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Biodiversity and the Science of Landscape Ecology

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The development of landscape ecology

The first time the term 'landscape ecology' turned up was probably in 1939 in an article on 'air photos and ecological soil science' written by the German biogeographer Carl Troll. In this article he elaborated extensively on the perspectives of air photo interpretation with many examples from all over the world. Towards the end he put 'landscape ecology' into a concluding remark, only once and almost offhandedly, saying: *Luftbildforschung ist zu einem sehr hohen Grade Landschaftsökologie. Die Luftbildforschung wirkt auberdem in hervorragendem Mabe wissenschaftsverbindend [Air photo research is to a great extent landscape ecology. In addition, air photo research integrates science extremely well]* (Troll, 1939) . For Troll the goal was a broad marriage of geography and biology. Within physical geography a geo-ecological school developed in central Europe uniting the different subdisciplines into a landscape study with emphasis on integrated structural studies with the most important result being the distinction between the topological and the chorological dimensions and the classification and hierarchical ordering of landscape types in the chorological dimension (Neef, 1956) . This was closely paralleled by a bio-ecological tradition among botanically oriented biologists, which was the result of a development within a spatially oriented vegetation science (Tüxen, 1968) . Although differences still exist in the terminologies and foci of these studies, it is clear that a geo-bio-ecological integration has been established and that landscape ecology as an interdisciplinary field has furthered this integration into what Zonneveld has called the ecology **of** the landscape (Zonneveld, 1995) .

Zoologists, however, went in quite another direction. Starting their landscape ecological interest with the practical perspectives of conservation biology, their interest for the spatial aspect developed rapidly in the wake of the incipient island-bio-geography of the late sixties (MacArthur og Wilson, 1967) , resulting in the development of dispersal ecology and metapopulation theory (Hanski og Gilpin, 1991) .

Up until the last few years, however, this development can also be seen as an internal specialisation within biology - as the introduction of the spatial dimension in biology - rather than as a result of an interdisciplinary co-operation (Merriam, 1995) . Zonneveld has called this spatial biology for ecology **in** the landscape, stressing the difference from the former geo-bio-ecologically oriented ecology **of** the landscape. An important goal in modern landscape ecology has been to integrate especially these two traditions in the study of landscape functions often considered to be the core of landscape ecology. The integration of these two trends Zonneveld calls Landscape ecology *sensu strictu*.

Around this core of landscape ecology sensu strictu a 'theoretical foundation' for landscape ecology has been formulated and the contribution of different disciplines and applied sciences to this theoretical foundation has been mentioned (Forman og Godron, 1986;Zonneveld, 1990) (Zonneveld, 1995) (Forman, 1995;Farina, 1998) .

The modern broadening of the scope of landscape ecology

In this development, it has been stressed how new perspectives, especially within cultural aspects of landscape ecology have widened the universe of landscape ecology (Naveh og Lieberman, 1994) . This has partly been due to initiatives taken by the International Association for Landscape Ecology (IALE) - founded in 1982 - involving scientists interested in landscapes, coming from social sciences and the humanities (Svobodova, 1991) , and partly due to a steady involvement in landscape ecology from especially American landscape architecture and planning (Fabos, 1981;Ahern, 1991;Nassauer, 1997) . An additional paradigm of global cooperation among all types of disciplines with relevance to landscape studies has been formulated, stating that landscape ecology is a science not just 'combining sciences (which is multidisciplinarity), not 'in between' (which is interdisciplinarity), but above a series of sciences and integrating them: namely a transdisciplinary science for the study of the Total Human Environment. Especially Zev Naveh the brothers Isard and Ian Zonneveld have put much effort into the formulation of a metatheory for this transdisciplinary science based on general system theory, biocybernetics, information theory, fuzzy set theory, hierarchy theory etc. (Naveh og Lieberman, 1994;Zonneveld, 1994;Zonneveld, 1995;Naveh, 1998).

This shift in the general opinion on the strategic goals of landscape ecology is clearly expressed in the mission statement, published by IALE in January 1998:

"The International Association for Landscape Ecology (IALE) aims to develop landscape ecology as the scientific basis for the analysis, planning and management of the landscapes of the world".

"Landscape ecology is the study of spatial variation in landscapes at a variety of scales. It includes the biophysical and societal causes and consequences of landscape heterogeneity. Above all, it is broadly interdisciplinary."

"The conceptual and theoretical core of landscape ecology has become distinct and recognised, effectively linking natural sciences with related human disciplines. Landscape ecology can be portrayed by several of its core themes:

1) the spatial pattern or structure of landscapes, ranging from wilderness to cities,

2) the relationship between pattern and process in landscapes,

3) the relationship of human activity to landscape pattern, process and change,

4) the effect of scale and disturbance on the landscape".

IALE (1999)

This statement clearly expresses the character of landscape ecology as an applied science. An applied science that is needed in our time, facing the necessity of a transition towards a sustainable development. It is on the political agenda.

The most important practical tool for this, being in the focus of landscape ecology, is manipulations with the **land cover**, first of all through planning, change, and regulation of the **land use**.

The Land Cover is all what is material present at the surface of the earth.

The Land Use expresses for what purpose and how we use the land, certainly influencing land cover. Therefore land use should be central formulating the goals and perspectives of landscape ecology, although it not necessarily has to belong to the core of the science, sensu strictu.

The different tasks and landscape concepts within landscape ecology

If the overall practical role of landscape ecology in our modern society in general is to support a sustainable development by giving a scientific basis for a better adjustment of our land use

- to the natural structure and dynamics of our landscapes,
- to the preservation of biodiversity at the different landscape levels, and
- to the development of more sustainable needs within the future organisation of society in our landscapes,

we can distinguish between three basic tasks that have to be dealt with:

1. The study of basic landscape structures and types of landscape dynamics that express the landscape potential to which society should purposefully adjust its land use to ensure a rational resource management and at the same time prevent unsustainable types of land use.
2. The study of actual (and historical) land use and land cover (including its biodiversity) to elucidate present (and historical) landscape interrelations and barriers in the landscape.
3. The study of social landscapes and landscapes in the minds of groups and interests in society, and how the ecology of our landscapes are perceived among individuals and groups. This will contribute to the understanding of landscape ecological conflicts in society, and assist the development of an ecological planning, management and use of our landscapes, as a part of a sustainable development.

These three types of studies are related to three very different types of landscape concepts. To stress these landscape conceptual differences we could name them in parallel as the study of:

- The primary landscape structure and dynamics, comprising the geo-ecology and the potentials of our landscapes,
- The secondary landscape structure and dynamics, consisting of land cover, land use and their dynamics, and
- The tertiary landscape structure and dynamics, dealing with the landscapes of our minds and interests so essential for land users and the decisions of landscape planning and ma nagement.

The most difficult task in landscape ecology is to get a fruitful cooperation between these different types of concepts.

The primary landscape structure and dynamics
Modern geo-ecology is based on the assumption that a landscape can be considered as build up hierarchically, basically consisting of characteristic patterns of homogenious types of land units, places (gr. *topos*) to be described as elementary types of geocomplexes, typically called physiotopes or ecotopes, that is an area, where the complex of abiotic, and sometimes also biotic, conditions can be considered homogeneous within the area, thereby presenting the same potential for use or external influence.
Characteristic combinations of different such basic topological units can be collected into typical types of heterogenieous landscape elements, actually the smallest type of a landscape, a socalled chorological unit, often called a nano- or a microchore. These again can be nested into a hierarchy of chorological land units, meso- and macrochores, higher levels of landscapes, where they will meet with a classical division of landscapes into sub-landscapes, from above.
Basically the study of this type of landscape ecology is dealing with structural and dynamic linkages between the in-going components, typically collected into groups like parent material, climate, relief, water and soil. This tradition of landscape ecology has its roots in Germany and Eastern Europe.

The secondary landscape structure and dynamics

The landscape concept of the secondary landscape structure, is basically dedicated to the land surface, especially the land cover. The main paradigm within this type of landscape ecological studies is the matrix-patch-corridor-model developed within spatial ecology, where the landscape is seen as different units and types of patches seen as distinct islands in a more or less hostile matrix of dominating land cover that might be overcomed by the presence of more or less conductible corridors. According to this model (Forman og Godron, 1986) has defined a landscape as a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout.

The ecosystem concept and the primary and secondary landscape structure

If one imply these two landscape models from the first and the second type of landscape studies to the same area, you will come to very different spatial results. However, Formans definition of a landscape can be used in both cases, due to the ambiguous character of the term 'ecosystem'. In practice Forman uses the ecosystem concept often as a term for all distinct land cover elements in the fragmented cultural landscapes typical for the developed parts of the world. But ha applies it also more generally by a flexible spatial use of the term ecosystem. And if one consider geo-ecological ecotypes as basic units for a hierarchy of chorological combinations of ecotopes, his definition will fit perfect into most German and East-European schools of geo-ecology!
In both models the spatial structure is in focus. This has often given rise to a critique against these types of studies: Again and again the need for dynamic studies has been stressed and it is in general one of the most common conclusion of landscape ecological investigations, that more

studies on landscape dynamics and processes in landscapes are needed. Already at the first international congress in Holland on landscape ecology in 1979, the main honorary speaker, Ernst Neef from the former German Democratic Republic in his review of stages in the development of landscape ecology put emphasis to the need of a coming stage of dynamic studies within landscape ecology (Neef, 1982).

It could be interpreted as a warning against further studies in landscape structure. But this would be in my opinion totally wrong. Certainly there is an enormous need for dynamic studies in landscape ecology, but the practical goal of such studies will in fact often be to establish a better understanding of the linkage between function, dynamics and structure of our landscapes. Studies of the dynamics of and in landscapes are not only difficult, they are in general extremely time-consuming and expensive and we will never get out of a position where such studies will only cover a tiny bit of our landscapes. So, we will always be forced to apply - as good as we can - these small bits of knowledge on the dynamics to structural models that - due to at least a certain stability and the possibilities of remote sensing - will stay as the most efficient empirical basis for a better management of our landscapes for at least the next hundred years, I am sure. Consequently, the study of structure and dynamics of landscape should never be separated. And one could formulate the demand for structural studies in the way that they are only useful as far as they permit interpretation on the dynamics and the processes in the landscape. It has however to be realised that many planning-oriented tasks necessarily has to be based on the idea that relevant goals e.g. concerning biodiversity or landscape stability can be related to landscape structure, seeing land use and land cover changes as the most important instruments. The ultimate expression of this idea has e.g. been expressed in the search for a regression equation, formulating the relation between habitat parameters and the biodiversity of indicator species. Certainly as non-committal scientists, we have leaned to be sceptical to such statements, and indeed we really do not know very much on such regression equations, but it is still a clear task for us to search for it!

In this connection it is especially interesting to study the results of modern plant ecological studies (Zobel, 1997;Ericksson, 1996) on the possibilities and problems of implementing the spatial ecological theories of remnant, source-sink and metapopulations to regional plant dynamics. These studies clearly shows that the relation between time and spatial scale in plant dynamics in general is so complicated that spatial non-correlation between areas with similar geo-ecological conditions has to be expected.

On the other hand, it is obvious that the general success of the theories of spatial ecology, developed among zoologists - both concerning the scientific success, and in practical planning - is closely related to the very rigid way of handling space that are used in these studies. Thinking back to the dreams of Carl Troll on the marriage of geography and biology, it is a bit ironically that one of the obstacles to this marriage was precisely the resistance among biologists toward spatial thinking that at that time in general was considered a matter of non-scientific description of unique features in a continuity of space. The biologists of that period were time-oriented towards a non-spatial evolution-theory. Only some botanists, vegetation sociologist, were inclined towards the spatial dimension and they had in general a low status among the experimentally oriented scientists - maybe because of their humble way of managing the obviously extremely complicated spatial dimension. This was also the case for the geographers. With the (re)development of ecology during the 60ties, the ecosystem concept came into focus, but mostly as an abstract almost non-material term, thereby allowing for a purely non-spatial interpretation. How an ecosystem developed in time was in focus. That it also must develop in space was mostly ignored.

And then within a short period around 1970 the zoologist came and made everything cut-clear, easy and understandable: Instead of different layers of soil, vegetation, relief etc. that mostly did not really fit together they had only one layer of patches and corridors embedded in a matrix, dedicated to quantitative spatial statistics. Certainly they were also lucky that the development of computers, GIS and Remote sensing in the same period made it practically possible to handle these simplified spatial data in a quantitative way.

Having been through all the difficult obstacles to the development a plant-oriented theory on meta-populations, resourcesinks and remnants, the humble botanist Ove Eriksson conclude: 'Grimm (1995) argued that the patch, as a fundamental spatial unit, may be the basic building block in models integrating population , community and levels of organisation. This argument highlights the need to give the often-elusive ecosystem concept a specific spatial definition. A firm knowledge of regional dynamics of plant patches, mechanistically determining the features of communities, will then be essential for such a development of theory.' (Ericksson, 1996)

In other words: If the ecosystem concept should mirror the material reality of the environment, it has also to be spatially concrete. Probably one of the main principles keeping landscape ecologists together as a distinct science is the acceptance of this spatial reality in a situation, where science for generations has been educated in non-spatial thinking for the sake of general non-spatial laws.

The tertiary landscape structure and dynamics

The third dimension, namely the landscapes of our minds and of different groups and interests in space and time is not less interesting. Where the first dimension can be focused in geography, the second in biology, then the third could be centrered around landscape architechture. Where the first two concentrates on the analysis of the past and present landscapes, the third concentrates on how our cultural landscapes should develop in the future. The landscape concepts of this third dimension related to the social science and humanities are often of a totally different type than the concepts related to the different interpretations of the ecosystem concept. In fact, there is an enormous gap between the dominating geo- and bio-ecological concepts of landscapes as more or less concrete material systems of the environment and the concepts of landscape dominating humanities and social sciences as pure mental constructions, only to be understood and handled in a social and historical context. But also here, like in the situation with the loose ecosystem concept, the development of a firm and strict materialistically oriented spatial landscape concepts will be crucial. This is probably the most different challenge to landscape ecology and its practical application.

A critical discussion of the noösphere concept, commonly used in landscape ecological textbooks would be useful here. So (Naveh og Lieberman, 1994) are dividing our environment into a geosphere, a biosphere, a technosphere and a noosphere, the last referring to the landscapes in our minds. The concept stems back to the Russian geo-chemist Vladimir Vernadsky (1863-1945), that around the first world war formulated the theses of the biosphere, as the stage in the development of the earth where life, towards the end of Precambrian slowly took over as a dominating geological factor in the development of the earth. Certainly abiotic factors were still working, but life-processes took a more and more leading role, fundamentally changing and dominating the development pass of all aspects of the geosphere. It was to some degree an early and also cautious version of the GAIA-theory. Later, especially during the Second World War just before his death, he formulated his thesis of the **noösphere**, the emerging phase of the stage of the development of the geosphere, where man gradually became the dominating geological factor of the development (Vernadsky, 1945) . He described the geochemical consequences of this development very carefully, and in fact lead the ground for the long and unique tradition within East-European geo-ecology. Certainly the noösphere expressed the upcoming world as shaped in the heads of human beings, as social constructs. But not just as an image, an abstraction in our heads, quite the opposite: First of all as the resulting concrete cultural landscapes and material manifestations. The noösphere was the material results of our purposefully transformed environment. One could argue that it was the technosphere as the concrete man-made world that he described, but this would be a mistake: he did not divide our landscapes into man-made and natural landscape, rather he saw the earth being more and more shaped as a sort of an extension of the human body, serving ever-changing human needs, including taking care of this body for his own sake. And despite that he was placed in a threatened centre of the Second World War, he was basically optimistic concerning the influence of that development of the human beings as future caretakers of the earth and all its inhabitants. So, the noösphere-concept was not our present landscape dreams of today, but a concept of an emerging stage of the history of the earth dominated by mans conscious creation of his sustainable environment.

The relation between biodiversity and landscape ecology

In Gastons introduction to his textbook on 'Biodiversity - a biology of numbers and difference' (Gaston, 1996) , he present biodiversity in three different ways, namely as a concept, as a measurable entity and as a social/political construct.

In fact, landscape ecology as an applied science related to the problems of biodiversity, can be described in a parallel way (se fig. 1).

BIODIVERSITY	THE LANDSCAPE IN LANDSCAPE ECOLOGY
Concept	Hierarchy of holistic spatial units of the total human ecosystems at different spatial scales, to which the biodiversity concept can be applied.
Measurable entity	Quantitative description of structure, function and dynamics of landscapes, and their relation to quantitative measure of biodiversity
Social/political construct	The wish to shape landscapes as a part of 'mans making peace with nature and himself'. Shaping landscapes of a sustainable society

Figur 1. Parallels in the way of looking at biodiversity and landscape ecology.

The holistic spatial unit as a concept in landscape ecology: The central part of the landscape concept in landscape ecology is related to the herarchy of holistic spatial units, based on the concept of holism. Marc Antrop (1999) gives som good exemples for its explanation. One of the tricks within classical geo-ecology has been to use certain components as especially good expressions for the spatial structure of the wholes, in German often named Hauptmerkmale - main characteristics. At the lowest level, the ecotypes, typically the soil, at other spatial levels other components, e.g. relief or in some situations vegetation could be a main characteristic, used to delineate the whole, or the geo-ecosystem (Klijn, 1997) . It does not mean that the ecotypes are just soil-units, but that the distribution of soil has been used as a main source to describe the whole, because soil to a certain degree expresses the unity of the geo-system. Further, the relation between structure-function-dynamics, will typically take place within topological or chorological units at a certain level. One can discuss this holistic character with the use of many terms, often apparantly contradictory, like competition or equilibrium. (Zobel, 1997) has e.g. given some interesting hint to the concept of Symbiosis, that for strange reasons has become unpopular compared to concepts that can be paralleled to the dominating economic and political ideologies. There are still, for historical and probably also political reasons, many odds against holistic thinking, but there are also an urgent need for it. A crucial point for landscape ecology is to get spatial landscape units at all levels accepted both analytically and practically as both individuals and types of nature, and to consider the study of landscape structure as a form of a spatial taxonomy that can be paralleled to the study of species taxonomy. I am sure that there is no principal difference, with the exception that the spatial taxonomy is much more complicated.

The landscape as a measurable entity

This is not only due to the fact, that the space is continuous, in opposition to species. But also due to the extra dimension of spatial arrangement and contingency that is added to the description of variety.

In Figure 2 is shown information on different types of measured biodiversity in a very simplified example, namely 4 different birdcages. Depending on how one actually look at the biodiversity problems of the four cages one will get different results, and rank the cages different concerning their biodiversity qualities. However, if one parallel this situation to a taxonomy of landscape elements or ecosystems, used for a description of landscape heterogeneity as a parallel to species diversity (se Figure 2), it shows up, how the spatial configuration of the areas provide us with a whole new dimension necessary to handle. Thank to computers and the development of geographical information systems and satellite remote sensing it is today in principle possible to handle such complicated structures in a quantitative way. The main problem is that we mentally have difficulties in grasping the complexity in a lucid way. Here we miss concepts not only in science but also in our everyday life and common language.

	Cage 1	Cage 2	Cage 3	Cage 4
Number of birds	200	200	200	200
Proportion of	1,00	0,98	0,35	0,01
Proportion of canaries (P_2)	-	0,01	0,35	0,01
Proportion of nightingales (P_3)	-	0,01	0,30	0,01
Proportion of other birds (P_4 to P_{100})	-	-	-	0,01
Biodiversity (species richness)	1	3	3	100
Biodiversity (threatend species)	0	2	0	100
Biodiversity (lokal species)	0	1	1	>1
Biodiversity (Shannon index: $D= \Sigma P_i \log_{10} P_i$)	0,00	0,05	0,48	2,00
Biodiversity (Simpson index: $D=1/\Sigma P_i^2$)	1,00	1,04	2,98	100,00

Fig. 2. Different types of biodiversity in 4 different birdcages

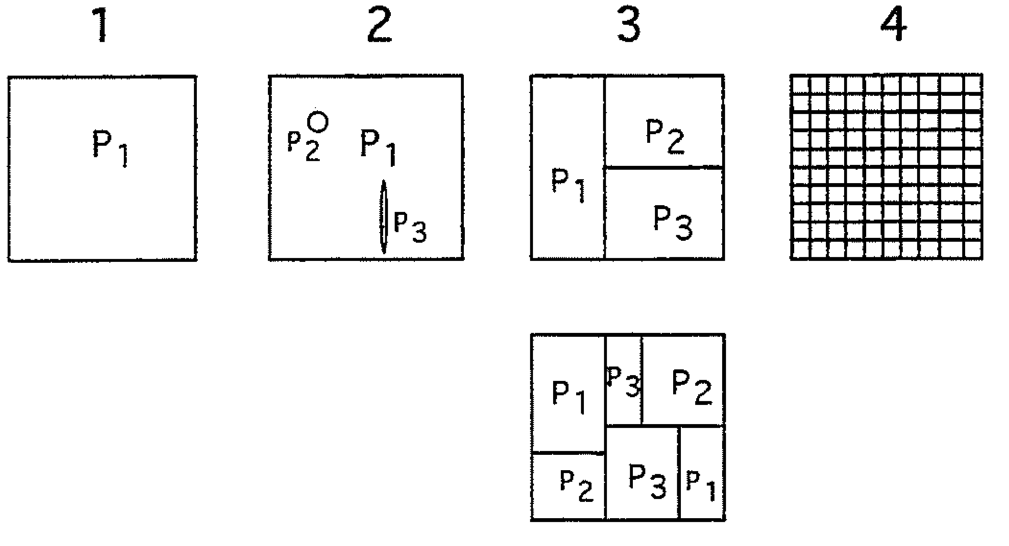

Fig. 3. Four different cases of spatial diversity corresponding to the species diversity in fig. 2.

Landscape as a social/political construct: This brings me to the third concept, namely the landscape as a social/political construct and its relation to biodiversity. How to shape the landscapes of a sustainable society? How to promote Biodiversity as part of a good and flourishing life (Arler, 1999). (Gadgil, 1996), p. 29 refer to the American philosopher Brian Norton for the following standpoint: *The most important reason for conserving biodiversity is its transformative value, its influence in moulding human values to be more friendly towards the natural world:* The need of marketing biodiversity. This moulding of human values is the one side of *'mans making peace with nature and himself*. This is not my expression, but a quotation of Friedrich Engels, in a description of a future communist society, or rather a description of socialism as a starting point of mans reconciliation with nature and himself. This might be seen as a provocation, but can just as well be seen as a documentation of a long tradition for dreams and hopes concerning a future sustainable society. And here the perspectives of the interrelation between the different landscape concepts within a transdisciplinary landscape ecology begins to be interesting:

If we go back to the different landscape definitions of the geo-ecologists and the spatial ecologists, the primary and the secondary landscape structure, we can observe some interesting differences concerning the perspectives for the transition towards the future. Whereas the secondary structure first of all expresses the present land cover and land use structure, thus providing a good basis for analysis of the present processes and functions in the landscape, it is not especially good for analysing future developments. So, in our biotope studies of Danish agricultural landscapes we have developed tools for a strict and precise monitoring, which is useful in many connections. But we cannot use it to predict future development of the land cover and land use of these landscapes. Here a parallel detailed geo-ecological survey would certainly have been a relevant tool, since it could provide us with useful information on the potential use of different parts and elements of the landscapes. E.g. that small dips in a moraine plain that might have been drained through the period of industrial agriculture of the 1970ties, can be potential wetlands, not only due to growing environmental interest, but also due to a more landscape-adapted agricultural technology in the future.

One could formulate the thesis that one of the reasons behind the urgent need for a sustainable development in our time is the growing discrepancy between the primary and secondary landscape structure; that the man-dominated land use and land cover to a still minor degree has been adapted to the geo-ecological conditions. You could also interpret a present tendency towards stabilisation of biotopes and a growing heterogeneity of our agricultural landscapes, as a sign of an emerging development of sustainable land use at the landscape level. With knowledge on such tendencies, a geo-ecological survey will provide spatial information relevant for such a landscape dynamics, thereby supplementing the land cover survey. On the other hand, to try to determine an optimal spatial structure solely based on a geo-ecological survey would be a new form of nature-determinism. Here we need some leading design principles and social landscape constructions, where the planning as a creative process supported by the landscape architect-oriented traditions within landscape ecology, and related to a political process, is necessary. This is in essence the rational perspective of modern landscape ecology.

Can the ecosystem people save the biodiversity and the landscapes of the world?

(Gadgil, 1996) divides the peoples of the world into biosphere people, ecosystem people and ecological refugees. The biosphere people are the first and second world, seeing the whole world as one total living system available for human exploitation at the global scale. The ecosystem people are depending on the use of a local/regional ecological resource base. The ecological refugees are the growing mass of former ecosystem people that has been pushed or pulled into an urban way of living, without any direct link or admission to a local ecosystem living permanently on the fringe to the global biosphere system dominating the urban life. Basically his message is; leave the conservation of biodiversity to the ecosystem people - they know best! Certainly this position is related to the present north-south conflict. It seems however to be too simplistic, not touching the core of the problem. Indeed there are examples of ecosystem people with a high general knowledge on biodiversity that will be extremely useful for conservation of biodiversity in a global perspective. Especially in the rain forests the Amazons and South East Asia, investigations have proved that local indigenous cultures can have accumulated enormous information on biodiversity and have build up sophisticated educational systems to maintain such knowledge (see e.g. (Kronik, 1999) . But this does not mean that it is a general characteristic of ecosystem people, defined as people that are mainly dependent on a locally adapted resource use. It all depends on the type of resource use or the type of cultural diversity: E.g. many grazing systems are highly specialised. There are no reason to expect that their knowledge of biodiversity not related to their specific resource use, is especially good developed or provide especially good information in a biodiversity conservation perspective. At least I know one good example:

Through more than 1000 years a very refined grazing system has developed at the Faeroe Island in the MidAtlantic, between Scotland and Iceland. This system has been highly regulated with detailed legislation on the numbers and the management of sheep. So, already in 1298 a special law for the Faeroe Islands, Seyðabrevit (the sheep letter) was passed, which among other points stated that '*the number of sheep to be kept on an area of pasture land shall remain the same as it was in previous times, unless men see that it can accommodate more*'. This figure, in the Faroese language called skipan - in fact an old form of the English shipping - expressed the carrying capacity of each individual location, and to this day it is used as an expression of the optimum carrying capacity for the various parts of the islands. Additional skipans for cows, horses, dogs, geese and so on were also developed (Brandt, 1984).

This could indeed be interpreted as an ecological optimisation procedure, with a detailed adaptation of the grazing system to the grazing potentials of the Faroese landscape. I have studied this process through a parallel survey of the grazing structure and the vegetation of a part of the Islands, to be interpreted as a sort of geo-ecological survey, due to rather clear reflection of the geo-ecological conditions in the vegetation composition. Through a statistical handling of the two sets of data I could determine the productivity of the different vegetation types, and relate the actual historical productivity to the landscape potentials for a more detailed study of ecological bottlenecks in the production system (Brandt, 1992). It was a sort of upside-down landscape ecological analysis, where I used historical production data as entrance to a better understanding of the ecological functions and processes in the landscape.

The information on the territorial organisation of the grazing came from old shepherds, indeed clever people with detailed relevant landscape knowledge - but not concerning biodiversity. Asking old experienced shepherds concerning their knowledge on the plant species (with only less than 600 species all in all at the Faeroes) gave a surprising answer: 'I don't know the names. I let the sheep investigate that'. But the shepherds knew much on the different weather situations and their importance for the sheep grazing. They knew the importance of drainage for the quality of the pastures and for the influence on parasites. However, they were especially skilled within one aspects of biodiversity: The Faroese language, a separate old Nordic language, has developed in a way, so that a Faroese shepherd with only a few words can describe every single sheep in a unique way. This has been important for the social, territorial structure of the grazing system.

This shows how knowledge on biodiversity is closely related to the production system of the biosphere people. This knowledge will be just as specialised as the resource system itself.

Looking at the landscape knowledge of ecosystem people, another problem is striking: For a long time I thought that this type of accumulated ecological and landscape knowledge on the production potentials of a grazing system would be a common feature among ecosystem people. This is not the case. I have in fact not found any other example of such a detailed historical developed regulation of the grazing, although I have found enough evidence to suppose that such type of knowledge often has been present in earlier times, but got lost. This has probably happened first of all through population movements, but also through the replacement of a landscape information based regulation with universal technique-oriented ways of regulation such as barbed wire etc.. Probably constant alterations of resource use also prevent such landscape-based information to develop, with the result that maybe the majority of our ecosystem based cultural diversity are of an ecological refugee-type, with only minor potentials in a biodiversity-conservation perspective.

Finally I have realised a third maybe even more disappointing fact from a landscape ecological point of view. The optimisation system and the sheep letter of the Faeroe Islands were not examples of a sustainable land use. It was a conflict-solving instrument. The Faroese pastures has been degraded through centuries, and despite the regulation there are certainly clear signs of overgrazing, although it has in general been denied be the ruling class. They have argued and do still argue that the Faroese outfields have always been eroded - which is true, because there has been overgrazing for some 1000 years.

To conclude: Although indigenous knowledge can be of very much value, I find it hard to believe that a global biodiversity-conservation-strategy could rely on the present biodiversity expertise of ecosystem people alone. In every case, it should be based on a detailed knowledge of the resource system, the social structure and the history of these people.

Biodiversity conservation and the biosphere people

As a consequence, I find it most likely, although not especially simpatico that a strategy for biodiversity conservation has to be based primarily on the development among the biosphere people.

The most important problem in the present system of the use of the biosphere is the process of parallel specialised intensification of land use on the one side and a general extensification on the other side, resulting in a concentration of land use activities at all spatial levels. This development can result in a landscape ecological disaster. Global specialisation is without doubt important, but it has to be kept under a certain intensity, and be heavily counterbalanced by a purposeful multipurpose planning and use of our landscapes.

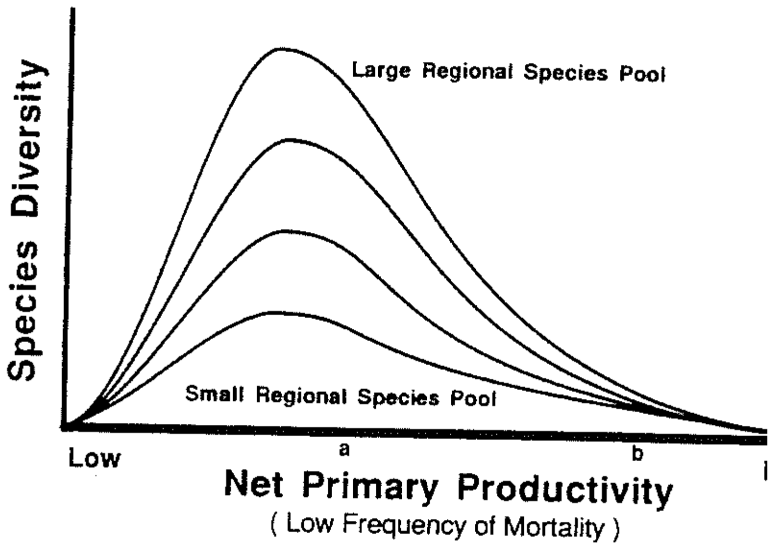

Fig. 4 Predicted variation in species diversity along a productivity gradient in regions with different total numbers of species (i.e., different regional pool sizes). Under low and high productivity conditions, species diversity is limited to low levels by local processes related to abiotic limitations and competitive exclusion, respectively. Only under conditions of intermediate productivity, where neither abiotic limitations nor competitive exclusion operate strongly, can the size of the regional species pool influence the total number of species that coexist locally (Huston, 1999) .

From a landscape ecological point of view, all material wealth is founded in the use of and the accommodation of our needs to the landscapes surrounding us. In a multipurpose land use the single types of land use can be kept under certain intensity and at the same time allow for an overall intensity of the multiple land use keeping and extending the resulting economic and social benefits along with this process. In this case the single types of land use will also be forced to keep under certain intensity due to the negative influence of intensive use on other types of land use.

Here the resulting consequences for biodiversity are of course especially relevant. From a theoretical point (Huston, 1999) has shown how species diversity in fact is related to a medium net primary productivity (Figure 4), whereas a very low as well as a very high productivity is related to a low species diversity. It is interesting to parallel this to the empirical knowledge on the linkage between agricultural intensity and environmental values, presented by Green, where the maximum value is also related to a middle intensity (Figure 5).

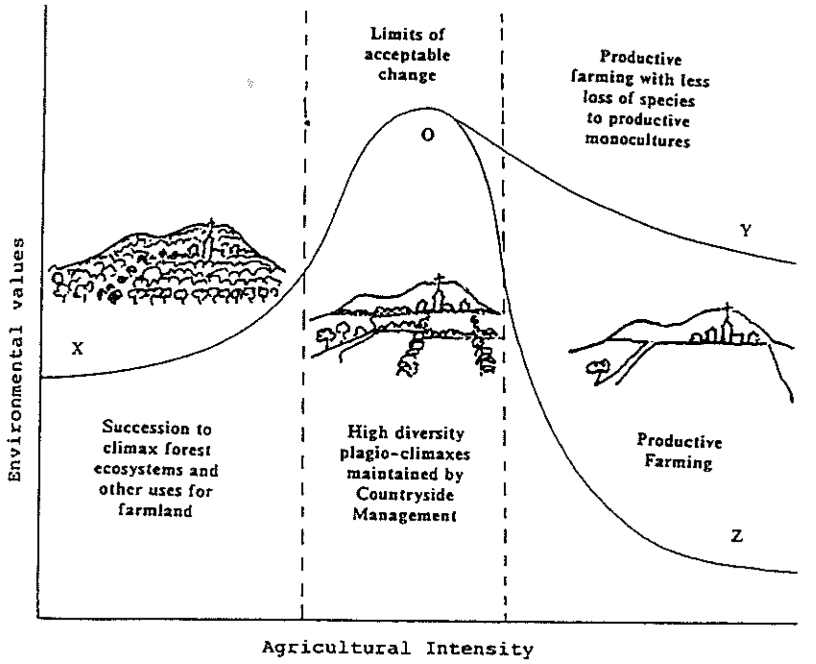

Fig. 5. A model based upon data from (Grime, 1979) relating species density in herbaceous communities to above ground standing crop and Connell's 1979 model relating species diversity in rainforests and tropical reefs to disturbance events. Agriculture may be considered a combination of these factors. It has diversified the environment by creating new biotopes such as grasslands and heathlands, often richer in species than the climax forest they replaced. Modern intensive agriculture however leads to loss of biotopes and species diversity. Overcapacity in agriculture offers the opportunity to
a) take land out of production which could be used for forestry, recreation and other purposes (O - X)
b) manage the countryside by traditional farming (Z - O)
c) develop more environmentally-benign systems of productive agriculture (O-Y)
(Green, 1993)

This is not only interesting for an improvement of biodiversity in intensively used landscapes, but indeed also for the biodiversity of the many areas under extensivation. One of the most famous landscape ecological examples of this sort is the detailed study by Vos and Storfelder of the Solona Basin, an old cultural highly diverse landscape in the central Tuscany. This has been transformed into extensive forests due to desertification, since all economic activities in Italy concentrate on the big plains and along the coasts. Vanishing Tuscan landscapes, the authors called the study (Vos og Stortelder, 1992).
Shortly after the publication I visited a landscape ecological meeting in Tuscany, where both the authors and many planners from the region were present.. The planners were deeply concerned with the problems. And they asked the landscape ecologists seriously: You are right. It's a catastrophe for nature and European cultural diversity. What shall we do? Tell us, and we will do it! Suddantly Villem Vos stand up, almost angry, shouting to the audience: 'I don't know what to do. But I am still so much of a socialist, that I cannot blame people for moving to the coast looking for a better life'.
In other words, maintaining cultural landscapes and the related biodiversity is a question of sustainability, showing that the ecological, economical and social aspects of the concept cannot be separated. Also biodiversity conservation has its economic side, basically in form of peoples actively using their working time - not spare time. So, here around this Danish agricultural landscapes farmers has to develop into conservationists, since it has to be considered a landscape ecological problem that when farm size double there will in general be half the time for taking care of each landscape elements, unless it is compensated for in another way.
Although Willem Vos was honest, I think he gave a wrong answer. He answered more as a specialised traditional soil scientist, than as a practical landscape ecologist. He should have stressed the necessity to change the land use and ensure the economic viability of the regional and local resource use, by reallocating economic activities from the coast to the hinterland.

This would be the only long-termed chance, although against present economic theory. It might sound hopeless. But let me close by quoting Gro Harlem Brundtland from her famous report Our Common Future: Although the answers to the serious problems confronting us are not present, we have no alternatives to keep searching (World Commission on Environment and Development, 1987). One place to search will be among landscape ecologically interested landscape architects and planners.

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