques and modelling of landscape structures.

It is a danger to regard landscape in this context just as scenery for the distribution and the behaviour of species. Regarding the landscape as a complex structure of functions needs the inclusion of abiotic patterns of processes. The water balance has an effect on wild bees as well as the micro-climate: these aspects were not regarded in this project. It was retorted that there was no need to analyse the whole landscape, but only to concentrate on the specific problem. This problem determines the number of parameters to be analysed. Moreover, it was not the aim of this project to explain the function of the ecosystem, but rather to understand the landscape functions. This statement has to be criticised since landscape functions are just causal if the ecosystem is understood. Another problem that has to be considered is the question of transferability of the results of models. A transfer to other regions is only allowed if all determining parameters are implemented in this model and statistically proved. The basic standard of transferability of methods is essential in landscape ecology. But, even the centres for ecosystem research were not able to develop the "real" ecosystem-model.

1.6 Definitions in ecosystem research exemplified by „ecosystem" and „sustainability"

Professor Dr. Michael Hauhs (University of Bayreuth, Germany) recommended the fundamental resolvability of problems. However, reorientation towards interactivity and memory is Indispensable. This is essential against the background of the dieback of experts with an overview of knowledge, and the devaluation due to recent environmental changes, respectively: Knowledge gets lost faster than explanations substitute it. The production of knowledge already antiquated is one risk. So, how long is the half-life period of knowledge? Crucial to this is the picture we have of ecosystems – a picture not only based on natural science but on an understanding of processes involving human behaviour as well. Knowledge of experts has to get operationalised, too. Models to educate landscape managers are consequently more valuable than scientific explanation models. The deduction of „key aspects" of expert reactions that are reproducible is a basis of these models.

The objection that experts do not give the right solution at any time or that they were mistaken – there are some examples from agro-management - can be countered by the fact that antiquated knowledge was used in these cases. This example shows that it is still not clear if failures of anthropogenic or technical origin triggered environmental problems. Complex problems are not solvable with function-analytical-deterministic approaches alone. It is possible to develop a simple (trivial) forest management system, but the integration of land management systems of other land users (farmer, fishermen, etc.) in case of regional planning fails. These problems are not solvable yet. Regional planners may be similar to pilots educated with a flight simulator: pilots are educated on real situations in a virtual world; regional planners have the challenge to realise a virtual situation into the real.

Essential for these new models are interactive influenceable reciprocal action-chains. This clarifies two different kinds of handling problems in principle. Models need not to describe nature exactly, but the behaviour of actors. It has to be scrutinised if logical structuring of the problem is a necessary assumption to describe patterns of behaviour, because, apparently, behaviour is not essentially logical. If the description of behaviour instead of the description of structure is preferred, then one comes across the phenomenon that the description of behaviours needs a structural frame. But, it is possible to choose the behaviour realistically without any structure. For example, a flight simulator (= behaviour) needs no engines (= structure), just like forest management can be done without considering photosynthesis. Validation of expert knowledge can only be conducted by experts themselves. Using the potential of information technology, 100 years of forest management can be practiced within 12 minutes, if consistent patterns of reaction from the experts exist.

1.7 Urban ecology = landscape ecology of the cities?

Urban ecology as to PD Dr. Martin Sauerwein (University of Halle, Germany) is based on a conception of research that integrates human ecology. Humans are at the same time constructors, causers, users and sufferers of the urban ecosystem. In principal, humans can be regarded as a passive changer of the framework or as an acting, human, ecological, and social part of the urban ecosystem. Following the former definition, the ecosystem is not explainable in full. The same statement is true if an analysis of an urban ecosystem does not include the surrounding area. But, which scale needs to be chosen to include all relevant processes? This is comparable to water ecosystems that are only explainable by regarding the structure and the dynamic of the total catchment area. In the context of urban ecology, structural types of the city are regarded as representative concerning matter and energy balance. Analyses of the matter balance in an urban area need to also include fluxes of information and capital, not only matter and energy fluxes.

The assignment of measurements to structural types of an urban area and the methodology of the measurements has to be discussed critically. Fluxes of capital and information in terms of their impact on builders influence the development of structural types of urban areas, in particular. In this context the discussion of space should be mentioned: Normally, decisions are based on the anthroposystem - mainly the interaction of social, political and economical networking - and are completely independent from structural types of urban areas.

Finally, the idea of urban nature conservation has to be mentioned. The usage of the term "nature" within an urban area has to be scrutinized: For example, the city provides good thermal conditions and acts sometimes as a habitat for endangered species. Hence, nature conversation takes place in an area created by humans.

1.8 Discussion and conclusions

Landscape ecology is considered as an interdisciplinary research field consisting of different disciplines. The challenge of landscape ecology is the analysis of interactions between landscape functions and land use patterns as well as their impact on the temporal dynamics of the landscape. It became apparent that the approaches of human ecology and natural sciences are contradicting, thus far. But, this is the essential characteristic of environmental systems. Therefore, we have to cope with the fact that some processes are not causal or linear, and that physical approaches are not practical.

Techniques are not the suitable answer to this contradiction of approaches. Much effort and hope have been spent on models, without any solution to the man-environment problem. Models have been developed for prediction purposes but are often used only as a communication tool. Aside from natural scientific and human scientific dimensions, further dimensions have to be regarded: Approaches oriented toward problems are to be distinguished from approaches of fundamental research and prediction. Landscape ecology as a comprehensive discipline can be practised by different disciplines. If landscape systems are regarded as man-environment systems, humans are not reducible to their matter and energy parameters. The integration of human scientific approaches is essential. Thus, interfaces between human science and natural sciences have to be identified and then filled by anthropogenic input parameters. The change toward enlisting human scientists is project dependent, because the meeting of different competencies happen at varying levels for varying problems. The landscape concept (Neef 1967) offers theoretical interfaces from a physical geographical point of view, but it will not be suitable for a new nature-society science.

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2 Discussing Landscape Ecology – A Dialogue between two Espressi (with a typical male distribution of the roles)

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2.1 Introduction

Visions need new perspectives. Thus, this contribution is entirely different to well-known research, perspective or review papers. Nevertheless is has elements of all of these types of publications summarizing and thinking ahead landscape ecological research and its perspectives.

2.2 Discussion

It was a November morning. The smell of two freshly percolated espressi dispersed in front of the large window of the cafeteria. Town centre and Limmat were approximately hiding from being seen from the roof of the ETH main building. Tony was impressed by the entire ETH building with its secret stairs to the lecturer's coffee bar and now got frustrated looking through the glasses.

Susan: That was hard stuff yesterday.

She was referring to a lecture Tony gave at her institute yesterday. They both knew each other from a conference some years ago and thus she invited him to present his work at the landscape ecology group of her institute.

Tony: Hmm.

Susan: All these systems, complex models and math-equations you presented ... what does all this have to do with landscape ecology?

Tony: What?

Susan: I mean you are talking about very abstract physical and mathematical ideas. Isn't that far away from landscape ecology?

Tony: Hmm, no. I think they are right in the focus of it.

Susan: Surely you are joking, Mr. You have a professorship for this field, haven't you?

Tony (frowning): Professorship for joking? Well, so tell me, what is landscape ecology?

Susan: You should know, as you have to teach it. But o.k., let me see if I can help you. Some people say the major question of landscape ecology is studying pattern–process interactions[1], other people say this there are a multitude of interpretations of this pattern-process-paradigm that may have caused a divorce of U.S. and German or Dutch-speaking scientists in this area of research[2]. Some people say landscape ecology is interdisciplinary[3] - or more rigorously they promote trans- or multi-disciplinarity[4] as a *conditio sine qua non* of landscape ecology. And finally I have read recently that "landscape" is a too imprecise term with a too high diversity of meanings to be used in the definition of a scientific discipline at all[5].

Tony: ...and others think that landscape ecology is an advanced form of gardening. To cope with this diversity of meanings, let me first of all ask: is the definition of "landscape" really a prerequisite for the definition of landscape ecology? Most people would agree on this[6]. But I feel this is a scholastic question, competing for exact definitions by neglecting urgent research needs. However, just for pragmatic reasons, I would like to tackle the problem like philosophers often do. They use terms and phrases in their discussions before finally defining or explicating these. My feeling is that this might be an appropriate procedure here as well. Look, there are projects studying biodiversity as a function of landscape(structure) resulting in papers that relate landscape structure on different scales to species movement[7] or species distribution[8]. This is what habitat suitability models tell you[9]. Looking at studies[10] related to the EU Water framework directive (2000/60/EC)[11], the landscape a watershed with its land use and the anthropogenic impacts. Other landscape scientists concentrate on energy or matter flows and storages in a certain area[12], or they investigate disturbance regimes influencing landscape pattern[13]. In all these cases everyone has his own, very distinctive picture of landscape, or let's say of his object of investigation, which of course should imply ecological problems and a spatial extent, granularity and scale.

1 GODRON (1986), TURNER et al. (2001), WARD et al. (2002)
2 STEINHARDT et al. (2005)
3 ZONNEFELD (1995)
4 NAVEH & LIEBERMANN (1994)
5 STEINHARDT et al. (2005)
6 BASTIAN & STEINHARDT (2002)
7 BOWNE et al. (1999), DANIELSON & HUBBARD (2000)
8 DEWENTER (2002), PATTEN (1992), GITHAIGA-MWICIGI et al. (2002), SÖNDGERATH & SCHRÖDER (2002), WESTPHAL et al. (2003), WALDHARDT et al. (2004)
9 MORRISON et al. (1998), KLEYER et al. (1999), GUISAN & ZIMMERMANN (2000), SCHRÖDER & REINEKING (2004), SCOTT et al. (2002)
10 e.g. DONOHUE et al. (2005)
11 EU, 2000. 2000/60/EC, EU Water Framework Directive. Official Journal (OJ L 327). European Parliament, Bruxelles.
12 BURKE et al. (1990, 2002), LESER (1997), MOSIMANN (1984), KUUSEMETS & MANDER (2002), JONES et al. (2001), BORK et al. (1998), WICKHAM et al. (2003)
13 RYKIEL et al. (1988), COFFING & LAUENROTH (1989), TURNER et al. (1993), HAYDON et al. (2000), COUSINS et al. (2003), CARMEL & FLATHER (2004)

Susan: Isn't this much too pragmatic? You'll tell me we do not need to define "landscape"?

Tony: Actually, yes. Or if we have to, we should define it in a pragmatic way, like: "A landscape is an area that is spatially heterogeneous in at least one factor of interest."[14] This means: our interest, the research question defines the relevant heterogeneities and relevant scales and thus: the landscape. *(Looking out of the window)* Try this one: Do cities belong to landscapes?

Susan: Hmm, no?

Tony: Wrong. It depends. If cities are functioning as important driving components of an environmental process in a part of our environment, I - as a landscape ecologist - have to cope with questions of urban ecology[15]. Susan, actually I believe, we do not need to provide an absolute definition of "landscape". Our research is focussing on the investigation of spatio-temporal dimensions of environmental processes, especially on those spatial and temporal scales at which human impact is visible.

Thus, let us start doing our work and forget about the infinite feedback loops of defining what "landscape" is. You won't be successful from scratch. Ontological questions may be answered specifically for each problem; if and only if, we run into problems along a project, start thinking about an explication of "landscapes". And then we should choose a simple understanding of landscapes that everyone involved can accept.

Susan: But in this case, there is no identity of the discipline! Then ecologists do the research of landscape ecologists!

Tony: Yes, sure, if they work with ecological phenomena in heterogeneous environments. Why not? The interactions of organisms and their environments can be studied from many different viewpoints. Hmm, see, in Germany there are several universities with a very successful curriculum called "Geoecology". Ecological processes are studied within a spatial context. The classes have a strong background in system science and math. They study biology, soil science, climatology, hydrology, physics, chemistry, environmental law, and math. They tackle water and matter transport processes as well as biotic processes using mathematical modelling. Grad students from "Geoecology" start their Ph.d. courses in biology, chemistry, landscape ecology,... where ever. The basic definition of ecology offers many equal approaches to our subject, and we shouldn't have any rejections against this.

Susan: But this holds true for landscape ecology, too. Is Geoecology an accepted independent science? I do not think so. And – in comparison with physics, chemistry, or mathematics – I am afraid landscape ecology isn't, as well.

Tony: No, that's not correct. Although we have discussed the high diversity of approaches before, of course there is a common object of research. There is a common methodology. There are common theoretical ideas. There are national and international

[14] TURNER et al. (2001)

[15] HOULAHAN & FINDLAY (2004), PICKETT, et al. (2004), BACCHINI & BADER (1996)

scientific societies. There is a scientific journal with a fairly good impact factor[16]. And it is my strong belief, that there are several developments from landscape ecology that have influenced other disciplines.

Susan: Surprise, surprise. Do you have examples?

Tony: You can find them whenever environmental processes are observed from a spatial point of view, whenever local distributions and configuration of ecosystem components are investigated. We may even go further and ask for one example of ecological interactions which is not dependent on location or space – that will be hard to find. Thus, there are lots of examples like ecology itself, meta-population biology, vegetation science, zoo-ecology, conservation biology, biogeography, hydrology, or environmental management, just to give some examples[17] etc. They all use the concepts of landscape metrics, work with GIS, and try to analyse the effect of spatial pattern on their response variables.

Susan: ... Wait. So you want to tell me that we are the centre of the world? Why isn't there anybody else believing this?

Tony: May be not totally in the centre, but not at the total periphery, as well. Another point: as we have agreed before, environmental problems have become more and more complex problems. Several processes interact over large distances due to nonlinearities in the transport behaviour, chronical de-localised effects, or due to complex food webs[18]. In a complex world, complex problems have to be solved. Therefore, disciplinary limits are loosing significance[19]. Solving and - may be much more important - understanding these interaction requires an interdisciplinary approach[20]. Thus, discussing disciplinary crises of scientific self-confidence may be contra productive if you refer to the problems which are waiting to be solved!

Susan: Oh, good to remind me. This is what I was noting in the beginning. It seems that you do not want to be found within a well-defined, enclosed "home" discipline, which provides security, orientation and comfort. Do you really believe that these trans- or multi- or interdisciplinarities are core attributes of landscape ecology?

Tony: What about "meta-disciplinarity" as another buzz word? On the one hand, sitting between the chairs can be rather comfortable and quite productive. On the other... , well, let us use a metaphor: As I know that you like hierarchy theory[21], we can create a hierarchy of problems. You will find different problem-holons, operating on different

[16] Impact LandEco:1999: 1.40; 2000: 1.41; 2001: 1.86, 2002: 1.68; 2003: 1.08

[17] e.g. Levin (1992), Wiens et al. (1995), van der Maarel (1996), Poff (1997), Ward et al. (1999), de Blois et al. (2002), Pinay et al. (2002), Watson (2002), Wiens (2002), Wolanski et al. (2004), Coulston et al. (2005), Sivapalan (2005), Wiegand et al. (1999, 2005)

[18] Ben-David et al. (1998), Philips et al. (1999), Ricotta (2000), Nakano & Murakami (2001), Ernoult et al. (2003), Baxter et al. (2005)

[19] Daschkeit (2000)

[20] Schönthaler et al. (2004), Müller & Li (2004)

[21] Allen & Starr (1982), Allen & Hoekstra (1992), O'Neill et al. (1986), Hari & Müller (2000)

spatio-temporal problem-scales. Each of them demands for a certain methodology to be understood and to be solved. Your "home" discipline might not be able to find a solution alone. So you look for persons who can help you analyzing the non-"home"-holons on their very specific scales with their very specific methodologies. Having done this you cannot define a scientific discipline saying it covers the disciplines a, b and c. What you need could in fact be called a meta-discipline, with a meta stability – keeping in mind the short half-life of these buzz words – perhaps necessary for that one project only. If we want to continue using metaphors, we could assign them to the dynamics of Holling's adaptive cycles[22] and insert Kuhn's paradigm shifts as basic elements of the "meta-disciplinary dynamics"[23].

Susan (while he was talking, she started sketching a figure on the back of an old flyer): No, no. You are playing with words. Let us return to our subject: As far as I got you, you'll suggest to work with the term "landscape" for pragmatic reasons, explicating wherever necessary and you tell me to define landscape ecology as focussing on environmental problems, which is a pragmatic definition again and doesn't make landscape ecology unique compared to other disciplines. So my last hope is the object, and I'm afraid you'll argue for a pragmatic solution, too.

Tony: Be patient, there will be some theoretically founded good answers.

Susan (still drawing): What I mean is: how do we perform our research? We cannot put a landscape into the lab, can we? What we need are really good tools to collect all information. Most frequently we do not have sufficient data, or we get overwhelmed from all the data obtained from remote sensing. We need complex software tools like GIS to compile and analyse our data. And this rarely helps to reduce complexity. And you told us yesterday that modelling can be a tool for structuring and solving all these problems. However you came up with more and more complex systems, the number of model equations was increasing more and more and finally your showed us all the limits of simulations by a simple Lottka-Volterra-example[24].

Tony: Got you. O.k. there is a lot of limitation and there are constrains of the modelling aspect, for instance start a discussion on uncertainty involved in ecological models[25]. Or just look at the questions of validation, verification etc[26]. Or, think about the question of integrating different model structures[27] or at the lost optimism concerning models of whole ecosystems or take a view on the debate of the real potential of models for predictions or forecasts.

However, the core idea is fine. A systems approach helps to cope with complexity, to reduce complexity and much more to solve the questions we raised above: We do not need to ask what is "landscape", we need to ask what the system of interest is and which

[22] Gundersson & Holling (2003)

[23] Kuhn (1962)

[24] Seppelt & Richter (2005)

[25] Finke et al. (1999), Beven & Freer (2001), Jager et al. (2005)

[26] Oreskes et al. (1994)

[27] Beckling & Asshoff (1996)

processes are interlinked in this system[28]. And again, modelling, simulation and system analysis are of course interdisciplinary fields of research[29]. However it has a proven base in systems theory[30] and this is what landscape ecology needs to make use of[31].

Susan: O.k. thus you vote for using systems science and math as a general language and as the methodology for integrating different disciplines. I feel that there are multiple conceptual and methodological problems arising from this concept. How do you maintain communication in such interdisciplinary teams? Do they understand your complicated math? Even yesterday just a few could follow your entire lecture – how do you motivate these guys? Managing this interdisciplinary must be a tremendous job in coordination and organization.

Tony: As I mentioned before the best way of tackling these problem is start doing good education either in undergraduate or graduate classes or in Ph.d. programs. For solving present and upcoming environmental problems as well as for doing high standard research we need students that are able to understand mathematicians as well as ecologists. And this is only possible if they have joined their classes. It's a matter of organization, of organizing curricula and organizing projects. You can learn this. We have to learn this.

But the more important issue is that there really is a deficit in putting together different methodological approaches and concepts, not only between for example landscape ecology and systems theory. Also within systems theory itself there are different paradigms of modelling. Thus, I read in Ecological Modelling[32] that "we have produced an enormous redundancy". This is especially true, because there are lots of different modelling approaches but there is not much to be found about integration.

On the other hand, there are several very good examples for the similarity of methodologies and applications in different fields, e.g. agent-based models are used to analyse population dispersal as well as the dynamics of urban-peri-urban traffic occurrence[33]. But these are specific examples. There are more concepts that have the ability to be general, interdisciplinary theories. I think of, understanding landscapes as hierarchies[34], or of searching for interactions between scales[35]. You can investigate landscapes as gradients of patterns and processes[36] or you describe their dynamics on the base of orientors[37]. There are many integrative ideas, however here we are really just at the beginning, and we are starting to develop a respective theory. By the way, what are you painting there?

28 Einschlägige Zitate
29 SEPPELT (2003), COSTANZA et al. (1993)
30 JOERGENSEN (2000), JOERGENSEN & MÜLLER (2000)
31 NAVEH (1994)
32 MÜLLER (1997)
33 GRIMM (1999), BATTY et al. (2003), TOPPING et al. (2003)
34 O'NEILL et al (1986)
35 ENQUIST et al. (2003), SEPPELT & VOINOV (2003)
36 MÜLLER (2000)
37 MÜLLER & FATH (1998), MÜLLER & JOERGENSEN (2000)

Susan: I'm still not convinced. But I see that landscape ecology can win a lot from quantitative and systems approaches, as other disciplines do. However, isn't this imported knowledge? Don't we just use these quantitative theories as metaphors in a non-adapted field of science? What about "endemic" theories in landscape ecology, are there any?

Tony: Do we really need those? What is the difference between ecological theory and ecological theory for ecologists working in heterogeneous environments? If we select a systems approach, we will have enough work to understand the theories of systems sciences. And whenever we apply these to landscapes, we are performing landscape theory. There may be difficulties due to the original methodological requirements which sometimes can hardly be fulfilled, but in many cases the causalities are obvious and parallels can be formulated whenever you check the basic requirements of the theories. Look at what ecologists have made out of thermodynamics, network theory or information theory . It works fine and the results are very interesting, provoking many landscape oriented questions.

On the other hand, in fact there is an "endemic" landscape theory. If you look at the ideas of Troll, Neef, Haase, Leser, Haber and many others, you will see that many of these theoretical ideas have been growing from directly the landscape aspect . The integration with systems theory has started later. So do not worry too much about this point.

I remember a discussion in Keith Beven's group in Lancaster. You know him? His filed is hydrology. At a seminar he raised the question "What do we really know in hydrology? We know water is moving downhill, anything more?" They haven't been able to find any other item after a long discussion. So, what do we really know in landscape ecology?

Hey, this sounds very pessimistic. My point is, there a rarely good intrinsic theory in a field of research.

Susan: Good to see that you are happy. Another open question is this: Is the anthroposhere part of a landscape or landscape ecology, or is it not? There are some general struggles about this question between, I think.

Tony: Is this really an important point of discussion? Do we really have a choice? Of course it is thrilling to study undisturbed ecosystems in Southern Africa, either because of a specific relevance, or for acquiring third party founding or for the location where your research is localized. And you can do really good research on this. But, mankind modifies ecosystems faster than ever and thus any science that deals with environmental issues needs to cope with anthropogenic influences , call it disturbance ecology or whatever. You cannot exclude man. It's a scholastic question, if landscape ecology is valid if, and only if , anthropogenic influences are considered – it's just a question of our research problem. And nowadays, many if not most urgent research needs derive from human impact. Remember: Landscapes cannot be put into test tubes. And furthermore, if you look at all the existing landscape definitions or at the ideas of the founders of the discipline: Man has always been included.

Susan: This is too weak I my eyes. But even including man has turned out to be not very helpful for ecology, although there are so many problems. Ecological arguments and environmental problems have lost significance in the public. Did you apply for third party founding the last month?

Tony: True, but I'm still pretty sure: If mankind will continue drawing ecosystem services from our environment in the same intensity as we do now, we'll face a 6th extinction and much more environmental problems that need to be solved more quickly. No, we build the stock of knowledge that we'll need in the next years. Still badly funded, but still important.

Susan: O.k. I agree: Environmental problems will be there with or without landscape ecologists. But what will we have to cope with? And what will be the scientific questions of the next year.

Tony: Just a moment. He grabbed his laptop out of his backpack and started his literature database, finally he opened a PDF-file with a Landscape Ecology paper and finally browsed to a table in this paper. There was a meeting on one of the last IALE conferences. Some of the big shots in landscape ecology met and discussed the top 10 research topics in landscape ecology. Jingle Wu and Richard Hobbs put this together into a perspective paper. They identified many topics we have discussed before. This is their list:

- ecological flows in landscape mosaics,
- causes, processes and consequences of land use and land cover change,
- nonlinear dynamics and landscape complexity,
- scaling,
- methodological development,
- relating landscape metrics to ecological processes,
- integrating humans and their activities into landscape ecology,
- optimization of landscape patterns,
- landscape conservation and sustainability, and
- data acquisition and accuracy assessment.

And as we heard from Felix Kienast, the IALE Switzerland has developed a similar list of future questions, including interesting items, such as the influences of demographic change, population mobility, virtual worlds, globalization, global change, etc. on the landscape. So, I think there is no reason for any frustration.

Susan: But...

Tony: Oh, Susan let us stop this discussion at this point. I don't want to be asked to write a perspective paper on this like Wu and Hobbs did. And if so, I'll do this in a similar manner like August et al. did in AIR. Or we can simply print the minutes of our talks today.

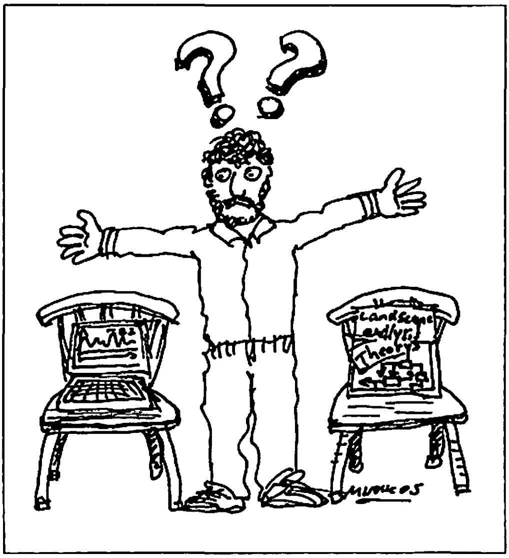

Fig. 1 Susan's illustration

Susan: O.k., but what are your specific plans?

Tony (smiling): what about another espresso? Turning to the coffee bar he smiled and asked for two espressi.

Susan (smiling, turns around the figure she sketched during the discussion and moves it to him waiting for his reaction, see Fig. 1).

Acknowledgements

Special thanks are to all who were involved in the discussion to this paper. Any similarity to former publication for instance by GALLILEO (1635) is intended as well as a possible association to the reason why Galileo wrote his scientific paper in the way he did it.

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3 The Collaborative Research Centre SFB 299: An example of landscape ecological research?

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3.1 Summary

All over Europe and beyond, extensive research on sustainable agriculture and multiple functions of agricultural landscapes, such as habitat function, has been conducted at various spatial scales. Main goals in this research field are the widening of knowledge and understanding of relations between land use and indicators of landscape functionality and the derivation of predictions on future trends in landscape functionality. Expertise of a wide range of specialists needs to be brought together in related interdisciplinary research at the landscape scale.

As an example of such research, the Collaborative Research Centre (SFB) 299 of the German Research Foundation (DFG) 'Land Use Options for Peripheral Regions' at Giessen University (Germany) is presented. This long-lasting interdisciplinary project comprises 16 subprojects in five thematic blocks. At the core of the project is the development of an integrated methodology towards the development and evaluation of economically and ecologically sustainable options for regional land use based on spatially explicit modelling. In two highly contrasting landscapes, ecological, technological, socio-economic and cultural concerns, as well as and spatial and temporal heterogeneity are simultaneously taken into account.

In view of the main goal, the interdisciplinary approach, and methodology the SFB 299 shows characteristics of landscape ecological research. The question whether or not the SFB 299 as a whole – or at least three subprojects that have investigated animal and plant distribution patterns – is an example of landscape ecological research, is discussed here by referring to four statements from leading landscape ecologists. These reflect well accepted aspects of perceptions of landscape ecology and reveal the multifaceted understandings of this scientific discipline. They focus on i) methodological questions referring to spatial heterogeneity, ii) the choice of spatial scales and elementary units, iii) appropriate techniques such as spatial modelling, or iv) the understanding of the term landscape and the necessity of applied research that aims to counteract ecological problems in landscapes.

3.2 Introduction

Over centuries, Europe's biodiversity has been strongly influenced by human impact. Due to agriculture, forestry, and settlement, nearly all terrestrial ecosystems have undergone multiple changes. In many cases, these changes have led to a decrease of biodiversity during the last century (FREEMARK, 2005). 'Managed' land as well as most terrestrial and aquatic ecosystems that are considered to be unsuitable for land use, have suffered from land-use related processes. To counteract these processes, the maintenance of biodiversity is an explicit policy goal in Europe (c.f. EUROPEAN COMMISSION, 2001) and beyond.

But, what is essential to counteract further ecosystem damages and to maintain biodiversity? Besides the protection of (near) natural ecosystems, such as moors, within the 'managed' matrix the implementation of sustainable land use, and especially of sustainable agriculture, is urgently needed. Although fundamental principles of sustainability (DRESNER, 2002) are well accepted and, after all, have been considered in forestry since more than 100 years (HÖLTERMANN and OESTEN, 2001), they will remain little more than hollow words as long as they are not widely applied to agricultural land management at multiple functional and/or spatial scales (e.g., patch scale, farm scale, landscape scale). The outstanding importance of agricultural land use is highlighted here, because agriculture is well known to cause severe negative effects on habitat function and thus on biodiversity over large areas. E.g., according to KORNECK et al. (1998) both intensive agricultural management and abandonment of marginal farmland, are amongst the major drivers of plant species loss in Germany.

The implementation of sustainable agriculture implies scientific research focusing on the development of sustainable land-use systems. At the patch scale, this research primarily requires collaboration of agronomists and ecologists. Expertise of a much wider range of specialists, including, e.g., economists and sociologists, needs to be brought together in research at broader scales. Furthermore, the maintenance of biodiversity is just one goal in this context. Multiple ecosystem / landscape functions and services, such as to provide land for production of agricultural goods, settlement and recreation, have to be considered to reach a balance between the ecological, economic and social requirements of sustainability. This is reflected in the slogans 'Multifunctionality of Agriculture' and 'Multifunctionality of Agricultural Landscapes' (e.g., EUROPEAN COMMISSION, 1999; BRANDT, 2003; RENTING et al., 2004; BRUNSTAD et al., 2005; FISCHER, 2005; MAYKOVIČ et al., 2005), again phrases that need to be filled with life.

All over Europe, researchers strive for this goal (e.g., GRABAUM and MEYER, 1998; ANDERSEN et al., 2004; DOBBS and PRETTY, 2004). In this spirit, the collaborative research centre (SFB) 299 of the German Research Foundation (DFG) 'Land Use Options for Peripheral Regions' was established at Giessen University in 1997. The main goal of this long-lasting interdisciplinary project is the development of an integrated methodology towards the development and evaluation of economically and ecologically sustainable options for regional land use, which are site-specific and economically differentiated (FREDE and BACH, 2002; cf. http://www.uni-giessen.de/sfb299). In this ongoing project, consequences of land-use changes on an extensive set of landscape functions have been analysed under consideration of multiple spatial scales and evaluated based on a model network (SHERIDAN and WALDHARDT, 2006).

In view of the main goal, the interdisciplinary approach, and methodology of this project – which will be presented and discussed in more detail in the following chapters – one may question whether the SFB 299 as a whole is an example of landscape ecological research for sustainable agriculture in Europe. To discuss this question (Chapter 5), principles and issues of landscape ecology are recapitulated based on four statements from leading landscape ecologists, and these statements then are related to the research in the SFB 299 (Chapter 4).

Hence, this paper addresses two main topics: How is research organised in the SFB 299, and what does landscape ecology mean in the SFB 299 context and beyond? For a better understanding, a breakdown of the organisation of the SFB 299 is provided in Chapter 3. The study areas for the development of methods, their application, and validation are briefly described next (Chapter 2).

3.3 Study areas of the SFB 299

Two regions were exemplarily selected as core study areas of all research groups in the SFB 299 (Fig. 1): The Lahn-Dill Highlands and the Wetterau, both in Hesse (Germany). Although the borderlines of the study areas are not in accordance with the

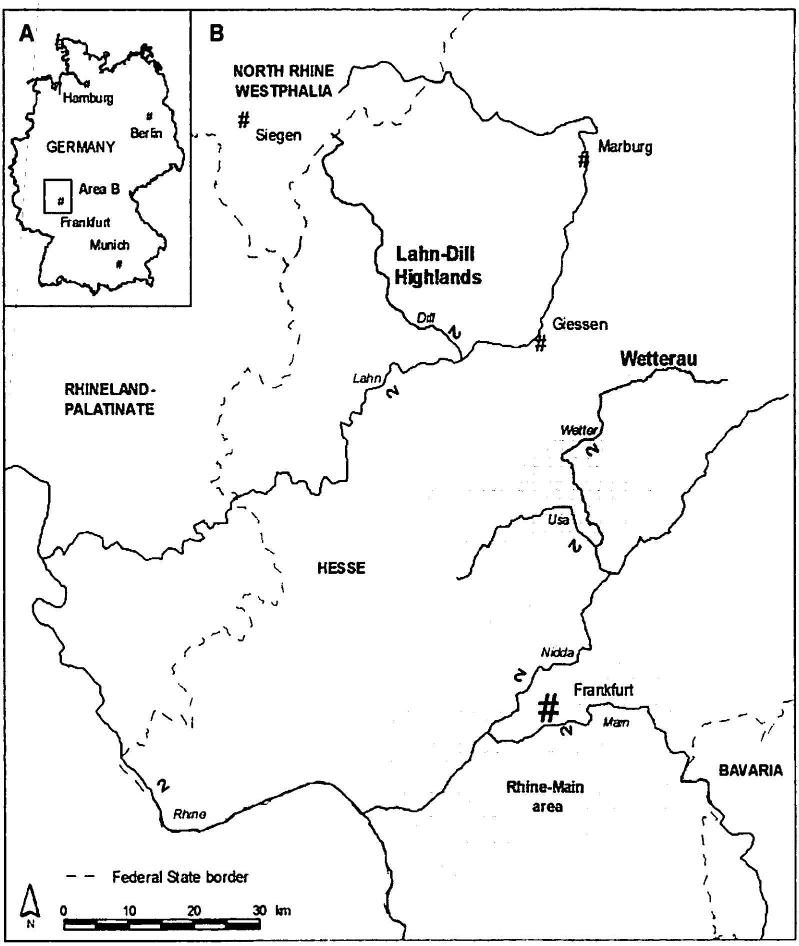

Fig. 1 Location of the study areas *Lahn-Dill Highland* and *Wetterau* in Hesse (Germany)

For details on the delimination of the study areas, see Chapter 2. The border of the functionally linked Rhine-Main area is according to ***Planungsverband Ballungsraum Frankfurt/Rhein-Main*** (http:/www.pvfrm.de/atlas/str/karte.html).

borderlines of two biogeographical regions sensu Meynen and Schmithüsen (1957) that bear the same names, the study areas are widely congruent with those. However, for reasons resulting from requirements of the SFB 299 model network (for details see Chapter 4), the delimitation of the Lahn-Dill study area is in accordance with the Dill watershed upstream of the gage station Asslar, while the Wetterau comprises the Wetter watershed down to its confluence with the tributary Usa.

The Lahn-Dill Highlands

From 1997 until 2005, research took place in the Lahn-Dill Highlands. This former mining area with altitudes between 200 – 600 m a.s.l. covers about 700 km² and represents the eastern ridge of the Rhenish Uplands (Rheinisches Schiefergebirge). The area is characterised by rough and rather damp climatic conditions (mean annual temperature: 6° - 8°C; average annual precipitation: 650 - 1100 mm) and a small-scale pattern of acidic shallow regosols to cambisols over Devonian clay slates and greywackes on upper to mid-slopes, and planosols to gleysols on lower slopes and alluvial plains (classification according to FAO, 1998). These unfavourable abiotic conditions, traditional heritage customs, and predominance of part-time farming are the main causes of a highly fragmented land-use pattern. About 57 % of the entire area is afforested, but agricultural land use (32 % of the area) still dominates the slopes and valleys (Reger et al., submitted). The mean field size is around 0.4 ha. Until 1960, about 25 % of the entire area was under arable cultivation (HSL, 1956). This proportion decreased significantly in favour of grasslands and old fields. According to Nöhles (2000), only about 10 % of the area was cultivated in 1998. Particularly in the western part of the area hardly any field is ploughed today (Reger et al., submitted).

Against the background of this directed land-use change, the area may be addressed as 'marginal region'. However, the region is also characterised by a steady growth of its settlements. This process is mainly due to the favourable access to employment markets in the nearby Rhine-Main area and, to a lesser extent, the cities and surroundings of Siegen, Giessen and Marburg. We therefore address the Lahn-Dill Highlands a 'peripheral region', and adopted this term for the title of the SFB 299 (Frede and Bach, 1999).

The Wetterau

From 2006 until 2008 research will concentrate on the Wetterau. Regarding land use and abiotic conditions, this second study area (300 km²) of the SFB 299 is highly contrasting to the Lahn-Dill Highlands. In the Wetterau arable cultivation has predominated since hundreds of years (Hildebrand and Kramarczyk, 1983; Schmidt, 1994). About 40 % of the entire area is under cultivation and about 60 % of the arable land comprises contiguous areas of more than 5 ha (Kühne et al., 2000). Forests (29 %) and grasslands (11 %) have relatively low proportions of the total area. The agricultural land use in the Wetterau is favoured by low altitudes (100 - 200 m a.s.l.), highly productive loess-soils (mainly luvisols and chernozems), and advantageous climatic conditions (mean annual temperature: 9° - 10°C; average annual precipitation: about 500 - 600 mm). Far more than the Lahn-Dill Highlands, the Wetterau is functionally linked to the spatially overlapping Rhine-Main area. This is reflected in increasing population density and settlement, and in an increasingly important trade market. However, due to its land-use pattern this study area of the SFB 299 is addressed an 'intensive agricultural region'.

3.4 The SFB 299: Breakdown of the organisation

Since 1997, the SFB 299 has been divided into five thematic blocks with, today, 16 subprojects (Tab. 1). At the core of the entire project is the development of the above named methodology (cf. Chapter 1) based on spatially explicit models (thematic block A: 3 subprojects) as part of the model network ITE^{2}M (Integrated Tools for Ecological and Economic Modelling). The developed models have been tested and at least partially validated using data that result from research in the thematic blocks B (soil and biotic data: 5 subprojects), C (agronomic data: 4 subprojects), and D (agricultural policy and political science: 2 subprojects). Coordination of research and scientific consultation has been improved by block E (2 subprojects).

However, communication and data exchange are not limited within a thematic block, but are common in the interdisciplinary project as a whole. Furthermore, since about 2000 modelling is not restricted to block A, but has become more and more important in several subprojects of block B (cf. Tab. 1). Meanwhile, 9 years after project start, modelling of relations between land use and variables that indicate landscape functionality is the research focus in both blocks.

Not all of the current subprojects have been part of the SFB 299 since its beginning and some subprojects ended before 2006. This results from in-between evaluations of the entire project after intervals of three years. In the first project phase (1997-1999), research in many subprojects focused on relations between land-use and dependent variables at the patch or field scale. Thereafter, and until today, research on broader scales has characterised the SFB 299. In general, basic as well as applied research has been conducted in most of the subprojects. Some examples are given in the next chapter.

3.5 Principles and issues of landscape ecology and their application in the SFB 299

In this chapter, selected statements of landscape ecologists reflecting well accepted aspects of their perception of landscape ecology are related to the research in the SFB 299. The compiled statements certainly do not reflect the multiple facets of landscape ecology. However, they highlight different views on and aspects of landscape ecology. As well, the given examples of research in the SFB 299 do not consider all the subprojects in detail. In this paper, research in the thematic blocks A and B is stressed. Thematic and methodological links to other subprojects of the SFB 299 are, however, pointed out, whenever necessary.

Statement 1

> *"Landscape ecology focuses on the reciprocal interactions between spatial pattern and ecological processes, and is well integrated with ecology. [...] Analyses conducted at multiple scales have demonstrated the importance of landscape pattern for many taxa and spatially mediated interspecific interactions are receiving increased attention."* (TURNER, 2005)

Tab. 1 Subprojects of the SFB 299 in the fourth project phase (2006 - 2008)

No.	Discipline	Keywords	Acronym*
A1	Farm Management	Value added and land-use patern; policy advice	ProLand
A2	Resources Management; Hydrology	Land-use dependent hydrological processes; surface runoff and interflow; water-mediated pattern of nutrients	SWAT-G
A4	Agricultural and Development Policy	Cost benefit analyses; trade-offs between landscape functions	CHOICE
B1	Soil Science and Soil Conservation	Soil pattern; geo-radar	
B2.3	Waste Management and Environmental Research	Land-use dependent concentrations of heavy metals and PCBs in soils; sorption behaviour of heavy metals in soils	ATOMIS
B3.1	Landscape Ecology; Vegetation Ecology	Land-use dependent floristic species richness; plant species pattern; probability of plant species occurence	ProF
B3.2	Landscape Ecology; Animal Ecology	Land-use dependent animal species richness	GEPARD
B3.3	Landscape Genetics; Gene Ecology	Land-use dependent genetic diversity and drift in and between insect populations	
C1.1	Grassland Management and Forage Growing	Year-round outdoor stock keeping of suckler cows	

C1.2	Animal Breeding and Genetics	Behavioural traits in cattle and sheep races	
C2.1	Plant Breeding	Oilseed rape variety types; low-input rapeseed cultivars	
C2.3	Plant Breeding	Relations between site conditions; genotypes and crop yields	
D1	Agricultural and Food Market Analysis	Regional income effects of producer support; effects of agricultural policy measures on gross transfers to farmer	
D7	Agricultural and Development Policy	Voluntary exchange of land	
E1	Biometry	Web-based information systems; GIS support; mathematical and statistical support	
E2	Resources Management	Secretary, project coordination	

subprojects modelling at the landscape scale

In the fourth phase (2006-2008) of the SFB 299 three subprojects (B3.1 to B3.3; cf. Tab. 1) explicitly deal with the ecological meaning of spatial pattern (i.e. landscape structure) under consideration of multiple spatial scales. In general, research in these subprojects concentrates on three questions: To what extent does landscape structure affect the distribution of plant and animal species, and genetic diversity? To what extent does species composition at the patch scale contribute to species composition at broader scales? To what extent does landscape structure influence species interactions?

In this context, extensive datasets on the spatial distribution of species ('response variables') have been collected at the patch and the landscape scale: Species composition has been documented for defined homogeneous patches (e.g., 25 m² within a field), and heterogeneous multi-patch-plots (e.g., 20 ha within a mosaic of arable fields and grasslands). Additionally, datasets on 'predictor variables' such as patch dependent soil nutrient levels have been investigated. Measures of landscape structure and dynamics (e.g., proportions of nonlinear and linear habitat types, age structure of habitat types) have been generated as predictors at the landscape scale, and both datasets have been related by means of sophisticated statistical methods (e.g., multiple regression analyses, multivariate GRM analyses, principal component factor analyses, partial canonical correspondence analyses, Mantel tests). The outlined research mainly aims at the derivation of quantitative relationships between investigated response and predictor variables, the testing of ecological concepts that enables modelling of future trends of biodiversity, and the validation of model results.

In these investigations, data collection und analyses have been mainly organised within one subproject. However, valuable data exchange between the three subprojects was carried out frequently. Additionally, data from other subprojects (e.g., soil data from subproject B1 and data on land-use practices from C1.1) and commonly available data (e.g., digital elevation models) have been included in the analyses.

Important results of the related empirical studies in the Lahn-Dill Highlands were: Landscape structure is of minor importance for the spatial distribution of plants, as mainly sessile organisms, than for the investigated animal groups such as insects and birds (e.g., DAUBER et al., 2003; HIRSCH et al., 2003; WALDHARDT and OTTE, 2003; DAUBER et al., 2005; SANDER et al., 2006; WELLSTEIN et al., accepted, submitted). Patches that form 'patch-neighbourhoods' (cf. FORMAN, 2002) in the agricultural landscape, differ in their contribution to landscape species richness. Linear elements and habitat configuration do not contribute to landscape species richness. Determinants of landscape species richness are in accordance to predictions that may be derived from Duelli's mosaic concept (SIMMERING et al., accepted). Species interactions and other ecological processes are determined by landscape structure. The degree of interaction and the spatial scale of relation differ between habitat types and species groups (e.g., SIMMERING et al., 2001; WALDHARDT et al., 2001; HIRSCH and WOLTERS, 2003; SIMMERING et al., 2003 a, b; PURTAUF et al., 2004; ZAITSEV et al., 2006). These results hold true for the highly fragmented agricultural land of the Lahn-Dill Highlands. Given the example of the Wetterau region, ongoing studies aim to explore the transferability of results to less fragmented landscapes.

Statement 2

> *"The realization that a system is not homogeneous [...] poses a dilemma that will recur throughout this work: the choice of spatial scale and elementary units."* (BUREL and BAUDRY, 2003)

The finding of meaningful spatial scales and elementary units has repeatedly been a crucial process in many subprojects and the SFB 299 as a whole. As already mentioned in Chapter 2, e.g., the boundaries of the SFB 299 study areas result from requirements of its model network. The hydrological model SWAT, part of this network, explicitly refers to watersheds and sub-watersheds as referential spatial extent. This public domain model, which is actively supported by the Grassland, Soil and Water Research Laboratory (USDA, Temple, TX, USA) has been developed for more than 10 years (Arnold et al., 1993; Srinivasan et al., 1995), and is now being modified and adjusted by subproject A2 to be applied in the study area (ECKHARDT et al., 2002). Hence, considering that these borders also reflect culture-historical tradition and identity, all subprojects have agreed to the delimitation of study areas by watershed borders as given in Fig. 1.

Within the two study areas, landscape functions have been investigated at varying spatial scales and in varying elementary units. In general, the spatial resolution and the choice of spatial units were driven by output demands rather than input data supply (cf. SHERIDAN and WALDHARDT, 2006), and were thus mainly depending on the precise research question, the nature of the investigated 'response variable', but also on demands on 'predictors' (cf. WEINMANN 2004), and their available spatial resolution and accuracy (cf. BACH et al., 2005, in press). Many of the above mentioned empirical studies chose the field as the elementary unit, as this smallest land user's decision unit is – at least in the highly fragmented Lahn-Dill Highlands – also an ecologically meaningful functional unit. Data exchange between the subprojects of the SFB 299, and especially between the modelling subprojects, thus has retained spatial information from a comparatively small spatial unit and has allowed, again meaningful, upscaling of results (e.g., WEBER et al., 2001; STEINER et al., 2002; HUISMAN et al., 2003; ARNOLD and FOHRER, 2005; SIMMERING et al., accepted; GOTTSCHALK et al., accepted; REGER et al., submitted; SHERIDAN and WALDHARDT, 2006; WALDHARDT et al., 2004).

Statement 3

> *"Spatial models are particularly useful for comparative use, such as in scenario studies. [...] Although we cannot predict the future, we can make projections into the future based upon our knowledge of the present and the past and the processes that cause the change."* (VERBOOM and WAMELINK, 2005)

This third statement is closely related to the SFB 299 model network ITE²M, an extensible network of transferable, GIS-based models supporting decision makers and stakeholders in their assessment of possible future land-use scenarios (MÖLLER et al. 2002a). Today, the network consists of five GIS-based landscape models referring to small sets of 'response variables' that indicate landscape functionality (Fig. 2). All models are linked by the output data on land-use pattern from the economic model ProLand (MÖLLER et al., 1999; WEINMANN, 2002). Here, the term land use stands for detailed information on silvi- and agricultural production systems that have been stored in tables and visualised in maps at varying spatial scales. The model output of ProLand is part of the input data of the remaining four models:

- ATOMIS — Assessment Tool of Metals in Soils (REIHER et al., 2005)

  Output data: concentrations and spatial pattern of Cd, Pb, Cu, Ni, Zn, and PCBs distribution in the soil

- GEPARD — Geographically Explicit Prediction of Animal Richness Distribution (GOTTSCHALK et al., accepted)

  Output data: Animal species numbers; spatial pattern of species distribution

- ProF — Prognoses on Floristic Richness (SHERIDAN & WALDHARDT, 2006)

  Output data: Plant species numbers, probabilities and frequencies of species occurrence; spatial pattern of species distribution

- SWAT-G Soil and Water Assessment Tool (ECKHARDT et al., 2002)

  Output data: Spatially explicit data on surface runoff and interflow; spatially explicit data on water quality.

However, these models may also generate land-use pattern to be used as ProLand input data.

Additional necessary information on 'predictors' that are not commonly available and applicable in the ITE²M model network have been provided by further subprojects of the SFB 299 and considered in the modelling. This holds especially true for data on costs of production systems depending on e.g., labour requirement and potential yield of crops and other agricultural products. In the SFB 299, these variables have been jointly calculated in subproject A1 and the subprojects of block C (e.g., STERZENBACH, 2000; GAULY et al., 2001; OPITZ V. BOBERFELD, 2002; MÖLLER et al., 2002b), mainly based on results of empirical studies.

As an interdisciplinary result of the model network trade-offs between landscape functions have been derived (e.g., BREUER et al., 2005; GOTTSCHALK et al., accepted).

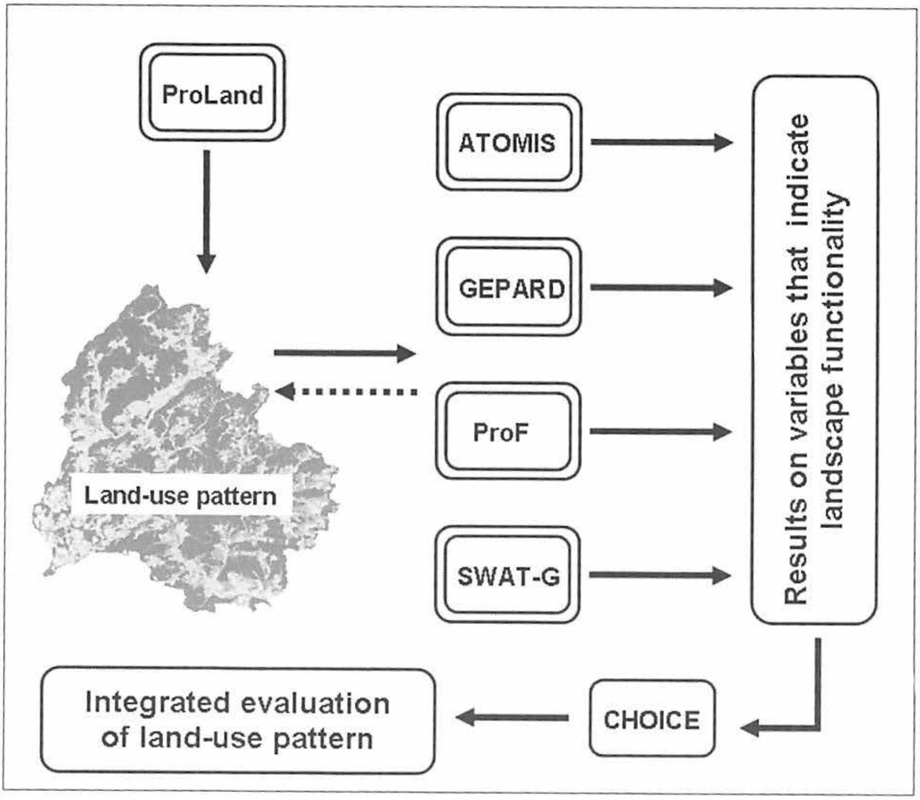

Fig. 2 **Schematic diagram of the data flows in the SFB 299 model network ITE²M (Integrated Tools for Ecologican and Econiomic Modelling)**

Further, the evaluation framework CHOICE (Borresch et al., 2005) utilises the disciplinary and interdisciplinary results of the five models to perform cost benefit analyses and assess potential multiple trade-offs.

Statement 4

> *"The object of landscape ecology is not to describe landscapes, but to explain and understand the processes that occur within them. Thus, the description of landscape pattern as an end in itself is limited. [...] Most of all, we have to extend our thinking to the analysis of pattern in a cultural context. Only then we can meet the challenge of helping people understand the significance of pattern for the landscapes in which they live and work."* (Haines-Young, 2005)

As outlined in the introduction, research in the SFB 299 aims at the development of an integrated methodology towards the development and evaluation of economically and ecologically sustainable options for regional land use. The development and testing of this methodology in the 'peripheral region' Lahn-Dill Highlands was the research focus until last year. Ongoing research concentrates on the question of its applicability in an 'intensive agricultural region', i.e. on necessary adaptation and alignment of models and the entire network. In general, the developed methodology allows integrated calculation of effects of land-use changes on landscape functions (Möller et al., 1999; Möller and Weinmann, 2001; Frede et al., 2002). These changes may result from, e.g., policy measures such as the decoupling of agricultural subsidies from production according to the Luxembourg Agreement signed in 2003. Several modelling results (e.g., Sheridan & Waldhardt, 2006; Weinmann et al., in press; Gottschalk et al., accepted) and integrated evaluations (e.g., Schmitz et al., 2003a; Borresch et al., 2005; Borresch et al., in press; Borresch and Weinmann, submitted) referring to this and other scenarios have been published.

Research in the SFB 299 takes the cultural context into account: Land-use history and the socioeconomic context has been considered in several analyses (e.g., Hietel et al., 2004, 2005, in press; Reger et al. submitted) and extensive questioning of farmers and other groups of persons on, e.g., land-use preferences has been conducted (e.g., Müller and Schmitz, 2002) and considered in the integrated evaluation process.

So far, research in the SFB 299 may be viewed as applied science that aims to support, e.g., stakeholders in decision finding (Fohrer et al., 1999; Sheridan and Waldhardt, 2006), and to provide perspectives on future land uses (e.g., Opitz V. Boberfeld et al., 2002). These are based on scientifically sound, ecological and economic evaluations of land-use systems (Schmitz et al., 2003b). However, at the same time, research in the SFB 299 aims at the broadening of basic knowledge on relations between agricultural land use and landscape functioning, i.e., on the understanding of the underlying network of processes at multiple spatial scales. Thus, research in several subprojects contributing to the model network also deals with questions such as the relative importance of 'predictors' on biodiversity measures at the patch and landscape scale (e.g., Simmering et al., accepted; Wellstein et al., accepted, submitted).

3.6 Discussion

This discussion will not focus on the organisation of the SFB 299 and its methods in relation to other projects and networks in the same field. Examples would be the interdisciplinary project at Oregon State University (USA) "to envision futures for agricultural landscapes that offer alternatives to current conditions and trends" (SANTELMANN et al., 2004), the Lebensraum Börde project (e.g., GRABAUM et al., 1999), or Landscape Europe (e.g., MANDER and JONGMANN, 2000). Such comparisons are given in many of the cited publications of the SFB 299. Besides all limitations that were partially outlined in Chapter 4, the SFB 299 has succeeded in bringing together social scientists and ecologists who integrated their approaches. They have successfully developed, applied, and validated a model network, which is based on empirical studies, modelling, and scenario technique. Thereby, land-use change and its consequences may now be investigated from the local to the regional scale in "a more holistic way", as suggested by MATTISON and NORRIS (2005). Thus, research in the SFB 299 provides a landscape perspective that is urgently needed for "understanding the negative and positive effects of agricultural land use for the conservation of biodiversity, and its relation to ecosystem services" (TSCHARNTKE et al., 2005). However, mainly due to funding limitations, not all landscape functions that may be relevant in this context have been considered in the SFB 299. But the developed ITE^{2}M model network is, as mentioned earlier, extensible, and, e.g., the combination of landscape ecology and population genetics may allow to integrate models of landscape genetics (c.f. MANEL et al., 2003) - a somehow new research field in landscape ecology, but eventually not another new subdiscipline of ecology - in the future. So far, the SFB 299 stands for agricultural landscape research that was, in 2005, highlighted in a DFG memorandum as a key future perspective of agricultural sciences (DFG, 2005). In accordance with this memorandum, research in the SFB 299 conceives agricultural science as a system science. The agricultural landscape, in this respect, represents the system that is characterised by landscape structure and dynamics, landscape functions, and human demands.

Referring to the statements 1 to 4, research in the SFB 299 has clearly adopted and enhanced landscape ecological methods, and dealt with the central topic in landscape ecology: interactions between heterogeneity in space and ecological processes. In many subprojects of the SFB 299, and in accordance to statement 1 and FAHRIG (2005) "the 'response variables' [...] are abundance / distribution / process variables, and the 'predictors' are variables that describe landscape structure." However, Lenore Fahrig, as Monica Turner, pronounces the biotic nature of 'response variables' in landscape ecology. Also other well accepted landscape ecologists (e.g., FORMAN and GODRON, 1986) highlight that landscape ecology is well integrated within ecology, the study of interrelationships between organisms and their environment.

But does this mean that in the SFB 299 no more than the three subprojects dealing with animals and plants pursue landscape ecological research? Or, do they at all? Keeping in mind the research network of the SFB 299, the first question may be rejected. All the subprojects and the organisation of the entire project have indirectly or directly supported the scientific progress in the 'biotic' subprojects and thus have contributed to landscape ecology. This is especially true for the economic subproject and its model ProLand, although here, the modelled land-use pattern aggregates the 'response variables'.

Two answer the second question, at least two other crucial points that are obviously essential for the self-understanding of landscape ecologists have to be discussed before:

Firstly, what is a landscape? Is it, e.g., "an area that is spatially heterogeneous in at least one factor of interest (TURNER et al., 2001)" (TURNER, 2005) or "the total spatial and visual entity of human living space, integrating the geosphere with the biosphere and its noospheric man-made artefacts" (according to TROLL (1970); cf. NAVEH and LIEBERMANN, 1994). Do we essentially need extensive statements, descriptions, and discussions on what a landscape is (e.g., VOLK and STEINHARDT, 2002; BASTIAN, 2002; STEINHARDT et al., 2005)? These are undoubtedly helpful to bridge (alleged) gaps or discrepancies in perception, but are they needed to define landscape ecology? The flexibility of Monica Turner's definition, which emphasises merely the spatial heterogeneity, allows us to apply the term landscape across spatial scales and to adopt it for different systems (TURNER, 2005). Therefore, the answer may be no. We do not need a more elaborate definition of landscape to do landscape ecology. By the way, Monica Turner's definition indirectly also refers to landscape dynamics, a highly important research field in landscape ecology, as long as we focus on interrelations between the spatial pattern of, e.g., land-use changes and its effects on ecological processes rather than on descriptions of landscape dynamics.

However, Monica Turner's definition of landscape does imply that landscape ecology may be characterised by methods and methodologies. Multi-scale designs and their underlying theories and concepts are more important than descriptions of the term landscape. This is in accordance with WU and HOBBS (2002), who summarised a special session entitled 'Top 10 List for Landscape Ecology in the 21st Century' and stated: "Most participants thought that scaling is most essential in theory and practice of landscape ecology". Further, Monica Turner's definition also means that research 'at the landscape scale' or 'in landscapes' does not necessarily belong to landscape ecological research, unless at least one variable indicating spatial heterogeneity is considered as 'predictor' and related to at least one 'response variable' indicating biotic conditions or processes. Empirical studies are, by the way, indispensable in landscape ecology, not only for this reason. Such studies as well as, e.g., modelling based on results from empirical studies may be conducted at a fine or broad scale, since not the absolute scale, but spatial heterogeneity, is the research focus.

Secondly, is it in general essential to consider the cultural context in landscape ecology, or is the cultural context just a necessary extension of the set of 'predictor variables' when research is conducted at broad spatial scales, i.e. when the landscape under consideration is congruent with what humans conceive as landscape? For the understanding of, e.g., spatial distribution patterns of animals or plants within landscape tracts of a few hectare size, the cultural context that has influenced land use in this tract would not contribute to understand the small-scale pattern of the 'response variable(s)'. However, at broader spatial scales, as it may be learned from, e.g., research in the SFB 299, the cultural context will become important. Further, the cultural dimension is essential in applied research that aims at, e.g., the development of sustainable land-use systems.

Thus, to go back to the question, if research in the SFB 299 is landscape ecological research, even under consideration of the last three paragraphs, the answer may be yes, at least with respect to the research in the 'biotic' subprojects.

The author is conscious of the fact that the thoughts discussed in this paper did not consider all questions regarding landscape ecology that may deserve it. E.g., the repeatedly discussed question, if inter-, multi- and / or transdisciplinary approaches are target-oriented (e.g., LESER, 1997; NAVEH, 2000; BASTIAN, 2002), was neglected here. However, it's the author's opinion that statements regarding this question are - similar to the question of what a landscape is - not really essential to define landscape ecology. In contrast, these issues may gain importance when discussing "transdisciplinary landscape research" in the context of "transdisciplinary landscape science" sensu NAVEH (2005). Landscape ecology, as a subdiscipline of ecology, may contribute to landscape science, but should not be equated with it. Further, the author is conscious that some of the statements given here are provocative. However, they will hopefully contribute to the ongoing discussion on the understanding of landscape ecology.

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4 Landscape Ecology: A discipline or a field of trans-disciplinary research and application?

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4.1 Landscape Ecology – an amalgam of diffuse views?

The term „Landscape Ecology" often seems to have been used in an uncritical way in many discipline areas with very different meanings. The aim of this paper is to present a new perspective on Landscape Ecology that builds on but develops the original definition by Carl TROLL (1939), who saw Landscape Ecology as a wholly within the discipline of Geography. Such a revision is necessary because ideas about the nature of Geography and Landscape Ecology have changed alongside wider views about the general relationship between science and society (KATES et al. 2001; LESER 2002; NOWOTNY et al. 2001). For example, ideas about landscape are now clearly not exclusive to any one discipline area. We have, in a sense, returned to the holistic view of landscape proposed by Alexander von Humboldt, who saw „Landschaft ist der Totalcharakter einer Erdgegend" („Landscape is the total character of a defined part of the Earth's surface"). As is illustrated by the European Landscape Convention, Landscape is now often viewed as an arena in which a range of disciplines can meet to confront problems that extend beyond the reach of any one of them. Landscape „expertise" therefore exists across many subject areas, and it is perhaps not longer appropriate to think of a single package of knowledge called „Landscape Ecology".

There is no common understanding of what landscape or Landscape Ecology is, rather we face a multitude of definitions each reflecting the concerns of different discipline areas and perspectives. Such a situation is problematic because when disciplines come together to tackle a „real world" problem, no common or shared understanding of the arena of interest may exist. Often landscape definitions fail to represent landscape as a „system" or more precisely a „landscape ecosystem", and do not relate to the spatio-temporal character of the landscape system in which all processes are set.

Contemporary Landscape Ecology therefore can be seen to have many roots. On the one hand it has its origins in classical Ecology (Fig. 1), while on the other it has its beginnings in the types of spatial analysis undertaken by geographers. Landscape Ecology therefore neither belongs to either Biology or Geography, nor is it simply an amalgam of the two. Today Landscape Ecology is something that adds to and goes beyond these traditional perspectives. This can be illustrated by reference to the recent development of the field (e.g. POTSCHIN & HAINES-YOUNG 2006; TRESS et al. 2002).

From 1939 until 1942 (TROLL 1939; SCHMITHÜSEN 1942), Landscape Ecology was mainly dominated by a perspective derived from geographers (LESER 1992, 1999; LESER & RODD 1991); this is illustrated by the early 'paradigmatic' textbook of Leser (1976) and the others that followed (LESER [4]1997; NAVEH & LIEBERMAN 1984, [2]1993; RICHLING & SOLON 1994, [2]1996; BASTIAN & STEINHARDT [Ed.] 2002; STEINHARDT, BLUMENSTEIN & BARSCH 2005).

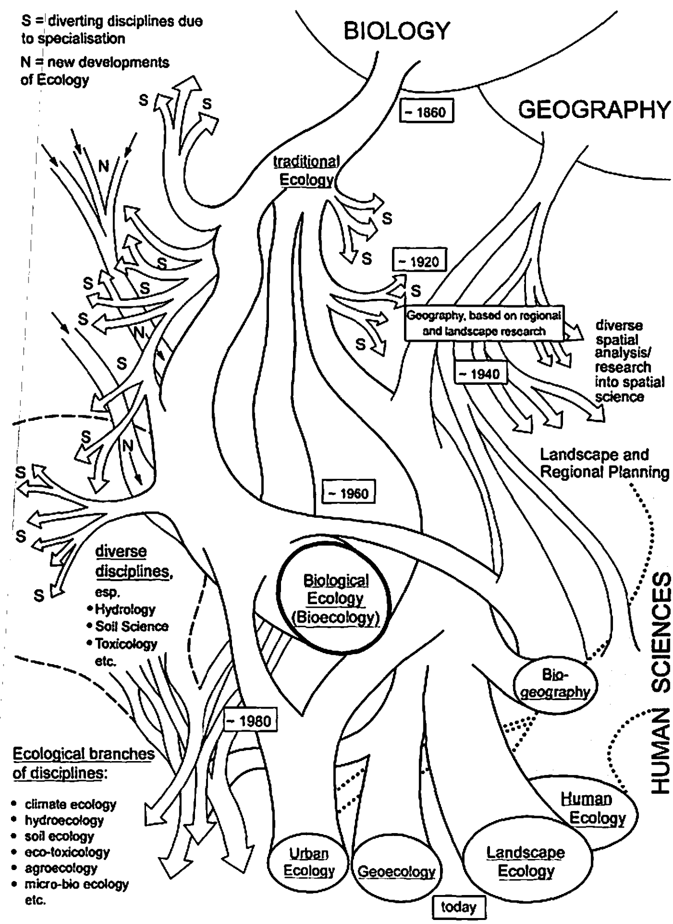


Fig. 1 **Biology and geography as the roots of landscape ecology (developed from H. Leser 1995; graphic design by L. Baumann)**

To the original rather homogenous „Classical Ecology" of E. Haeckel and K. Moebius another element such as geographical spatial and landscape research was added, the so called spatial-functional view. At the same time the biological influence into Landscape Ecology was pushed through Ecology; „bio-ecology" was established. Parallel to this movement another stream developed out of Landscape Ecology (C. Troll, later E. Neef), the Urban Ecology (e.g. H. Sukopp), the Biogeography (based in Geography; e.g. J. Schmithüsen) and the Geoecology, a more on the geosciences based Landscape Ecology (H. Leser, T. Mosimann, H. Neumeister). The human Ecology – as a rather broad discipline (e.g. P.R. Ehrlich, A.H. Ehrlich & J.P. Holdren; W. Nentwig et al.) tended to move back toward the humanities. Increasingly, however, the spatial analytic approaches of Geography to landscape have been taken up in other research and application fields, such as such as Geoecology, Biogeography, Botany, Landscape Management and others.

Tab. 1 The „Landscape Ecology" „of different disciplines and their methodological deficiencies (initial design and graphic design by H. Leser 2005)

Disciplines	Approaches	Deficits
Geoecology	abiotic, esp. metoabolic cycling and water balances	biotic
Biogeography	zoological, esp. faunistic	abiotic factors and processes
Botany	botanical, esp. physiological	abiotic factors and processes; spatial arrangement
Landscape Management	cultivated and planned landscape by visual approach	geo- and bioecological processes
etc.		

The first column only presents a small part of discipline areas. The characterization of the different approaches reveals the respective focus of investigation. Referring to figures 2 and 6 only a limited part of the landscape reality is obviously dealt with. These limited theoretical approaches must consequently lead to methodological deficiencies.

The „Landscape Ecology" undertaken by these different areas weighted or emphasised the various aspects of landscape in different ways. The loss of von Humboldt's overall view of landscape has resulted, in Landscape Ecology's „Fall from Grace".

The term landscape has now come to mean „all things to all men" and workers often use it in an unproblematic way without a clear definition of what it is. Thus papers are represented as, or assumed to be, taking a „landscape ecological perspective" without any clear connection to the definitions of the terms „landscape" or „ecology". For many disciplines „landscape" is simply the „stage" on which they investigation takes place. The spatial aspects of landscape or its quality as a system are not considered. Moreover, even the term „Ecology" is constructed differently by different workers. If „Oikos" means „home"/"household", then „Landscape Ecology" must have something to do with the science or theory of that place.

As a result of this situation, a number of problems can be identified in relation both to the broad methodologies and specific methods used to study landscape:

- An uncritical „free for all" approach to definitions results in poor communication between disciplines. This conceptual confusion increases when terms are taken up and used by practitioners who are concerned with application rather than basic science.
- Differences in methods, theories and approaches proposed by the different disciplines are never resolved by subjecting them to critical comparison and testing, and so different perspectives are never aligned.
- There are contextual and methodological shortcomings evident in the different disciplines dealing with landscape, for example, in „biological" approaches to Landscape Ecology, the treatment of abiotic processes is often limited or missing, whereas in geoecological approaches the biotic is often deficient. Moreover, both of these approaches often ignore the human dimension of landscape system and way the actions of people influence landscape structures and processes.

As a result we can conclude that disciplines are working on landscape in an isolated, discipline specific. Such a situation departs significantly from perspectives embodied in both „Landscape Ecology" and „classical" Ecology. Even early workers such as HAECKEL (1866) and MOEBIUS (1877) sought to understand the connection between the biotic and abiotic components and the way they functioned over space. Thus some current work fails to apply or extend the theories and definitions of those who have studied landscapes as biotic-abiotic process-response systems. This can be seen, for example, in recent discussion of biodiversity and its relationship to geo- and landscape diversity (LESER & NAGEL 1998).

4.2 Landscape Ecology and the Landscape Ecosystem

The situation described above, namely that contemporary Landscape Ecology is an amalgam of diffuse views, is consistent with the view that a transdisciplinary approach to Landscape Ecology and its focus on the „landscape ecosystem" is an appropriate one. However, such a transdisciplinary approach to Landscape Ecology requires an all embracing and commonly accepted conceptual framework that links nature, society and technology (NEEF 1967, 1969, 1979).

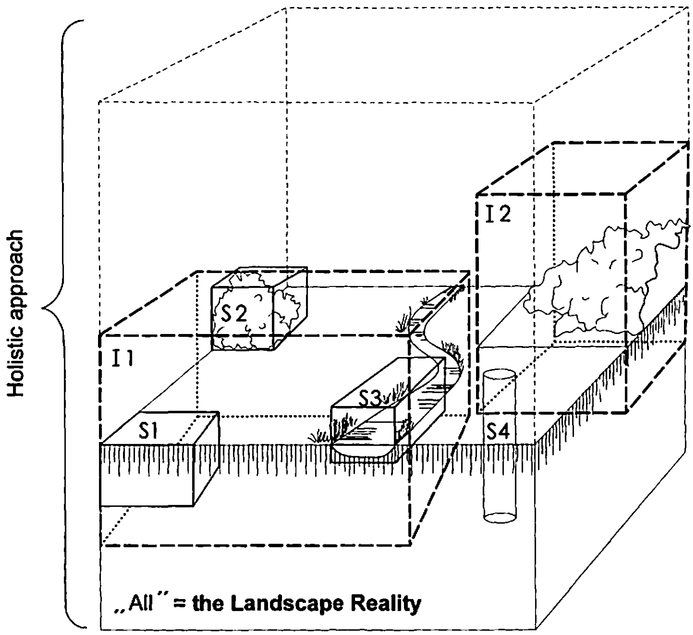
If the focus of Landscape Ecology is the landscape ecosystem then studies need to conform with definitions such as those given by LESER ([4]1997, 2005), namely:

> *„A landscape ecosystem is a highly complex process-response system formed by the linkage of nature, society and technology, with numerous biotic, abiotic and anthropogenic factors that lead to the three subsystems: geosystem, biosystem and anthroposystem."*

Such a definition is reflected by recent commentators such as TRESS & TRESS (2002) in their account of the total 'human ecosystem', ad the conjunction of the noosphere, geosphere and biosphere. If we accept such definitions of a landscape ecosystem, and set these in the context of the contemporary need to apply our knowledge[1] then:

- Landscape Ecology is, according to LESER ([4]1997, 2005), the discipline that deals with the inter-relationships between the factors that form the landscape ecosystem, which are represented both functionally and visually in the landscape, for example, in a complex territorial structure. As landscape has so many different facets, it can be investigated by different disciplines and knowledge can be applied in many different ways. Disciplines not only have different interests and concerns, but practical constraints man that they may only be able to focus on certain aspects of the whole system (Fig. 2).
- Landscape Ecology is presently viewed in Europe as the scientific basis for land and land use planning, management, conservation, development and reclamation. As such it has overstepped the purely natural realm of classical bioecological science and has entered the sphere of human-centred fields of knowledge – the socio-psychological, economic, geographic and cultural sciences connected to modern land use (NAVEH & LIEBERMAN 1984, 1993).

[1] In contrast, for example, to Troll (1939), who saw Landscape Ecology only as a basic science.



Legend: I = Integrative Approach, I1 = landscape ecological approach with several geo- and bioeco-factors (for example applied to the topic and choric dimension); I2 = Geoecological approach with several mainly abiotic geoecofactors (for example applied to the topic and choric dimension). S = segregated approach; S1 = pedological approach (for example in the sub-topic up to the topic dimension); S2 = biogeographic approach (for example applied in the topic dimension); S3 = hdyroecological approach (for example applied to the topic dimension); S4 = pedoecological approach (for example applied to the sub-topic dimension).

Fig. 2 Integrated or Separatist approaches of different ecological-related disciplines to „Landscape Reality" (initial design by H. Leser 2005; graphic design by L. Baumann)

The landscape reality is modelled in the so called landscape ecosystem. Research works on the landscape ecosystem in a rather pragmatic way by „cutting" the part out from reality, which is of interest for the individual research question. However reality itself is holistic, a unique appearance.

4.3 Landscape Ecology - a transdisciplinary field

These definitions make it clear that Landscape Ecology is not a single subject but a view of a complex reality. The „landscape ecosystem" is that model of the complex reality, and it is the focus for a range of disciplines. Landscape Ecology is thus a platform for a number of disciplines. Recent understandings of the theory of metasciences demand a transdisciplinary approach. Our understanding of transdisciplinarity is summarised in Fig. 3. Transdisciplinarity means: several disciplinary specialists that partly overlap a very complex problem area of the complex reality (here the landscape) which is then approached in an open way. In the real world of science this means that the approach is essentially „problem focused". The research question defines which disciplines are relevant and how they combine.

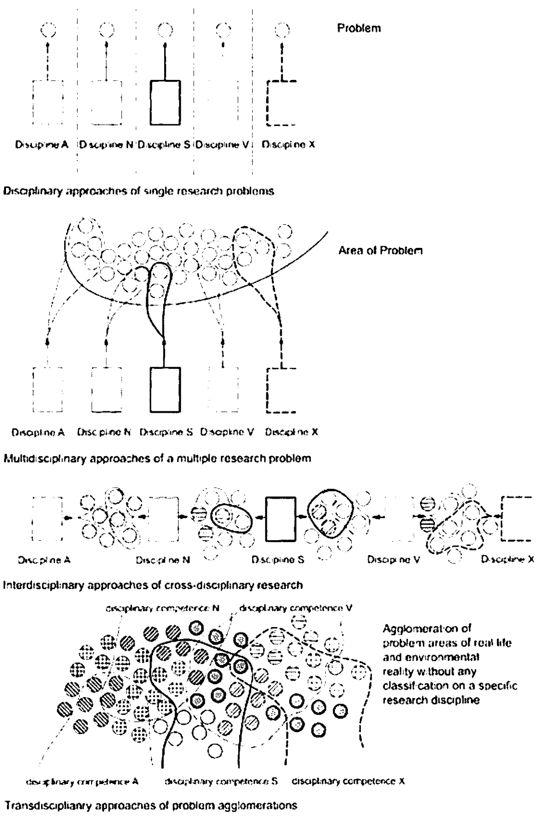


Fig. 3 **Different approaches to research – from disciplinary to transdisciplinary modes (from H. Leser 2002; graphic design by L. Baumann)**

The simplified graph (modified according to several authors) demonstrates several possibilities of scientific and practical work. The graph shows that multi-, inter- and transdiscipliantry approaches can be followed by different defined views and approaches. Sometimes it is difficult to distinguish between the different views. In research therefore a rather pragmatic approach to those views is taken. Usually the interdisciplinary approach is chosen, which means equally to multi- and transdisciplinary method a „discussion about the problem".

For comparison, Fig. 3 also summarises other scientific methodologies, such as disciplinarity, multidisciplinarity and interdisciplinarity. The transdisciplinary approach is the most complex one, in that it also involves non-scientific actors, such as practitioners, activists and publics.

Thus we can conclude that because of the variety of factors and actors, the impacts and the processes they initiate, and the variety of possible but necessary perspectives, Landscape Ecology must be done in a transdisciplinary way. It is based on a real complex, combination of nature, society and technology expressed in space. Landscape Ecology presents itself not only as an area of basic science but also as applied science.

4.4 Landscape Ecology – also an applied science

The theory therefore says: that if Ecology is the study of plants and animals „at home", Landscape Ecology is the study of the entire household represented by that complex formed of the process-response system that is the entire landscape. Again, the object of the „landscape ecosystem" is not only the focus of scientific interest, it is also the object of study for practitioners in their many fields of activity as long as they concentrate on this spatially explicit combination of nature, society and technology. The approach and methodology of Landscape Ecology is represented in Fig. 4. Here „landscape reality" means the process-response system of the functional combination of nature, society and technology (NEEF 1967, 1969, 1979). This also includes systems that are entirely human creations such as urban landscape or an industrial landscape. It embraces not only abiotic and biotic components, but also the built environment and humans as the regulating factor on that stage (through their political, economic and planning decisions).

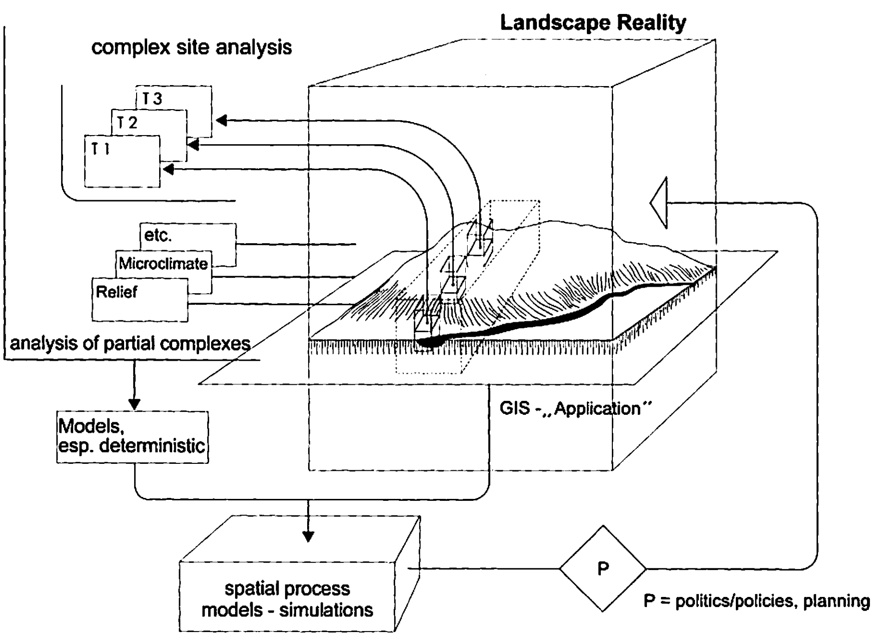


Fig. 4 **Basic principles of landscape ecological method (initial design by H. LESER 2005; graphic design by L. Baumann)**

Here a part of the landscape in reality is shown, which is at the same time the object of the investigation. One works on several levels of methods at the same time. Together they form the „landscape ecological complex analysis“. Mostly static geofactors such as georelief, soil, and microclimate are dealt with (mostly mapped) spatially within the framework of partial complex analysis. They are described with the help of geographic information systems (GIS). The measurement of the entire ecological household is carried out at landscape ecological sites (the places of measurement are so-called „Tesserae“) within the framework of complex site analysis. The sites are selected representative sites forming a catena on a slope. Both, the data referring to space as well as those referring to processes, feed for example deterministic models. They are partly caught up with in processing models referring to space with the help of simulation. These models in turn can be used by politicians and planners when it comes to forming landscape in reality.

Also from the perspective of the practitioners, we talk of Landscape Ecology, for example, nature conservation, environmental conservation, planning and use of resources, etc. as done in science, but the terms like „Landscape Ecology“ or „landscape ecosystem“ are often used in an unreflective way. Often this happens in an opportunistic way, where the label Landscape Ecology is seen as a useful badge to help someone sell a „product“.

What does it mean to practice or apply Landscape Ecology? Landscape Ecology in practice turns, almost at random, to a number of problem areas, as is illustrated in Tab. 2. This table also shows the use of the landscape ecological complex analysis (MOSIMANN 1984) applied to different practical problems. As tools (see Fig. 4) the „complex site analysis“ and the „partial complex analysis“ techniques are used, and these together form the „landscape ecological complex analysis“. This is a tool which is not linked to any one specific discipline, but can be used universally.

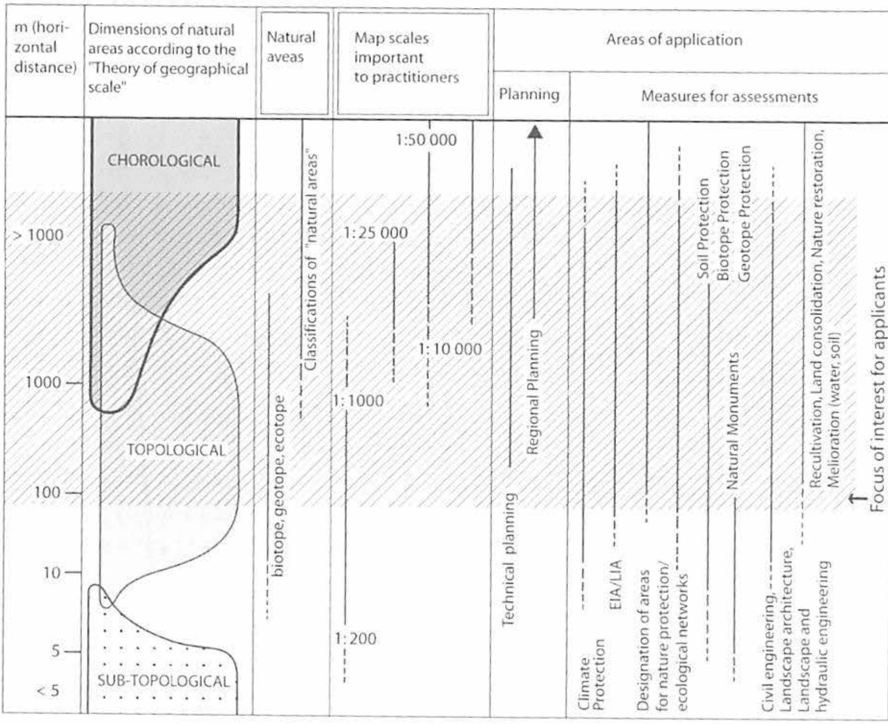


Fig. 5 Landscape ecological approaches in practice: dimensions and approaches (design: H. Leser; graphic design by L. Baumann)

When various discipline areas work on landscape ecological problems a central point of interest arises concerning the dimension of investigation and presentation. According to E. Neef (1967) and further authors this is the topic and choric dimension. Here the method of „landscape ecological complex analysis" (T. Mosimann 1984; H. Leser [4]1997) can be applied most favourably.

Applied Landscape Ecology in Planning for nature and environmental conservation, amelioration, landscape and hydraulic engineering and climate protection takes place on ownership parcels in cities and open space areas. In Europe these parcels are usually „small", up to 1000 m in diameter. From there one can derive: this needs working on a large scale. This is where the technique of landscape ecological complex analysis can be applied (see Fig. 4 and Tab. 2). This means that the scale of analysis for both practitioners and basic scientists lies between 1 : 1'000 and 1 : 25'000/1 : 50'000 (Fig. 5).

Fig. 5 and Tab. 2 demonstrate a variety of applications:

- The breadth of practical interest in Landscape Ecology;
- The set of landscape ecological tools is useable in many applied areas; and,

- For many applied areas, the landscape ecological complex analysis represents a universally useable methodology – at least for the topic up to the choric dimension[2].

Tab. 2 The use of the landscape ecological complex site analysis applied to practical problem areas (initial design by H. LESER 2005, graphic design by R. Gisin)

	Geoecofactors / Partial analysis of geoecofactors					Complex site analysis	Range of scales		Application of methods	
Fields of practice	Landforms	Water	Climate	Substratum and soils	Bios		~ Upper limit	~ Lower limit	direct	via rating
Agrarian land use	●●	●●	●●	●●●	●	●	1: 500	1: 10 000	x	x
Land consolidation	●●●	●●	●●	●●●●●	●●●	●	1: 500	1: 10 000	x	
Nature conservation	●●	●	●	●	●●●●●	●●●	1: 500	1: 25 000	x	x
Forestry land use	●●	●●	●●	●●●	●	●	1: 1 000	1: 25 000	x	x
Industrial parks	●	●●●	●	●●	●	●●●	1: 500	1: 10 000	x	
Power plants	●●	●●●●	●●●●	●●	●	●●●	1: 500	1: 5 000	x	
Town planning	●●	●●	●●●●	●●	●	●	1: 500	1: 5 000	x	
Mining area restoration	●●●●●	●●●	●	●●●●●	●●●	escorting	1: 10 000	1: 10 000	x	x
Gravel pit restoration	●●	●●●	●	●●●●●	●	●	1: 500	1: 5 000	x	x
Soil conservation	●●●●	●●	●	●●●●●	●	escorting	1: 5 000	1: 25 000	x	
River protection	●●	●●●●●	●	●●●	●●●	●●	1: 500	1: 10 000	x	x
Ski-run installations	●●●●●	●●	●	●●●●●	●●●	●●●	1: 5 000	1: 10 000	x	x
Tourist landscape planning	●●●	●●	●●●	●	●●●●●	●	1: 5 000	1: 25 000	x	x
Urban green planning	●●	●	●●	●	●●●●●	●	1: 500	1: 10 000	x	

2 Within Landscape Ecology there is also a diverse selection of methods for large scale but also small-scale investigations. This paper does not reflect on those. This paper concentrates on the space-and-system-scale in which practitioners mainly work.

The column titled „Fields of Practice" lists practical measures as to forming or planning the landscape. The adjacent columns show the demand of landscape ecological methodology (the more dots, the bigger the demand). This also refers to geofactors which are often (but not only) recorded by mapping. This is done within the framework of partial complex analysis. Depending on the problem in question, requirements differ when it comes to examining the complex site analysis which first and foremost focuses on processes. The columns titled „Range of Scales" hints at the fact that predominantly large-scale facts („data") are required. The data that are the results of research work can be directly applied. In some fields of practice the subject matter (for example of climate, soil, relief, etc.) will have to be additionally evaluated as to its suitability.

The critique of different Landscape Ecologies described in part 1 is also true in relation to practitioners. This means that in practice terms such as „ecosystem", „ecology", and „landscape" are used in an unreflective, imprecise way. Again this means that there is a lack of a common language and understanding between applied and basic science, and between the different fields of application. Typical examples of the conflicts of terminology that can be observed are between „geoecology" and „bioecology", and „geosciences" and „biosciences" respectively. Practitioners approach the landscape ecosystem in the same fragmented way that the different disciplines do, as shown above (Tab. 1). We must demand of both basic science and practice that when they try to solve problems at the landscape scale, they use terms in a consistent way.

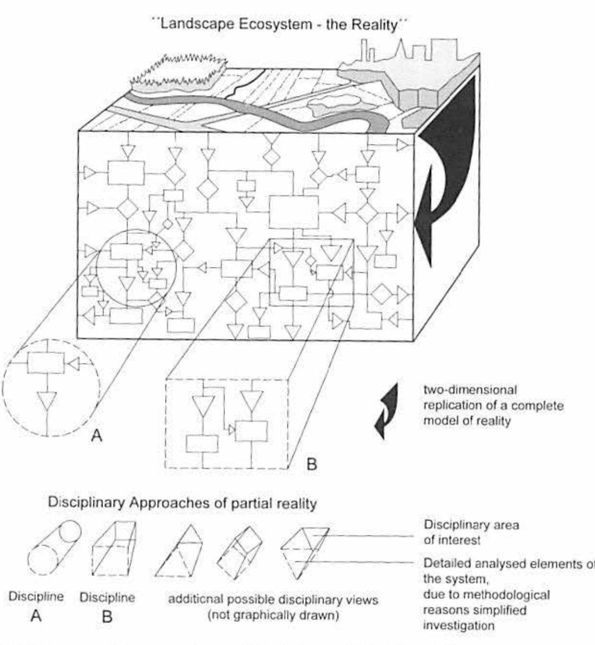


Fig. 6 **The Landscape Ecosystem – Model and Reality: The „real" landscape ecosystem and its methodological simplification (from H. LESER 1992; graphic design by L. Baumann)**

The upper part of the block diagram shows the real landscape ecosystem in the form of a control system. The different ecological disciplines (i.e. the various „ecologies" for example 'A', 'B', etc.) determine the section under investigation (marked areas). It explicitly corresponds with their understanding of „ecology". For technical, methodological, monetary or other reasons, however, only one part (= part brought out in front of the disciplinary block diagram) is being examined. This means: ecological results often refer to only a limited part of the complex reality of the landscape ecological system.

In reality, of course, a fragmented approach is widespread (see Fig. 2). For practical reasons things often have to be done in a simplistic way (see Fig. 6), but this neither reflects theory of Landscape Ecology or the idea of transdisciplinarity. Given the constraints that practitioners and scientists are under they approach issues in a compartmentalised way or only focus on elements that are of interest. This is legitimate providing they communicate what is being done, e.g. having worked in a small element they should not extrapolate results to the whole system. The focus of interest needs to be declared at the outset, each time a new problem is explored. Only this approach is likely to produce a clear understanding between scientist and scientist, science and practitioners, and between the different practitioner communities. Unfortunately, the lack of clarity within science and practice is overlooked and not regarded as problematic.

For Landscape Ecology as an applied science it can be concluded:

- The clarity of methods and methodology used by practitioners are limited by the clarity achieved by basic Landscape Ecology;
- The discipline of Landscape Ecology therefore needs to be clear about its methods and on what has gone before; its historic development needs to be recognized.
- Practical applications do not need new terminologies since they should follow standard definitions;
- Practitioners need to be aware of the tools that already exist (theory, terminology, approaches, and methods) and be able to apply them in a different situation. The conceptual framework has long been available through the work of Ernst NEEF (1967, 1969, 1979) who considered the relationship between nature, society and technology; and,
- If practitioners or decision makers concerned with planning took this into account then problems would be solved move effectively because issues would be resolved in an integrated and holistic way, thereby contributing to the development the theoretical foundations and understanding of Landscape Ecology.

4.5 Conclusions and Implications

There are always alternative approaches to problem solving that could be considered, but appreciations must respect definitions and the way terms are used. The concepts of Landscape Ecology and the landscape ecosystem are inherently inter-disciplinary in character, and they must be used in this way. Definitions stand as guidance for disciplines or practitioners and are independent of the way they would like to look at the ecosystem. Reasons can always be found for looking at problems in a compartmentalized or reductionisted way, but it should not be called „Landscape Ecology". Faced with the complexity of the real world, no one discipline has a special claim to superiority over the others.

The unreflective use of the terms „landscape", „Ecology", „landscape ecosystem" and „Landscape Ecology" shows a poor understanding of-the historical development of the subject and suggests something lacking in the way the discipline is taught. For transdisciplinary subjects such as Landscape Ecology, the rules of the philosophy of science and the theory of meta-science must also be respected and followed.

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