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Karl - Friedrich Schreiber (Hrsg.)

Connectivity in Landscape Ecology

Proceedings of the 2nd International Seminar of the "International Association for Landscape Ecology"
Münster 1987

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Foreword

Ten years ago, the general theme of the meeting of the (German) Association for Ecology held in Münster was „Ecological Fundamentals for Planning". By choosing this theme, I wished to give the association an impulse which would lead to its dealing more than it had done in the past with the growing task of the practical realization of ecological findings and their use in practice.
„Connectivity in Landscape Ecology" was the theme of the workshop of the International Association for Landscape Ecology (IALE), which took place in Münster in July 1987. Here, too, an overview of what landscape ecologists can offer in practice was given; ist was shown how – in increasingly cleared out and ecologically impoverished cultural landscapes, especially in Central Europe – a renewal or an increase in the density of connective migratory structures and an increase in the size of refuge areas can be planned and realized.
The meeting and most of the contributions printed in this volume show that we are only just beginning to master the tasks of chiefly applied scientific work. Landscape ecology together with all scientific disciplines concerning ecology in the bio-sciences, geo-sciendes and planning cannot evade these problems if we do not want to leave to our descendants a desolate countryside functioning more and more onesidedly and thus becoming less adaptable, a monotonous countryside poor in recreational value.
I am most grateful to the Federal Ministry of Research and Technology for taking over the main part of the printing costs as the financial contributions to the meeting did not cover these.

Münster, September 1988

Karl-Friedrich Schreiber

Contents

CONNECTIVITY IN LANDSCAPE ECOLOGY

A few thoughts on the concept of the network of biotope systems in the agricultural landscapes of central Europe

K.–F. Schreiber

1. Introduction

"Connectivity in Landscape Ecology" is, in principle, a very wide field. It includes the entire complex of relationships in and between ecological systems. Correctly understood, it is the concept of landscape ecology that CARL TROLL, the founder of landscape ecology, originally formulated. Not only the interrelationships in communities and between organisms are meant, but also the network of interactions and flows between the biotic and non–biotic compartments of the ecosystem. The investigation of these interrelationships separates ecology from biology and places it as a discipline between biology and the geo–sciences.

However, from my point of view, we can here only deal with one aspect of connectivity in landscape ecology, one which concerns a burning problem in western Europe and the Common Market countries. Each year, enormous amounts of agricultural products are produced in the rural areas, some of which lie in the most densely populated areas of the world, products that can no longer find a market. Fixed price guarantees and the expense of storage are costing the taxpayers in the Common Market countries millions.

2. Model ideas for withdrawal and rededication ("Flächenstillegung und -umwidmung") of agricultural land
Chances for an ecological recovery of agricultural landscapes

Among other aspects, including those concerning business administration, two possibilities are being discussed – especially in central Europe – which should not merely be of interest to the ecologist, they should in fact challenge him to make his contribution. These possibilities are: extensive cultivation of agricultural areas and/or rededication of areas, i.e. the withdrawal of lands from the present agricultural production and the development of new concepts of land use.

Here lie the chances for, and at the same time the responsibility of landscape ecology, of nature protection and conservation. This situation gives us the probably unique chance to bring to a halt a development in the man-made central European landscapes which we have been criticizing for years: the so–called "clearing up" of the countryside. By this is meant destruction of natural elements such as hedgerows, thickets, ridges of stones collected from the fields, brooks and ditches in the course of land consolidation. This process, which results in a dissection and isolation of biotopes in countrysides once so abundant in structures and species, can possibly be reversed. At present, mainly two models are being discussed (c.f. KNAUER 1987):

- the segregation model
- the integration model (according to MADER 1986).

The segregation model involves, especially in the Netherlands, a further intensification of a smaller area of agricultural land, while the withdrawn areas are given over to extensive use or nature conservation. However, this intensification means a further increase in the use of chemicals as fertilizers, for plant protection and pest control. The immediate result of this will be a further destruction of plant and animal populations in these areas. Indirectly it also effects the adjoining areas which are either used for agricultural purposes or withdrawn from cultivation. Even sleeper ecological gradients will develop between the border areas and the centres of the areas provided for nature conservation. In addition, there will inevitably be an increase in the transfer of nutrients from the intensively cultivated areas: this will result in an increased groundwater pollution.

The so–called integration model involves an overall reduction in the intensity of cultivation together with a selection of areas for a biotope network system. KNAUER (1987) suggests that the integration model be realized in three steps. The first step should be an overall reduction in the intensity of land use, the second a withdrawal of large areas for nature conservation – each about 10 – 100 km² in size. The third and last step should be the meshing of these conservation areas and biotope complexes together with those already existing.

We can only hope there will be no further increase in the intense cultivation of agricultural areas, even on a small scale. We do not wish to discuss here the agro–structural pros and cons of intensive and/or extensive cultivation. However, we should like to point out to the ecological problems in this field, to the possibly irreparable negative effects on the life of mankind.

Ecologically, a landscape does not gain much if the withdrawal of areas is only short–term. Land rotation lasting only a few years would probably not even result in a notable reduction of agricultural production. As will be shown later, measures which lead to new, sound agricultural structures only take effect if planned long–term.

Whichever model is finally accepted in the environmental and agro-political discussion – we cannot evade the scientific and practical challenge of ecology, its contribution to the "where" and "how" of the rededication of areas and the creation of a meshing which functions together with its connective structures. We cannot evade this challenge by withdrawing into the academic field.

Therefore, the preliminary announcement to this meeting and the request for contributions focussed on this topic. It could be summarized as follows:

"Biotope Connectivity in Theory and Practice".

3. Starving of eutrophic, over–fertilized areas in the case of rededication ("Flächenumwidmung") to connectivity–systems as prerequisite to the realization of ecological functions

The first questions which we have to ask ourselves in view of the extremely rapid increase in the intensification of agriculture in central Europe in the past decades – probably the most intensive in the world – should be: will our agricultural land, saturated and often overloaded with nutrients and pollutants, if withdrawn from use, be able to develop not only the required structures but also the functions necessary both for the migration and exchange movements of plants and animals between individual corebiotopes as well as the functions indispensable for their survival? Is the level of eutrophication in many soils not too high to offer even a temporary habitat to plants and animals which can only compete and survive under oligotrophic conditions? Will we able to starve these soils, will we able to withdraw enough nutrients from them in a relatively short time in order that they may provide shelter to the especially endangered species needing oligotrophic surroundings? It is biotechnically possible to "build" structures, although a great deal of work is often necessary to set them up and maintain them. But functions are, especially for plants as the carriers of structures and functions, often more or less strictly bound to site conditions. These have, however, especially when they were of an extreme nature, to a great extent been eliminated by amelioration measures, by use of fertilizers and chemicals for plant protection. Instead, more or less uniform landscapes with uniform sites have been created. It is, in fact, possible to withdraw nutrients from a soil. SCHIEFER (1984) for example reports on results of grassland experiments: if grasslands are cut twice or three times annually as green phytomass or hay without fertilizer being added, a gradual reduction of the nutrient level can be registered. The withdrawal of nutrients from the soil in the form of green fodder or hay leads to a lowering of the level of nutrients in the soil despite the fact that a considerable amount of atmospheric nitrogen is bound in the soil (Federal German Republic: 2O–6O kgN/ha/a (ULRICH 1982, ELLENBERG jun. 1985, BACH 1987).

Our experiments with fallow lands in Baden Württemberg (SW Germany) also show this trend even when the cut grass is not removed and no nutrient export takes place. After a preliminary rise in yields of the bi–annually mulched[1] plots on especially productive sites the annual production of phytomass above ground decreased significantly after about 5 years. Especially these areas showed a slight chloritic colouring of the young grass which, in agriculture, is known as a sign of a nitrogen deficiency (cf. SCHREIBER &SCHIEFER 1985).

However, these symptoms occur neither in those plots which are mulched every second or third year nor in the undisturbed succession plots. When treated in this manner the plots rather showed a gradual increase in the production of phytomass during the last years. Studies of the nutrient content in the new growth on the succession plots during various stages in the vegetation period show an obvious relocation of the nutrients from the dying shoot to the base of the shoot. In the plant stands mulched irregularly or not at all a considerable internal nutrient relocation occurs without nutrient loss. (cf. Fig. 1) At the end of the vegetation period only part of the nutrients remain in the above ground dead phytomass of the succession plot; these are mineralized in the following year when the temperatures rise and according to the increase in the nutrient absorbing roots (cf. SCHREIBER & SCHIEFER). Thus the external nutrient flow leads via decomposition and mineralization back to the plant with little loss through leaching. The stand of plants on a succession plot is, therefore, in view of the nutrient household a relatively economic system in which in time an accretion is to be expected (cf. SCHREIBER 1987). Almost the same applies to those plots in which a cutting late in the vegetation period permits an internal rearrangement of nutrients, especially if the plots are not cut every year. However, the system works differently in a greenland mulched bi–annually. The plant mass above ground is cut shortly after maximum nutrient storage has been attained. Accordingly, rapid mineralization follows under usually good decomposition conditions, at least after the first cut – 4OOO–6OOO kg/ha often within one to two months. This remarkable catabolism in June/July seems to proceed regularly together with a large reduction in the root mass, especially in the nutrient–absorbing root tips (SPEIDEL & WEISS 1973; SCHREIBER & SCHIEFER 1985). Therefore, at times of great precipitation with resulting percolation of water through the upper layers of soil, a loss of nutrients has to be expected. Also the second, but much slower catabolism after a mulching in August takes place in the second half of the vegetation period (cf. SPEIDEL & WEISS) during the reduction of the root mass in the ground so that a further nutrient loss in autumn is to be expected. A leak occurs as a result of the external route of decomposition and mineralization of the organic substances (cf. Fig. 1) due to which a probably considerable amount of nutrients is lost. Exact amounts have yet to be established.

[1] Mulch: A method in central Europe by which the phytomass is removed from the greenland after cutting but remains there for decomposition.

4. Denitrification – A "natural" elimination of the nitrogen eutrophication in(re–) wetted brook and stream lowlands ("Auen") as possible basic structures for a biotope network system

A further aspect of the "cleansing" of our nitrified landscapes in central Europe which is directly related to the development of connective structures is the creation of green strips alongsidewatercourses. Especially the damp to periodically damp border areas of outfalls could take over an important function in landscape hygiene, which is a concept of increasing importance. The reductive milieu in the soils often lacking in oxygene leads to a high denitrification rate already pointed out to by MEYER in 1957. Nitrogen compounds are set free from the soil in form of N_2–gas which escapes into the atmosphere. This is a more or less harmless process, apart from the somewhat problematic intermediary product N_2O. To my knowledge, little use has been made of this natural and harmless nitrogen reduction until now (cf. SCHREIBER 1972). It is, in fact, an inexpensive possibility and bonus if one uses the still relatively damp sites alongside the outfalls as routes or corridors for the greening of agricultural landscapes and for the creation of connective structures. Water held back by dams in parts of the wetlands drained and lost in the last decades in countless lowlands and valleys, streams which have been returned to their almost natural state: these structures could serve this function well.

Through sufficiently broad grassland strips on both sides of ditches and brooks a considerable reduction in the direct transfer of nutrients into the surface water can be achieved. The erosion cargo remains mostly in the border strips. Dissolved nutrients such as nitrates transferred via water into the soils are removed from the system in the manner described above. The unusually low values shown in the nitrogen analyses carried out in connection with our wetland project in Northrhine Westphalia as well as the mineral nitrogen determination in the experiments with fallow land in Baden Württemberg confirm this presumtion. Apart from phosphate, only the dissolved potassium, which is of little importance in those waters, remains in the greenland sites. However, both act less selectively and destructively to species variety than nitrogen, a fact which all fertilizing experiments prove without doubt (cf. e.g. KÖNIG 1950).

On the other hand, such grassland strips or corridors have a high potential for migrants. If extensively cultivated – with, at the most a minimum addition of fertilizer, should that be at all necessary nowadays in our over–fertilized landscapes – they quickly develop into the type of meadow now lost, rich in variety of species, which used to be mowed for hay twice a year. A pronounced moisture

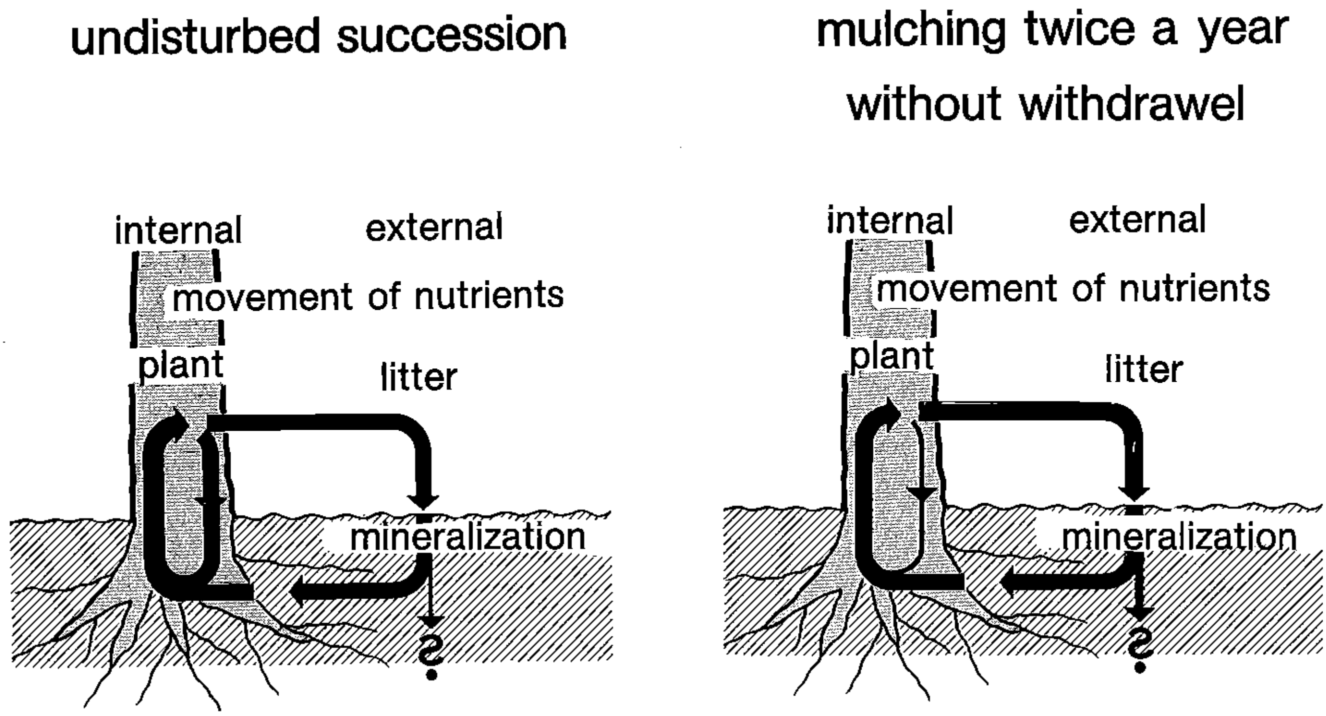

Fig. 1.: With "undisturbed succession" nutrients will be shifted internally in the plant (cf SCHREIBER 1987), whereas with "mulching two times a year" the back flow of nutrients will take place mainly externally through mineralization of the mulchmass which is rich in nutrients. With it, there will be the risk of increased losses by erosion of the nutrients. Mulching twice a year means in Central Europe a method, by which the phytomass is not removed from grassland after cutting but remains there for decomposition.

gradient exists between the edges of arable lands situated higher up far from the groundwater and the banks of the outfalls: this permits an interfacing of a great variety of species with differing moisture demands. Even migrants, though certainly not all, can find a temporary domicile here. In this way, watercourses which have always belonged to the natural migration paths in the woodlands of central Europe can once again become important migration routes.

The land consolidation authorities with their know–how of buying, exchanging and reallocation of plots of land as still intact instruments are – as the enforcement authorities of a specific agricultural policy – responsible for many of the ecological problems which they could now solve. The additional experience of the water authorities who are increasingly involved in returning watercourses back to their original state makes us hopeful that the situation described above may well be realized in the future. Especially if the public disquiet regarding the billions of DM required for the storage and administration of the surplus production increases.

5. Further aspects of connectivity of biotopes in central European landscapes

Besides the network of watercourses as the natural basic structure of a biotope network system (cf. SUKOPP & WEILER 1984) in a grassland landscape which could surely be utilized and cared for in a different manner, there are numerous other possibilities as regards the connectivity of biotopes. This is especially true in the case of sub–alpine mountain, cuesta and young moraine landscapes which possess a denser pattern of natural or man–made structural elements: hills with shallow soils, hogbacks or ridges, old field terraces and many other structures which could be integrated into such a network. Nevertheless, intervention in biological systems is unavoidable, e.g. the broadening of skirts (strips), the development of new fringes along side woods, hedgerows, ditches and roads as well as a densification of the structure of hedgerows. The latter, even when wide enough, demand special regular care in order that multiple structures be maintained or created. Such structures existed in the past due to the rotation of the use of hedgerows.

Strips on the borders of fields which are less frequently sprayed with chemicals nowadays and which accompany larger cultivated areas, serve as connective structures and refuges providing shelter to many plant and animal species dislocated from the more intensively cultivated areas, thus offering them new chances for survival. By incorporating woody patches and groups of trees as well as for example the small woods common in the Münsterland countryside, a network system can again be created in the central European agricultural landscapes which will counteract the impoverishment of species and biotopes we have furthered in the last 15O years (cf. SUKOPP 1981; SUKOPP & WEILER 1984; Fig.2).

One of the main prerequisites for the functioning of such a system is, however, as previously mentioned, a noticeable reduction of the present nutrient level in the landscape. We have greatly reduced the previous variety of sites, hereby creating uniform sites with ubiquitous species. The original habitat pattern must be recreated, at least in part, if our efforts to preserve inhabitants of extreme habitats are to succeed.

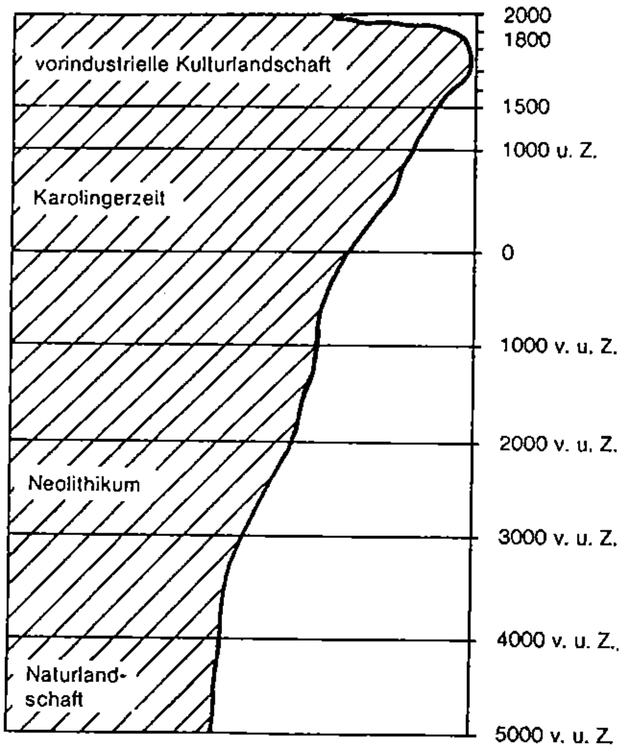

Fig. 2.: The changes in the variety of the flora in the middle of Europe starting with the natural woodland till the preindustrial and industrial man-made landscape. The last 500 years with the decline of species since 1800 are depicted superelevated (FUKAREK 1979, quoted from SUKOPP & WEILER 1984).

6. Agricultural land use asa necessity for the maintainance of valuable biotope complexes and their internal interlacing

In my opinion, in the case of larger ecological sections of the landscape or of a larger complex of connected biotopes, the internal interlacing seems just as important as the external interlacing through banded structures, corridors and stepping-stone biotopes. This often demands the maintenance or even the reintroduction of continual human intervention. However, land use should be less intense and fewer agrochemicals should be used than in the intensively cultivated areas.

The following description of an example of our work will show not only the importance of internal meshing but also the necessity of further agricultural land use in order to preserve functional systems:The Niedervieland in the largely mineral-alluvial mud Wesermarsh west of Bremen is an old grassland which has been used extensively uptil now. Until recently it was largely unexplored and it was only at the beginning of the eighties that its floristic and faunistic value was "discovered". Because of its ecological richness and its size of over 2000 ha it is of European and international importance. Large stands of blooming water soldier (*Stratiotes aloides*) with large species of dragonflies such as *Eschna virides* and *Eschna isosceles* in the dense ditch system, are accompanied by flowering rush (*Butomus umbellatus*) and water violet (*Hottonia palustris*). In addition to the shore communities with numerous species listed as endangered, there are grassland communities of the humid meadow and pasture type now rare and worth protecting. The area is an eldorado for waders such as the Curlew (*Numerus aquata*), black tailed godwit (*Limosa limosa*), redshank (*Tringa totanus*), snipe (*Gallinago gallinago*), for the whinchat (*Saxicola rubetra*) or the now extremely rare bluethroat (*Luscinia svecica*) as well as for many other species on the Red List which need wide, open meadows and pastures in order to survive.

It is possible that this grassland with its dense network of ditches has gained its present ecological value as a result of the recent additional irrigation which is carried out when the ditches dry up in winter. Due to the more or less even moisture of the ground, wetland birds are able to search for food throughout the year. The water soldier used to be frozen during the winter months in the formerly dry ditches. This no longer occurs and that is possibly why it covers such large areas today. Different stocking-times on the pastures, usually fairly late mowing dates on the meadows, changes in the utilization of meadows and pastures as well as a short-term fallow period of areas with difficult access have created the important multiple grassland structures necessary especially for meadow birds. These are able to raise their young undisturbed in spring, they can always find shelter in the neighbouring vegetation structures and since the meadows and pastures remain damp even in summer the area is a source of nourishment all the year round.

The dike authorities will prevent silt-fill of the ditches by clearing them regularly every few years. This used to be done by hand, now it is done by machine. Because of lack of time only part of the ditches were cleaned. That is the reason why today you will find ditches in all stages of clearance: some have just been cleared and seem almost sterile, others are silt-filled, others are in between. Seeds and regenerative parts of plants as well as fishes or insects in various mobile stages of development can be reintroduced into the system at any time. Almost as soon as the ditch has been cleared, the first light-demanding floating leaf communities with the accompanying fauna develop. They are followed by stands of flowering soldier in various stages together with flowering rush which, overshadowed and hemmed in by bank communities, in their turn are succeeded by stands of water violet. Finally, reed communities develop in the silt-filled ditches which are then cleared out again. Then the rapidly proceeding succession described very briefly, simply and incompletely above, begins once again. Only the regular clearance of the ditches which until now have been filled with mesotrophic water and which are situated amongst moderately fertilized and relatively extensively cultivated meadows and pastures can contribute to thesurvival of many short-lived but valuable ditch and ditch-bank communities.

The dense internal meshing is guaranteed by the very dense system of ditches. The distance between the majority of ditches is 20-60m. Numerous small drains ("Grüppen") and depressions ("Blänken") in the grassland area which temporarily carry water result in an even denser network of wet sites, some of which are only episodically wet. Animal footprints on the wet borders of ditches and depressions create a multi-contoured micro-relief with numerous kinds of niches. Varied small forms serve as connections between the water and the adjoining grassland areas. The interlacing via the food chain and the sleeping, living and feeding habitats is rich in diversity and variety. Any reduction of these manifold structures, especially of the basic pattern of the ditches and utilization would inevitably lead to a reduction in living space. This in turn would lead to a reduction in the population density. In order to regain the original population density, the dimension of the area would have to be increased should it be impossible to reconstruct the original manifold structures and functions.

This very superficially described highly interlaced biotope is, however, a "second—hand paradise": the system only exists as a result of the grassland utilization and cultivation which has been carried out until now; and it will only continue to exist if the present utilization and management is continued. Should the system be left to develop on its own a change in the type of growth would occur: tall perennial herb communities and bushes would appear. This would mean a limitation of the biotope and a change and impoverishment of species. On the other hand, an increase in the intensity of cultivation would disturb the balance, one which seems ingeniously planned but which is more or less a coincidence. Such an increase would also lead to a change of species and a diminishing of variety, an ubiquiste society would be the result.

7. Concept for biotope—management as a necessary prerequisite for the creation and interlacing of biotopes.

Finally, this brings us to the last important point when contemplating the concept of an interlacing biotope system. In order to create successful connective structures which will actually function as anticipated, careful consideration will have to be given to an effective management of the areas and their surroundings. (cf., among others, SCHREIBER & SCHIEFER 1985, SCHREIBER 1986)

It goes without saying that the basis of such biotope management should be the knowledge and the consideration of the present site conditions, of the possible changes which might have occurred as a result of the previous, longstanding utilization and of the site's suitability for the proposed purpose. In one of the following contributions we have presented a few brief aspects of ditch management in the course of compensation measures for the Niedervieland area described above. (cf. LECKE, HANDKE, KUNDEL & SCHREIBER 1988, in this volume)

Great efforts will most certainly be required in order to compile present knowledge on biotope management for general use. For the necessary measures are as manifold as the number and type of biotopes. It might even be necessary – as we have seen – to first reduce the nutrient and/or pollutant level step by step, a measure which might turn out to be the normal procedure.

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CONNECTIVITY AND THE THEORY OF LANDSCAPE ECOLOGY

M.J. MCDONNELL AND S.T. A. PICKETT

Introduction

Landscape ecology addresses questions of the nature and significance of spatial heterogeneity on the"landscape scale" (10s of meters to kilometers). With its long history in europe (NEEF 1963, TROLL 1968, SCHREIBER 1986) and its recent emergence in North America (RISSER et al. 1983, FORMAN and GODRON 1986, TURNER 1987), landscape ecology has been applied to a wide variety of topics, including land management (NAVEH 1971, SCHREIBER 1977, FRANKLIN and FORMAN 1987), nature conservation and protection (PICKETT and THOMPSON 1978, NOSS 1983, LOVEJOY et al. 1986, OPDAM 1984, VAN DORP and OPDAM 1987) and the study of population dynamics (HOUTE DE LANGE 1984, MERRIAM 1983, MIDDLETON and MERRIAM 1981, WEGNER and MERRIAM 1979, HENDERSON et al. 1985) to name a few.

The diversity of approaches associated with the recent explosion of interest in the field of landscape ecology suggests the need to synthesize current concepts and to develop a common conceptual framework or theory to facilitate the advancement of the science (HASSE 1984). The purpose of this paper is to identify the components of the developing theory of landscape ecology and to examine the concept of connectivity as it applies to the framework. The importance of developing such a framework is not motivated solely by philosophical concerns. A framework is useful because it helps to (1) evaluate progress in the field, (2) identify fundamental questions for future research, and (3) explain why the study of landscape ecology is important.

Components of a Conceptual Framework or Theory

Theory is a conceptual device (SUPPE 1977) or tool which helps to advance understanding. Discussions of theory in the literature are generally philosophical in nature (cf. MCINTOSH 1980, ROSENBERG 1985, and STEGMULLER 1976, SUPPE 1977, LEWIS 1982, NOVAK and GOWIN 1984) and usually are not directly useful to landscape ecologists or do not address all the components of theory. To overcome these problems, we and other members of the Institute of Ecosystem Studies (PICKETT et al., in prep) have attempted to enumerate the components (conceptual devices) of theory in a clear and simple ecological context. Because it is impossible to characterize in detail all of the components of theory in a short paper, we have only briefly outlined the components (Table 1).

Theory is not restricted to any one of the components or conceptual devices, but is embodied in all of the components in Table 1. In fact, all of the components combined form a higher order conceptual device. It is important to stress here that each component is subject to refinement, alteration, or rejection. In a well-developed theory the conceptual devices will be distinct from one another. In incipient theories, they may be vaguely defined or intergrade or several may be absent. In the next section we will compare the components of the emerging theory of landscape ecology to the enumeration of the components of theory in general (Table 1). Our purpose here is to be indicative and not exhaustive in our presentation of the components of a theory of landscape ecology.

The Development of a Theory of Landscape Ecology

In this section we will characterize conceptual devices or components of theory and give examples as they relate to landscape ecology. Our discussion will begin with pre-theoretic components, such as notions which are usually not well developed, and progress to more precisely elaborated components such as facts, confirmed generalizations and laws.

Notions are initial or singular observations that motivate theoretical development. They are often personal subjective ideas that stimulate generalization, clarification or unification. Landscape ecology includes the following notions:

1. Landscapes are recognizable features of the surface of the earth.
2. Landscape structure influences function and dynamics.

Concepts are explicitly defined, or general, abstract ideas. NOVACK and GOWIN (1984) define concepts as regularities in events or objects designated by a label. Concepts can be communicated, and can form the basis for other constructs in science. Landscape ecology includes the following concepts:

1. Landscape subunits exist and exhibit values of parameters such as size, shape, composition and function that differ from their surroundings.
2. Landscapes are composed of repeating patterns of structurally and functionally distinct subunits that vary in composition, size, shape and arrangement.

We have intentionally used the general term "landscape subunit" to describe units smaller then a landscape in order to make the theory more robust and applicable to a variety of approaches. The definition of an operational landscape subunit (e.g., ecotope, biotope, ecosystem, patch, matrix) is scale dependent (cf. TANSLEY 1935, HUTCHINSON 1967, ALLEN and STARR 1982, O'NEILL et al. 1986, MEENTEMEYER and BOX 1987) and related to (1) the questions at hand, and (2) the nature of the other theories (e.g., geography theory, ecosystem theory, landscape planning theory, vegetation theory, etc.) in which the questions are couched. Thus, for most landscapes there is no a priori definitive classification of functional subunits. Any one landscape may be subdivided in numerous ways depending on the questions at hand and the scale of the processes involved.

The other components of the theory of landscape ecology are presented in outline form (Table 2). The remaining component we will discuss is the framework itself. A framework is a general model of the structure of an entire theory. It includes statements or examples of all components of a theory and explicit connections between them. This definition of theory as a high- level, i.e., a general, system of conceptual devices to explain and understand ecological phenomena and systems, is the only one that merits the term "theory" (STEGMULLER 1976).

Although our enumeration of the components of the developing theory of landscape ecology was not exhaustive, three conceptual areas appear to be in need of attention. These include (1) developing testable empirical models, (2) identifying universal laws, and (3) developing translation rules for applying the theory to different scales and organizational levels.

Connectivity and the Theory of Landscape Ecology

MERRIAM (1983) was the first to apply the term connectivity to the study of landscapes. He refers to connectivity as a parameter "...which measures the process by which the subpopulations of a landscape are interconnected into a demographic functional unit." FORMAN and GODRON (1986) define connectivity as "a measure of how connected or spatially continuous a corridor or matrix is." In the conceptual framework presented above, connectivity is classified as a landscape phenomenon which describes a relationship between landscape subunits. The more connections between similar landscape subunits, the greater the connectivity of that subunit in a landscape. A landscape with many connections between similar subunits can be considered to have a higher level of connectivity than one with only a few connections between similar subunits. A growing body of literature suggests that landscape connectivity is important to the persistence of both plant and animal populations in fragmented landscapes (WEGNER and MERRIAM 1979, MIDDLETON and MERRIAM 1981, FORMAN and BAUDRY 1984, HENDERSON et al. 1985).

As pointed out by FORMAN and GODRON (1986), landscape subunits may also function as physical or biotic barriers. A landscape with a connected network of barriers would exhibit high dis–connectivity (1 – connectivity). Studies by WILLIS (1974), OXLEY et al. (1974), KARR (1982) and LYNCH and WHIGHAM (1984) indicate a number of landscape subunits (e.g., water bodies, fields, roads) can function as barriers to bird movement. These and other landscape subunits may also form barriers which restrict movement of other animals (BIDER 1968, OXLEY et al. 1974, WEGNER and MERRIAM 1979, MIDDLETON and MERRIAM 1981, ADAMS and GEIS 1983, HENDERSON et al. 1985), arthropods (MADER, this volume), and plants (FORMAN and BAUDRY 1984). Following from our previous discussion of defining functional landscape subunits, whether or not a landscape exhibits connectivity or dis– connectivity also depends on(1) landscape structure, (2) the process of interest, and (3) the question at hand.

Conclusion

Using a broad idea of what theory consists of, we have identified empirical and conceptual areas of the theory of landscape ecology that need development. The areas that require attention include (1) developing testable empirical models, (2) identifying universal laws, and (3) developing translation rules for applying the theory to different scales and organizational levels.

The identification and classification of functional landscape subunits is important to the study of landscapes and the application of landscape ecological concepts for solving practical problems. Landscape subunits are not a priori fixed in a landscape, but are defined by the processes involved andthe questions being asked.

Of all the components of the theory of landscape ecology, the study of the phenomena of connectivity sets it apart from other traditional disciplines. As subunits are not fixed, the connectivity of a landscape is not fixed. Connectivity of a landscape depends on the questions at hand and the scale of the processes involved.

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Table 1. Components of theory and brief characterization of each. Based on PICKETT and KOLASA (in prep) and PICKETT et al. (in prep). The components cannot be considered exclusive and distinct because they change, are added, or are superseded as theory develops, nor are they all present in every theory.

Notions

Initial or singular observations motivating theoretical development.

Personal ideas that stimulate generalization, clarification or unification.

N.B., Notions are strictly pre–theoretic and usually not well-developed.

Concepts

Labeled regularities in events or objects. May be simple or derived from other concepts.

Assumptions

Statements setting the conceptual or mechanistic limits of a theory.

Specification of the general nature of relationships included in a theory.

Objects to be Defined

Statements of the concepts of objects or units to be included in the theory.

Definition of Interactions and Phenomena

Statements of the concepts about interactions between objects covered by the theory.

Statement of the concepts of phenomena (spatial or temporal patterns or events) to be included in the theory.

Relationships

Qualitative or quantitative correlations or causal connections required to advance the theory or to make hypotheses from it..

Scope

Recognition of the level of generality of the theory, i.e., inclusive compilation of the spatial extent or classes of objects covered by the theory.0A Recognition of levels of organization appropriate.

Facts

Repeatable singular observations. Facts are confirmable records of phenomena.

Generalizations

Abstractions of numerous singular facts. (N.B., Implies nothing about whether the generalization itself has been explicitly tested.)

Conceptually derived statements about relationships of objects or phenomena that have survived explicit tests.

Laws

Universal conditional statements (i.e., "if–then") about objects and phenomena of the theory. These apply throughout the domain of the theory. They may be based on confirmed generalizations of either type, or derived logically from other components of theory.

Models

Conceptual constructs showing the relationships between objects, interactions, and phenomena. May be quantitative or qualitative, static or dynamic.

Translation Rules

Quantitative, symbolic or mechanistic constructs to allow applicationof the generalizations or other conceptual constructs of the theory to the natural world.

Framework

A high–level (i.e., very general) model of the structure of an entire theory. Includes statements or display of all components and explicit connections between them.

Table 2. Components of the theory of landscape ecology.

Notions:

1. Landscapes are recognizable features of the surface of the earth.
2. Landscape structure influences function and dynamics.

Concepts:

1. Landscape subunits exist which exhibit an arrangementof parameters that are different from their surroundings.
2. Landscapes are composed of repeating patterns of structurally and functionally distinct subunits that vary in composition, size, shape and arrangement.

Assumptions:

1. Unique combinations of (1) climate, (2) geomorphology, (3) abiotic resource availability, (4) biotic resource availability, (5) natural and man–made disturbance, and (6) man–made manipulations produce identifiable landscape subunits.
2. The size, shape and arrangement of areas composing a landscape are important to the function and persistence of each individual area and/or the landscape as a whole.
3. The composition, size, shape and arrangement of subunits in a landscape affect the flow of energy, nutrients, water and organisms.
4. Distinct areas which make up landscapes are internally heterogeneous (e.g., possess interior and edge).

Objects to be defined:

1. Landscapes
2. Landscape subunits (e.g., landscape elements, ecosystems, ecotopes, biotopes, communities)
3. Energy: heat, kinetic, chemical
4. Nutrients
5. Water
6. Organisms (Populations, individuals)
7. Disturbance (Natural & Man–made)
8. Man–made features (farming, houses, forestry, etc.)
9. Interior
10. Edge
11. Matrix
12. Corridor
13. Patch
14. Network

Interactions and Phenomena:

1. Connectivity
2. Flow
3. History
4. Disturbance
5. Behavior
6. Genetic processes
7. Invasion
8. Dispersal
9. Extinction
10. Coexistence
11. Competition
12. Herbivory
13. Predation
14. Parasitism

Relationsships:

1. Internal heterogeneity of landscape subunits varies with their size, shape and arrangement in the landscape.
2. Species diversity on a landscape scale varies with size, shape, and arrangement of landscape subunits.
3. The amount of energy, nutrients, water and organisms that flowcross landscape subunits is, in part, affected by the number, size and shape ofsubunits present.
4. The total flux of energy, nutrients, water and organisms within a landscape varies with landscape structure and the level of disturbance of landscape subunits.
5. Interactions between landscape subunits varies with distance between them, and their structural and functional similarity.
6. Connection of subunits with similar structure and function increases interactions within a landscape.
7. The impact of a disturbance event through a landscape varies depending on the composition, number, size, shape, and arrangement of landscape subunits.

Scope:

1. Applies to spatial heterogeneity at all scales.
2. Applies to pattern recognition and implications at all hierarchicallevels and scales (e.g., global, ecotope, ecosystem, community, population, etc.).

Facts:

1. Species lists
2. Nutrient pools
3. Movement patterns
4. Flow rates
5. Sizes and shapes of landscape subunits

Confirmed Generalizations:

1. Larger landscape elements support more interior species.

Laws:

1. Geometric relationships concerning the size and shape of Landscape subunits and the amount of edge and interior habitat.
2. Several assumptions or relationships stated earlier may eventually functions as laws or confirmed generalizations.

Models:

1. Graphical models of relationships, above.
2. Regression models of relationships, above.
3. Regression models suggesting other factors not incorporated in the original relationships.
4. Mechanistic models

Translations Rules:

1. Class 3 and 4 models from above.
2. Problems to be solved: Defining structurally and functionally important landscape subunits.

Framework:

A very general model of the structure of an entire theory and is embodied by the relationships between all of the components.

CONNECTIVITY AND CONNECTEDNESS: FUNCTIONAL VERSUS STRUCTURAL PATTERNS IN LANDSCAPES

J. BAUDRY and H. G. MERRIAM

INTRODUCTION

The developing theory of landscape ecology focuses on interactions among landscape elements (FORMAN 1981 ;BAUDRY & BAUDRY–BUREL 1982; FORMAN & GODRON 1986; FAHRIG & MERRIAM 1985).The concepts of connectivity (MERRIAM 1984) and connectedness (BAUDRY 1984) have emerged from research dealing with these interactions. These concepts are useful in design and management of landscape systems as well as in theory.

In many parts of the world structural elements are being added to and removed from landscapes (BARR et al.1986; BAUDRY & BUREL 1984; MERRIAM1984; HARMS et al.1984; BALTENSPERGER 1987). These landscape changes can vitally affect ecological processes and ecologists and planners together must focus on effects on regional species survival and the resultant dynamics of community structure. Nutrient fluxes are also affected, which may have dramatic consequences on water resources quality. This require landscape planners to work from both structural and functional points of view.

This paper discusses relationships between landscape structure and ecological processes that can be used effectively in planning.

THE CONCEPTS

Connectedness refers to structural links between elements the spatial structure of a landscape and can be described from mapplable elements .

Connectivity is a parameter of landscape function which measures the processes by which sub–populations of organisms are interconnected into a functional demographic unit.The concept can also encompass other processes such as sub–units of nutrient pools interconnected by fluxes into a landscape nutrient pool.

Landscape processes related to connectivity are most easily exemplified by populations of small mammals in small woods. Such sub–populations can become so small, that they suffer local extinctions by stochastic events. Persistence of the species in the landscape can depend on recolonization by movements from other sub–populations . Thus there is a 'metapopulation' operating in the landscape system and its functioning depends on the landscape structure (Merriam,1984) . Similar processes are at work in nutrient redistribution at the landscape level (WOODMANSEE 1979;BAUDRY et al.1987).

A study by DICKSON (1982) demonstrated clearly that structural landscape elements differ from their functional dimensions. The fencerows studied were measured structurally in the usual way (width,canopy height,etc.) and their functional dimensions were obtained by trapping deer mice that used the fencerows. Functional fencerow width was measured for resident mice and for transient mice. It differed for the two groups. Activity of both groups was oriented along the fencerows but movements also took place in a band 15 m out into fields from the structural edge of the fencerows. That is , for a fencerow with a structural width of 15 m, the functional width was 30 m. Dickson found further that this relationship between functional and structural dimensions was variable seasonally. In summer, structurally wider fencerows had narrower functional widths as perceived by mice . This relationship also varied with land–use of the field along the fencerow so that functional width became greater if corn (Zea mais) was grown in the adjacent field .In this illustration functional connections followed the so–called landscape infrastruture, i.e. normally mapped features such as fencerows, even though they were not identical. In many other examples, functional corridors may not follow normally mapped infrastructures.

CONNECTIVITY

The elements of connectivity have been investigated by FAHRIG et al(1983), FAHRIG and MERRIAM(1985) and LEFKOVITCH and FAHRIG(1985) for one woodland study species, the white footed mouse, *Peromyscus leucopus*. Connectivity is a parameter of processes and, in the case of animals, receives its value according to the process of the animals actually moving among landscape elements. Habitat relationships, life history and population features, behaviour and chance are important determiners. Therefore, results are likely to be species–specific to some degree; For *Peromyscus*, field studies and associated computer simulations indicate that two fundamental elements of landscape struture determined the level of connectivity. These were 1) whether or not a wooded patch was connected by hedgerows to another wooded-landscape element and 2) the size of the geometric unit of landscape elements to which it was connected. For this case, the number of hedgerows connected to the wooded patch was not an element of connectivity (LEFKOVITCH & FAHRIG 1985). This undoubtedly would not be true for other species such as slow–moving plants (HELLIWELL 1975;GAME & PETERKEN 1984 ;BAUDRY 1984).

The elements of landscape structure determining connectivity for chipmunks, *Tamias striatus,* were only sligtly different from those for *Peromyscus* (HENDERSON et al. 1984).

For birds, the elements which must be considered to measure connectivity were essentially similar in Ontario (WEGNER & MERRIAM 1979) and in New–Jersey (MCDONNELL & STILES 1983). The level of connectivity was much higher in Brittany, as estimated from dispersal of plants by birds, than in Ontario and New–Jersey where the grain size of the hedgerow networks was larger and prevented birds from moving directly between parallel hedgerows (BAUDRY 1985).

CONNECTEDNESS

In contrast, the elements of connectedness are structural landscape features related to topological distances between elements. The matrix (dominant landscape element) is the most connected element of the landscape (FORMAN & GODRON 1985). Usually connectedness is considered with reference to other landscape elements (patches of wood, wetlands, built structures, etc.) which are more or less distinct within the matrix. Connectedness is described in terms of: patch size, distances between patches of the same type, presence of corridors (e.g. hedgerows, riverine strips, road margins, etc.), frequencies of various types of hedgerow intersections and mesh size of hedgerow networks (FORMAN & BAUDRY 1984; BAUDRY 1984; BAUDRY & BUREL 1985). Hedgerow networks often have the highest connectedness other-than the matrix.

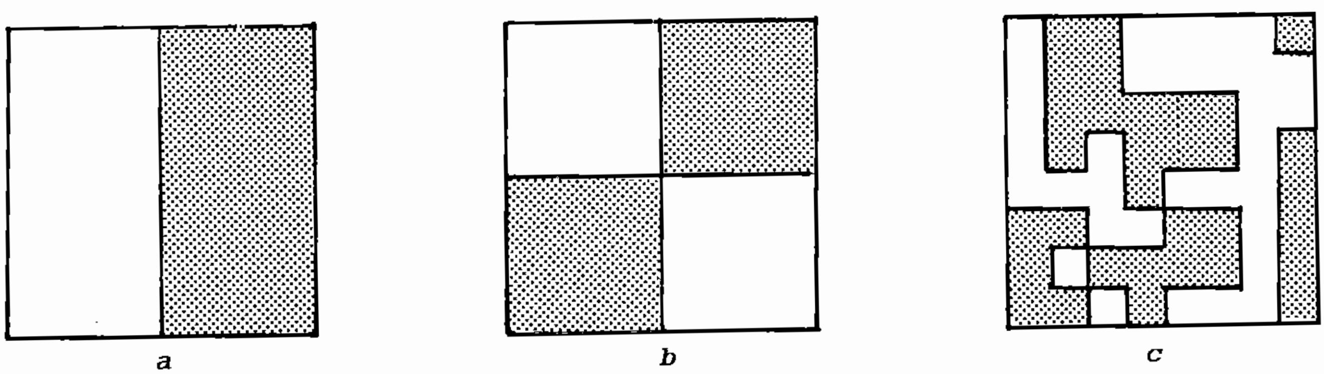
SPATIAL STRUCTURE

In the simplified case of landscapes with only two types of elements, these elements can be arranged to give very different spatial structures (fig.1). In figure 1a the two elements are in two large patches. In 1b each element is in two connected blocks and in 1c, they are in many connected patches. In figure 1b and 1c species can move in the same element without crossing a different habitat, but there are bottlenecks that may slow movements between fragments. In figure 1d and 1e the patches are isolated by other habitat, but in 1e they are interconnected by corridors that may allow species movements.

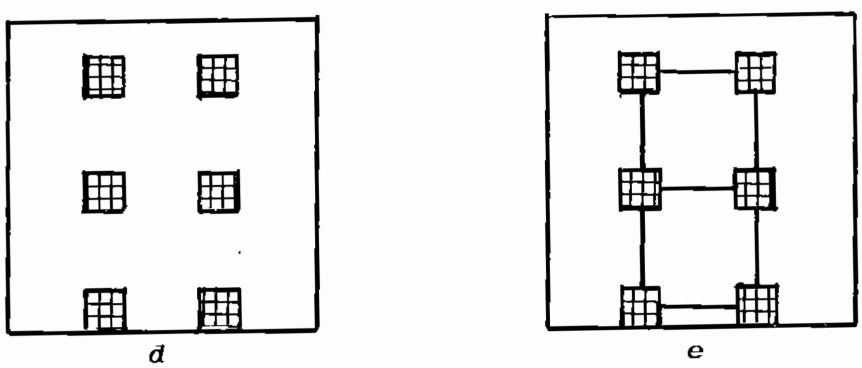
If we consider a landscape with more than two types of elements (fig. 2), we may address the question of contiguity and boundary-distinctions between contiguous elements. A crop field adjacent to a forest may stop any movement out of the forest whereas a shrubby old field may allow movement. An example is given by HARRIS (1984) for forest management. If an old growth forest is surrounded by agricultural or urban land–uses, forest species will not move out of the patch and colonize new habitat; that may reduce metapopulation size and lead to species extinction.In a particular landscape mosaic, various arrangements are possible.In some cases connectivity between two adjacent elements may be only temporary. An example is by *Peromyscus* using corn during the summer, but not after harvest (MERRIAM this volume). Different types of elements can be distributed almost randomly or in some pattern such that specific elements have highly organized probabilities of contiguity, some high, some low. BAUDRY and BUREL (1982, 1985) propose a measure of such organisations.

RELATIONSHIPS BETWEEN CONNECTEDNESS AND CONNECTIVITY

Work of MCDONNELL and STILES (1983) exemplifies the relationships of connectedness and connectivity and shows particularly that the elements of connectedness ultimately are revealed through their importance in processes. McDonnell and Stiles showed that expansion or replacement of bird–dispersed plant species consists of of the processes of flying into particular landscape elements, perching on particular structures and depositing seeds by defecating.

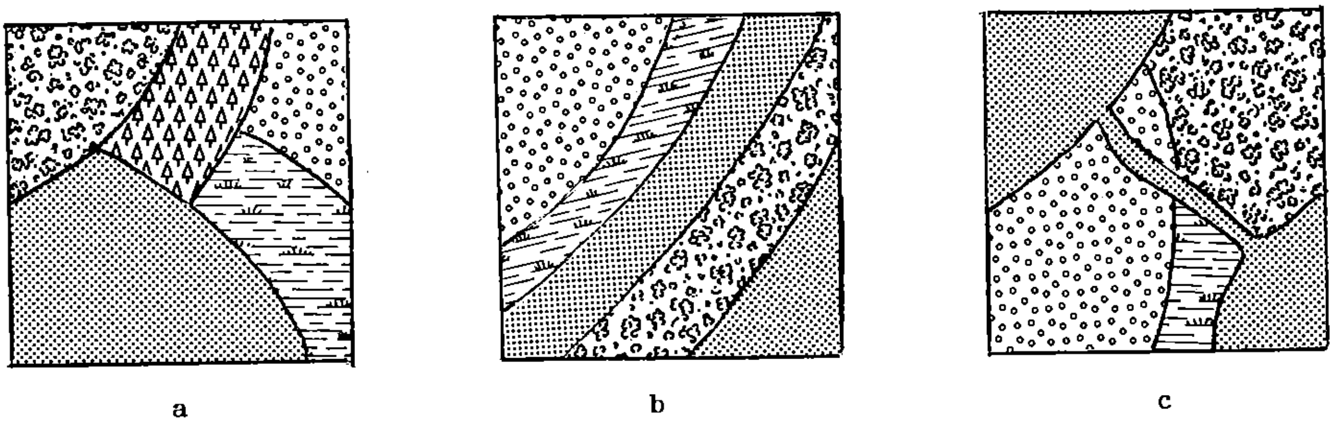


The areas of both types of landscape elements are equal in a, b, c differences in spatial distribution give differences in connectedness of the landscape.



In a patches are dispersed and potentially isolated by the matrix, in e patches are linked by hedgerows and connectedness is higher.

Fig. 1 Structural patterns and connectedness in the simple case of two landscape elements



In a) most of the landscape elements are contiguous to any other element ; in b) there are strong contraints on the pattern : each element is contiguous to a specific one ; c) two patches of an element (one habitat) are connected by a corridor of the same type.

Fig. 2 Structural patterns in a landscape mosaic

The movement of these plants depends on the deposition of the seeds which is controlled by the presence of perches (saplings) which are taller than surrounding vegetation. Thus a point–form structure of the landscape is transformed into a linear, saltatorial, or wave–form landscape process. Connectedness is a function of the point–form distribution of perches; connectivity refers to the colonization movements, or dispersal, of the bird–dispersed plant species.

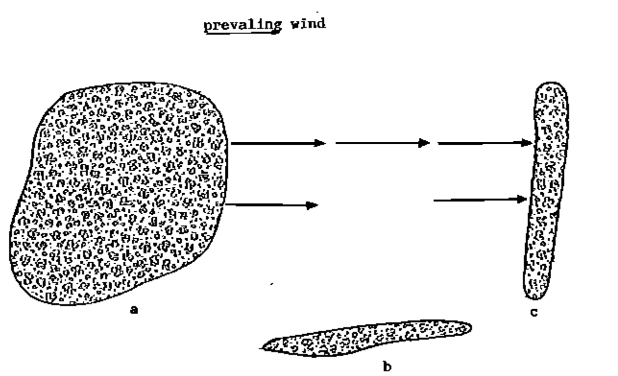
The role of barriers and gaps in connectivity

Two landscape elements may have high connectivity (are functionally joined) when they are also spatially linked (have high connectedness) but connectivity and connectedness commonly are inversely related also. Wind dispersed particles are common examples. For these particles connectivity between two elements is related to the presence of a barrier which lessens wind speed. Two parallel landscape habitats will be connected if wind speed is sufficient to carry propagules, colonists or particles from one point to the other and if at this point wind speed decreases enough so that the propagules will fall onto the ground (fig.3). So, two perpendicular elements may be not connected at all.

Among species following this pattern are plants with wind dispersed seeds (Salix, Populus, Acer, ...) and ballooning spiders, which can be dispersed over a long distance.

It must be pointed out that if prevailling winds are constant at the time of the dispersal stage, connection is unidirectional. This is also the case for dispersal by running water. Observations of colonization of neglected banks of brooks by Impatiens capensis (BAUDRY 1985) show that this species is common when the stream is coming from a wood where Impatiens is present and uncommon,if not absent, when the brook flows from a field into a wood.

Gaps between landscape elements (e.g. woods) and corridors (e.g. hedgerows) do not always reduce connectivity(cf FORMAN & GODRON 1985). The relationship between connectivity and connectedness must be interpreted in functional terms. A five meter break in a corridor may stop dispersal of a plant with vegetative reproduction, but may have little effect on a bird or a flying insect. For some active dispersers such as bats, local flyways have been observed to follow routes through such gaps in fencerows (BARCLAY 1978).



A and c are functionally connected because c in a barrier for wind induced movements, while b is isolated.

Fig. 3 Connectivity in the case of wind dispersed elements

Structure and ecological function of a single corridor

As has been pointed out, the structural and functional widths of a corridor can be different. In some cases a structural corridor may have no connectivity function at all. For example, it has been found (BAUDRY & FORMAN, unpublished data) in New–Jersey that wide (more than 8 m) hedgerows connected to narrow ones (less than 4 m) are seldom colonized by forest plants because the forest plants do not disperse along the narrow hedgerows. In contast, wide hedgerows connected directly to a forest are followed by the forest plants. Though they are part of a structuraly connected system,these narrow corridors have no connectivity value for these plants.

Functional need of structural redundancy in landscapes

It has been established in information theory that redundancy is useful to insure trustable information between two points (SHANNON & WEAVER 1949);redundancy is designed to keep the message significant even though some information is destroyed by noise. In landscapes structural redundancy is also helpful:if two patches must be connected to allow species movement, one connection might be enough, but this connection may be destroyed at some time, to insure population stability in a patch, two or more connections are safer because they also provide alternative routes. Redundancy is a factor of system stability in presence of random perturbations (cf LEFKOVITCH & FAHRIG 1985).

APPLICATIONS TO LANDSCAPE DESIGN AND MANAGEMENT

Principles for landscape planning and management can be derived from the concepts of connectivity and connectedness, as planning mostly consists in adding to or taking away landscape elements. Planning procedures and most of the ecological studies forming their basis concentrate on structures of systems because study of ecological function is generally too long and too expensive. Planners and ecologists have to be aware of the effects of structural changes on functions. We will present examples of how careful study of landscape structure at the beginning of the planning process may help to design new ecological functions of the landscape.

General principles

Different structures can be designed to achieve specific characteristics of fluxes through the landscape. Connectivity for a type of landscape element may be achieved by a continuous element, a set fragments linked by corridors or by being within dispersal distance of a sub–population without structural connections.

Full continuity of a landscape element is maximum connectedness, whereas maximum connectivity is maximized ease of mobility among landscape patches as measured for some particular species, dissemule or particle.

EXAMPLES

Three types of planning operations are considered: land consolidation, road construction and urban planning.

Land consolidation is done to regroup a farmer's holdings into one or two land parcels. It is a common planning operation in western Europe. Most of the time this leads to field enlargement and removing of ecological infrastructures such as hedgerows and ditches (BAUDRY & BUREL 1984). In some countries (France, Netherlands) environmental studies must be undertaken to introduce ecological constraints in the process of design. Conservation of hedgerows is important from both agronomical and ecological points of view (FORMAN & BAUDRY 1984). Planners must focus not so much on the total length of hedgerows as on the network structure which can enhance or inhibit movement of species using hedgerows as corridors (plants, ground insects, small mammals, birds).

The network may also be design to control water and nutrients fluxes, to prevent erosion and to slow down wind speed. Knowledge of processes involved and of their relationships with landscape struture are the bases for landscape design. There is a hierarchy in the processes that constrain the design.Ecological infrastructures for water flow control are bound to slope direction. Windbreaks must be across prevaling winds. There is less constraint in choosing places for biological corridors (fig. 4). A detailed example is presented in BAUDRY and BUREL (1984).

Road construction creates new corridors (road plus roadside margins) which can enhance the dispersal of some species (e.g. *Microtus pennsylvanicus* in Central U.S., GETZ et al. 1978) or be a barrier stopping the movement of others species move either

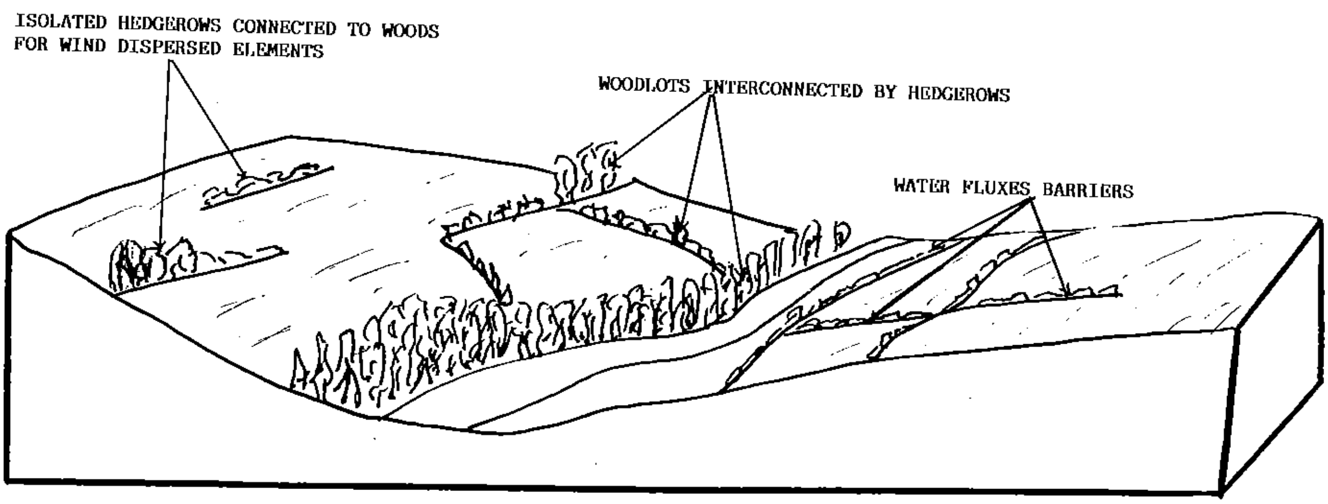


Fig. 4 Functional units in a hedgerow network landscape

because they need different types of landscape elements (wood, water, open areas) or because they migrate. The first case can be illustrated by road construction along a river, separating from upland, this can prevent animals from coming to the river and/or be a cause of accidents.

This barrier effect can be overriden by constructing tunnels or bridges (REED et al. 1974). This has been done in France for toads and deer crossing major highways (MINISTERE DES TRANSPORTS 1981). To insure connectivity, the connecting devices (elements of connectedness) must include appropriate habitat and must be implemented at the place where animals used to move before the construction. These can found by studying animals tracks; the tunnel or bridge must connect the two parts of tracks cut by the road (see fig. 5,after MULLER & BERTHOUD 1977, for example)

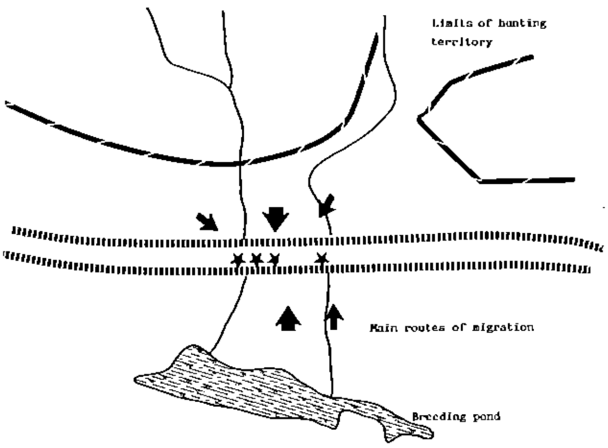


Fig. 5 Effect of road construction on toads migration

In urban planning, GREER (1982) reports an experience in Washington State U.S.A., where fragmented urban parks are linked between themselves and to the rural area by a creek. It has been designed as a corridor allowing a duck population to enter the city parks from the so-called rural reservoir.Elsewhere, horseback riding paths lined by hedgerows on both sides have created corridors that could connect urban open spaces. Urban forest areas can be planned to provide corridors both as walking paths for people and to increase connectivity for other species. Urban waterways present possibilities for easy connectivity terrestrially, on their banks, hydraulically, along their flow and by wind, in the clear channel above. Clear wind channels below the tops of tall buildings should be given special consideration in urban areas.

CONCLUSION

The two concepts presented are related to two different aspects of landscapes as ecological systems.

Connectedness is known from description of the structure, so it can be determined not only during basic research but also during ecological surveys done for planning and management.

Connectivity is determined from the functioning of the system so it commonly requires basic research to get a measure but with great care it may be interpretable from landscape structure if knowledge of the species or the particles is sufficient.

Focusing on interactions among landscape elements, landscape ecology has already pointed out that the ecological characteristics of an element (species composition, nutrient pool...) are highly dependant on the characteristics of the surrounding ones. We are, now, beginning to be able to determine ecological functional units in a landscape as in fig.4. Connectivity is the process by which the different elements of a landscape are integrated into these functional units. Planners deal mostly with mapable elements, and processes are seldom mapped, but structures are.So we need to know the relationships between processes and structural patterns to make planning decisions based on the latter and to predict the ecological impacts of a new design.

Connectedness and connectivity are interrelated variables which are useful to design experiments and to design landscapes.

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THE STATUS OF ISLAND BIOGEOGRAPHIC THEORY AND THE HABITAT DIVERSITY HYPOTHESIS IN ECOTOPE FRAGMENTATION

D. MCCOLLIN, R. TINKLIN & R.A.S. STOREY

ABSTRACT

It is twenty years since the publication of MacArthur and Wilson's Theory of Island Biogeography and there is still much debate on its application to island (including ecotope) systems. In this paper selected works of advocates of competing schools (MACARTHUR and LACK) are reviewed and apparent confusion in each approach is indicated. Many systems previously studied appear to exhibit some, if not all, area, isolation and habitat diversity effects although measurement of isolation in highly fragmented landscapes has often been problematical. It is argued that a new approach is now emerging encompassing aspects of each school.

Patterns of habitat utilization and tolerance to ecotope fragmentation are considered. Further, it is argued that area, isolation and habitat effects are meaningless in terms of planning and conservation unless extirpation–prone species are identified. A clearer understanding of species tolerance to ecotope fragmentation in terms of life–history strategies is now needed.

INTRODUCTION

The process of ecotope fragmentation in landscapes is of great concern to both planners and conservationists. Fragmentation leads to an increasing number of ecotopes of decreasing sizes which are increasingly isolated from each other (e.g., BURGESS & SHARPE 1981). Such changes in ecotope configuration, often accompanied by changes in disturbance regimes (e.g., increased grazing (HOWE et al. 1981, WHITNEY & SOMERLOT 1985), and cutting (WHITNEY & SOMERLOT 1985)) may have serious consequences for the dynamics of populations and communities in landscapes in some cases leading to local and regional extinctions.

This paper is concerned with the theoretical background to studies of ecotope fragmentation with particular reference to the work of Robert H.MacArthur and David Lack. Both were ornithologists who studied island birds and who made a significant and lasting contribution to ecological research. The need for a re–examination of the works of MacArthur and Lack is expedient since our understanding of the biological consequences of ecotope fragmentation is based on models developed by them on oceanic islands. The analogy often made is that ecotopes surrounded by different types of land use are habitat 'islands' in a 'sea' of unfavourable landscape (MACARTHUR & WILSON 1967). For example, woodlands in agricultural landscapes may be habitat islands for woodland–dependent organisms(AMBUEL & TEMPLE 1983, ASKINS et al. 1987, BUTCHER et al. 1981, GOTTFRIED 1977, HOWE 1984, HOWE et al. 1981, LYNCH & WHIGHAM 1984, MOORE & HOOPER 1975, OPDAM et al. 1984, OPDAM et al. 1985, OPDAM & SCHOTMAN 1987, VAN DORP & OPDAM 1987, WHITCOMB 1977, WHITCOMB et al. 1981, but see HELLIWELL 1976, MIDDLETON & MERRIAM 1983).

MACARTHUR and WILSON (1963, 1967) developed the Equilibrium Theory of Island Biogeography (hereafter known as Equilibrium Theory) and this model has been widely accepted in studies of organisms in ecotopes (e.g., BROWNE 1981, MOORE & HOOPER 1975, WhITCOMB 1977). Equilibrium Theory is based on the assumption that the number of species on an island is a balance between the rates of immigration and extinction; the rate of extinction being inversely related to island size and the rate of immigration being inversely related to isolation from the adjoining mainland. The model produces some fairly novel predictions although there is much controversy over experimental evidence in support of it (BOECKLEN & GOTELLI 1984, GILBERT 1980, 1981, MCCOY 1982).

An alternative hypothesis explaining the number of species on islands was described by David Lack (LACK 1969, 1976)in response to Equilibrium Theory. Lack's ideas were essentially qualitative and he explained the numbers of species on different sized islands in terms of habitat differences. He did not regard isolation as being of major importance, to birds at least, and limitations on more isolated islands were invariably due to habitat limitations and not to dispersal abilities.

This paper looks at the confusion caused by regarding the two theories as competing hypotheses when a closer examination of both Lack and MacArthur's works suggests that both isolation and habitat differences may be important. The MacArthur–Wilson Model is beguilingly simple and has been described by WILLIAMSON (1981, 1983) as true but trivial with much of the turnover at Equilibrium being due to transient species. On the other hand, Lack's hypothesis requires a clear definition of habitat (CONNOR & MCCOY 1979) and will not be readily accepted until a quantitative model is produced (but, see later).

THE EQUILIBRIUM THEORY OF ISLAND BIOGEOGRAPHY

Equilibrium Theory has received much critical attention (e.g., ABBOTT 1980, 1983, GILBERT 1980, 1981, MCGUINESS 1984, SIMBERLOFF & ABELE 1976, WILLIAMSON 1981, ZIMMERMAN & BIERREGAARD 1986) especially in relation to the design of nature reserves (e.g., MARGULES et al. 1982) but, the Theory is unsubstantiated (GILBERT 1980, 1981) and even in very simple systems there has been difficulty in demonstrating its tenets (DICKERSON and ROBINSON 1985, HOCKIN 1982, KINKELet al. 1987, WALLACE 1975, but see BUCKLEY 1985).

The Theory predicts newly fragmented (or 'land–bridge') islands should have reduced immigration and higher extinction rates leading to 'relaxation' and a reduced equilibrium number of species. Barro Colorado is one such island and there has been a demonstrable loss of species since its isolation in 1914 (WILLIS 1974). However, closer inspection has shown that many of the avian extinctions may be explained by factors such as predation and (successional) habitat change (KARR 1982a). Further, population variability (and not rarity) was found to be the most significant predictor of extinction probability (KARR 1982b).

Advocates of Equilibrium Theory now appear to believe that the numbers of species on islands is controlled by area per se. However, this interpretation of Equilibrium Theory may not have been intended since MacArthur clearly believed that area acted through the effects of habitat heterogeneity. For example,

'If we examine any small apparently homogeneous area we are likely to find that the number of species depends upon the structure of the habitat.' (MACARTHUR 1965, p. 515) Hence, MacArthur clearly believed that there was a habitat component affecting the numbers of species on islands and later added, 'Multiple regression analyses have shown that area alone accounts for most of the variation in species numbers on islands. But area itself is correlated with environmental diversity which exerts a more direct effect on species numbers and is a quality that has only begun to be described and measured.' (MACARTHUR & WILSON 1967, p.65) This adherence to habitat diversity was not, perhaps, all that surprising since it was MacArthur who described the relationships between bird species diversity and the structural diversity of vegetation (MACARTHUR 1964, MACARTHUR & MACARTHUR 1961, MACARTHUR et al. 1962). Few have supported this interpretation of Equilibrium Theory although a number of workers (e.g., ABBOTT 1974, GOLDSTEIN 1975, JOHNSON 1975, JUVIK & AUSTRING 1979, WERFF 1983) have been reluctant to interpret species–area relations due to direct causality but noted the, 'high degree of covariation between area and habitat diversity' (JUVIK & AUSTRING 1979, p. 215) GILBERT (1980) warned against attributing causal effects to species– area relations without fulfillment of three main criteria implicit in the Equilibrium Theory, and MCGUINESS (1984) noted that in very few studies had alternative hypotheses been tested. NILSSON & NILSSON (1982) were able to demonstrate a relationship satisfying Gilbert's criteria for plant species on islands in a Swedish lake; but even so were able to explain only a small proportion of the variation in immigrations and extinctions on the basis of Equilibrium Theory.

In fact, twenty years after the Theory's publication, habitat heterogeneity has only just begun to be measured and two recent studies (BOECKLEN 1986, FREEMARK & MERRIAM 1986) have demonstrated the underlying effects of heterogeneity on species–area relations, and only recently have fragmentation studies been undertaken considering alternative hypotheses (e.g., AMBUEL & TEMPLE 1983)

There is no doubt that the Equilibrium Theory has been successful in stimulating a research programme and the apparent simplicity of the model probably led to its unjustifiable acceptance as the paradigm. However, even MACARTHUR & WILSON (1967) believed that, 'a great deal of faith in the feasibility of a general theory is still required.' (MACARTHUR & WILSON 1967, p.)

THE HABITAT DIVERSITY HYPOTHESIS

The Habitat Diversity Hypothesis is often attributed to WILLIAMS (1943, 1964) who was concerned with the exponential model of the species–area relationship. However, CONNOR & MCCOY (1979) pointed out problems in attributing causal effects to species–area relationships noting that no particular significance may be attached to best–fit models.

It was LACK (1969, 1976) who, in response to Equilibrium Theory, argued most forcefully for the importance of habitat to account for the differences between species numbers on islands. Lack's opposition was not, perhaps, all that surprising given his life's work, the main body of which was concerned with the problems of population regulation, but both prior, and subsequent to this work Lack was concerned with the numbers of species on islands.

His most famous work from the early period was his book on the Galapagos Finches (1947) and in a series of papers Lack also pioneered work on successional changes in bird communities due to afforestation (LACK 1933, 1939, LACK & LACK 1951). In these studies he made particular reference to habitat selection in different bird species to explain how structural changes in habitat over time could affect the composition of the constituent bird communities. Lack also pioneered work on the habitat distribution of British woodland birds in relation to broad vegetation types with reference to specific components of habitat required by bird species (LACK & VENABLES 1939).

Lack's arguments on habitat diversity were most clearly stated in a largely qualitative account of the numbers of bird species on British islands (LACK 1969). This was followed up by work on the landbirds of the West Indies culminating in Island Biology which was published posthumously in 1976. However, GRANT (1977) pinpointed a conceptual weakness in Lack's arguments. Lack regarded the failure of bird species to breed on far islands, not as a lack of dispersal ability, but due to habitat differences, i.e., he equated dispersal with colonisation potential. REED (1987) and WILLIAMSON (1981) provide several examples where Lack's argument may have been confused this issue.

Lack's argument was actually a re–statement of the argument expounded by WALLACE (1892). Wallace compared the avifaunas of Bermuda and the Azores and, in part, explained the differences in the numbers of resident species due to area and habitat effects. Wallace, however, regarded differences in dispersal as being of most importance in determining the numbers of species on oceanic islands. Lack was particularly insistent that isolation was unimportant and in a study of the numbers of species of hummingbirds in the West Indies (LACK 1973) he presented the following regression equation:

$$S = 1.70 + 0.00107.Alt - 0.00535.Dn \qquad ...(1)$$

$r_2 = 50.8\%$

where, S is the number of hummingbird species, Alt is the altitude of the island (which Lack regarded as a measure of habitat diversity), and, Dn is the distance to the nearest island.

Lack was reluctant to believe that the distance measure in this regression had any real significance since hummingbirds frequently travelled between islands and that such a relationship was absent for the West Indies landbirds as a whole.

Appendix 10 to Island Biology (LACK 1976, p. 384) presents a table (compiled by Peter Lack) on the numbers of landbirds on islands in the West Indies together with island characteristics. A regression of these data gives the following relation:

$$\ln S = 4.28 + \underset{(7.43)}{0.147.\ln A} - \underset{(-6.50)}{0.345.\ln D} + \underset{(3.95)}{0.0602.\ln Alt} \qquad ...(2)$$

r_2 (adjusted for 49 d.f.) = 79.7% where, S is the number of landbird species, A is island area (sq. km.), D is distance from the mainland (km.), and Alt is altitude (m.).

Figures in parentheses are t–values for constants.

This regression suggests that, after the effects of area are accounted for, isolation may be a limiting factor for the numbers of landbird species in the West Indies. Altitude accounts for only a small additional percentage of the variance in the number of landbird species after both area and isolation have been accounted for. However, earlier than both the publication of Equilibrium Theory and Lack's response, MARLER & BOATMAN (1951) stated:

'It is a general rule that the more isolated an island is the fewer the number of breeding species of terrestial birds.'

(MARLER & BOATMAN 1951, p. 90)

This statement, although not attributed to any authorities, was probably, in part, influenced by the earlier work by Lack on islands, one of which at least, has been curiously overlooked. In 1942 Lack published an account of the numbers of landbird species on islands off the British coast. He described a progressive reduction in species numbers with isolation from the mainland and concluded,

'Other small islands also demonstrate that the smaller and more remote the island the more impoverished the bird fauna compared with the mainland. This is due partly to habitat limitations, partly to the small size of many island populations and hence their liability to extinction and partly to the sea acting as a temporary check to spreading species.' (LACK 1942, p.33) Clearly, Lack pre-empted MacArthur and Wilson's idea on the effect of area on extinction rates and the paper describes in detail the distribution of bird species in relation to habitat differences, recognising that in some cases that there were gaps in avifaunas, 'not attributable to habitat or other environmental differences.' (LACK 1942, p.30)

Also, 'even discounting all cases due to habitat limitations, the islands in every case possess fewer land and freshwater species than does the nearest mainland.' (p.30)

These views were rather at variance with those views Lack was later to express in his analysis of the numbers of landbird species on British islands (LACK 1969). In this later paper Lack attributed most of the distributions in relation to habitat or other environmental differences although in a more extensive quantitative re-analysis of the numbers of breeding landbird species on islands around the British coast. REED (1981) confirmed both the importance of number of habitats and isolation.

IMPLICATIONS FOR THE STUDY OF ECOTOPE FRAGMENTATION

1.) The measurement of isolation, dispersal and refugia

Isolation has long been recognised as an important limiting factor-for the dispersal possibilities of organisms in landscapes (BUDNICENKO 1955, TURCEK 1957, VOLCANICKIJ 1952); but only recently has the importance of isolation, as a quantitative variable, been explored in habitat-island studies (e.g., WEAVER & KELLMAN 1981, WHITCOMB et al. 1981). The statistical significance of isolation in regression studies implies that certain areas may act as 'habitat mainlands'. PICKETT & THOMPSON (1978) suggested that extinction may be the prime force on restricted populations, hence, if immigration is to continue to be important in the future 'habitat mainlands' must be identified and conservation measures taken to protect their status.

The measurement of isolation in studies of ecotope fragmentation has not always been straight forward. In habitat 'island-sea' analogues measurement has been readily achieved by reference to the nearest extensive ecotope by use of maps and aerial photographs (e.g., HOWE 1979, HOWE et al.1981, NILSSON & NILSSON 1982, OPDAM et al. 1984, OPDAM et al. 1985). Problems have arisen in studies where there has been no obvious 'extensive' mainland and in these cases the decision of which, and from where, distances should be taken has depended on a subjective process based on the size of ecotopes being studied, their spatial configuration, and the dispersal abilities of the organisms concerned. Generally, the less readily identifiable the supposed mainland has been the more complex the isolation measure that has been used (e.g., MOLLER & RORDAM 1985, WEAVER & KELLMAN 1981).

Whilst it is an ecological truism that each species has its own unique set of habitat requirements particular 'target' species must be identified if conservation measures are to be effective. Patterns of habitat utilization are an important factor (HUMPHREYS & KITCHENER 1982) and species of 'mature' ecotopes appear especially prone to the effects of ecotope fragmentation (HENEBRY & CAIRNS 1980, OPDAM et al. 1985, OPDAM & SCHOTMAN 1987, WEBB et al. 1984).

Two models demonstrate the effects increasing ecotope fragmentation may have on susceptible species. CARTER & PRINCE'S (1981) epidemic model explains how distribution limits could be determined by differing infection rates. The application of this model to animal and bird populations may not be so unlikely since birds, at least, are highly site-tenacious (LANYON & THOMPSON 1986, MIKKONEN 1983, OSBORNE 1983, WIENS & ROTENBERRY 1981a) and even long-distance migrants show high return rates, e.g., 25% for territorial *Phylloscopus trochilus* males in Finland (TIAINEN 1983) and between 20-70% in *Phylloscopus collybita* populations in English lowland farmland (HALE 1986). Post- breeding dispersal often fits a geometric model (BUECHNER 1987, GREENWOOD et al. 1979) so that there may be a substantial surplus non- breeding component to populations which are available to occupy territories if they become vacant (e.g., GARCIA 1983). Intraspecific competition may regulate dispersal from optimal into sub-optimal habitats (e.g., EBENMAN & NILSSON 1981, KREBS 1971, ULFSTRAND et al. 1981, WASER 1985, WOLFF 1980) and infection rates of new sites by animal and bird species may be determined by increasing isolation and decreasing size of ecotopes (ASKINS etal. 1987, BUTCHER et al. 1981, GOTTFRIED 1977, HELLE 1985, LYNCH & WHIGHAM 1984, OPDAM et al. 1984, 1985, OPDAM & SCHOTMAN 1987, VAN DORP & OPDAM 1987, WHITCOMB et al. 1981).

HANSKI'S (1985) model demonstrates that if some sites exist where large local populations are unlikely to become small, species in other sites may fluctuate in numbers between long-term commonness and rarity. Hence, stochastic processes are far more likely to cause extinction of small populations in isolated sites if numbers fall below some critical threshold level.

Recent work on the recolonisation of seabird colonies after local extinctions due to oil spillages demonstrate that such 'safe' sites or 'refugia' were readily identifiable (CAIRNS & ELLIOT 1987). There is a growing body of opinion that this concept may be applied to other ecotope-types in landscapes and corroboration comes from a variety of sources. WIENS & ROTENBERRY (1981b) suggested that populations may exist in states of 'sinks' and 'sources', with immigration topping-up the former from the latter (sensu BROWN & KODRIC-BROWN 1977). The geography of sinks and sources may be taxon-specific depending on patterns of ecotope utilization and dispersal of organisms and the spatial configuration of ecotopes. Their boundaries may vary depending on population size.

Hence, demographic factors may be important (LYNCH & WHIGHAM 1981, MAY 1981, WHITCOMB et al. 1981) and TIAINEN (1983) suggested that non- breeding components in populations of Phylloscopus trochilus contributed to the stablity of populations in good habitats. More research is needed to determine whether there are large non-breeding components to populations in relation to ecotope isolation and to further our understanding of the dynamics of populations in relation to ecotope fragmentation.

2.) Nature Reserve 'Design'

The application of Equilibrium Theory to nature reserve 'design' is a result of the need for a valid system to assess site values, both objectively, and with reproducibility (ADAMS & ROSE 1978). There has been much recent debate about the application of Equilibrium

Theory to the design of nature reserves (for recent reviews see: BLAKE & KARR 1984, SOULE & SIMBERLOFF 1986, ZIMMERMAN & BIERREGAARD 1986).

The debate has centred on simple numbers of species. This is a direct result of the influence of Equilibrium Theory and the emphasis it places on species number. In practice, conservation policies have been formulated on a wide variety of criteria. The number of species in ecotopes is just one, usually minor, attribute considered in nature reserve aquisition and 'nature reserve design' gives no consideration to species abundance, species identity, rarity, historical factors, etc.

New approaches for systems of reserve planning and conservation recognise the need to identify extirpation–prone species and place conservation in the context of regional strategies in terms of rare and endangered species distribution patterns (MILLER et al. 1987).

NEW APPROACHES AND CONCLUSIONS

SEAGLE & SHUGART (1985) used a first–order Markov model to simulate colonization of a landscape by animal species differing in habitat requirements. Model runs suggested that elements of both the area per se hypothesis and the habitat–diversity hypothesis contribute to species–area relationships through the interaction between area and landscape dynamics.

New approaches recognise the need to incorporate species–specific habitat preferences into existing models. BUCKLEY (1982) considered the numbers of plant species on an archipelago off Western Australia by comparing the 'classical' MacArthur–Wilson approach to a 'habitat– unit' model in a regression study. Buckley found significantly better predictions of species richness by the habitat–unit model but admitted that there was still imprecision. One reason for this is that there are often species characteristic of more than one habitat and a shared–species term may be needed (e.g., RAFE et al. 1985).

As mentioned previously patterns of habitat utilization may be an important factor in the effects ecotope fragmentation has on organisms. However, rarely have patterns of life–history characteristics of organisms in relation to ecotope fragmentation been considered. This would appear to be essential if future effects of fragmentation are to be predicted. Exemplorary in this respect was WHITCOMB et al.'s (1981) study of the effects of forest fragmentation on the avifauna in the eastern United States. They found that neotropical migrants – mostly ground–nesting, forest–interior species, where most susceptible to fragmentation. Recent studies (AMBUEL & TEMPLE 1983, LYNCH & WHIGHAM 1984) have reaffirmed these results, whilst in Northern Europe HELLE (1985) noted that sedentary hole– nesting species appear to be most at risk. WIENS (1985) model on the effects fragmentation has on patterns of response depending on species life–history characteristics may provide a clue to the disparity between those patterns found in Eastern U.S.A. and Northern Europe.

To conclude, it has been shown that Equilibrium Theory and the Habitat Diversity Hypothesis have considerable overlap and further support for this is provided by NEWMARK (1986). It has also been argued that to understand fully the biological consequences of ecotope fragmentation aspects from both approaches need to be considered. 'Islands' in landscapes differ considerably from oceanic islands by the interspersion of large areas of sub–optimal habitat in which there exists substantial populations (RAFE 1983). Consideration of patterns of habitat utilization in relation to ecotope fragmentation may lead to new insights.

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NETWORK OF COMPENSATIVE AREAS AS AN ECOLOGICAL INFRASTRUCTURE OF TERRITORIES

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Corresponding to our conception the most important principle in the planning and management of rural landscapes is the maintenance of optimal diversity of landscape pattern. That can be realized with the help of a heterolevel system of the compensative areas and ecological infrastructure of the territories.

The term "system of the compensative areas" is nearly of the similar meaning with "ecological carcass", "natural carcass", "zones of ecological equilibrium", "areas of virgin nature of a polarized landscape", "areas of ecological preference" etc., advanced by different authors.

The term "compensative" is given a broad meaning by the authors and compensative areas are related with functions as follows:

- to accumulate matter and energy, in the first place the kind of energy in the dispersion of what man is involved;
- to receive and make harmless all that is unsuitable for cultured areas: polluted water, air and solid wastes;
- to return, regenerate resources;
- to refuge natural populations, conserve the fund of genes;
- to serve as a dispersion-tract for biota (including man), also for air and water;
- to recreate man;
- to serve as a barrier, filter, buffer;
- to serve as a support-carcass for the matter-cycling and energy fluxes and settlement system of the region;
- and consequently – to compensate, equilibriate the inevitable output of human activities.

The system of compensative areas can be observed as a subsystem of cultural landscape, an infra-part of the main ecosystems such as forests, fields and settlements – an ecological infrastructure. On the other hand the ecological infrastructure guarantees the realization of the main ecological functions in landscapes.

It must be considered that compensative areas with areas of intensive human activities form a strongly unequilibriated (polarized) system. Systems of this kind have the ability to reduce entropy and increase order by selforganizing. This principle must be taken into account in the planning and management of cultural landscapes.

The compensative areas form a hierarchical heterolevel system. There are very different components in this heterolevel system. At first, naturally, all conservative areas but also large forests, swamps, coastal seas and other large natural communities are supposed to belong to the higher levels of this system.

On middle levels extensively economized agricultural lands such as meadows in margin lands or areas of alternative agriculture form the network of compensative areas.

And there are a lot of compensative communities on lower levels of this hierarchical system, such as woodlots and small forest islands, banks of rivers, forest buffer-strips of water-bodies, traditional farmsteads, still standing in our rural landscapes, hedges alongside (ways) roads, windbreak forest-stripes, banks of ditches with diverse biota, fences of stones as traditional elements in some landscapes etc.

The main phenomena in compensation of rural landscapes are edge-effects on different ecotones. We observe an ecotone as a section of space where ecological conditions change more rapidly in comparison with adjacent sections and where it brings along more rapid changes in structure, function and composition of biota. An ecotone manifests itself functionally as a transition-ecosystem, and at the same time territorially-projectionally, as a border.

Ecotones manifest on different levels of space, for example, in the borders of patches, merocoenoses, coenoses, coenose complexes, regions and formations. The area of swiftest change of integral gradient of ecofactors can be understood as the pike (maximum) of any ecotone (Fig.1). It is important to remark that the pike of an ecotone and the border of community need not coincide.The disrupt areas of ecotone influence can be observed as secondarily, tertiarily etc. induced ecotones. Their extent and number depends on sensibility of observation. It is the optimal place for designing new elements for an ecological infrastructure (e.g. stepping-stones).For example roadside hedges increase the pollution load between the road and the hedge and decrease it behind the hedge. The pollution load brought forth by turbulence reincreases at certain distances from the hedge (Fig.2).

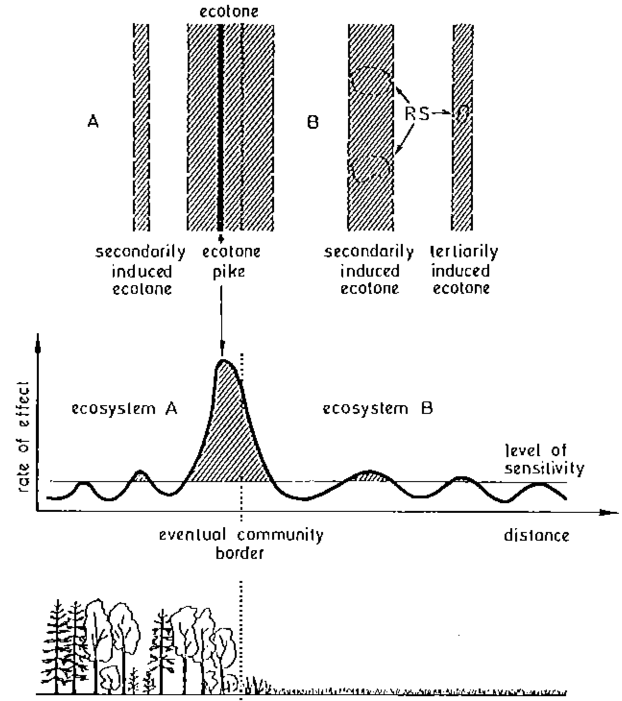

Fig. 1. Principal scheme of ecotone inducing. RS – recommended "stepping-stones".

The attractivity of ecotone ows much to the edge-effect. It is a more general phenomenon, characteristic of the whole space and time, e.g. for barrier-layers in semiconductors, contact fronts of cold and warm air inthe atmosphere etc., that can be determined by contacts of heteroqualitative spaces. In broader ecological sense the edge-effect marks the complex of several heterolevel changes within natural borders of different kinds, comprising both biotical and abiotical components. For example the abrupt change in light regime, substrate water conditions, species composition and other factors in the forest edge characterize it.

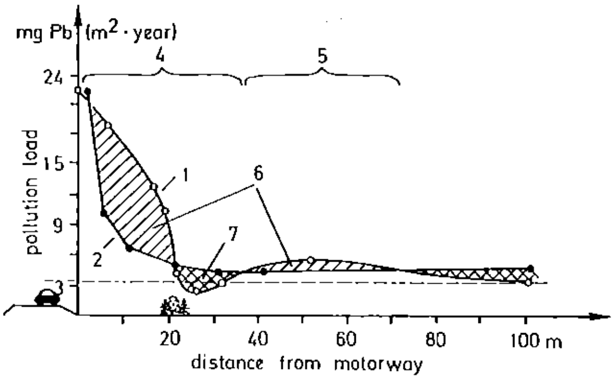

Fig. 2. An example of edge-effect, ecotone and secondarily induced ecotone: The roadside fir-hedge (height 3 m; traffic density 1300 vehicles per day) affects on the pollution load with lead; 1 – open field, 2 – field with hedge (adjacent to No 1), 3 – ecotone pike, 4 – ecotone, 5 – secondarily induced ecotone, 6 – increased contamination nation, 7 – decreased contamination.

Edge-effect in a strict biological sense is known as a cumulation of life into ecotones. Although the cumulation does not have to occur. Also a "negative" edge-effect can appeare in some cases, e.g. in ecotones with unsuitable conditions for biota of both adjacent communities. Any ecotone effects selectively on different biotical taxons. Three groups of ecotone-related biota can be distinguished: 1) over-ecotone biota – biota uninfluenced by edge, 2)ecotone-level biota – biota influenced by edge and 3)under-ecotone biota – biota specialized on edge. The desirable composition of species could be reached operating with the mosaic of ecotones in the agricultural landscape (patch size included) (JAGOMAEGE, KUELVIK, MANDER 1988).

An other kind of edge-effect is revealed in matter-fluxes through landscape. Differently from surrounding agroecosystems with simplified structure, there are forest-stripes, shore-zones of water-bodies, woodlots, structured margin-lines of forest and other ecotones with quicker local matter-cycling, e.g. increased bioproduction and accumulation can be observed. Characteristically to the edge-effect in ecotones the change of matter-cycle gradients takes place exponentially. For example it manifests itself in exponential absorbing growth of biogenes and organic matter in forest buffer-strips of water-bodies (Fig.3).

It is essential to take into the consideration that for transforming the fluxes of energy, matter and organisms, vast areas are not needed. Taking into account the exponential nature of edge-effect, narrow strip-structures with knots on different hierarchical levels are enough. Transitions and gradients are of the main importance. To put it short: in landscape ecology the main role is played by edges not areas.

Thanks to the weighty part of ecotones in landscape functions it is possible to use them as evaluating criterion for several purposes. The authors of this paper have used density of ecotone grid as a criterion of landscape diversity. The index I' indicates the ratio of ecologically compensative area of rural landscapes (MANDER 1978):

$$I' = \frac{\sum_{j=1}^{n} l_j \cdot p_j}{S - S'} \cdot \sqrt{\frac{S}{S - S'}} \qquad (1)$$

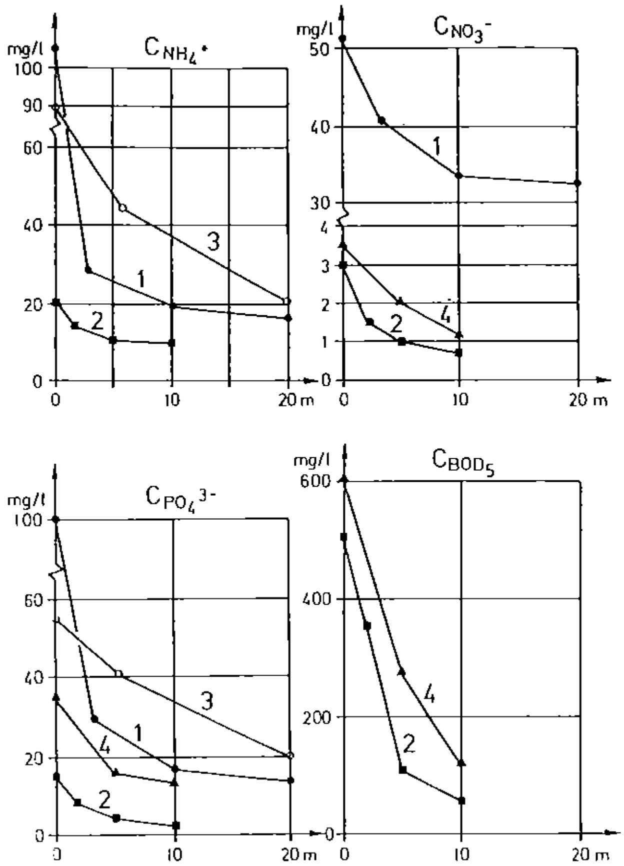

Fig. 3. An example of edge-effect: The content (C) of some biogenes and the value of biological oxygen demand (BOD(5)) in polluted overland flow decreases exponentially according to increasing of distance from the edge of buffer-strip (see x-axis); 1–3 – alder wood, 4 – willow brush (after MANDER 1985).

where l(j) – length of j-ecotone (m); p(j) – width of the influence zone of j-ecotone (m) (determinated with the structural diversity of ecotone and its hinterland); S – area of the research territory (ha) (e.g.of a meliration object); S' – area of natural or seminatural biogeocoenoses inside the research territory (ha).

The index I, simplificated on the basis of this ratio (formula 1), indicates the density of ecotone grid on the research territory in metres per hectare:

$$I = \frac{\sum_{j=1}^{n} l_j}{S - S'} \qquad (2)$$

The index I is called the index of ecological diversity of landscapes. It characterizes a man-made or a secondary structure of rural landscapes. The degree of simplification of a secondary landscape structure dI also plays an important role in evaluating landscape changes:

$$dI = \frac{I_1 - I_2}{I_1} \cdot 100\,\% \qquad (3)$$

where I(1) – value of index I before simplification e.g. amelioration) and I(2) – the same after simplification.

In comparison to the rate of heterogeneity of a potential or primary landscape structure, that was found after the factor R , it made it possible to use these parameters for determining an optimal diversity of different landscape types:

$$R = \frac{e^{\frac{M}{N}}}{S} \cdot \sum_{j=1}^{n} L_j \; c_j \qquad (4)$$

where R – rate of heterogeneity of apotential (primary) landscape structure (investigated on the basis of detailed soil maps at scale 1:10,000 or 1:5,000); M – number of soil types; N – whole number of individual units in soil pattern; c(j) – degree of contrast ("might") of j-boundary between the two soil units (can be determinated in metres); L(j) – length of j-boundary between the two soil units (m); S – area of the research territory (ha).

It's essential to take into the consideration that the density of the network of ecotones is obliged to be greater in the landscapes with simple and decomposed potential structures. The optimal value changes between the range of 30 to 80 metres per hectare. On the other hand the ecological simplification must be the least (from 40 to 50 %) in the landscapes with very simple (e.g.marine sandy plains) and decomposed structures (e.g.morain-hilly landscapes). The criterion for these optimal values was the probability that adverse anthropogenic processes such as erosion, deflation etc. may arise or be enhanced in these landscapes (JACUCHNO, MANDER 1984).

The hierarchy of compensative areas, included the hierarchy of ecotones can be theoretically expressed on a hexagonal equivalence-areas model of ideal functioning. The hexagonal cultivable piece of land, surrounded by anthropogenical ecotones serves as an elementary area, which ideally identifies the maximal density of ecotones. According to the conception the ecological diversity and stability of landscape is guaranteed by heterolevel structure of ecotones and a network of compensative areas. A more real picture can be recieved drawing the structure on an elastic deformable sheet (Fig.4). This scheme is similar to the hexagonal model of the central place theory in settlement research and planning.

According to our conception the hierarchical system of compensative areas is recombinated with principle of the polarization of landscapes and functional zones of land use (RODOMAN 1974; JACUCHNO, MANDER 1984). The intensity of anthropogenical pressure decreases from one "pole" – town – to other "pole" – maximal naturally ecosystem (large national park or natural reserve). There are also different functional zones with multifunctional use along this gradient. They play the role of different buffers and guarantee the continual transition of anthropogenic load. This ideal structure can be the basis to comparise it with really existed landscape structures and on the other hand, a goal for controled landscape developement.

The practical use of this conception of compensative areas was started ten years ago already with the planning and designing of melioration objects and also with the planning of the territories of collective farms in Estonia.

Finally – this conception has been realized all over the territory of Estonia. In figure 6 a general network of compensative areas as an ecological infrastructure of Estonia is shown. That is made at scale 1:100,000 as a perspective plan until the year 2000 and it considers all other important perspective plans for our republic. The planning of conflict regions (industrial NE-Estonia, hinterland of Tallinn, W-Estonian archipelago) was composed in more detail.

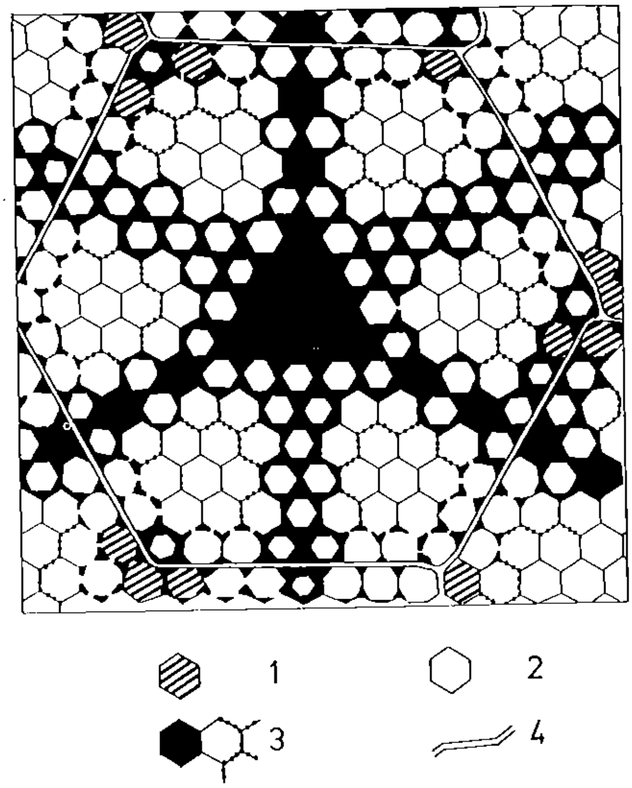

Fig. 4. The ideal structure of rural landscape: Ecological diversity of landscape is guaranteed by heterolevel structure of ecotones and network of compensative areas; 1 – urban areas, 2 – fields, 3 – compensative areas (forests, swamps, woodlots, buffer-strips etc.), 4 – main roads.

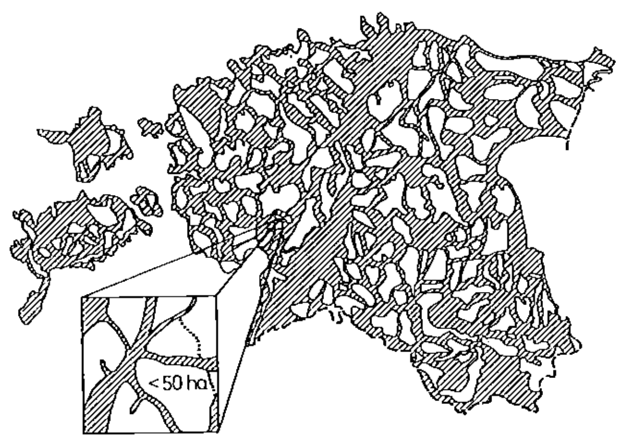

Fig. 5. General network of compensative areas (indicated with hatching) as the ecological infrastructure of Estonia at scale 1:2,500,000; with the detail fragment of structure (after JAGOMAEGE 1983).

The conception has also been the basis of making up schemes of water-protection of river basins (the Matsalu and Peipsi basins).

It's also of interest, that the borders of counties in ancient Estonia coincide with the main axes of the present ecological infrastructure and, on the other hand in the LANDSAT photo of Estonia we can see the present structure of landscape, which is similar to designed ecological infrastructure.

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GEOGRAPHICAL INFORMATION SYSTEMS FOR LANDSCAPE ANALYSIS

D. Bartlett (with contributions from D. Gray, J. Irvine, B. Morris and C. Nailer).

Abstract

A major requirement in any landscape ecological study, whether at the regional or the strictly local level, is the collection, storage, manipulation, analysis and eventual presentation of data. Frequently these data are spatially defined. Computer–based geographical information systems (GIS) are important tools for landscape ecological investigations, since they combine the ability to store and process large amounts of spatial data with the equally important ability to output these data in graphical (normally cartographic) form.

The two principal components of a GIS are the database management system and the graphics/cartographics software. The minimum requirements of a system are that it can to locate a feature; record one or more attributes for that feature or location; assign suitable topology; and permit rapid retrieval of the relevant record. Within these parameters, the ability to correlate between data entities, and between the data and the output facilities, determine to large degree the efficiency of a GIS. Thus, the connectivity within the GIS is an important determinant in assessing the suitability of that system for landscape connectivity studies.

Edinburgh University Geography Department is acquiring a growing reputation for excellence in the teaching, development and application of GIS.

1. Introduction

Landscape ecologists seek an integrated view of land in all its complexity. In order to achieve such an holistic perspective, account has to be taken of a wide spectrum of attributes, including geology, landform, climate, water, soil, vegetation, animals and human activity.

Until relatively recently an integrated approach to landscape management has been difficult, for reasons that include (a) the lack of suitable conceptual tools to transcend the barriers of academic and professional specialisms; (b) variations and inadequacies in the quality of raw data available for integration; and (c) logistical problems over handling, manipulating, collating, synthesising and disseminating the vast amounts of data that a truly holistic landscape study can produce (BARTLETT 1986). Technically, these data only become "information" after they have been processed for a particular application (TOMLINSON 1972).

It is usual in landscape ecological studies to concentrate on the intricacies of relationships between and within landscape elements, and between these elements and the resident biota. However the flow of data, and of information, about these landscape elements should also be considered in any landscape ecological study. Most of the data required or produced by landscape ecologists are spatially defined: they can be referenced within the landscape in terms of latitude, longitude and elevation with respect to a datum point. The traditional method of storing information about spatial relationships is in map form. According to the United States Committee on Integrated Land Data Mapping (Reprinted in Marble et al, 1984), the first map was created before the first alphabet. Therefore, they suggest, 'it is clear that we have been working on the creation of efficient spatial storage and display devices for many thousands of years'(p1–3).

Maps are extremely useful forms of data store and presentation. They are an inherently visual means of imparting information, and can be very versatile. In the hands of skilled interpreters (and if compiled by skilled cartographers) the amount of information that can be obtained from a single map is enormous. They may also be important as a means of imparting a sense of 'place' to planning personnel who might otherwise have limited visualisation of the area under scrutiny. Unfortunately there are also several problems that may arise as a result of using maps as sources or stores of information. These may be summarised as follows:

1) Problems relating to the actual creation or acquisition of the maps themselves, and their subsequent storage. Cartography is an exacting science and is a skill that the landscape ecologist might be lacking.

2) Maps may go out–of–date. The consequence of this is that either the user has to 'make do' with inaccurate data, or superceded maps have to be replaced at regular intervals. Often this is prohibitively expensive.

3) Maps generally present spatial data in the form of points, lines or areas. However, depending on the scale of the map and the skill of thecartographer (and the interpeter), a certain degree of generalisation of information is inevitable (see, for example, BURROUGH 1984, p4). In many cases, a complete field examination of the whole area covered by the map will not have been achieved, and some measure of interpolation between sampling points will have been required. This enforced generalisation of data in the source map may easilly be overlooked by the user. The imprecision is therefore likely to be further carried through if the maps are themselves used as sources of information for subsequent data analysis or aggregation.

4) Maps are relatively rigid and inflexible forms of data presentation. Differences in acceptable resolution may require the creation or storage of several maps of the same area but at different scales, and this will further exacerbate problems of cost, acquisition, and physical storage and retrieval.

5) Lastly, trying to combine the data held on two (or more) individual maps into a synthesis may be extremely difficult, especially if such inconsistancies as different scales, symbolism or even projections have to be taken into account. One approach to this latter problem involves the use of map overlay techniques, whereby data are synthesised by overlaying two (or more) thematic maps and combining the attributes onto a third (or subsequent) map as required. Until relatively recently, the overlay technique was achieved using no more than paper and coloured pencils, thematic maps, air photos, light tables, tracing paper and the printing press (BURROUGH 1984, pp4–5).

2. Geographic Information Systems

'In the past 20 years, a host of professions have been in the process of developing automated tools for the efficient storage, analysis, and presentation of geographic data...This rapidly evolving technology has come to be known as "geographic information systems." The uses of this technology are vast and cross cutting across virtually all professions' (DANGERMOND 1984).

Geographical information systems (GIS), also known as geographic processing (or geoprocessing) systems, constitutes a still very young and rapidly developing branch of Information Technology. It is a somewhat loosely-defined group term, used to describe the common ground between information processing and the many fields using spatial analysis techniques (TOMLINSON 1972).

A typical GIS will include facilities for four discrete data handling functions: data input, data storage, data manipulation and data output. Often, but not invariably, the data output will include the generation of one or more maps or graphs.

Geographical information systems have the potential to resolve most of the problems of using conventional maps for landscape ecology:

1) Computer cartography packages make the design and compilation of thematic maps a task easilly accessible to the non-cartographer, especially if the packages are inherently user-friendly, or if a user-friendly 'front-end' has been created.

2) In many GIS environments, the data is stored completely separately from the cartographic plotting components of the system. This means that the data may be easilly updated at any time, without this requiring new maps to be produced. Well- designed interfaces between the two functions may permit rapid data recall whenever required for a particular task.

3) The usefulness of a GIS is, as is the case with any other form of data store and presentation, only as good as the raw data fed into the system. However, computers have enormous capacity for storage and processingof data- and are increasingly able to collect the raw data themselves (e.g. where remotely sensed data are concerned, or for time-series recording of certain energy/matter/organism flows in the landscape). The enhanced data handling capacities permit much closer-spaced point sampling of land attributes or even, in certain situations, continuous sampling over space or time.

Careful database design also offers a release from costly and time-consuming duplication of effort and redundancy of data. A central data store or a well-designed distributed database, if properly managed, may be made accessible to a wide network of users, who may need the data for an equally varying range of applications.

4) The separation of data storage functions from information processing and graphic output mean that raw data may be stored in non-aggregated form, for subsequent merging and manipulation as required by individual applications. In the words of BURROUGH (1984, p8) one result 'is that in place of a static, heirarchical classification of landscape in which the thematic map is both data store and landscape model, we have a digital data base that can be transformed, classified and displayed as required'. This flexibility easilly encompasses such parameters as the scale of map to be plotted or the amount of detail to be included.

5) ARC/INFO (MOREHOUSE 1985) and a number of other GIS packages offer the ability to perform polygon overlay, synthesis and analysis, as well as overlay and synthesis of air photographs, digital images, maps and even text information (such as listings of points of interest). These computer-based techniques are able to perform irrespective of the scale or projection of the source materials.

3. Geographical Information Systems at Edinburgh University

The development and application of geographical information systems constitutes a major area of endeavour within the Geography Department of Edinburgh University. This research and teaching commitment has resulted in several major GIS-based commercial research and development contracts being awarded to the Department, including assignments from GIS-producing software publishing houses.

The commitment of the Department to GIS is also reflected in the teaching programme within the Department: throughout the four years duration of a typical undergraduate degree course, students are introduced to a wide range of computing skills, and are offered a number of optional courses including geographical informations systems, geocartographics, digital image processing, and computer software and modelling.

At postgraduate level, enquiries about the 1-year M.Sc. course in Geographical Information Systems continue to exceed available places by a large margin. This course has attracted students from Canada, the United States, the Netherlands and Hong Kong, as well as from the U.K.

A number of 'turnkey' geographical information systems are available within the Department. These include ERDAS and GEMS digital image processing workstations; the CAMAP system for mapping and analysing agricultural census data (HOTSON and KIRBY 1978); and ARC/INFO (MOREHOUSE 1985). This last-named system is, perhaps of greatest interest to landscape ecologists, since it was specifically developed for the automation of the map overlay technique discussed above. It does this by linking the 'ARC' topological module (which represents feature locations and topology) and the 'INFO' relational database module (for handling feature attributes). ARC/INFO is able to process and synthesise data derived from maps produced at different scales or projections, and can be used for buffering selected zones or corridors of data. A further enhancement is the ability to interrelate and synthesise digitised map information and remotely-sensed imagery.

Interfaces between topological and relational modules also feature in other GIS-related activities within the Department. One result is GEOLINK, a general-purpose interfacing package written by Tom Waugh (a member of the Teaching Staff of the Geography Department). Amongst other applications, GEOLINK has been harnessed to provide an interface between the ORACLE relational database management system (dbms) and the GIMMS mapping software. This enables data to be spooled from the database directly into source files for plotting as thematic maps.

Other interfaces in various stages of development include bridges between ORACLE and ARC/INFO, between GIMMS and ARC/INFO, and between ARC/INFO and the GEMS image processing system.

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CONNECTIVITY, PROXIMITY AND CONTIGUITY IN THE LANDSCAPE INTERPRETATION OF REMOTE SENSING DATA

P. JANSSENS and H. GULINCK

The following text presents research results of the Belgian scientific research program in the field of spatial remote sensing (SERVICES OF THE PRIME MINISTER – SCIENCE POLICY OFFICE). The scientific responsibility is assumed by its authors.

Introduction

This paper investigates the relevance of spaceborne remote sensing data of the type 'SPOT' for landscape ecology, more specifically for the study of connectivity of vegetation features.

FOLVING (1984) already gave an overview of the possibilities and constraints of Landsat MSS data for landscape ecology. ANTROP (1986) stressed the importance of the knowledge of structural landscape information in the interpretation of remote sensing data.

The newer earth observation satellites such as SPOT have a spatial resolution that provides a much greater detail in comparison with the Landsat MSS generation. More 'textural' and 'structural' information of the landscape becomes available, and satellite remote sensing evolves towards the 'landscape level' of geographical survey.

On the other hand, the evolution of landscape ecology towards a more structural approach, which is manifest through concepts such as connectivity, is a coincidence that should be turned more explicitly into useful methods and applications.

Figure 1 resumes this general relationship as a two–sided supply/demand interaction, and gives furthermore the essential characteristics of the SPOT–images.

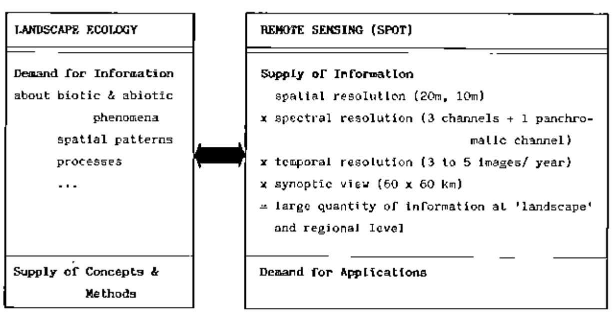

Fig. 1: Landscape ecology and remote sensing: a supply/demand interaction

Landscape and landscape interpretation

Distinction is made between the landscape itself and a landscape approach to information sources.

Landscape is considered as a part of the total environment, and the landscape approach is a specific attitude, which is different from other, more current interpretations, such as land–use classifications or diagnostic uses of remotely sensed information. The former cases search for between land–use class spectral contrasts, and have a survey or cartographic character. The latter are more ecological in character and look for diagnostic deviations from some normal spectral characteristics, within land categories, which can be related to variations in soil quality, vegetation vigor etc.

Contextual information (texture, pattern etc.) of structured nature is increasingly used as an additional diagnostic criterium to improve those 'classic' applications (STAKENBORG, 1987; TAILOR et al.,1987), but is rarely a research object in se. A landscape interpretation, on the contrary, tries to find meaningful interpretations of the very spatial organization of landscape features, be they of biotic, abiotic or anthropogenic kind.

Generally, a landscape interpretation consists of two main stages: the detection and description of relevant landscape elements and components, such as land–use categories, biotic linear elements, trees etc. (ANALYTICAL STAGE) and the processing of this information into concepts of structured nature, such as connectivity, diversity, interweaving etc. (SYNTHETICAL STAGE).

Most of the implemented techniques in this process are adopted from existing sciences, such as soil science, landscape ecology, geography, spatial mathematics, environmental psychology, image analysis etc.

This general methodology has been explained in greater detail as a framework for landscape interpretations of remote sensing data in another paper (GULINCK et al., 1987).

Our central question is then how remote sensing, in casu SPOT data, maybe used as a tool for landscape ecology.

Towards the study of connectivity using SPOT–data.

A. The analytical stage

1. Theoretical background

From a bio–ecological point of view, we assumed all high vegetation, except agricultural crops, as relevant landscape elements.

The detection of the separate elements (woods, woody hedges, tree groups,...) up to the smallest possible detail with respect to the relatively limited image resolution, asks for specific identification techniques, ordered in a decision tree (figure 2).

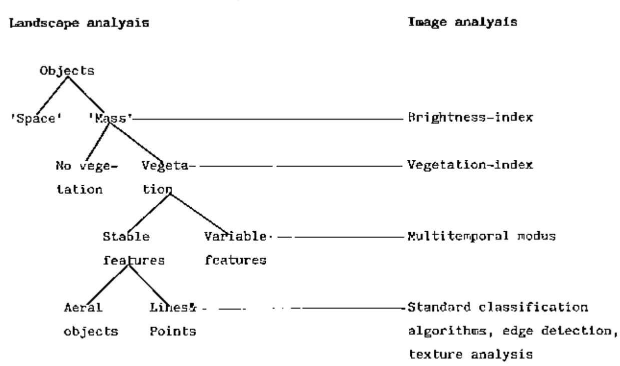

Fig. 2: Landscape analysis and image analysis: a decision tree

The discrimination decisions are made according to image analysis principles based essentially on the well known red/near infrared spectral contrasts of the SPOT HRV channels #2 respectively #3.Open spaces (agricultural fields, large squares, but not water bodies) can in general be well distinguished from mass (woodland, densely built–up areas, including open water) through a "brightness index", a linear combination of the grey levels in different channels. Vegetation clearly differs from non–vegetated areasand the discrimination is possible using a "vegetation index", a ratio of the red over the near infrared channel, corrected for the atmospheric path radiance (GULINCK 1980).

A brightness index in combination with a vegetation index is very useful in the discrimination of open water, tall vegetation, low vegetation, built–up areas and poorly vegetated open areas (figure 3). Since woody vegetation is in a certain extent and certainly compared to agricultural crops, spectrally "stable" throughout the year, a multitemporal modus can profitably be used to enhance such discrimination.

In final instance, we also try to identify correctly small and narrow woody elements, although through their size, their spectral response deviates from that of "pure" categories, i.e. "homogeneous" areas extended over several contiguous pixels. The quotes stress the need to be careful with these qualities, both in geographical terms and in terms of image processing. What we interpret to be topically homogeneous in the field may be spectrally heterogeneous, and the reverse.

2. Application

The technique was applied on a multitemporal image (30 April and 28 September 1986) over an area including and near the city of Leuven, covering urban, peri–urban and agricultural land. The discrimination of the areal categories of land–use mentioned above poses no problems. This is however not the case for linear and point–like elements. The edges of woodlots can be reconstructed through edge–detecting or texture transformation algorithms.

Small vegetation points and narrow vegetation lines, such as road verges, hedgerows etc. don't cover a whole pixel (20X20M) (Mixed pixels). The detection of sub–pixel woody features in simulated SPOT imagery was studied by FOSCHE (1986). In the bivariate plot (figure 4) the mixed pixels appear in the transition belt from the pure category 'woodland' to other categories. This gives valuable clues about the spatial context of small landscape features, which can eventually be interpreted from an ecological point of view. A classification result for a part of the study area is depicted in figure 5.

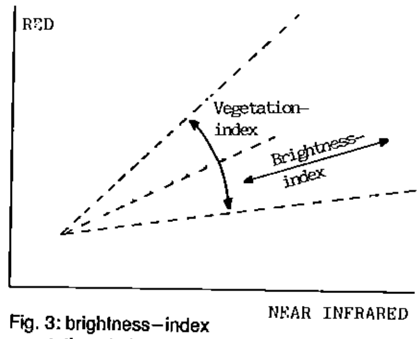

Fig. 3: brightness–index vegetation–index

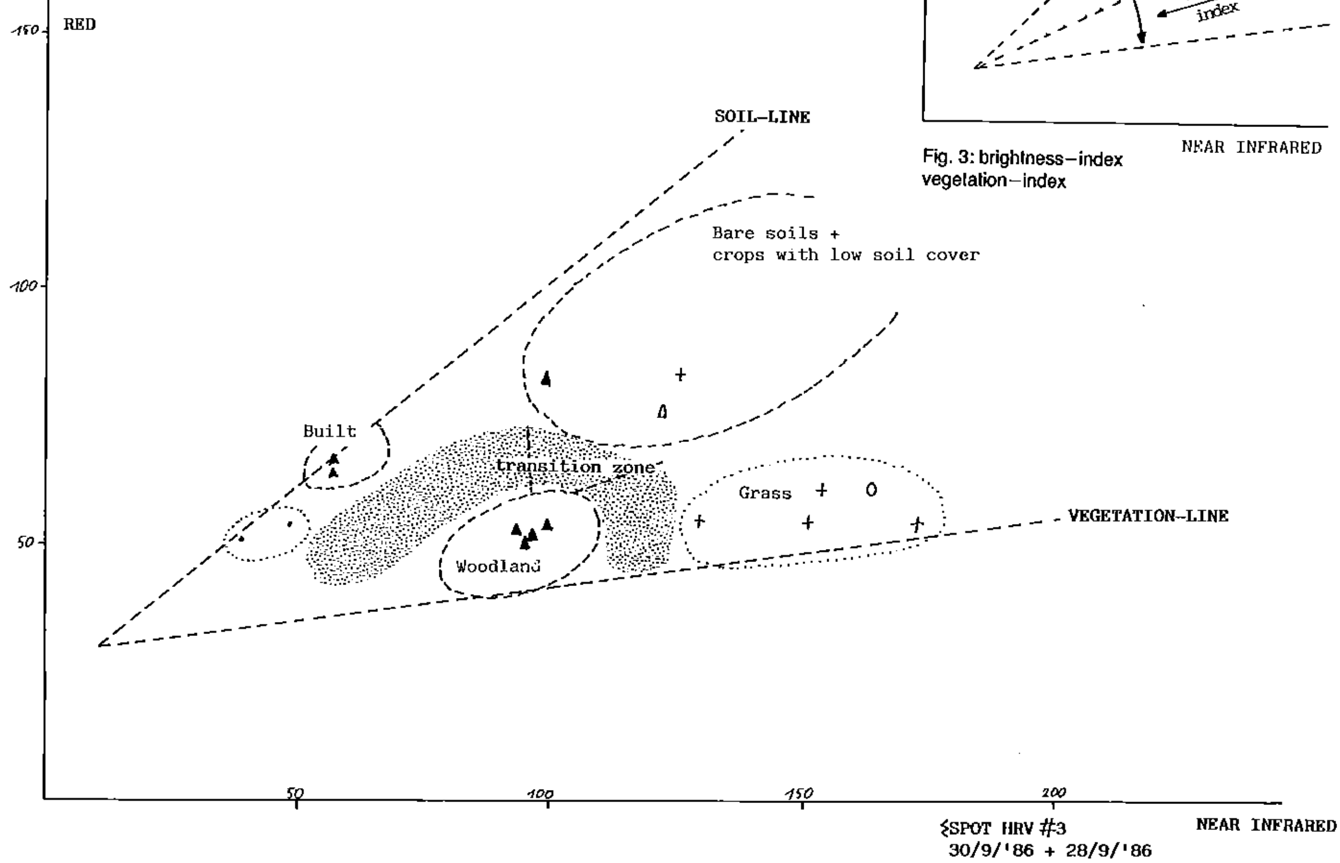

Fig. 4: bivariate plot

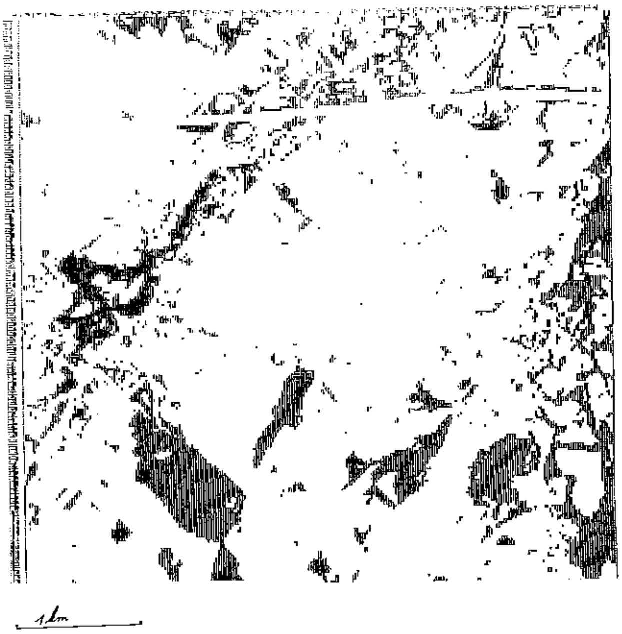

Fig. 5: Classification result

B. The synthetical stage

1. Theoretical background

Looking for clear definitions of the connectivity concept, we met some different interpretations.

Image analysts, on the one hand, often interpret connectivity in the sense of adjacent identical or similar pixels. Through this connectivity, individual objects are defined in the image (JOYCE– LOEBL 1985). This connectivity may refer to the whole object field, or to the edge pixels. It is worthwhile to stress the fact that in image analysis, besides the term connectivity, also the terms 'adjacency', 'contiguity', 'vicinity' etc. are used and that specific software and hardware techniques have been or are being developed for their implementation.

Landscape ecologists, on the other hand, seem to adopt the connectivity concept from spatial mathematicians and traffic planners. This approach distinguishes nodes, associated to hospitable biotopes, and links, associated to corridors between those biotopes. By this way,, and –indices can be calculatedand related to the dynamics in this biotic network. (MERRIAM 1984)

This approach assumes species movements along physical corridors in the landscape. However, many species, such as birds, have a 'bridging–over' capacity between hospitable biotopes (MAC ARTHUR et al. 1967). KOLLEN (1986) proved that isolation (distances between) and density of hedgerows are relevant to the number of flora species in an area.

We assumed this bridging–over capacity should be incorporated into the connectivity concept, thus bypassing in a certain extent the limits imposed by the spatial resolution in the detection of small biotopes, but also stressing the relativity of the barrier effect of the landscape matrix sensu FORMAN et al. (1984).

So, the connectivity in landscapes is a combination of "contiguity" and "proximity". MAC ARTHUR et al. (1967) bore into consideration the width of the source island, the angle included by the recipient island and the survival chance, dependent on the distance. The bridging–over capacity depends on the species, thus a species–specific connectivity should be considered.

2. Application

The application technique we used here is quite straight forward, and inspired by current image analysis techniques (JOYCE–LOEBL 1985). Given a classified image, the edges of vegetation units are reconstructed. All edge pixels belonging to the same spatial unit are stored as chains in memory, by scanning the image. Through this operation we are able to reconstruct the contiguities in the image (figure 6).

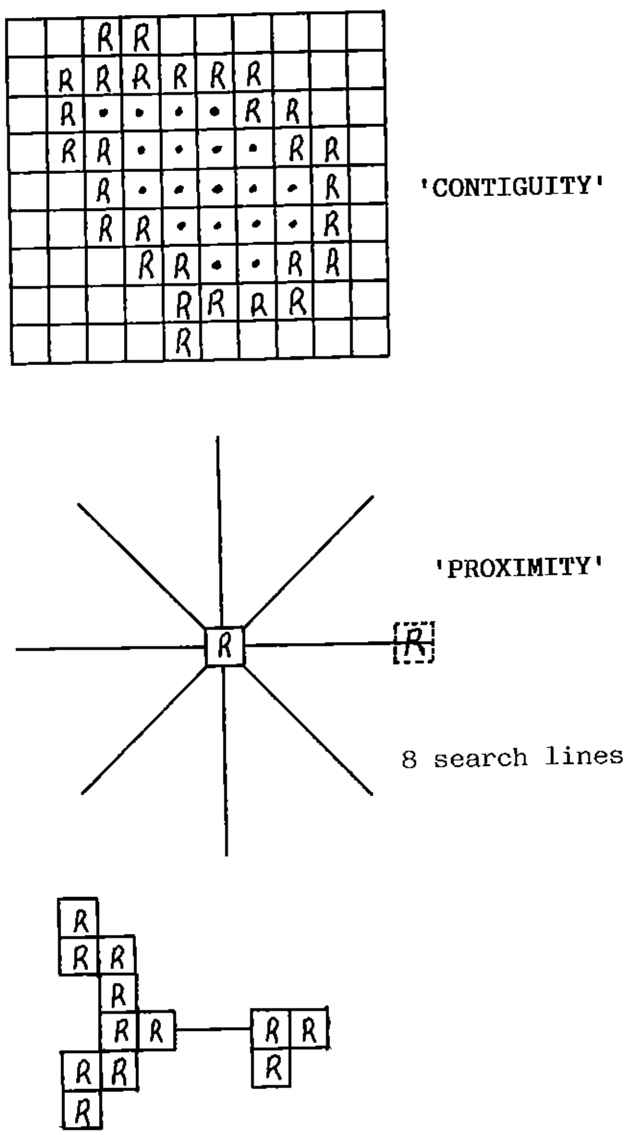

Fig. 6: Image analysis: "continguity" and "proximity"

Then, within a search circle corresponding to a pre–defined threshold distance from edge pixels of a certain spatial unit, edge pixels of other units are detected. This threshold proximity may be related to criteria such as maximal bridging–over distance or even acceptable loss ofspecimen. As soon as a below–threshold distance is detected, a line between the two pixels is drawn. The total number of "bridges", an aggregation of individually detected below–threshold proximities, could be considered as a measure of proximity in highly fragmented landscapes. Some results are given in figure 7.

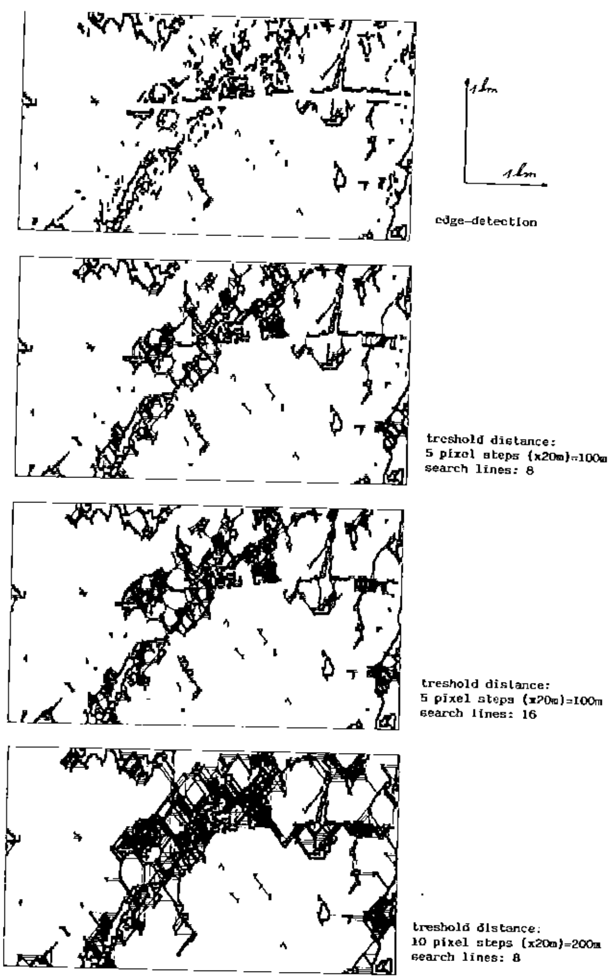

Fig. 7: bridge detection: some results
a) edge detection
b) treshold distance: 5 pixel steps (x 20m) = 100m
search lines : 8
c) treshold distance: 5 pixel steps (x 20m) = 100m
search lines : 16
d) treshold distance: 10 pixel steps (x 20m) = 200m
search lines : 8

Some remarks must be made to this technique. The number of search lines is importantly related to the accuracy of bridge detection. The further an object is situated from another, the smaller is the chance a bridge will be detected, and the larger the number of search lines has to be. This means that no conclusions about bridges between two particular objects can be made. However, the total number of detected bridges in an area could be considered as a measure of 'proximity' in an area.

Drawing lines has the disadvantage that there is a line or there is not. In other words, by this way we can't represent the continuous varying survival chance. This representation neglects a lot of information about proximity in landscapes.

3. Outlooks

Some outlooks and constraints can be formulated. It is possible to include direction as a bridging–over criterium, for instance in order to take into consideration the dominant wind direction.

Similarly, a distinction could be made between the kind of area to be crossed (highways, cropland, urban areas,...). For example, highways could be considered as very strong barriers, and agricultural areas as easier to cross.

Ecological planning could profitable make use of this kind of analysis and synthesis, for instance through the detection of strategic areas, where the creation of stepping stones or the removal of barriers could improve the connectivity. Even, evaluation of simulated implantations can become possible.

Further research should be done for the overlay of connectivity maps computed for representative species. Also, a definition of connectivity indices, including concepts such as bridging–over capacity, could be envisaged, as complements to the , and – indices. The various methods and techniques offered by image analysis could be very inspiring. However, this will give some problems. It is, for example, not clear on which base nodes (biotopes) and links (corridors or bridges) are defined. Is this on vegetation dependent criteria, on shape dependent criteria or on measurement criteria (perimeter, area..)?

Some general conclusions

Remote sensing images offer potential information otherwise hardly obtainable to landscape ecology. On the other hand, landscape ecology offers useful synthesizing concepts in the interpretation of remote sensing data, thus widening the applications of this technique in a field hitherto generally neglected.

A landscape approach to remote sensing information implements existing techniques, but also develops new algorithms, inspired by concepts, used in spatial sciences, such as landscape ecology.

The distinction between an analytical and synthetical level is useful for various reasons. The analytical level allows a useful distinction between various relevant landscape–ecological elements and components, and clearly sets the limits imposed by the resolution of the imaging system. From this level, a wide fan of synthetical concepts developed in landscape ecology can be applied. The confrontation of these concepts with the techniques offered in the field of image analysis and spatial mathematics is a challenge for both remote sensing and landscape ecology

The effort to apply the concept of connectivity on SPOT–derived datasets makes clear that it is necessary to define this concept more clearly. This remark is also valid for other structural concepts in landscape ecology.

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UPON THE USE AND ABUSE OF THE NOTION OF ECOLOGICAL CATASTROPHE

T. Bartkowski

In order to understand better the notion of ecological catastrophe one must consider firstly the notion of homeostasy. It means the ability of a given set to return the former state after a temporary disturbance of its course. Homeostasy can be represented graphically as a line of continuous "up's" and "down's" following in time and not as a straight line indicating a steady state of such a set. Do not misunderstand this parable! It shall only stress the point that in the homeostatic set the "down's" of its curve are its common, its constituting feature. We can visualize it on the example of some mammal or insect where the grogradation phase ends with an abrupt decrease of the population (retrogradation).

Now we are facing the problem of an ecological crisis. It means firstly the state after the tourning point that lasts till the next tourning point that can be either the beginning of the next progradation phase or of a temporary (short) low, steady state. Taking this into account we must conclude that such crises are nothing exceptional, that they are the commonest thing in the existencein the duration of a population. Crises are the nature's way of regulation of the size of the population and because of this we should be not afraid of crises. Despite this conclusion we are still afraid. Why? Because we are humans and for humans each retrogradation phase means death of human persons. We know, that man fears death but we consider this fear as a natural, exactly "human" thing as man's fate. Now, retrogradation means something different– an extraorinary, sudden, massed death of persons and for Him it is no consolation at all, that such are laws of nature. Man considers also such crises as something bad and therefore he abuses the terms calling these phenomena catastrophes.

How to understand such terms? Let us look at animals populations! There can happen, in the course of continuous "up's" and "down's" of the population curve the one "down" where population extincts: is either exterminated by manor by a predatory species or when the ecological niche (biotope, site) is destroyed (f.i. by volcanic eruption). In these cases, where there occurs a cessationof the duration of the population we could use the term of a catastrophe but wemust be aware that it has local character and that we must ask: for what time sector? The well known example of the little island Krakatau, where were destroyed not only the biological life but equally the ecological niche proves, that such local catastrophes are of short duration and the "invincible life" has taken into posession the island again after only several decennies since the eruption in 1883 (the same case exemplify the volcanoes of Vesuv and Etna or the Montagne Pele of Martinique, where the eruption of the year 1902 has caused a sudden death of 26000 of inhabitants but the destroyed town S. Pierre lives again). It were also temporal local catastrophes and the succession of life forms has led to a populational revolution: the exchange of the old biomes by the new ones. It was also not a decided, final, absolute catastrophe. A final, absolute catastrophe (the very true catastrophe) would occur only in the case of destroying of all life on Earth (the case of a possible atomic world war).

In order to visualize this situation, when referring it to the case of the human species let us consider the adjoined ideogram showing the use of the discussed terms in the cathegories of the notions of ecology in general and of landscape ecology in the detailed view. The consideration of this "ideogram–model" begins with the notion of ecological paradigm. It means that, when studying human populations we must always consider the relations between the basis (material, physical, technical) and the overstructure (society's organization), because these relations consist in the flows (see arrows) of matter, energy and information between them, indicating homeostasy and this is the essence of all ecology.

Of course homeostasy, as already hinted consists of continuous crises (indicated by the sign) but some of them can be more deep as the common, light ones, partial crises. These crises can become manifest either in the area of the basis (as f.i. deterioration of physical life conditions, as diminution of the number of population in "sudden deaths") or in the area of the overstructure (see the perception). The crises can be of differentiated intensity (see "deep crisis") and when this deepening occurs in both the areas simultaneously there can occur a state of revolution: as well a populational one (when one population is exterminated or expulsed) or a social one (classes changes, then theproblem of social justice reforms, emancipation of "poor" classes, of slaves, other changes).

We will remark that till this moment we didn't consider ecological catastrophe in the very sense of the word. In all these cases the existence of both the elements of the ecological interaction: the basis and the overstructure, although subject to changes, was nevertheless continued, that is "life" persisted despite the crises. Catastroph can occur only in the case of total annihilation either of the basis (basis catastrophe) or of the overstructure (overstructure catastrophe) when their continuation is not possible (even through revolution). Total, absolute catstroph occurs only when both theelements of the interaction are revocably, simultaneously annihilated (hypothetical atom world war).

Finally the model indicates the respective areas ofinterest of both levels of ecology: in a narrow sense, when concerning the basis and in the broader sene, this one of landscape ecology, when concerning the relations basis–overstructure (indicated in the model as the core of ecological paradigm) relations between the subject of the interaction set and the outerspace (compare E. HAECKEL'S definition 1866!)

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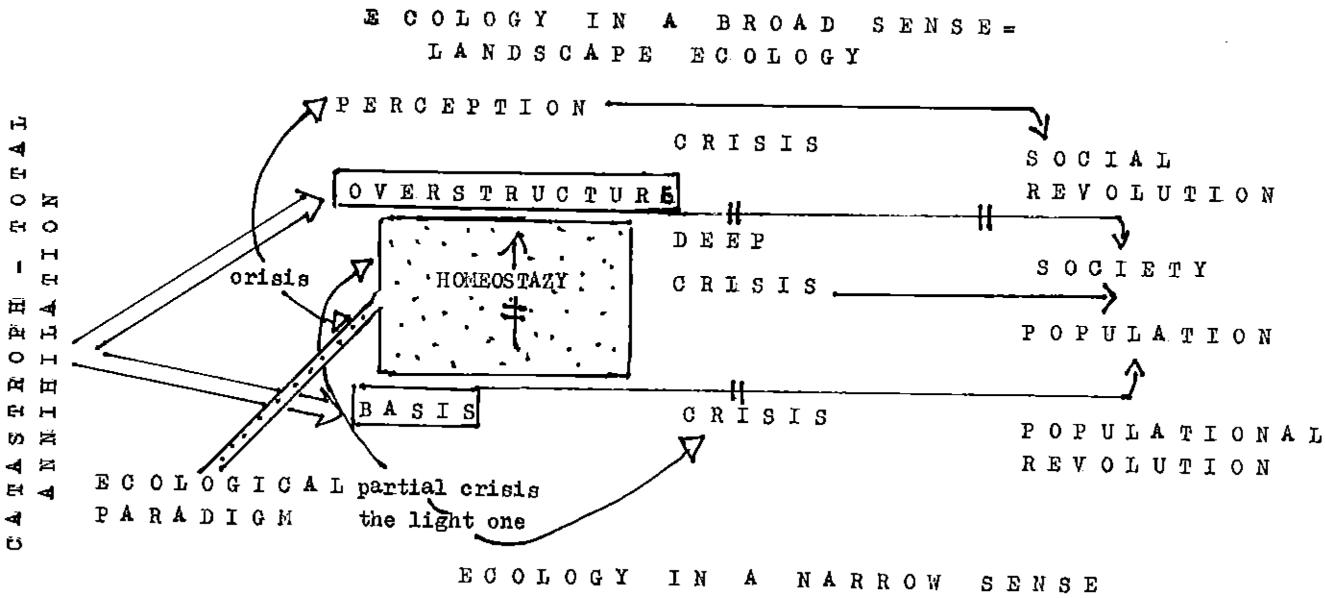

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CONFRONTATION OF THE NATURAL SPATIAL UNITS PATTERN IN THE TOPIC DIMENSION WITH THE ARTIFICAL SPATIAL UNITS PATTERN IN THE LIGHT OF CONSIDERATION OF THEIR CONNECTIVITY AND COMMUNICATION.

T. BARTKOWSKI

In order to understand properly the aims of the task, indicated by the title let us define firstly what means "natural" and what "artificial". The first, seemingly obvious, explanation would be: natural is what is originated by nature and made by natural forces and artificial is what is originated by man and made by man's technology, by man's application of additional matter and energy to the task of transformation of nature in the so called geotechnical metabolism (encompassing in "nature" as well the living as the non living matter).

And by this first explanation , presenting antinomy "nature–man", we are meeting first conceptual difficulties. Let us quote the Authors (T. BARTKOWSKI 1986a) considerations concerning the so called "anthropogenic landscapes" . What is "anthropogenic landscape" ?There are but very vew places on Earth that should not bear any imprint of human activity on them–an imprint of immediate or of intermediate use of nature by man. Even landscapes, that seem to be natural in our perception, such ones as equatorial rain forest in Amazonia, the african Savanne, badlands of different type, landscapes of wandering dunes belong here although man appears in these landscapes mostly only as stimulator of landscapeforming processes (then "man's =anthropo=genic!") of wholly natural character (forces of nature). We must call all these landscapes "anthropogenic" accordingly to the first explanation.

Sometimes the anthropogeneity of the landscape is even more subtle, when it is the result of indirect, very remote influence of man as f.i. the extermination of a predatory species in a mountaineous area by man that preyed on goats and mouflons. This extermination of this predator has led to unhindered repreduction of goats and mouflons and to their immense multiplication. The effect of this in the landscape is an increased slope erosion and the formation of recent badlands morphology (and of all dependant effects in the landscape ecological sight).

The demonstrated case proves the existence of anthropogenic landscapes formed by totally natural forces and processes. Nevertheless such landscapes stand in certain opposition to such unmistakeable anthropogenic landscapes as arable, cultivated lands in Europe, cultivated densely populated lands of monsoon Asia,as irrigated lands of oases of the near east, even as chinampa fields of Mesoamerica etc. Because of these facts one should discern also, in the cathegory of anthropogenic landscapes in general a subclass of "anthropic" landscapes, of these that are immediately used and maintained by man.

We must then modify our first definition of "natural" and "artificial" and resign from the condition of "being made by natural forces" and "being made by man's technology" or as "application of additional matter and energy" and focus on the condition of "being in immediate use and being maintained in functioning by man". Then we must come to the conclusion that the most logical definition of the problem of "naturality" and "artificiality" of surfaces concerned in these considerations (and named "topes" because of the topic dimension) should finalize in the establishment of a certain set of two extremal and a certain number of intermediate situations in which factors"nature" (natural (and "man") artificial) interact in an antinomy in the manner demonstrated in the following "ideogram":

```
                     Space units = topes
                              Semi:
natural ——→ natural ←——→ artificial ——→ artificial(anthropic)

     naturogenic                    anthropogenic

physio + biotopes ——→ ecotopes ————→ anthropotopes
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The ideogram don't need explaining–it speaks for itself. After this the Reader will now understand why "artificial" means "anthropic" , why "anthropogenic" contains in it "semi–natural" and "semi–artificial" (with changing degree of "naturality" and "anthropogeneity") and will now understand why in the following explanation of a new group of notions the Author is cautious in using terms referring to genesis and uses instead the commonly used adjectives–prefixes "homo"– and "hetero"–"genous", the compositions "homo"– and "hetero"–"logous".

In order to introduce this second group of notions we must state that there exists a fundamental difference between two points of reference of basic landscape surface units, also units of so called topic dimension, as related to two types of organisms, considered as subjects of reference:

- of immobile plants, "standing" on their "sites" and forming a kind of biotopes named "phytotopes"
  - of mobile animals, wandering on and between different biotopes–phytotopes, forming thus their biotope– zootope (their "space of life") that can be named equally their "territory".

The first group of surfaces belongs to the cathegory of physio– and eco–topes (generally named "geotopes") where occurs, in different way (comp. the notion of "cascading" systems of CHORLEY–KENNEDY 1971) flows of matter and energy and in this case in the course of transportation (of flow) the most important feature of their spatial location is the neighbourhood. However the most important feature of the structure of these geotopes is that they are homologous . It means that the conditions of supply and of growth of plants are fairly uniform on all the surface of given physical unit (the physiotope) in the "view" of interests of "higher" in size plants (we exclude microbes and parasites and other very small sized organisms). The units that have common limits enjoy the value of being intensively connected when they are neighbours and enjoy intense exchange of matter and energy (it is esspacially the case of so called "catenas", where occurs a longiludinal flow of matter in a "vectoral horizontal system"). They are in essence gravitational flows.

Contrary to this second group of geotopes that is described by landscapes ecologists (esp. see R.T. FORMAN 1981) in terms of patch , matrix, corridor, interior and edge biotope, ecotone, are basically heterologous. They are not so much uniform surfaces as rather "contact lines", spots, lines crossing the matrix or ecotone surfaces (even patches, although may be great in size, are differentiated in edge and interior sites, are also hetereologous). It is equally the same case when we are dealing with man as subject of the reference (man as living being, also an organism) and with his land use (manas intelligent being using technics). He is the greatest "source" of most of the heterology of anthropic landscapes.

This second group of surfaces, that arenow under discussion is discerned on behalf of animals, including man, beeing able to move, to communicate between different productional surfaces of nature (phytotopes) and thus to change places in seeking food (or equally for other purposes–comp. the notion of territoriality that will be explained later). Also movement, possibility and opportunity to wander, to move, are of vital importance for animals and it is here that enters in full the notion of connectivity. The common extended limit is not as necessary as only the sole connexion (with exception of birds and of some flying insects – they can equally transport parasites)that allows the physical wandering to places where animals can find food (or for other purposes) and, as a special case of such needs, water. Of course the possible extended, the "common" limit, facilitates this connectivity enormously but this is not an absolute necessity and of course for "flying" animals both these properties are not necessary. In this case of importance would be "neighbourhood" (that does imply unavoidably connectivity).

On the other hand man's way of life and man's use of space does not oblige him to live constantly within the limits of the productional surfaces, because he can gather, collect and transport the products of nature, such ones as food, raw materials (in this fuels) needed for this specifically human way of production– the secondary production – and he uses for this purpose a special kind of "to" and "away" conveyers (field) paths and roads, motor– and railways, pipelines, aqueducts and water channels etc. (he behaves in such way since the slopping of nomadic life, since the age of steady, immobile occupance of land, since the establishment of permanent settlements. It is right here that we are coming to the notion of oecumene–of of the "inhabited earth"–and to the problem of its evolution. It is here that appears the problem of "superimposition" of oecumenes in the course of history of man and the besettlement af a given terrain (comp. the Authors contribution T. BARTKOWSKI 1986b). The connectivity important for man depends upon finding places –optimal sites– where are meeting most kinds of productional surfaces and it is here that man settles, constructs houses. It is worth of mentioningthat in the Polish language a settlement kind known as a town is named "miasro"and this comes from "miejsce" that means literally "place" (–comp. T. BARTKOWSKI 1986b).

At this place one remark! The habit of "bringing home" materials, necessary for living, is not specifically human because numerous animals do the same (ants, bees, hamsters, squirrels etc). Some of them transform even these materials into new products (f.i. bees) and we could conceive it as a kind of secondary produktion–man is very proud of. The remarkable point of it is that it exiges mobility of these organisms– ability to move, to find and to establish paths of circulation, ability to recognize and to utilize heterology of terrain. Heterology is the fundamental reason and basis of their existence and of surviving and of "interest" of their respective subjects and their functions.

Nevertheless we must remark, that man's secondary production is different from this one of animals. Man's production provides not only means to live (food) and to survive but equally well other goods, satisfying other, specifically human, needs (as related to man's culture–needs of "higher" order). Also in general man's connectivity of surfaces, that services different man's need, is quite different from the connectivity, servicing animals. It is also understandable that in these three dimensions of consideration of these kinds of flows as occuring in "neighbourhood", in "communication" and in "connectivity", are developed in the landscape, in the topic level of consideration, that is in terms of "geo–topes" different spatial units patterns, superimposed one upon another, as the reflection of their successive appearance in the course of development of the so called cultural landscape. We can also discern the following pattern types:

A. The homologous type

1) Surfaces where occur physical flows, called "physio–geo–topes", described in terms of transfer, of neighbourhood and communication and considered in two fundamental dimensions, the vertical and the horizontal ones.
2) Surfaces where occur trophic flows in the area of plants biotopes named phytotopes and forming the so called sites (this phytotope includes pedotope too) described in terms equally of "neighbourhood" and "communication" (in general: horizontal flows).

B. The heterologous type

3) Surfaces of the trophic flow in the area of animals biotopes called in general "zootopes" where occurs the utilization of space by animals as well on surfaces, named matrix, ecotone, patch as equally well in places or along lines described in terms of edge and inerior sites, as corridors of different nature and "seized up " in terms of connectivity , communications, of dispersal dispersivity.
4) Anthropic "land use" surfaces (can be named "anthropotopes"), whereoccurs utilization of space in the most complete and various way , on "surfaces", "in points", "along lines", described in terms of "neighbourhood", of "communication ". A special importance posesses there the notion of "nearest spot" (see "miasto " = "place"). The "anthropotopes" when used in collaboration with nature form in general parts of so called (after CHORLEY–KENNEDY 1971) "control–systems" (f.i. irrigational systems , dams on rivers) or, when predominanz is man's constant vigilance, the so called (see BULATOV 1977) "skeleton systems" that is wholly anthropic ones and because of this, wholly artificial (such ones as towns and other settlements, then factories, railway stations etc) representing man's utilization of space in points and along lines.

In each pattern type the flow of matter and energy occurs in different way and when it occurs especially in the intense cultural landscape as
encoutered in denseley populated areas, there occurs a very distinct superimposition of one upon another in a "multistoried" way and because of this these flows are being constantly modified (see the problem of superimposition in T. BARTKOWSKI 1986b and the problem of the s.c. landscape stories by H. RICHTER 1979). In the cultural landscape (comp. T. BARTKOWSKI 1986a) there is a mighty, one would say , an overpowering, impact of additional matter and energy provided by man that influences in a vital measure, all these flows and transfers.

Finally one should consider a special cathegory of factors that are of importance in the exchange of between different topes namely the information that comes from differentiated spatial behaviour of organisms themselves and that stems from the area of ethology (in certain manner).As already explicated communication and connectivity are dependant upon the abilities or disabilities of organisms : of plants as being immobile and animals asbeing mobile.

It is first general division but these abilities (and disabilities) of organisms appear to be more sophisticated. We will explain this firstly with the help of the notion of dispersal and dispersivity, indicated spatial pattern of organism in such terms as "uniform" or "regular" or "homologous" and "irregular", "in clusters (groups)" forming a heterologous pattern. These features of spatial pattern ale differentiated after general "behavioural" programs. There can be discerned in general two such types of programs:

1 – program of seeking food and feeding

2 – programs for other activities

The first program exiges steady presence of animals on surfaces where food can be found, that is food for the plantivores – also the phytotopes– and for carnivores (consumers of the second order – the zootopes). This explaines why the plantivores most of their lives spend in phytotopes in which they are interested, are literally bound of them, are spatialy "plant true" and because this their zootopes are mostly identical with phytotopes. In this case these zootopes are of homologous type it is especially true in respect to plantivores "specialized" in concrete plants they are consuming (f.i. numerous insects).

Contrary to this other animals, that are not "specialized" in consumption of specific food, are not bound to a specifical biotope and their nutritional surfaces can be very heterologous– especially by predators. It is however not their exclusive ability because some great plantivores as deer or sheep, when not specialized in plants, are to be found grazing as well in wood as in grassy formations (even on man's fields). These plantivores can be at most specialized in preference to certain types of these formations, f.i. in woods undergrowth types, in meadows types etc. In summing up this part of these considerations we may conclude that the bespoken programs of food concerned behaviour let us distinguish two groups of surfaces in dependance of this circumstance the food is being sought by animals"specialized on food" or not specialized. In the first case it will concern homologous surfaces of the phytotopes being "exploited" by the consumers of the1–st and 2–nd order and in the second case heterologous surfaces of either a special group of plantivores able to exploit different, in most cases neighbouring, homologous surfaces being their nutritional area or of carnivores (consumers of the 2–nd order). And now, when arrived to the consideration of the problem of behaviour programs for other activities we must now consider with more attention the notion of territory (that was logically implied in the first group of discerned units but was not specifically mentioned). Let us quote E.P. ODUM's (1971) two sentences upon the notions of dispersion and of territoriality . "Territoriality is developed among vertebrates and some arthropoda–animals of complex reproducting behaviour, as reflected specifically in nest building, deposition of eggs, care for progenity and its protection." ODUM includes however in this notion each kind of mechanism that lead to dispersion in space of individuals or of groups of individuals. In this sense the notion can be applied not only to the dispersion of animals but equally well to dispersion of plants and of various microorganisms of different taxonomic position. Territoriality can be then considered as "a general ecological phenomenon".

It follows from these considerations that in the case of such conceiving of territoriality the spatial features of such territories depend primarily upon the properties of space, where these differently selected life spots or life areas are used by these organisms. In other words it depends upon the "offer" of this space for different needs and for the resulting behaviour of organisms.In consequence of this this "space of life" (compare the "Lebensraum") of all animals can be considered as composed of two kinds of surfaces:

I. Surfaces servicing the nutritional needs of animals (in this case we find surfaces , ceteris paribus, homologous of biotopes= zootopes of plantivores and of zootopes of the consumers of 2–nd order (carnivores preying on plantivores)),

– surfaces of heterologous biotopes of carnivores (in general of predators) mostly concordant with the first homologous surfaces and of some plantivores not specialized in food.

II. Surfaces servicing other needs of animals that were mentioned in E.P. ODUM's (op.cit) description of the notion of territorality. These surfaces are in essence heterologous and in natural conditions are encoutered on the limits or fringes between the already mentioned homologous biotopes that is phytotopes, also on "lines of contact", including in this such special types as "corridors" or "strips" (exemplified by creeks or river beds, beaches ridges= escarpments or ridges "strips" etc).

In the condition of artificial, anthropic landscape and especially in agricultural areas the number of the heterologous spots or of lines (f.i. corridors) and surfaces (f.i. agrar fields with rotation) is in general many times greater but this depends upon the specific features of agricultural system of production introduced by man and especially upon the system of land property (ownership). It is dependant upon the size of productional plots (then hedges, fences, other kinds of limits) the system of gathering yields (of harvesting – then field paths and roads) and of communication lines. And it is in this place that comes to value the notion of agricultural system, that is the notion of land use by man. In systems that use great productional surfaces (name of plots would be inadequate) also in the colectivistic system or in the plantation systems (including great crop farms in as f.i., in the wheat belt of the USA or soviet tshernosem areas of USSR) the established great , productionally "homologous", surfaces efface the natural much greater heterology of terrain (in theview of physical differentiation of of soil and subsoil). The "homologous" surfaces of this kind are also in some degree artificial. Contrary to this in systems that use small sized productional plots, with a great number of property limits (land dismembering) there is a tendency to establish a great number of heterologous biotopes in the form of the so called corridors such as hedges, hedgerows, wood belts or strips of small patterned matrix surfaces of fields with rotation, of permanently used orchards, pastures etc. In this case one can say that "man's land use" increases the number of zootopes as well of for food oriented as for other behaviour programs of animals also that this land use has as well modified as multiplied the possibilities for animals to find food and to create territories for other programs. The land use by man causes also the superimposition of heterologous zootopes lastly described upon both the heterologous as homologous biotopes– zootopes and phytotopes of the group "1". And this fact of superimposition leads to the following fundamental statements:

– in anthropic landscapes is the problem of the concept of anthropogeneity of landscape and of zootopes in its most blatant form presented. Ruled by natural laws, the behaviour of animals is dependant in some way upon biotopes formed artificially by man and this pattern of biotopes is as well anthropogenic as anthropic (problem of rotation, of steady supply of matter and energy by man, of application of information coming from agrotechnics and agronomy).
– This phenomenon of man's influence forming an artificial – natural (semi– artificial?semi–natural?) spatial pattern of biotopes is the result of confrontation of two main factors operating in the space: natural and artificial, as reflectingthe fundamentals antinomy "nature –– man's culture".
– The notion of homology and of heterology of biotopes appears as being vitally dependant upon two factors encountered in a given area.

a) organisms, in this especially animals with their "spatial behaviour"
b) the "offer" of the area that isthe possibilities and facilities presented to the organisms, dependant upon physical conditions of primary production of this area, to perform this behaviour.

- The spatial behaviour depicted in terms of communication and connectivity by using the concepts of dispersivity and of territoriality, allows very well the explication of the essence of the notions of phytotopes and of zootopes and helps even to depict spatial behaviour of man, this time in terms of "land use" (in the cathegory of "anthropotopes" or, in a wider sense, in the already coined terms of "anthropic– or technoantropo–cenoses" and the "control" or even the "skeleton" systems– in this see J. DEMEK 1984, R.H. CHORLEY andB.A. KENNEDY 1971, V.I. BULATOV 1977)
- in analysing the above discussed notions, and bearing in mind that considered are the "geo–topes" we must be aware, that they concern all space, spatial units , and that in this moment we enter the domain of physical geography –more precisely this of complex physical branch geography in its special branch called "landscapes science" and sometimes recognized as "landscape ecology". This constatation puts before the landscape ecology the task of establishing the right taxonomic position of such fundamental landscape ecological units as physio– and ecotopes, in the basic physiogeographical system of division of landscape.
- of special importance will be there the problem of relations of the units of ecotope type to this of the two kinds of biotopes designated as phyto– and zoo– topes. This problem deserves its special treatment in another study.

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ECOLINES & GEOLINES: CONNECTIVITY IN NATURAL LANDSCAPES

P. Bridgewater

Connectivity is a term used to describe an attribute of landscape structure and function. Landscapes are mosaics of patches linked by corridors. Connectivity is one characteristic of corridors or networks. There are mathematical models of connectivity, based in transport geography, but there are also qualitative aspects to connectivity which help understand landscape structure and function.

Much research effort into connectivity has occurred in the northern hemisphere, with considerable emphasis on the role of anthropic structures such as hedgerows or fencerows. Tropical and southern hemisphere countries often do not have such anthropic structures as a major constituent of their landscapes. None the less all landscapes, "natural" or modified, have connectivity as a property of their inherent networks.

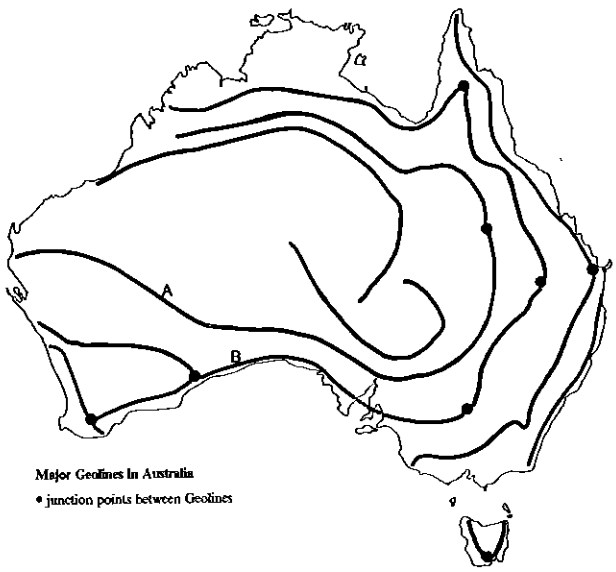
Landscape ecologists, therefore, need to perceive connectivity as a basic landscape property, which can help develop an understanding of temporal change and spatial variety in the landscape fabric. LEEUWAN (1966) had alluded to many of these concepts, but mainly in terms of boundary phenomena, rather than linkage.

FORMAN & GODRON (1986) give details on wildlife movements through corridors. Particularly small vertebrates (mammals, birds) have received considerable study – the main conclusions of which are that such species depend for survival on the ability to colonise linked habitat patches following local extinction. For Australian forest and shrubland vegetation there is evidence that some fauna require a mosaic of habitat patches resulting from regeneration sequences after burning. COCKBURN (1978) documents this for *Pseudomys shortridgei* in the Grampians (Victoria), where species survival depends on the availability of a particular phase in the fire regeneration sequence of a plant communtiy. Other authors make similar observations e.g. BRAITHWAITE & GULLAN (1978), FOX & FOX (1978).

Connectivity is a matter of scale: Connexions between landscape patches exist at both macro and micro scales. Corridors between landscape patches are recognisable, in a broad sense, at a continental level, and the term "geoline" is proposed for such corridors. At the local level the term "ecoline" to cover any corridor, natural or otherwise is proposed. (BRIDGEWATER 1987).

Geolines are simply intended to indicate trajectories along which biota, energy and nutrients are able to flow around or between major landscapes zones. Such trajectories are found through homogenous landscape types, or between landscape types. Examples of geolines for Australia are given in Fig. 1, with geoline A an example of a "through" type and Geoline B an example of a "between type".

At the local landscape level ecolines are prominent features. Fire–related regeneration patches are major determinants for ecolines in Australian landscapes. In well–watered regions streamlines are prominent ecolines, although the high levels of moisture present in these environments may make them unsuitable as routeways for many species. In semi–arid regions usually dry watercourses tend towards high indices for circuitry – as well as providing numerous isolated "islands" of dryland vegetation between their anastamosing branches. BRIDGEWATER (1987) provides some specific examples derived from colour aerial photography.



Major Geolines in Australia
• junction points between Geolines

In natural landscapes, circuitry tends to be lower than for semi– or sub–natural landscapes (terms sensu WESTOFF 1971). Ecolines can be detected in all three landscape types. A knowledge of ecolines and their linkages form a valuable part of developing management strategies for conservation and sustainable land use.

Where natural vegetation "islands" or fragments exist without linkages, these should be created as part of any management strategy. Where areas of natural vegetation exist as intact landscapes, but are threatened with development, then the ecolines need to be identified and given top priority for conservation. This would provide a means for linking fragments which may be left, deliberately or accidentally, as the development proceeds.

Research programs devoted to the identification and understanding of ecolines in natural and semi–natural landscapes are needed urgently. Ecolines, although spatial in nature, also have dynamic aspects which need attention in any management studies. Ultimately, the function and survival of vegetation fragments in a cultural landscape and their contribution to nature conservation will depend on the linkages (ecolines) provided through the surrounding matrix. These ecolines are as important for the promotion and maintenance of landscape richness as they are for the movement of animals (and plants) within landscape.

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INVISIBLE CONNECTIVITY IN RURAL LANDSCAPES

M. Antrop

INTRODUCTION

Man conquered the land effectively by settling down. Then he started to adapt his natural environment to fulfill his needs and thus started to create a cultural landscape.

Many of his needs were not purely biological but also psychological, social, cultural and religious. Consequently, he organized and shaped his landscape accordingly. The choice of the site for his settlement was vital for his survival. The creation of a settlement has always been a important act and is still associated with some rituals. Primary, the choice depended upon the natural resources available. When the population increased or the carrying capacity of the land was restricted for the number of new settlers, his choice also depended upon the activity of his neighbours. The same factors influenced the way he could organize and extend his territory. In the case of a communal, concentrated settlement these invisible forces, connecting the different villages, created the territorial shapes and distribution patterns which shaped in an important manner the cultural landscape we can recognize still today. The analysis of the spatial distribution of the village sites and the shapes of their associated territories may reveal some of the ecological, spatial and psychological factors which were active during the time of settlement and the shaping of the landscape. A theoretical and methodological basis for this can be found in geographical models of spatial analysis. Information theory offers a possible framework to integrate all the different approaches (M.Antrop 1987).

TERRITORIAL CONTROL : A QUESTION OF COMMUNICATION

To understand the social territory it may be interesting to consider a settlement as an 'information centre'. The information transfer between the site and its territory can be described using information theory. In landscape ecology the channel of information transfer is the geographical space and distance is one of the most important factors inducing noise. Information transfer by man in the landscape can be done in four ways :

1. visual signals which makes a visibility analysis in the landscape surrounding the site necessary ;
2. auditive signals which have only a limited range unless a 'relais' system is built ;
3. by messenger moving from one place to another carrying the message. In this case terrain accessibility and road connectivity should by studied ;
4. by electromagnetic means (telephone, radio,...) as used commonly today, but which are not at all significant for studying the origin of the sites in a historical and archeological perspective.

SPATIAL SETTLEMENT PATTERNS

In the continuous geographical space, settlement sites should not be considered as isolated features but as different elementary nodes in a large structure with complex topological relations. Random settlement patterns seldom occur, instead two opposite significant deviations are frequently mixed together : the concentrated and dispersed settlement pattern. Each indicates a different 'generic' force : attraction or repulsion.

Concentrated settlement occurs when people needed to unite their forces to survive. Difficulties and danger may occur from the physical environment or in uncertain times. In the western world concentration may be considered as the initial agrarian settlement form. Small communities searched fertile soil which was easy to cultivate with the technology available that time. They selected a site to install their settlement in such way all vital natural resources where easily accessible and the site was safe. The origin of dispersed settlement lies in a growing population pressure in these centres exceeding the capacity of the land already cleared. If most of the good soils in the neighbourhood were already occupied by surrounding villages, new land clearance was only possible upon less fertile and marginal soils at the limits of the existing territories. Many of the dispersed settlements reflect land clearance during peaceful and prosperous periods. Two variants are possible according to the technology and organization available. Individual land clearance resulted in a more 'random' pattern and land clearance by great landowners resulted in distinct systematic settlement patterns such as street villages.

SHAPE ANALYSIS

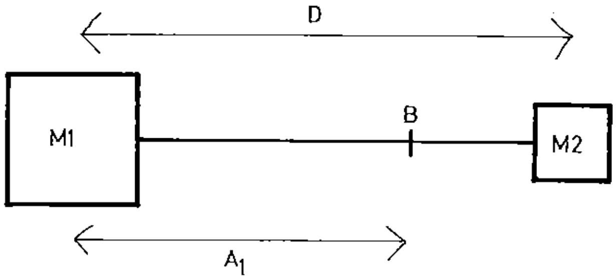
Shape analysis allow a quantitative description of territorial shapes as well as the evaluation of the centrality of the settlement within. Two types of territories are distinguished : the natural and the social ones.

The shape of the natural territories is mainly determined by geology, relief, lithology and soils. The sites for settlements are searched along the zone with fertile soils, giving a good visual control over them, but also situated near the connection node between different land units, such as the cropland (ager), the extensive grazelands (saltus) and the woodland (silva).

The shape of the social territories is determined by the extension of the land occupation starting from each settlement and by the competition with the adjacent sites. In the case of a isotrope (homogeneous) natural environment without social competition, compact circular shapes may be expected from a spontaneous and non–planned settlement and occupation of the land. In an isotrope natural environment but with heavy social competition hexagonal shapes may be expected. Thus, the contact number (=number of neighbours) equals 6. In anisotropic (heterogeneous) natural environments each community tries to cover a territory which has the largest diversity in environmental conditions (BAKER 1971). Consequently, the shape may become more elongated and the site is chosen so that each natural land unit can be reached easily. Theoretical approaches to explain the observed shapes can use the gravity model, the potential model and the hexagonal model.

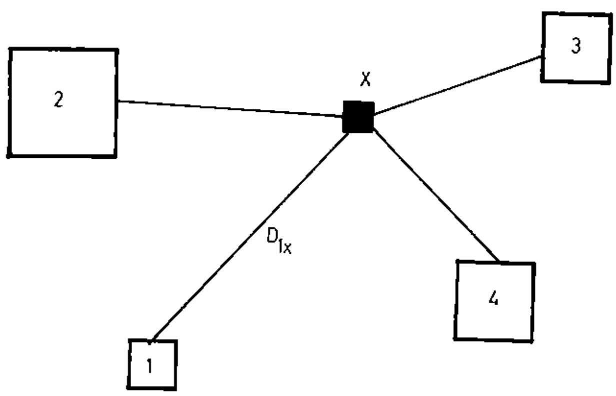
DETERMINING ZONES OF INFLUENCE : GRAVITY MODELLING

The gravity model describes the relation between the gravitational force (G) between two or more objects (fig.1). It is proportional with their 'masses' M1 and M2 and decreases with the distance D. The exponent b expresses the 'friction' of the distance (normal value = 2). The breakpoint B is located where the attractive forces of the two centres are equal. A_1 is the breakpoint distance from M1.



$$A_1 = \frac{D.(M1/M2)}{1+(M1/M2)} \qquad G = a\,\frac{M1.M2}{D^b}$$

Fig.1 : The gravitiy model and the determination of the breakpoint between two objects.



$$I_x = a \sum_i \frac{M_i}{D_{ix}^b}$$

Fig.2 : The potential model

Mass can be expressed in different ways: population, technology, land quality,....Distance can be expressed in metric units, but also as 'time–distance', 'effort–distance', 'cost–distance'.

The potential model is a variant of the gravity model. It determines the potential influence Ix at any point X in the geographical space caused by the attractive forces of the surrounding centres at distances D.x (fig.2). According to the gravity model, the influence of the settlement decreases with the distance from it. Vital resources (ex. good soil, water,...) and valuable crops demanding intensive care, are found close to the settlement . Land use becomes more extensive with increasing distance from the village.

A complete discussion of the rationale and use of these models can be found by HAGGETT (1975),THOMAS & HUGGETT (1980), EBDON (1977),TAYLOR (1977),UNWIN (1981) and SMITH (1975).

AN EXAMPLE : THE HILL–TOP VILLAGES IN THE PROVENCE (FRANCE)

The natural environment

The geomorphic structure of the region of interior Provence has been mapped using a holistic land classification based upon aerial photographs at scale1/60000 (fig.3). The large limestone plateaus and mountains are strongly folded and fractured and a large number of distinct tectonic basins have been formed. Most of them contain fertile tertiary sediments. Each of them has been cultivated and forms the ager of one village. The limestone gives the extensive grazing land (the saltus) and offered wood for the community (the silva). Most of it is nowadays forested land.

The social environment

The primary settlement consisted of hill–top villages. Dispersed settlement is secondary. The hill–topsite ('village perch') is a typical defense site. They are situated near the border of the arable land (ager), avoiding to spill any good soil for building. The site is always elevated and isolated. It allows easy access of the agricultural land as well as the extensive grazing land on the limestone plateaus and hills. A location is choosen as near as possible to the centre of gravity of the territorial shapes. The natural territory corresponds to the extension of the arable soils and corresponds to the ager. The social territory also includes the grazing lands (saltus) and woodland (silva). The boundaries of the parishes can be used in this case because they date from the early times of occupation history (fig 3).

Shape analysis of the territories

In general, the shape of the natural territory is more irregular and less compact then the social territory. The centrality indices for the hill–top villages are very high, except for the ones at the foot of a major mountain or escarpement.

Two shape types for the social territory dominate : the 'circular' and the'rectangular'. Nevertheless, in both cases the index of centrality of the site is high and the contact number averages six as expected from the hexagonal model. Clearly the extension of the social territory reflects the search for the largest diversity in natural conditions as possible considering the neighbouring settlements. The try–square shape of the village Regusse (R) is in fact an association of two 'rectangular' territories grouped in one administrative unit. The valley–community lived in the main village (R) and its social territory extended in a similar way as that of the neighbouring village Moissac (Mc). After the occupation of the valley land, a large individual settlement was established on the plateau north–west of Regusse and this became the node of the small hamlet of Villeneuve (v).

Visibility analysis

The land visible from each village can be determined using detailed topographical maps and stereoscopic aerial photographs supported by field work (fig.4). The intervisibility between adjacent sites show a visual isolation of each village with a maximal visual control over the ager.

Gravity modelling

The factors of 'mass' and 'distance' should be defined in terms which were important during the formation of the social territories. Vital aspects of these settlements were : availability of arable land easy to reach by walking from the hill–top site which gave the protection against invaders. Figure 5 shows Thiessen polygons calculated from the gravity model using the proportion of soils suitable for agriculture accessible in 15 minutes walking from the settlement. This time–distance corresponds approximately with 1/

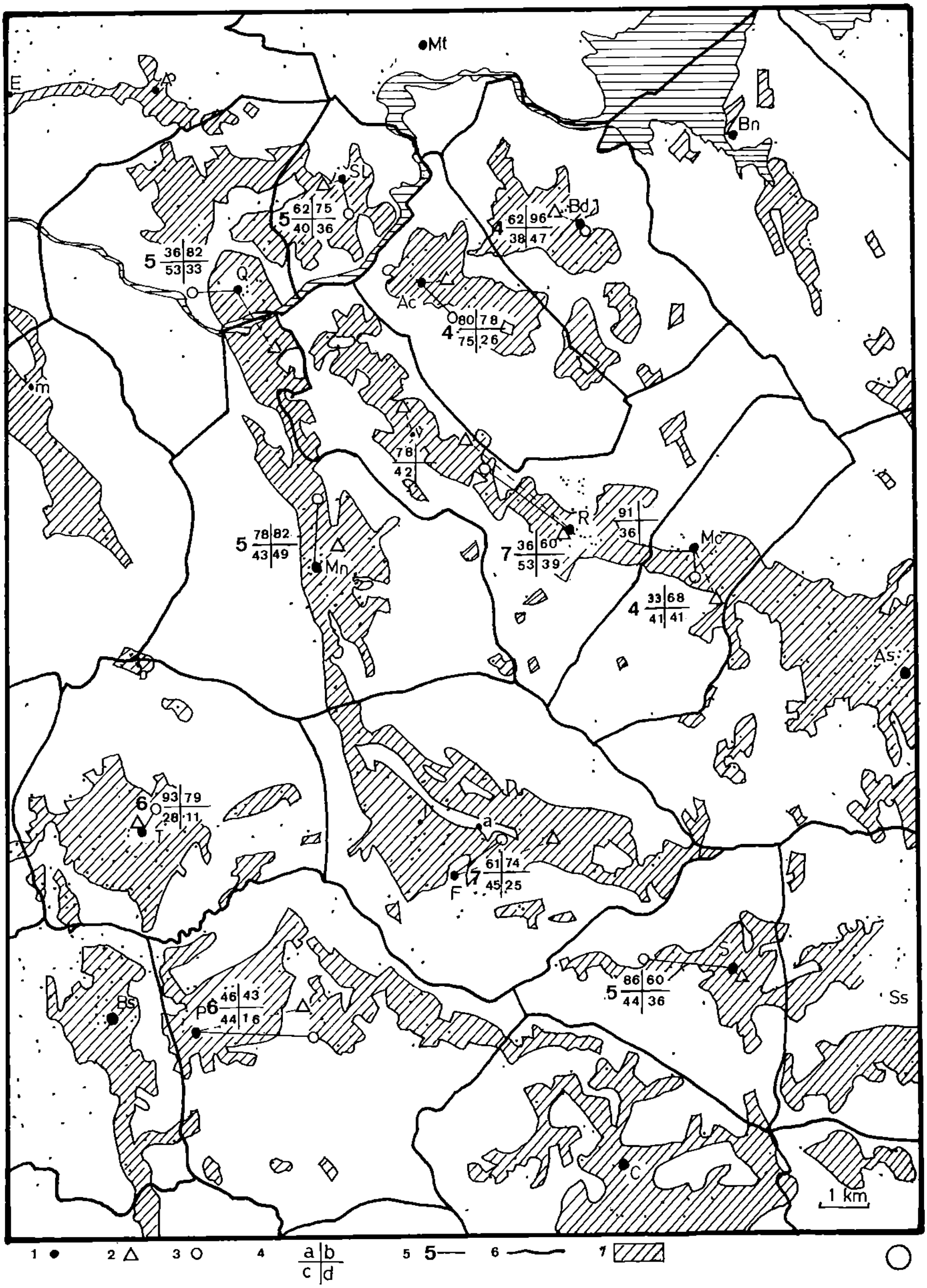


Fig.3 : Shapeanalysis of natural and social territories
1 : settlement (P,F,T,Bs,.. hill–top village; v,a,l,... hamlets);
2 : centre of gravity of the ager (kernel ofthe physical territory);
3 : centre of gravity of the social territory (communal boundary);
4 : shape indices : a: centrality index (%) of the ager; b: centrality index (%) of the social territory; c: coefficient of variation (%) of the vectors describing the shape of the ager; d: coefficient of variation (%) ofthe vectors describing the shape of the communal territory;
5 : contact number;
6 : communal boundary;
7 : individual settlements ('mas', 'bastide', 'chateau');
8 : tectonic basins and limit of the cultivable soil (ager–zone).

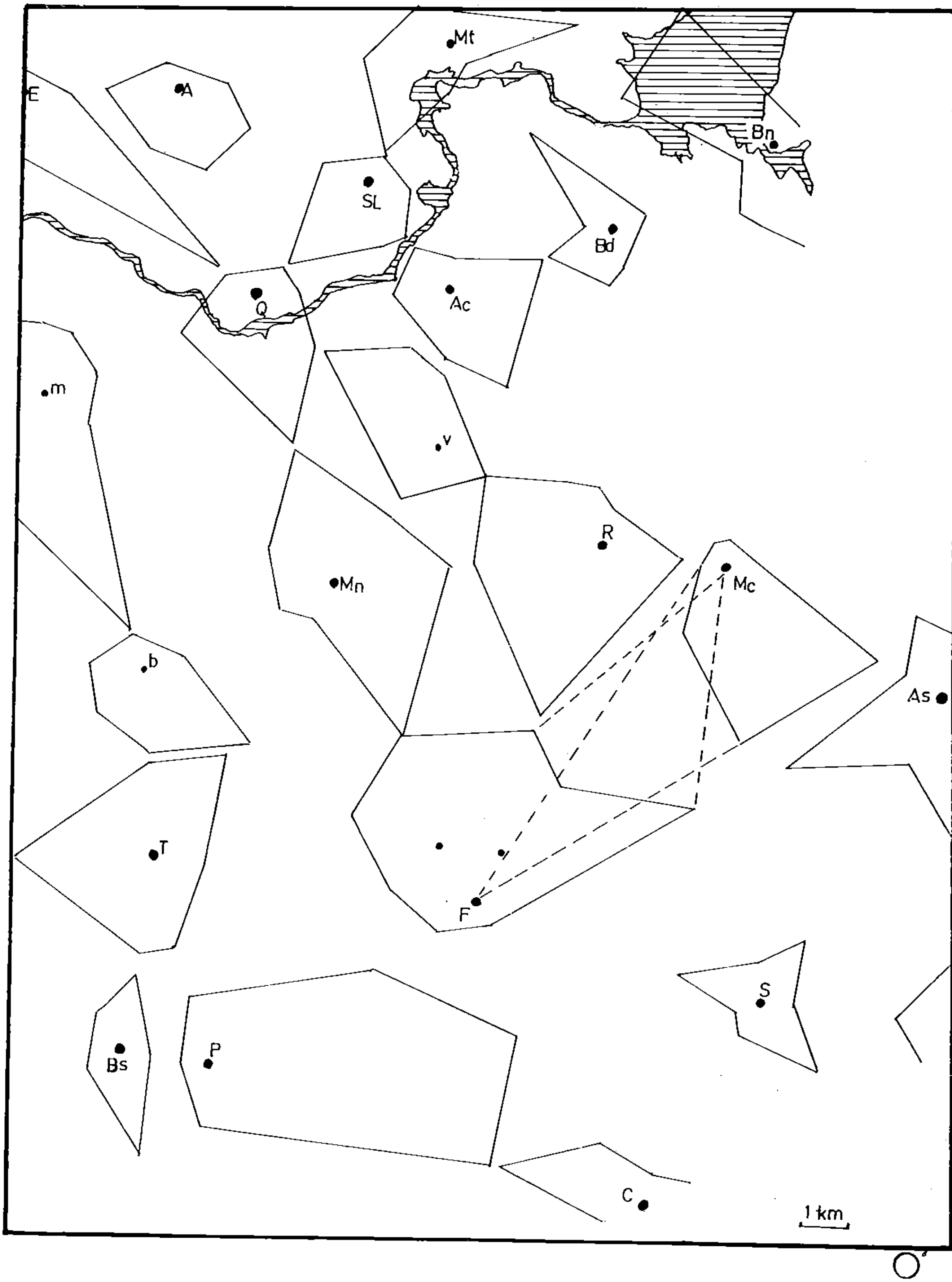


Fig.4 : Visibility analysis : landscape visible from each village(polygons based upon intervisibility vectors).

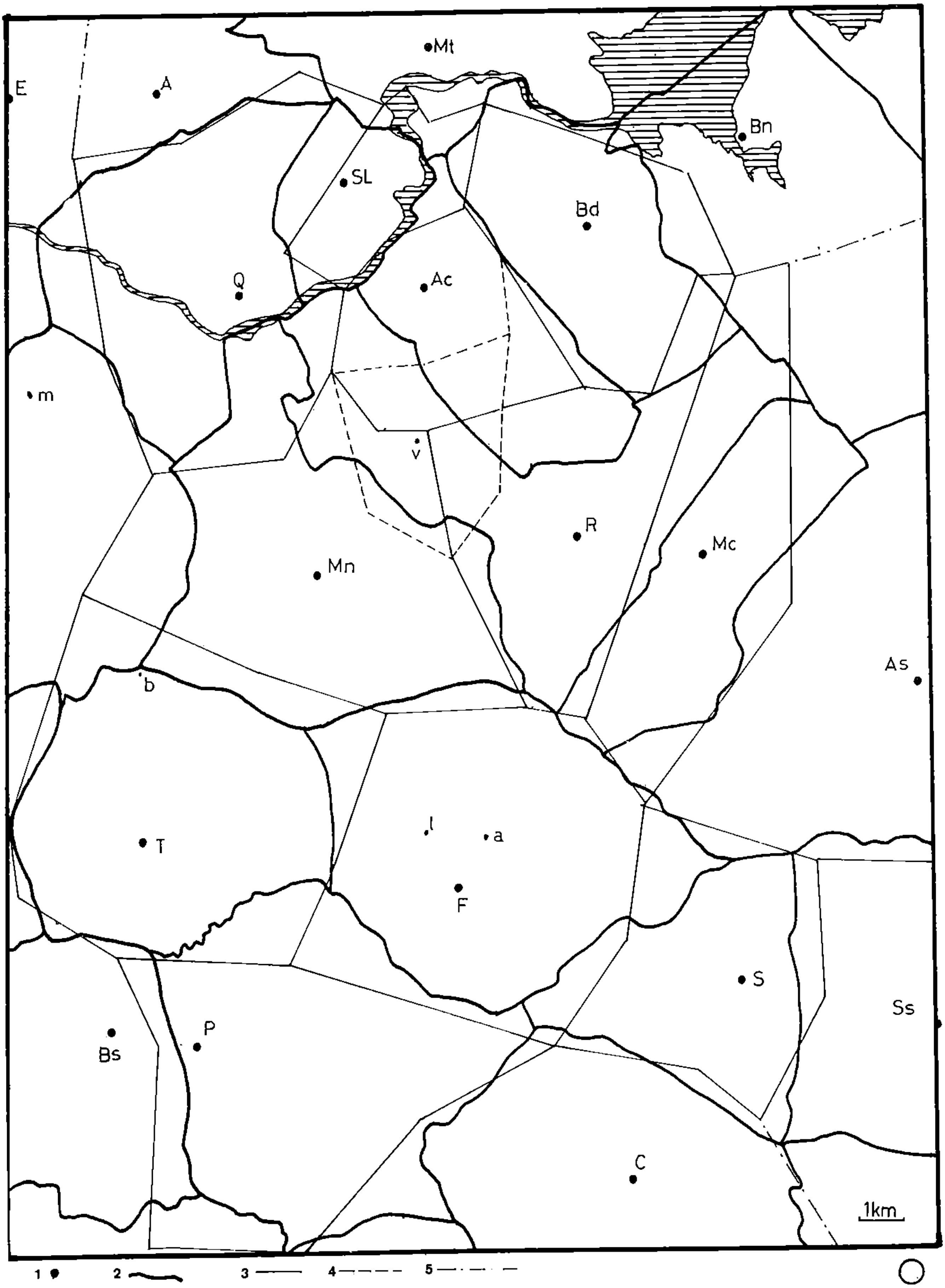


Fig.5 : Thiessen polygons showing the zone of potential 'influence' for each village based upon the gravity model using the proportion of fertile soils accessible within 15 minutes of walking time from the village:
1: village; 2: communal boundaries; 3: polygon of potential influence of each village; 4: polygon of the potential influence of the hamlet of Villeneuve (a secondary settlement); 5: uncertain limits.

4 of the average visible distance. The limits of these polygons show a remarkable high correlation with the actual communal boundaries. Good soils in the close neighbourhood seem to have been an important factor for the possibility to extend the social territory.

CONCLUSIONS

Spatial analysis and modelling proved to be a valuable approach in the field of settlement studies. Invisible connections between villages can be important factors in the shaping of the landscape. They reflect forces of power between villages and way of controlling each territory. Human perception and information transfer in the landscape have be considered as significant factors in landscape ecology.

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Looking back, I think it was more difficult to see what the problems were than to solve them.

Darwin

ECOLOGICAL INFRASTRUCTURE: A CONCEPTUAL FRAMEWORK FOR DESIGNING HABITAT NETWORKS

A.J. van Selm

Abstract

The development of landscape ecology is seen as being dependent on the advances in the sciences it makes use of. Some recent developments in animal ecology are sketched, and their meaning for landscape ecology is evaluated. The shift from a global to a species specific approach is seen as very important. Up until now, landscape ecology has relied too much upon black box approaches. A new method for designing landscape ecological plans is sketched.

1. Relation of ecology and landscape ecology

In the past decades there has been a shift in the science of ecology from the general or synecological approach to the species specific or autecological approach, and also from the study of static patterns and of community composition towards dynamic phenomena as population extinction, colonization, isolation, migration and dispersal.

This important development was set into motion after the famous book of Andrewartha and Birch appeared in 1954: The Distribution and Abundance of Animals. They proposed a very dynamic picture of the process of persisting populations, being a balance between the extinction of local populations (which together make up the population) and the founding of new local populations. Since then this trend has gathered momentum, and has generated a lot of research and articles (e.g. DEN BOER 1970). Parallel to this development, the older ideas about an inherent stability in nature, especially in old, complex ecosystems, have lost a lot of ground. This socalled diversity–stability hypothesis is seen now by most animal ecologists as outdated, being a far too simple approach (GOODMAN 1975).

Landscape ecology should be based upon a sound scientific basis, and therefore it must follow the changes in the sciences it makes use of, such as animal and plant ecology, geology and hydrology. This means that the shift in ecology from the general tot the species specific approach must be incorporated and that more attention should be paid to dynamic phenomena as colonization and dispersal.

The use of the concepts of connectivity and habitat networks in landscape ecology is therefore a useful step, but only a first one. Because the aim is to maintain ecologically valuable landscapes, a critical consideration of the ecological value of those connected structures is indispensible.

A valuable discussion about the dynamic phenomena of colonization and extinction was brought about by the "Equilibrium theory of island biogeography" (MACARTHUR & WILSON 1967) and its subsequent application on continental situations, "islands of nature" lying in an "ocean of agricultural land" (e.g. DIAMOND 1975, OPDAM et al. 1984). The discussion about the "truth" of the equilibrium theory of island biogeography is now almost over, and very serious and detailed doubts have been raised (GILBERT 1980). The tentative conclusion that I draw is that this theory is another black box approach: it is only concerned with the number of species in an area of a certain surface on a certain distance from a "mainland". Many facts that according to the authors prove the theory, are in fact just new demonstrations of the species–area–curve, which has been described in detail 30 years ago (PRESTON 1948). Some authors proposed to open the black box of the theory, and to approach the phenomenon of extinction and colonization from the fact of the species' capacity for dispersal (DEN BOER 1983).

In the Netherlands this discussion stimulated a resumed interest for the isolation of nature reserves and for linear landscape elements as hedgerows, road and railway verges, and ditches. As a result a national report on physical planning for nature conservation payed a lot of attention to these elements, and considered them as necessary migration corridors for species moving from one nature reserve to another. (SNLB, 1981).

Returning to the concept of connectivity, which has sprung from the equilibrium theory, several simple but very important questions arise. For which species are these connected structures of value? And how? As habitats, as corridors for dispersal? Or as both? Does their function vary in time for the same species, or does it remain constant throughout the seasons? Of course different species use the same landscape and its elements in different ways. The whole science of ecology consists of detecting these differences.

This leads inevitably to a very important conclusion: the measure in which species thrive by an increasing amount of interconnected linear landscape elements will be different. These differences result from the measure wherein the species' environmental demands are met by the abiotic and biotic properties of the linear element: is its (only) food plant present? Gives it shelter against its predators? Is it easy enough to make burroughs? This is a very different approach from questions like connectivity being good or bad, and which measure of connectivity is best. In essence, reasoning in terms of connectivity on itself is a black box approach. This approach therefore does not lend itself for landscape ecological design, because a black box per definition cannot give the exact answers for a design geared at reaching specified aims. Of course connection of (linear) landscape elements will result in ecological changes, but the results are rather unpredictable. For instance, is the result of connecting a 3 meter broad hedgerow consisting of thorny bushes and bramble with a one meter broad windbreak of 20 meter high poplars a connection or not?

For a realistic design aimed at reaching specified ecological goals, it is necessary to make explicit choices for certain species. In a black box approach it seems that no choices have to be made – but this is only superficial appearance. In fact a choice is made for whatever species will remain or establish themselves in the resulting structures – mostly quite common species, whose ecological demands are low and therefore met in many places. In animal ecology they are called the generalists, as contrasted to the specialist species who need very special types of environment as oligotrophic freshwater marshes etc.

The approach advocated above leads to several questions:
a. which species should be promoted most in which areas?
b. are there enough ecological data available on the environmental demands of the chosen species available to make adequate landscape ecological designs for these species feasible?
c. is it possible to construct a method for designing a landscape ecological structure which is useful for many species?
d. are landscape ecological designs aiming at the conservation or establishment of particular species feasible in (intensively used) agricultural land?
e. is this seemingly laborious method worthwhile in designing landscape plans?

The first three questions are answered in the subsequent paragraphs of this article.

The answer on the fourth question is: yes, provided that the abiotic and biotic environmental demands of the target species are met. If they are not met for part of or for all the target species, a different set of target species can be chosen, whose demands can be met. This method of iteratively chosing target species and designing a landscape plan based upon these species has advantages over just designing landscapes (whether or not with connective structures) as identifiable goals are chosen. In this way the designs, once realised in the physical reality can be evaluated, and the method or the parameters used in the designing process can be adjusted. When no clear goals are set, evaluation of the landscape design (landscape design, because it is then NOT a landscape ecological design) is impossible.

As regards the fifth question, the method proposed here is quite normal in all other engineering and designing sciences and practices. Agricultural science has very concrete and identifiable aims, though by comparison with landscape ecology they are rather simple. This holds true for all (mechanical) engineering. As long as landscape ecology does not define aims on the same level of accuracy as the other engineering sciences, and does not possess the knowlegde to reach the chosen aims in the physical reality, it finds itself in a comparatively underdeveloped state.

As long as it does not pose the right (species specific) questions, the real problem of landscape ecology will not be faced, and landscape ecology will wander astray in the ocean of reality, desperately jumping from one icefluke to another (diversity–stability hypothesis, preservation of diversity, island biogeography, and now connectivity). And as long as these species specific questions are not put forward by the people who could use the data gathered by the academic science of ecology, ecology will not provide the answers. Such are the laws of supply and demand.

From this it follows that we, landscape ecologists, find ourselves in a rather uncomfortable state of underdevelopment. When we recognize this state of our art, solution of our problems will become possible in the long end.

This state of landscape ecology is clearly perceived by many people outside landscape ecology, e.g. by agricultural engineers. The use of very general concepts, like in the past the diversity–stability hypothesis, and today the preservation of diversity (which mostly boils down to a wish to conserve the landscape in the form of the year 1900 or so –at least in the Netherlands) coupled with a desire to conserve everything in the landscape as it is, make the acceptance of ecological and landscape ecological claims by e.g. agricultural engineers psychologically difficult. It is hard to get grips with those ecological people: what do they exactly want, do they know themselves?

2. Demands upon scientific landscape ecological design method

A scientific method must consist of a systematic and repeatable procedure. A procedure consists of several different and clearly definable steps.

The method will be applied to ecological data, which must be as accurate as possible. Data can be of a different accuracy: whether qualitative or quantitative, most can be ranged on nominal, ordinal or numerical scales.The last gives the most exact information and should be preferred. However, the state of ecology is such that only for very few species this information is available. Thus, mostly other types of data will have to be used.

As regards the ecological aspects of the steps of the method the following is to be kept in mind. As each species has its own environmental requirements, it uses different landscape elements in a different way, and its opportunities for migration and dispersal are influenced in different ways by the same landscape. This means that changing this landscape pattern, or restoring it in some way, influences all the species occurring there in a different way. Therefore the method should be concerned with:

1. a thorough analysis of the species actually present and of the species which potentially could become established,
2. the choice of a number of target species, for which sufficient possibilities should be maintained or created in the landscape considered, and
3. the appropriate design of structures which are useful to promote the populations of as many as possible of the target species. The general outline of this method was described two years ago in a Dutch journal (SELM 1985).

Resuming, first there should be a species–specific analysis of the landscape concerned, followed by a synthetic designing process. Without this ecological approach, landscape ecological design misses the essential (ecological) point, and is more or less a form of playing blindman's–buff. Landscape design which does not aim for reaching specified ecological goals is at best an "art", aiming at visual attractiveness. However, no clear criteria exist, though a lot of Delphi–research (i.e. asking a representative group of people what they like most) has been done.

3. The concept of ecological infrastructure

In the Netherlands the concept of ecological infrastructure has become increasingly popular among ecologists, conservationists and some politicians. As the word is often more or less used as a synonym for the existing amount of hedgerows and so on, this renders the term rather useless as a concept for design.

In this paragraph the term will be redefined in order to use it as a scientific concept, upon which a designing method can be based. Each species has its own type of environment to live in. Animals often need areas of a different type for sleeping/resting, breeding, hibernation and feeding. Those areas may be close together or far apart, depending among others on the locomotory capacities of the species, and the amount of variation in the landscape. And it must be possible to go from one area to another: there are areas which are only used by the species to go from one place to another. Plants need a place to grow, a medium as air or water or animals to disperse their pollen and seed, and sometimes their seeds need for germination a different type of environment than in which the mature plants grows.

If enough ecological data about the facts of life of a species and its relation with the abiotic/landscape environment are available, a species specific landscape structure can be designed which is optimal for that species. This structure consists of the places and areas which are necessary for the individuals of the species. They use this structure in a dynamic way: moving from one functional area to another. We call this structure a species–specific ecological infrastructure, or an ecological infrastructure s.s. (sensu strictu). However, in a real landscape or ecosystem hundreds of species live, and for each of them an ecological infrastructure s.s. could be designed, if enough ecological data were available.

In practice, for most species not enough autecological data are available for landscape ecological design according to the method proposed. This reduces the number of species to be considered for designing landscape ecological structures significantly. Furtheron, when a real landscape is modified, as in the process of rural reallotment, most species are not affected directly, but indirectly via changing abiotic conditions or by the disappearance of essential structures or landscape elements.

So arises the necessity for an efficient way to deal with the ecological demands of the many species affected, and to find a good compromise between the many and often more or less conflicting demands. In this integration process a number of rather subjective choices has to be made, as where which species should get a stronghold. The result of this integrative landscape planning is a design for an ecological infrastructure for that area. This is the ecological infrastructure s.l.(=sensu latu).

4. Outlines of a method for systematic design of ecological infrastructures.

Our proposed method consists of five subsequent steps:

1. in the first step a number of species is selected, for which something should be done. The selection is based upon explicit criteria, e.g. they occur on international Red Lists, they may be protected species according to the Nature Conservancy Act, they may be seriously endangered or rare species, or characteristic species for a particular landscape. Species which do not actually live in the area considered may also be selected if it seems likely that they could establish themselves there when a few necessary changes in the area are made. The clear identification of those target species, for which the ecological infrastructure s.l. should be constructed, is however essential.
2. the second step consists of literature research for autecological dat of the chosen target species. The amount of data required may vary appreciably, according to the level of accuracy which is necessary for the design of the ecological infrastructure s.1., and is largest when making a plan on a low level of abstractness for a real ecological infrastructure for many target species, which should be carried out in practice. The type of data required are a.o.: the different functional areas, resting or sleeping area, hibernation area, maximal distances between the daily used functional areas acceptable for the species: all described in terms of the required abiotic and biotic variables), required minimum population sizes, migration and dispersal capacities of the species. For many species, notably for the smaller invertebrates and for "lower" plants as mosses, linchens, fungi, etc. the required data are simply not available. This results in ejecting a species from the list of target species.
3. in the third step a rough environmental conditions table" is constructed on the base of the data gathered in step 2. Species are in rows, the different types of landscape elements which may be distinguished in the area considered are in columns, and in the cells is described in which way the species use that particular landscape element (breeding, foraging, etc.). This makes an explicit comparison possible between the species, and gives insight into their shared demands.
4. in the fourth step the final selection of species is made. From the table conclusions can be drawn about which species use the same (group of) landscape elements, and thus which ecological infrastructures s.s. can benefit from the maintenance, restoration or creation of specific types of landscape elements. Of course some of these ecological infrastructures s.s. can be mutually exclusive, e.g. those required for meadow–birds and those for hedgerow species. There are different possibilities to resolve the resulting problem: a choice between the species has to be made, the total area divided in a part adapted to one (group of) species and another part adapted to another (group), or another type of compromise can be found. This means that a modification may be made in the list of species resulting from step 1. Another type of modification may be the addition of some species which are very important source of food for one or more target species, or because they provide an essential environmental asset, like shelter, shadow or the like.
5. in the fifth step the real design of the ecological infrastructures s.s. and their integration in an ecological infrastructure s.l. is made. First a "species specific environmental conditions table" is made in which all remaining target species (in rows) and landscape elements (in columns) meet. In the cells the exact requirements of the species for that type of element are stated, preferably in terms of coded classes of variables. The construction of ecological significant classes may be an art in itself, but for many variables affiliation to existing classification systems is possible. Often a great number of the cells has to remain empty, simply because not enough autecological data in the literature can be found, just because research is not complete. Of course this is a serious drawback for designing well working landscape; but this drawback for designing well working landscapes; but this drawback not only affects this method, but all types of landscape design. The great advantage of this method is, that it brings to light which uncertanties and knowledge gaps actually exist in the field of ecology, and that identifiable goals are chosen. Secondly the facts of the "species specific environmental conditions table" are translated into ecological infrastructures s.s., in real designs for that species shown on maps. As to the exact places where what should be constructed or maintained for which (group of) species, there exists a significant amount of freedom for creativity. However it seems reasonable to link up with the places where populations of the target species already exist and with the existing (a)biotic conditions which conform to the species demands. Also the mutually exclusive demands of different groups of species should be considered in this stage.

The combination of the ecological infrastructures of the different species into one design leads to the ecological infrastructure for that area.

Of course in this designing process things as general efficiency and lowest costs, e.g. for acquisition of land and maintenance should play a role. This theme however, is out of the scope of this contribution.

5. Two examples of application of the method

This simple method of designing ecological infrastructures s.s. and integrating them in an ecological infrastructure s.l. for an area, can be applied to different scale levels: local, regional and national. The resulting maps are accordingly on a different level of concreteness, and this brings forth the necessity to "translate" more abstract plans into concrete local plans.

The question arises of whether it is necessary to have plans on a higher scale level, e.g. the national level. The answer is yes: as with all plans on a higher hierarchical level, they are necessary in order to prevent: 1) unfortunate duplications of similar local situations for which no real need exists, 2) the overriding of nationally important goals by local interests (e.g. habitats of rare species disappear for housebuilding) and 3)to give direction to ecological planning on the local level to prevent a random process of "ecological gardening".

Two examples of application of this method are presented, both in the poster session part of this seminar report. The first concerns an application of the method on the local level for an area which will be forced through the process of rural reallotment, the other a tentative proposal for an ecological infrastructure of the Netherlands. The first, based uponthe method developed by our agency, has been made in our charge by the "Institute for Environmental Studies" of the Free University of Amsterdam. Further details can be found on their poster "Upgrading of ecological structure at the landscape level", to be presented this afternoon. The second design was made in our agency in the frame of internal preparations for the fourth report on physical planning.

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MODELLING WOODLAND SPECIES ADAPTING TO AN AGRICULTURAL LANDSCAPE

G. Merriam

Our study area is in the Great Lakes St. Lawrence lowlands of eastern Ontario, between Ottawa and the St. Lawrence River. This a mixed farming region (maize, small grains, hay and pasture for dairy, beef and cash crop farms) with agricultural intensity ranging from low (many wide fence rows, 1 to 10 ha fields some old field succession) to moderately intense (non–woody or removed fencerows, 5 to 20 ha fields, intense use of agricultrual chemicals). Our subject species have been *Tamias striatus* (chipmunk) (HENDERSON et al. 1985, WEGNER and MERRIAM 1979) and *Peromyscus leucopus* (white–footed mouse) (MIDDLETON and MERRIAM 1981, FAHRIG and MERRIAM 1985).

In this landscape these species function demographically as metapopulations, i.e. a set of populations in individual patches or wooded fragments which suffer frequent (up to 5% of patches per year) local extinctions which are readily recolonized from other patches. In this way the connected set of patch populations, the metapopulation, survives. This demographic system was the basis for my proposal of the concept of connectivity (MERRIAM 1984).

Our earlier model of connectivity in this system (FAHRIG and MERRIAM 1985) assumed that only wooded fragments and fencerows were used by this species as indicated by a large and long literature. We have shown recently that this "woodland" mouse uses crop fields (except hay or grasslands) extensively (MERRIAM in press, WEGNER and MERRIAM 1987). In fact, under higher intensity agriculture, where fencerows do not have a complex structure of woody vegetation, these mice may use maize fields more than they use the adjacent fencerows. These same results, from capture and release studies, show that about 40% of mice in crop fields are captured only once and are never recaptured. This is due at least in part to the large scale of movements shown by recaptures; in farmland this species uses 2 to 5 times as much area as it does in forests. These animals are not just transients; we now can also show significant natality in maizefields. So, at least during the growing season, these mice not only survive but also reproduce in crop fields and move through these fields.

Recent telemetry studies (LANOUE and MERRIAM in press) confirm use of fencerows as movement corridors by this species. The scale of these movements is just as large as for those recorded by live trapping. Dispersing (experimentally displaced) mice move along fencerows like corridors, while resident mice move out into crop fields to a greater extent.

Apparently white–footed mice are adapting to make use of the rich production of farm fields and a satisfactory model of connectivity in farmland must incorporate these activities. An improved model must allow for corridor movement across the landscape within fencerows but also must incorporate use of both fencerows and crop fields as habitat and also must allow for diffuse movement across crop fields.

We are working with a model framework which treats each crop field, each woods, each refuge (such as barns) and each fencerow as a patch (see Fig. 1 right half) with fixed location. It computes together all data from all our spatial grid locations (e.g. trap stations) within that patch. Each patch has its time–specific (weekly) demographic parameters calculated from field sampling data (see Fig. 1 upper left). Each patch also has time–specific habitat characteristics. These change as a crop germinates, is tilled, grows and is harvested and also, on a longer scale, the use of the field by the farmer changes with crop rotation.

This model also requires field measurements of rates of movements between all specific pairs of patches (Fig. 1 mid). If these can be measured adequately, they will incorporate into the model both corridor movement and diffuse movement across fields. In addition we must account for movements between winter refuges and other elements of the landscape. This may be particularly important if, after winter, all the surviving population should have to recolonize the landscape from a few refuges. These movements could enforce a delay in beginning reproduction for that season which, in a population that performs almost like annuals, could severely limit seasonal population growth. If successful the model will permit experimentation with effects such as the demographic costs of redispersal from refuges.

Currently the matrix form of this model is very similar to that in FAHRIG and MERRIAM (1985), except that there are no corridors and a matrix of patch types. Output reflects a geometric increase from a few winter survivors over the growing season, to a moderate population which declines linearly through the winter. This simulates the known pattern. Stochastic events can produce local extinctions.

Ongoing work aims at incorporating the specifics which will bring the model closer to representing the relationship in the middle column of Fig. 2. The left column in this figure depicts a hierarchical arrangement of spatial scales for which the building blocks are territories of individual mice. The mid level is the whole patch containing those territories (and the temporal dynamics of that patch), and the top level is the landscape pattern. This top level controls the lower levels in that, for example, the patches are dictated by the landscape pattern. The right–hand column in figure 2 depicts the demographic dynamics at the level of the metapopulation, in a single patch and at the bottom, in the reproductive activities of individuals which assemble into the performance of the population. But that performance, here of the metapopulation, could be viewed hierarchically as controlling the levels below.

The objective for our model is to assemble operations in the middle column which exemplify the hierarchy of relationships that link the landscape pattern column to the metapopulation demography column. The conceptual point of interest is the relationship between the spatio–temporal hierarchy of elements of the landscape leading to survival or evolutionary failure of the species. In the short term the model needs to generate testable ecological and behavioural hypotheses about relationships between connectivity of landscape pattern and metapopulation demography. In the longer view it needs to generate new views of evolutionarily stable strategies of wild species adapting to new dynamics in the landscape generated by human agricultural use.

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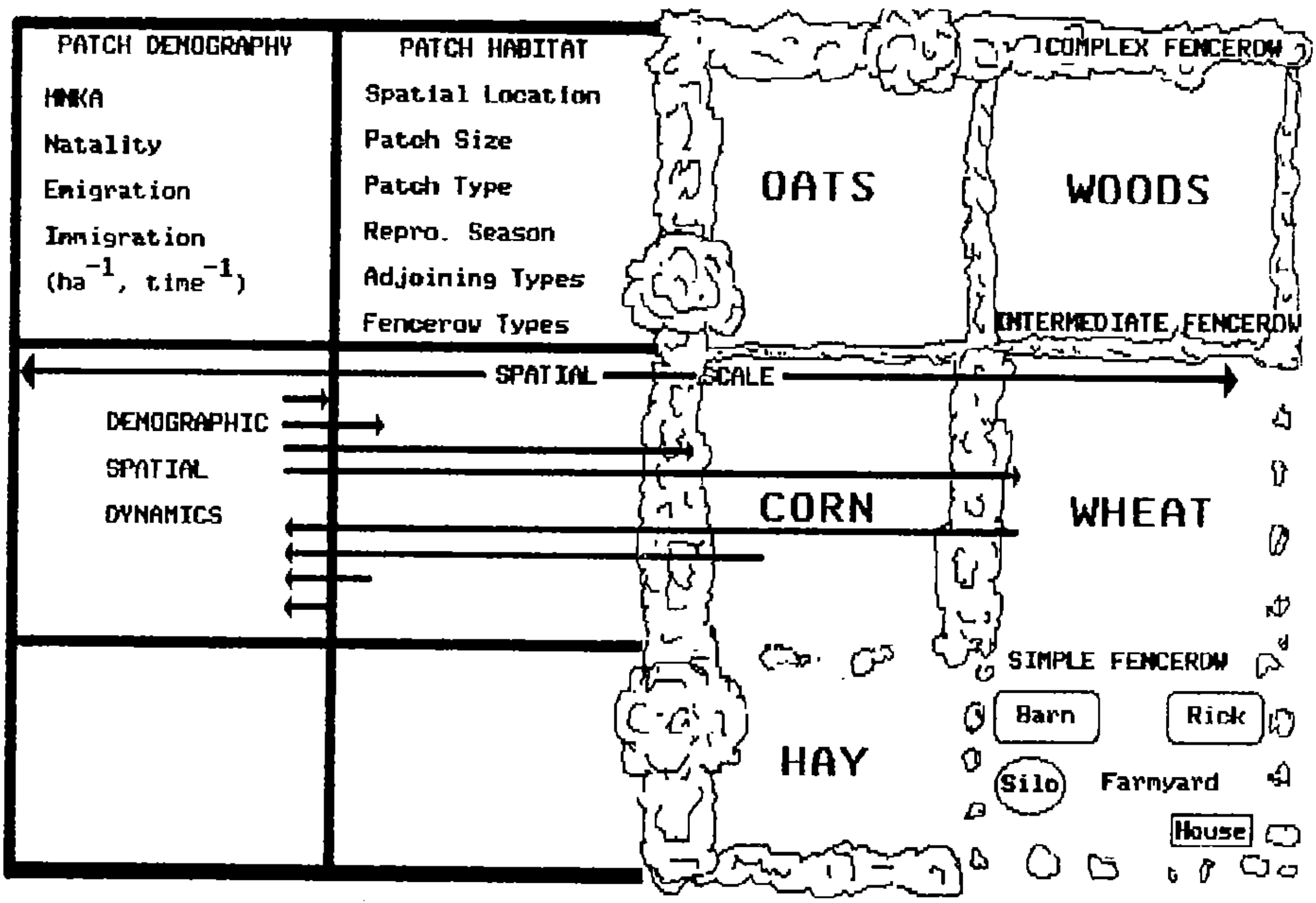

Fig. 1: Right half sketches the landscape to be modelled. Each field is treated as a specific type of patch, as are the built refuges and each different section of fencerow. The left half indicates the information needed to parameterizethe model. In the top left are necessary demographic values (MNKA = minimum number known alive, a conservative estimate of population size). Spatial scale (mid) indicates that the appropriate (understandable) amount of farmland to be modelled must be determined. Below that on the left are the various patch to patch movements for which rates must be measured. Movement from field into fencerow indicates that the animal subsequently moved along the fencerow as in a corridor movement. Movement from one field through the fencerow into another field measures diffuse movements through patches.

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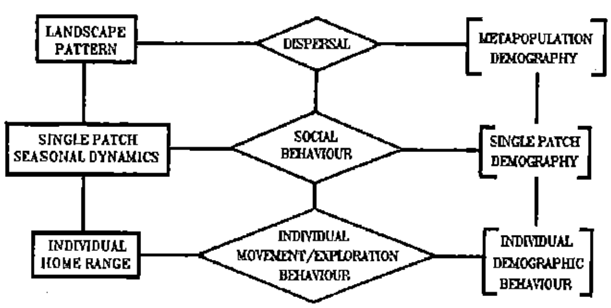

Fig. 2: Hierarchical representation of landscape pattern and its components, metapopulation performance and its components, and ecological and behavioural interrelationships between them. See text for discussion.

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DESIGN STEPS AND ECOLOGY

S.P. TJALLINGII

1. Introduction

In 1970, the English landscape architect Nan Fairbrother published "New Lives, New Landscapes", an eloquent plea to adapt urban and rural landscapes to modern life. She was certainly right in her assumption that many problems arise in mans relation to landscape as a result from his underestimation of the fact that landscape is a physical expression of a way of life.But the environmental problems of our time force us not only to consider a one way adaption of the old landscape to new lives. The crises in our "dialogue withnature" calls also for new lives creating conditions for a sustainable development related to the carrying capacity of nature. This implies not only a careful evaluation of the plans of modern technology. The best Environmental Impact Assessment methodology does not produce a good decision if no good plans are available to assess. Therefore there is an urgent need for new appropriate technology and a new "design with nature".IAN MCHARG (1969), MICHEAL HOUGH (1984), ANN WHISTON SPIRN (1984) and others have set the path for this approach.

What is the contribution landscape ecology can make to a better "design with nature"? This is the theme of this paper. More precisely it will focus on the question what landscape ecological theory can contribute to the design procedure for new urban landscapes.

The theory of island biogeography and the concept of connectivity both originated in what may be called an "organism approach" to landscape– ecology. Landscape structure is looked at as a set of conditions, notably for the immigration and extinction of certain species. In this paper a "resource approach" is chosen. A sustainable resource management is the prime incentive for landscape ecological research. Priority is given to the abiotic conditions for human–, animal– and plant life. As will be shown this approach produces concrete proposals for resource networks. Obviously these networks also create certain conditions for connectivity. In an earlier paper (TJALLINGII 1981) I followed the resource approach to formulate general principles and guidelines for environmental planning in urban areas. As both facts and values play an important role in planning, both should be made accessible to expert and public discussion. Therefore the design procedure should carefully formulate and present both data and values.

The present paper begins with some general considerations on design and research (2). Then some remarks are made on ecological theories such as the "relation theory" and the "island theory" and their relevance for design. (3) The next paragraph is a discription of a design method called PROSA, generated with the help of a conceptual framework provided by recent developments of the "relation theory".The design of a new urban watersystem is mentioned briefly as an illustration (4). Practical and theoretical implications of the method are discussed at the end of the paper (5).

2. Design and Research

What is design? Is it an art or a science? Is it the result of a public debate or do teams of technicians decide on it? Answers to these questions are required if we want to make clear the position of the ecologist in the process of spatial design. Do we expect him to indicate limiting factors, to produce relevant data, or is he invited to suggest ideas for management and maintenance or for the spatial arrangement of the plan? In this paper the ecologist is seen as a member of the planning team, active at all stages of the design process. If we try to sketch a more detailed picture of the possible contributions of the ecologist to this process a model might be helpful. Looking for suitable conceptual models inrecent publications about spatial design (TZONIS 1972; POLAK 1984; DE JONG 1978, 1981). I discovered that most idea's were variations on the basic concepts of Vitruvius. A good design according to Vitruvius should meet standards belonging to three categories: The venustas, the enchantment or beauty as experienced by the observer, the firmitas, the durability or firmness as it is constructed and the commoditas, the utility or appropriateness, the way it performs functions.

In the model (figure 1) the three categories of Vitruvius are related to the questions: What is it like? (form) How is it put together? (structure)And how does is work? (function).In form structure and function the abstract formulation of the plans objectives get a body.

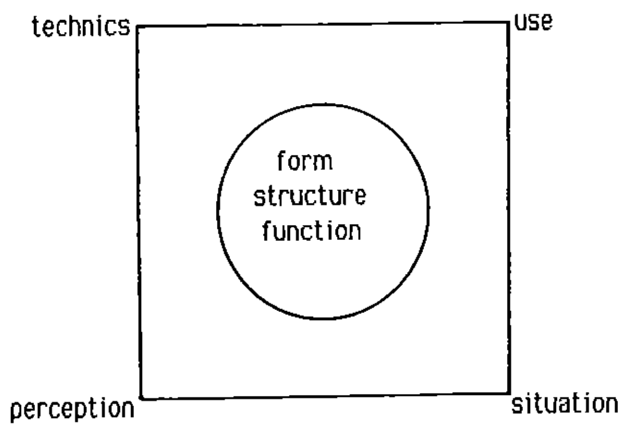

figure 1: Design and research, a model

The design process is not linear but circular. We continue to return to points of selection already passed, in order to achieve new syntheses. If this process is passing off satisfactorily, every time some progress is made. In the figure the integrated design–categories form, structure and function are therefore put in a circle. Speaking about the design of a new urban area "structure" not only refers to that which is built but also to existing structures of the original landscape that may be more or less modified, such as the watersystem. "Function" in this case not only refers to the social–economic but also to the ecologic–technical aspects.The circle is drawn inside a quadrat, the corners of which represent the research categories: "perception", "technics", "use" and "situation".Together they constitute the research programme vital to any spatial design.

In each corner the investigations can be analytic–descriptive. But if they turn inward towards the circle they become synthetic and design oriented. Data or systems are selected that meet certain existing or newly formulated standards. The investigator recommends them to become part of the plan. Arguments are advanced in support of these recommendations. They must be "good". Values are an essential part of this method and should be stated explicitly.

If the investigator turns his back to the circle this means the research project has its own empirical or hermeneutical objective. The results must be "true". Values are avoided, facts are looked for. The latter type of research is considered "scientific" and "objective" but the first category is most relevant to planning and design. According to DE GROOT (1986) the research orientations in a corner of the quadrat may be classified as in figure 2.

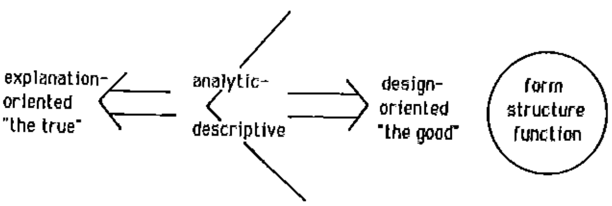

figure 2: The orientation of research.

The summation of results of all design oriented investigations will not automatically produce a good plan. The "good" results must also fit together. The good technical solution has to fit to this particular site and to suit the demands of use and perception of the people concerned. The job of the architect is to fit the different results together. Unlike the scientist he is not looking for the general but for the special.

Having outlined this framework it is possible to say a bit more about the possible tasks of the ecologist in the process of urban design. Each corner (fig. 1) is worthy of some special remarks. The investigation of the existing situation is a landscape-ecological analysis. In order to be useful the result should meet some requirements: 1. Lists of species or descriptions of communities are not sufficient. Spatial patterns have to be made clear, not as grid maps but with the real shape and size. 2. Ecological processes should be analysed and the results presented as a discription of conditons for the survival of the present ecosystems. 3. In a situation of changing land use it will be even more important to indicate possibly new developments under the present conditions both biotic and abiotic. The transformation of agricultural- to urban land use may include enrichment. Plant and animal life as well as the visual landscape may benefit. Whether this will happen or not will partly depend on the availability of data on the potential development of ecosystems in the area at an early stage of the design process. 4.The optimal use of ecological possibilities includes "horizontal" relations with the surrounding region. Of particular interest are waterrelations and the presence of "corridors" and "stepping stones" for the dispersal of plant and animal species. 5.Related to the design is the special character of the planning area compared with similar landscapes. 6.A historical analysis of mans role in landscape on this particular site is required. The design should be a new page in the book of history of this special area. The research carried out should produce the information needed for the choices relevant to this process of cultural and natural development. This is where most of the so called landscape evaluation maps fail. The technics research-corner has to make clear the technical possibilities for management and maintenance and for spatial lay-out and the application of devices. The development of an appropriate technology for habitat construction and -management but also for water- and road- systems and the parcelling into premises is conditional to the optimal use of the ecological potential of the area. Appropriate technology at the local scale may also alleviate environmental problems at regional- or even larger scale levels. Consequently research of technical possibilities should focus on the fluxes of energy, building materials, nutrients and water passing through the new urban area (DOUGLAS 1983). Design-oriented research carried out from the use corner is usually initiated by sociological disciplines, but this corner should not be reglected by ecologists. The quality of urban environments is highly dependent on the compatibility of use and the quality of abiotic and biotic elements.One of the important tools for the designer is the zoning of activities. The impact of noise, disturbance, trampling and pollution can be influenced by the zoning of the plan. The effects of zoning may be enhanced and implemented by a number of "selectors" like walls, ditches and hedgerows, thus creating conditions for both separation and integration according to the principle of "good fences make good neighbours".

Another type of use-investigations is connected with leisure activities. The time people have available for these activities is increasing and therefore there is a need to investigate the possibilities to combine them with management and maintenance of "nature in cities".

Perception is related with the attitude of people to their environment. How residents look at their district, how they feel about it, whether they feel responsible for it etc. Research at this corner may include the public-participation in the design process and the possibilities to leave some places free for private or cooperative initiatives. More closely related to the design is the question of form. Should form express an environmental approach to all aspects of design? Or would it be preferable to contrast the built and the non-built environment as sharp as possible? Whatever choice is made, design-oriented research at this corner as at the other corners should make clear the specific possibilities for this plan on this site.

3. Ecological theory and design

Though research from the four corners is needed, we will focus now on the situative and technical view points, where landscape ecology can contribute most. What can be learned by the designer from theories like the "relation- theory" (VAN LEEUWEN, 1966; VAN DER MAAREL & DAUVELLIER 1978) or the "island-theory" (MACARTHUR & WILSON 1967)?

The "island-theory" has drawn attention to the immigration and extinction of species and their relation to the size of the habitat and the distance plant and animals have to bridge before settling down. Though some authors like DIAMOND (1975) drew very specific conclusions for the design of nature reserves in a cultural landscape, empirical evidence does not justify these conclusions if only "size" and "distance" are considered (GILBERT 1980). To abstract from abiotic habitat conditons and management is neither logical nor practical. However, increased attention for biogeographic factors did produce fruitful ideas for the design of "ecological infrastructure", notably for "corridors" and "stepping stones". Concrete suggestions resulted for facilities helping certain species to bridge barriers like roads (PROVINCIE ZUID HOLLAND 1986; OVERBECK & VOLLMER 1986). Design proposals of this kind may be included in the plan and these practical experiments often produce interesting objects for ecological research from which we can learn. As stated earlier the information about existing ecological infrastructure in- and outside the planning area can be considered a vital part of landscape ecological analysis at the situation corner of our quadrat.

The earlier "relation–theory" also has been the object of criticism. Notably the validity as a general rule of the stability–diversity hypothesis has been rejected by theoretical biologists (SLOEP 1983; KWA 1987) None the less a fruitful practice has resulted from the relation–theoretical approach both in the fields of nature management and of habitat construction (VAN DER MAAREL 1975; LONDO 1977).

Noteworthy is the fact that the emphasis on abiotic and management factors (relation–theory) and that on size and distance (island–theory) to a certain extent support each other, being complementary aspects.

A general "law of nature" can be falsified by the demonstration of one exception. But as stated above, unlike the scientist, the designer is looking for the special. Design oriented research always include a careful analysis of the exceptional character of the area concerned. To some degree this may explain the paradox of the practical fruitfulness of some theories even if they are subjected to scientific debate. For designers operating with uncertainty is normal practice. But clearly this does not mean that it is wise to rely upon a bad theory. However even if a hypothesesis still under discussion, it may be the best one available. Provided the idea will be adapted carefully to local conditions a good design proposal may result.This has two important implications for the plan. First the results of "practical experiments" have to be evaluated by research once the plan is realized. And secondly the plan must be flexible. If necessary it must be possible to correct it. In conclusion one can state that the earlier relation–theory and the ecological infrastructure approach have a fruitful potential for design, notably at thetechnics and situation corners. Generally speaking the significance of these theories is at the substantial side of design rather than at the procedure side.

Recent developments of the relation–theory(Van LEEUWEN,1981,1985, VAN WIRDUM 1981) offer new perspectives, not directly for the form,structure and function of the plan, but rather for the procedure of the design process.The theory of "basic operations" and the theory of "basic functions", marked by Van LEEUWEN as parts II and III of the relation theory, deserve an elaboration for this purpose. In this case the word "theory" does not refer to an empirical theory but rather to a conceptual framework. In the theory of "basic operations" an ecosystem is conceived as a set of fluxes controlled by selectors and regulators. Energy, materials, nutrients, water, etc. are seen as fluxes moving from source to sink. Selectors (spatial) and regulators (temporal) channel the fluxes. As most devices or structures do select as well as regulate they are called "selecto–regulators". If we interfere in an ecosystem this will have some direct effects on the organisms(direct operations), but more important is the interference in the existing field of fluxes and the resulting indirect effects. Four categories of these indirect selecto–regulation operations are distinguished: sequential (time), expositional (direction), positional (place) and conditional (instrumental).

Before we can apply these concepts to the design process they will be illustrated with a small example (figure 3): if we plant a tree by the side of a road and it rains, then the tree roots and the stem getting wet is a direct operation. The water flux goes from the source (the rain) to the sink (the root). In its travel the drop of water can be influenced by indirect operations. If we provide a soil around the tree with a high potential moisture content, then the soil can absorb the water when it rains and in dry periods the tree roots can take up the water from this storage. This is called sequential operation, the temporal principle of storage is used. If the tree is planted in a hollow place the water will flow to the stem. For water quality reasons however, we may decide to make a mound around the foot of the stem. In both cases we use an expositional operation (flow direction). The planting distance of the trees from each other and from buildings are examples of the use of positional operations. The spatial structure acts as selecto–regulator. Finally different types of pavement may be used, with varying runoff– coefficients Or we can apply pipes that carry oxygene to the tree roots so that they can perform their water absorption in a better way. This category of operations is called conditional by Van LEEUWEN. As all selecto– regulation operations are conditional I prefer the term instrumental.

```
                 fluxes
source----------O--------------sink
                 |
             operations
 direct                    indirect (conditional)
   1              2 sequential (rhythm)
                  3 expositional (orientation)
                  4 positional (situation)
                  5 instrumental (appropriate technology)
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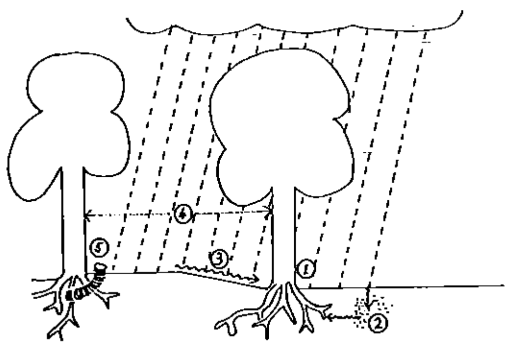

figure 3: An example of "basic operations"

From the example it becomes clear that the conceptual framework is useful if we try to improve the life conditions in a given area. This is what we try to achieve in design. An interesting possible implication for the design procedure appears. Giving attention to the operations step by step in this sequence an optimal use is made of time, orientation and space. Technical devices do not dominate but follow the plan. In doing so the design may prevent a number of environmental problems rather than repairing them afterwards.

Apart from the sequence of indirect operations chosen deliberately, the concepts of "basic operations" are relatively neutral. However if we try to solve environmental problems an explicit value statement is required to make clear which strategy is chosen. The motives have to be formulated in order to make discussion possible. The "theory of basic functions" does offer a scheme of the selecto–regulation of fluxes that can be useful for the formulation of strategies (figure 4).

Elswhere (TJALLINGII 1981, 1986) environmental problems and strategies to cope with them are analysed using this model. The general conclusion is that an attempt should be made to change the over–emphasis on input and output into more attention to the retention and resistance regulation. . This is particulary valid for the design of surface water systems in urban areas. Here storage and recycling are the key words.

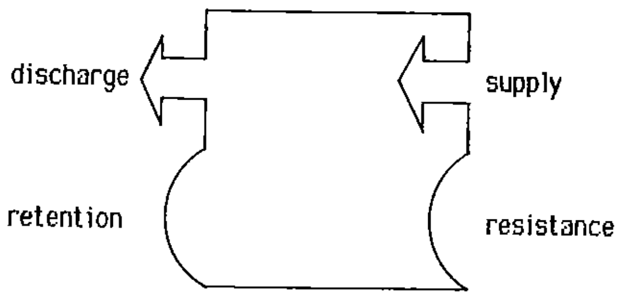

figure 4: A flux-regulation model of the ecosystem

4. PROSA, a design method for urban watersystems

Guided by the conceptual framework and learning from practical experiments a design method is developed. Figure 5 presents a general scheme. The steps are called Programme, Rhytm (sequential operations), Orientation (expositional operations), Situation (positional operations) and Appropriate Technology (instrumental operations). In other publications the choices made at different stages and the results are described in detail (KOLFF et.al.,1986; TJALLINGII 1987). Here I will focus on the methodology.

figure 5: PROSA, Design steps for surface water systems

PROGRAMME
- existing system (spatial, balance, problems)
- guiding principle (the selfreliant system)
- planned system (schemes, balance, planning conditions)

RHYTM
- existing rhytm (daily, seasonal/irregular)
- guiding principle (synchronizing, storage)
- planned rhytm (storage calculation)

ORIENTATION
- existing orientations (directions of flow)
- guiding principle (from clean to polluted)
- planned orientations (flow and zoning)

SITUATION
- existing situation (abiotic, biotic)
- guiding principle (using and creating spatial conditions)
- planned situation (first design sketch)

APPROPRIATE TECHNOLOGY
- existing devices (operation problems)
- guiding principles (adapting to time, space, management)
- planned technology (operation, steering, normal & emergency)

Together the PROSA steps are an attempt to elaborate the situation and technics corners of the design model given in figure 1. The resulting water structureplan being the product of a first round through the design circle offers the structural basis for the ecologic--technical function. A second round may include management and maintenance aspects of the plan. As a whole the water structureplan has to be integrated with other environmental plans such as those dealing with energy, noise and urban green. Together they are part of the urban design process including the parcelling into dwellings and private gardens, traffic structure, amenities etc. Form is conceived as one of the driving forces throughout the entire design process at all levels.There is a strong argument to start with the environmental design in an early stage because it is one of the weakest links and it interferes with all other aspects. The water structureplan is a good starting point because it structures the whole plan.

Each step consists of three parts: First the existing landscape. Secondly the guiding principles for the use of the existing situation and for the new system. In the third part ideas, sketches and calculations for the design are presented.

Preceding the other steps the programme is described. Here the general planning conditions are given, the main objectives, the limits of the budget, the procedure of decisions and participation etc.The scheme of the design process in figure 5 is made for the design of a water-system for a new residential area of 8 ha, planned for 3- 400 dwellings, with a small park. The resulting water-structureplan is given in figure 6. Details of the steps and of the final plan are discussed in TJALLINGII 1987.

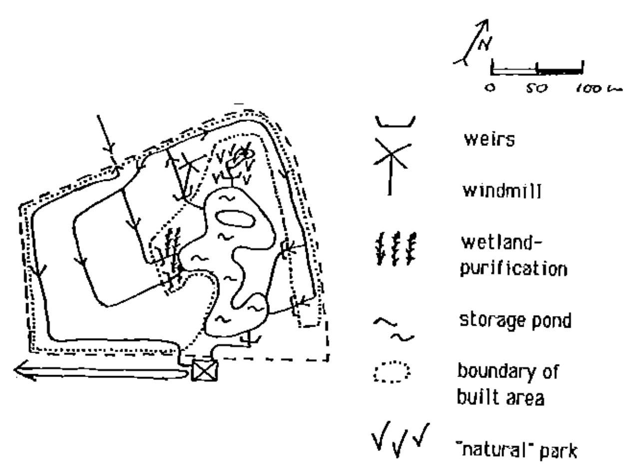

figure 6: Water-structureplan

5. Conclusions

The methodological reflexion described in this paper, touches on a number of differences between empirial theory and design theory. The first as a rule is concerned about "the true", "the general" and "knowing that" where as the latter focusses on "the good", "the special" and "knowing how". To some degree these differences even explain a surprising paradox : theories critisized by scientists sometimes produce fruitful ideas for the design and planning practice. Taking into account these differences, scientists and designers may cooperate to their mutual benefit. Scientific theories may contribute to the generation of design proposals and on the other hand practical experiments may be included in real plans. Both sucess and risk of this approach are highly dependent on cooperation.

Recent developments in theory and practice have opened new doors to concrete design proposals for the ecological structure of landscapes. The PROSA approach shows that some theoretical developments may also suggest new design procedures. The step by step process proposed here has to be tested for usefulness in other cases and possibly also for other fluxes. The method offers possibilities to insert new technologies of environmental design and management. Healthy systems of fluxes like water seem to be basic conditions for human, plant and animal life and therefore they seem to be good starting points for the structuring of urban and rural landscapes. The concept of connectivity might be useful in elaborating and refining the basic structures.

Public discussion and participation is essential for the development and management of our habitat. Therefore in every step of the method proposed here value statements are formulated explicitly. But only if statements and goals are translated into design proposals, the integration of environmental aspects with the use and perception of people will lead to new landscapes, that are both sustainable and inspiring. The PROSA–ic may then merge with the poetic.

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POPULATIONS IN FRAGMENTED LANDSCAPE

P. OPDAM

The concept of the metapopulation

In intensively used agricultural landscapes, like those in Western Europe, many plants and animals find their habitat scattered in more or less isolated, usually small patches. Each patch may contain a population of a species, but local extinctions may cause (temporal) vacancies. Recolonization of empty patches and of new patches may occur as long as individuals or seeds are capable of bridging the gap of inhospitable land between habitat patches, and a certain proportion of the patches is still occupied.

A set of populations in such a fragmented landscape is called metapopulation as long as the subunits (subpopulations) are interconnected by dispersing animals. Between–patch dispersal is then the landscape process linking the subpopulations in each patch, thus forming a population on a higher level of organization: the metapopulation. The concept was introduced by Levins in 1970 (WILCOX 1981) and is useful to describe population processes on the landscape level. This will be explained further.

Theoretically, the dynamics of the metapopulation, and basically its survival, depends on

- the dynamics of the subpopulations, i.e. the size of the patches and the habitat quality (extinction rate)
- the connectivity between patches, i.e. the dispersal rate (functional connectivity) and the landscape characteristics governing the dispersal flow (connectivity in astructural sense: interpatch distance, density of stepping stones and corridors, permeability of landscape matrix for dispersers) (recolonization rate)
- spatial and temporal variation in habitat quality among patches in combination with dispersal: spreading of risk, dampening of fluctuations in the size of metapopulation.

If the mean extinction rate of the subpopulations exceeds the recolonization rate over a sufficiently long time, the metapopulation will go extinct, unless a dispersal flow of a higher spatial level, originating from outside the metapopulation, is strongh enough to compensate for the deficiency in local dispersal.

Research on metapopulations

As in populations, ecosystems or landscapes, to draw a borderline around a metapopulation is difficult. It seems reasonable to determine boundaries relative to changes in the major characteristic of the metapopulation: the dispersal flow connecting the subunits. Thus, a boundary between metapopulations may be located there where the mean intensity of the dispersal flow changes, that is where interpatch distances or corridor densities change abruptly. Thus, metapopulation areas become congruent with landscapes.

Metapopulations can be investigated in several ways. The ecologist may go out in the field and measure dispersal rate as a function of variation in landscape pattern. He may also compare dispersal rate of various landscape elements or he may observe dispersal in different groups of the population (males compared to females, young compared to adults etc.). This may be successful in species in which dispersal can be observed as an active movement of individuals on a short–time base. Such species use corridors for transition only. In slow moving species, like plants or ground dwelling invertebrates, dispersal is rather observed as a diffusion–like process: a gradual spread through a corridor from generation to generation. In these species, 'corridors' are both habitat and transition pathways. Of course this difference is merely a matter of scale, but we should keep in mind that we fixed the level of observation to the landscape level: dispersal flows through a landscape greatly diverge between species. Instead of measuring the dispersal flow directly, the ecologist may base its research on the occurrence of subpopulations in the habitat patches and try to relate the distribution of a species to the landscape pattern, either in a short–term spatial study or in a long–term process–oriented study. This learns him more about the relationship between the metapopulation and the landscape pattern. The ultimate problem, predicting the survival chance, might be best approached in a model study with computer simulation. Such simulation studies should always be supported by field studies to ensure models as realistic as possible, and to make testing of hypotheses possible.

Evidence on metapopulations

Thus far, the study of dispersal has been apart of detailed population studies (GAINES & MCCLENAGHAN 1980, GREENWOOD & HARVEY 1982, HOWE & O SMALLWOOD 1982, DEN BOER 1983), but the step towards the metapopulation level was seldom made. Whether corridors and stepping stones influence the dispersal rate is poorly studied. Some small mammal species prefer corridors when moving through the landscape (HENDERSON et al. 1985, MIDDLETON & MERRIAM 1981, HANSSON 1987, VAN APELDOORN & VAN DER ZEE unpubl.), but the quantitative effect of corridor density on the survival chance of the metapopulation was not determined. That linear landscape elements may also act as barriers to moving animals is demonstrated by the work of MADER (1979). He found barrier effects of paved roads to small mammals and carabid beetles. Most evidence comes from correlation studies of birds in fragmented forest. Several species of woodland birds are much affected by patch size and little affected by the amount of wood in the surrounding landscape (e.g. HOWE 1984, O OPDAM et al. 1985, ASKINS et al. 1987, VAN DORP & OPDAM 1987).A positive effect of hedgerow density on the number of woodland birds in woodlots was only claimed by Van DORP & OPDAM (1987). Small and isolated woodlots tend to have less species and lower densities of forest bird species. The assumption that the absence of species was the result of higher extinction rates in the smallest woodlots and lower immigration rates in the remote woodlots could be supported by a three–year study of woodlots by VAN NOORDEN et al. (1987). In a few studies, the occurrence of small mammal and amphibian species in small habitat isolates was correlated to distance parameters (SMITH 1974, fig. 1, LAAN & VERBOOM1986). Convincing evidence for an isolation effect on invertebrates came from a study of WEBB (1984) on heathland spiders in heathland fragments in South–England and from unpublished studies on carabid beetles by Van Velden & Mabelis in Dutch woodlots and by Burel in French hedgerows. Another correlative study to be mentioned by BRÖNMARK (1985) suggested that the density of fresh–water pools positively influenced the abundance of snail species, and similar results were obtained by BIERE et al. (1983) and MÖLLER & RÖRDAM (1985) for aquatic plants. From these studies the effect of the amount of habitat patches in the surrounding landscape emerges as a general predictor of species presence and species abundance. The effect of connecting elements is poorly demonstrated. The evidence is inadequate to generate quantitative relations between landscape structure and metapopulation dynamics. Short–term studies does not seem appropriate to gain insight into the relation between a landscape

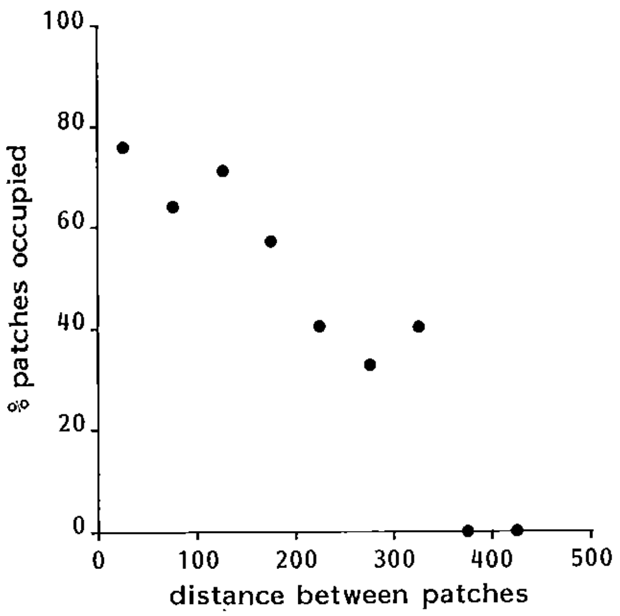

Fig. 1 : Frequency of occurrence of pikas *Ochotona princeps* in relation to interpatch distance (after SMITH 1974)

pattern and survival of a species in that landscape. The studies mentioned above do not learn us much about size and number of patches in relation to survival, or about the relation between the mean extinction rate of subpopulations and the mean recolonization rate. So, long-term studies should complete this pattern-oriented approach. However, in many species, the time scale of fluctuations of the size of a metapopulation would require studies covering a period of several decades (cf. DEN BOER 1986). Since this is often practically impossible, a more proper way of investigation will be modelling of metapopulation dynamics, supported by field studies over several years to collect parameter estimates and to test model predictions (which might be very well possible with one-year surveys). An illustrative example of this kind of approach is the study by VAN DER O EIJK (1987) on the water beetle *Gyrinus marinus*. This author studied subpopulations in fresh-water pools, measured several population parameters and simulated fluctuations in 20 subpopulations over 25 years, comparing different levels of dispersal (fig. 2). In another run he investigated the effect of the number of subpopulations, showing that in a metapopulation composed of five subunits, 38% of the subpopulations were extinct after 25 years, compared to zero in metapopulations consisting of 20 subunits.

Effect of differences between habitat patches

DEN BOER (1986) clearly demonstrated the effect of spatial and temporal variation in habitat quality among patches. He observed the fluctuations in metapopulation size in two carabid species over 25 years. Each metapopulation was composed of ca. 10 subpopulations. In *Pterostichus*, the subpopulation fluctuated asynchronically as a result of habitat differentiation: the size of the metapopulation shows the stabilizing effect of this 'spreading of risk'. On the contrary, subpopulations of *Calathus*, were triggered by a single environmental factor, affecting all the subpopulations simultaneously. When added, the parallel fluctuations of these subpopula-

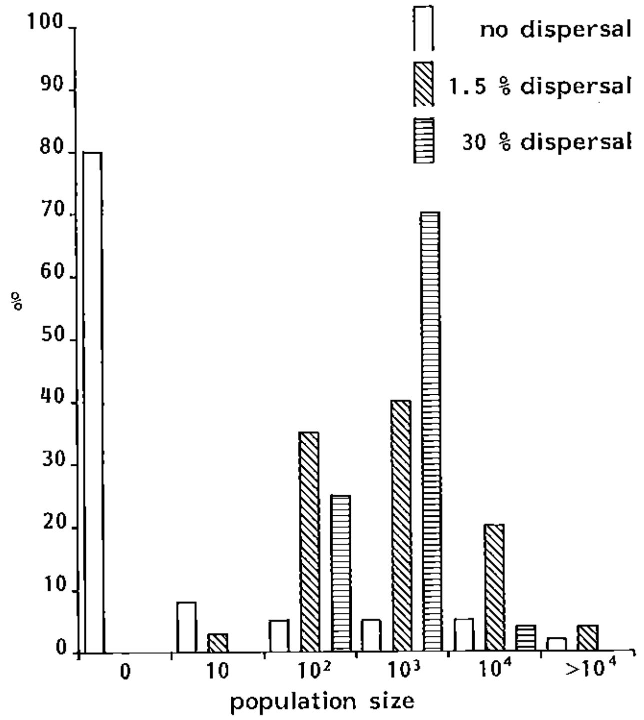

Fig. 2 : Meansize of subpopulations in a metapopulation of the water beetle *Gyrinus marinus* after 25 years, as similated by a computer model consisted of 20 subpopulations; three levels of dispersal rates are compared (after VAN DER EIJK 1987)

tions are magnified in the metapopulation size. This difference has profound effects on survival. *Pterostichus* has an estimated survival time of 1000–3000 years, whereas *Calathus* is likely to be extinct within a century. Heterogeneity among patches has another, but largely uncomprehended consequence: the relation between optimal and marginal habitats. For a species, a habitat type may be good enough to stay alive but in most years unsuitable to rise off spring. In such habitat patches the persistance of subpopulations may be completely dependent on dispersal flows from good patches. Practically nothing is known about the implications of such source-sink relations to the metapopulation behaviour. Marginal patches may serve as overflow sinks for superabundant individuals; that will move back to good sites in times of low regional densities (cf. KREBS 1971). In this case marginal patches are occupied irregularly. Another aspect of marginal patches is that they may be mainly inhabited by individuals with a high tendency to disperse, like young individuals, or individuals of one sexe (cf. KREBS 1971, GOTTFRIED 1979).

Conclusion

The concept of the metapopulation is useful in that it offers us a theoretical framework for structuring research and ideas about populations in fragmented landscapes. It stresses the dynamic aspect of the metapopulation, caused by the opposite effects of extinction of subpopulations and recolonization of empty patches. Evidence from literature supports the presented model of a metapopulation in qualitative terms:

- the distribution of a species in a fragmented landscape is dynamic,
- extinctions and recolonizations are frequent events,
- oftensome patches, mostly the small and isolated ones, remain unoccupied for one or several years.

However, we are still a long way from predicting survival time from a given set of landscape characteristics, and from planning landscapes in which a given species is expected to survive over a certain spell of time.

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THE POSSIBLE ROLE OF ROAD VERGES AND RIVER DYKES AS CORRIDORS FOR THE EXCHANGE OF PLANT SPECIES BETWEEN NATURAL HABITATS

H.J. VERKAAR

Abstract

So far little attention has been paid to the importance of linear landscape elements like road verges and river dykes for the migration of plants. The very few reports that are now available deal with pattern based studies on plant distribution rather than with studies focused on processes of dispersibility and of maintenance of natural populations.

In this paper a tentative grouping of a number of plant species is made to assess whether linear landscape elements may be important as 'ecological corridors' or not. And if so, for which species such 'corridors' may be important? A majority of plant species have evolved one of two different life strategies, i.e. either a good dispersibility and only a transient seed bank or a poor dispersibility and a persistent seed bank. Both provide a chance for populations to maintain themselves in already colonized habitats in spite of accidental mortality due to local catastrophes.

There are also groups of plants which does not share these features, e.g. some grassland and woodland plants. Moreover, in some conditions also other groups of plants may be vulnerable due to isolation. For these plant species in particular road verges and river dykes may be important for the connectivity between natural habitats. Conditions for this functioning are discussed.

Introduction

In many countries there is an overwhelming fragmentation of natural habitats going on due to the construction of roads, waterways and rail roads and due to traffic itself since last century. Together with a drastic change in land use, e.g. due to intensive agricultural management and industrialand urban expansion this fragmentation results apart from a tremendous reduction in area of natural habitats in an increased isolation for many organisms (MADER 1979, WILCOX 1980, OPDAM in press).

The expected vulnerability of more or less isolated populations in small natural patches in rural landscape leads to a generally growing concern. There is evidence from many studies on animal populations that small populations in isolated patches show indeed higher mortality than large populations in connected areas (badger (*Meles meles*)(BROEKHUIZEN 1986); woodland birds (OPDAM et al. 1984, VAN DORP 1986, OPDAM, 1986); reptiles and amphibia (BERGMANS & ZUIDERWIJK 1986); and invertebrates (GERAERDTS 1986). Also in plants local extinction of populations of rather rare biennial plants has been well documented (VAN DER MEIJDEN et al. 1985). These biennial plants can only recover after local disastrous events, which occur rather frequently due to e.g. drought and rabbit grazing and scratchings, if recolonization is possible from patches nearby or by regeneration from the seed bank.

Linear landscape elements that provide possibilities for the (re–) colonization of vegetation, say road verges, river dykes, hedgerows et cetera, may partly repeal the negative effects due to isolation, if their management is appropriate. Their possible role as 'ecological corridors' has been mentioned by several authors, but is mostly confined to animal species (e.g. MERRIAM 1984, DAVIS 1986, OPDAM et al. 1986). On the other hand, their function for the exchange of plants is sometimes considered as disputable (OPDAM et al. 1986). Other authors however attributed great possibilities to linear landscape elements for such an exchange of plants, e.g. in newly created habitats (FROMENT & JOYE 1986, DAVIS, 1986).

In this paper the possible role of road verges and river dykes as 'ecological corridors' for wild plants will be discussed and a possible explanation for the puzzling results of earlier studies will be given from the point of view of a plant ecologist. In this paper no attention will be paid to the rate of local extinction of populations. If such 'ecological corridors' for plants exist, it can be questioned for which types of species it may be important. Then one may facilitate the exchange of these types of species between natural habitats if favourable conditions for them can be achieved in road verges and river dykes.

Since McDonnell (1984) has extensively dealt with the exchange of bird–disseminated plants between landscape elements, no special attention will be paid to this dispersal type in this paper.

Plants and animals : Analogies and differences

For both plants and animals the exchange of genetic information between genotypes is necessary to maintain a certain degree of genetic variability. The degree of genetic variability necessary for maintenance differs between species. On the other hand, in general a minimum population size effective in reproduction is required of at least 50 in the short–term and not less than 500 in the long–term (FRANKLIN 1980).

In contrast with plants animals have a number of features that plants are lacking, e.g., 1. animals generally have an active locomotion, and 2. organs of sense enable animals to make choices between possible transportways. Plants in turn often show vegetative multiplication which occurs only in some invertebrates in animals. As plants do not have an active locomotion, an 'ecological corridor' for plants must be not only appropriate for transport, but also for all other requirements of the habitat.

Apart from transport as a result of vegetative expansion genetic information is generally transported during pollination and seed dispersal in higher plants and during spore dispersal in bryophytes and ferns. In these life phases transport generally occurs passively, i.e. transport with the aid of wind, convection and turbulence, water, animals, human beings, et cetera, although many plants have evolved features to perfect this transport (LEVIN & KERSTER 1974, VAN DER PIJL 1982). The trajectories covered by dust seeds of some orchid species and spores of some ferns and bryophytes may amount to hundreds or even many thousands of kilometers (SCHMIDT 1918, BURROWS 1975), but in most species they are limited from several centimeters to several tens of kilometers (e.g. FEEKES 1936, SHELDON & BURROWS 1973, SHARP & FIELDS 1982, VERKAAR et al. 1983) For sake of convenience the word 'seed' is used here to describe any dispersal unit containing one of more embryos.)

Compared to living creatures most plants do not have a more or less fixed life length as most animals have, if the survival in the seed bank is included. Especially in the seed bank phase dormant seeds of some species may survive a period of many decades or even many centuries depending on soil conditions, granivore attack and pathogen infection among other factors (LERMAN & CIGLIANO 1971, ODUM 1978, KIVILAAN & BANDURSKI1981, TOOLE 1986). Conversely seeds of some species e.g. orchids can only survive for a very short period. Also in the vegetative phase some plant species can survive fairly long periods of apparent dormancy remaining a small rosette under the canopy of surrounding vegetation.

Resilience in existing habitats and colonization in newly created habitats

If a plant population becomes extinct with regard to the obvious life phases, there are two mechanisms of recovery : either by invading of seeds from adjacent populations or by germinating from the soil seed bank. In pioneer phases of a primary succession and in newly created habitats, where no suitable seeds are available in the seed bank, only migration of seeds enables establishment.

These two mechanisms can be recognized as 'resilience by migration' and 'resilience in situ' (GRUBB & HOPKINS 1986, GRUBB 1987). Since there is a tendency in evolution to optimize traits adapted to evolutionary stable strategies, there may be a differentiation either in plants that evolved a long range dispersal capacity and most probably only little survival in the seed bank on one hand or in plants that do not have a good dispersibility, but of which seeds can survive in the seed bank for a long time on the other hand (LEVIN et al. 1984, DE JONG & KLINKHAMER 1986).

When both mechanisms are seen in greater detail, it is clear that both innate and environmental factors determine their relative importance (Table 1). Lack of dispersing agentia can strongly reduce the trajectory, whereas an abundant occurrence of granivores can markedly diminish the density of viable seeds in the soil.

Although DE JONG & KLINKHAMER (1986) found evidence for this hypothesis, they concluded that only a few combinations of data on dispersal and seed longevity could be found in literature. To assess seed longevity however they used data gathered from field situations where seed survival is measured as a result of both innate longevity of the seeds, seasonal variation in dormancy and environmental factors. If seasonal variation in dormancy and environmental factors are excluded as in the data set of PRIESTLEY et al. (1985) on crop species, there remains a negative correlation between seed longevity and seed dispersibility (Fig. 1). One note must be made here : storage conditions of these seeds are not fully comparable with storage conditions in the soil in field situations.

Tab. 1. A summing–up of factors that determine dispersibility and seed longevity.

FEATURE	DEPENDING ON :
DISPERSIBILITY	CHARACTERISTICS OF DIASPORES
	AVAILABILITY OF DISPERSING AGENTIA
	EXPOSURE TO AND/OR APPARENCY FOR DISPERSING AGENTIA (VEGETATION STRUCTURE (FRUIT HEIGHT OF THE PARENT PLANT
SEED LONGEVITY	INNATE LONGEVITY (E.G. METABOLIC ACTIVITY
	STORAGE CONDITIONS (E.G. SOIL HUMIDITY, OXYGEN AND CARBONDIOXIDE CONTENT, TEMPERATURE
	EFFECTIVITY OF PATHOGENS AND SEED PREDATORS

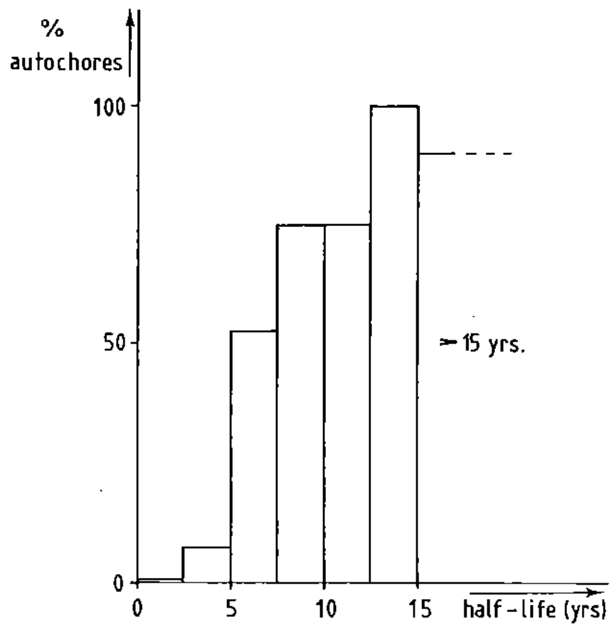

Fig. 1. The percentage of autochorous species (species with seeds without any obvious adaptation to dispersal) per half–life class as mentioned by PRIESTLEYet al. (1985) from data from several stations all over the world under open storage conditions in temperate climates. Total number of species amounts to 92. Dispersal characteristics are assessed with the aid of FEEKES (1936).

Based on a number of data derived from literature a tentative division into some groups of plants emerges (Table 2). Although this scheme is preliminary, incomplete and rather rough and most species involved deal with species from ruderal habitats, grasslands, woodlands and heathlands in moderate regions, some conclusions can be made. Indeed, a majority of plants seems to have evolved either a good dispersibility but a poor survival in the seed bank or a persistent seed bank but a poor dispersibility. There are however obviously members of some plants families that share both a good dispersibility and a long–lived innate seed-bank. On the other hand, one must note that there seem to be some groups of plants that do not share one of these features at all. The latter groups may be very vulnerable to isolation and may profit notably by 'ecological corridors' !

Tab. 2. A tentative division into some groups of plants based upon maximum dispersibility and maximum innate seed longevity. Derived from a variety of sources from literature (derived from the following sources : DENSMORE & ZASADA (1983), EGLEY & CHANDLER (1983), FEEKES (1936), GRANSTROM (1982, 1987), GRIME et al. (1981), KIVILAAN & BANDURSKI (1981), ODUM (1978), VAN DERPIJL (1982), PRATT et al. (1984), PRIESTLEY et al. (1985), ROBERTS (1986), ROBERTS & BODDRELL (1983, 1983), ROBERTS & NEILSON (1980, 1981a,b), SCHENKEVELD & VERKAAR (1984), SPIRA & WAGNER (1983), THOMPSON & GRIME (1979), TOOLE (1986), WILLIAMS (1983).

LONGEVITY	DISPERSIBILITY: HIGH MORE THAN CA 1 KM	DISPERSIBILITY: LOW LESS THAN CA 1 KM
HIGH MORE THAN CA 3 YR	some Compositae, some Chenopodiaceae Betulaceae and Typhaceae	many Cruciferae, Papilionaceae, Linaceae, Violaceae, Labiatae, Euphorbiaceae, Convolvulaceae, Boraginaceae, Polygonaceae, Chenopodiaceae, Aceraceae, Resedaceae, Ericaceae Umbelliferae, Onagraceae, Rosaceae, Ranunculaceae, Solanaceae, Scrophulariaceae, Malvaceae, et cetera
LOW LESS THAN CA 3 YR	some Compositae; Orobanchaceae, Orchidaceae, many ferns, Saliceae, some Onagraceae and Gramineae	some Gramineae and grassland species, many understorey species of woodlands many Fagaceae

In newly created habitats and habitats that are subjected to a drastic change in management regime however the group of plant species for which 'ecological corridors' may be important should be extended to all species which do not have a good dispersibility whether they have a persistent seed bank or not.

Unfortunately only a very few studies have paid attention to the migration of plant species under natural conditions.Therefore it is difficult to find evidence for the significance of the division mentioned in table 2. One of the studies on migration of plant species deals with the colonization of plants in road verges of three Dutch polders a number of years after reclamation from Lake IJssel (VAN DER TOORN 1969, NIP VAN DER VOORT et al. 1979). Although a very few seeds of saline as well as glycophyte plants may occur in the soil just after reclamation (JOENJE 1978), the soil in the newly created polders can be considered as virginile. In 1972 hydratochorous and efficient anemochorous species were found in all road verges whether they are old or new. Zoochorous, little efficient anemochorous and especially autochorous species however mainly occurred along old roads near the mainland.

Under conditions extensively influenced by man the situation is more complicate. BAUDRY (1984) mentioned a study on trees and shrubs in Breton hedgerows. Under field conditions seed longevity of most tree species is limited up to a few years. Although in this study generally a clear correlation is found between distance to the adjacent woodland (possible seed source) and the species abundance, the occurrence of some species was mainly determined by planting centuries ago.

To test preliminarly the value of the tentative division a pattern based case study has been carried out in an area of which the soil substrate was not virginile after reclamation.

A case study – a river dyke near Heerewaarden

In the Netherlands the Ministery of Transport and Public Works prepares extensive reinforcements of the dykes along the main rivers to assure the safety of the inhabitants. During last decade a number of such projects were already carried out. Then the former dyke body was heightened sometimes for several meters and the new dyke was commonly covered with the top soil layer of the former dyke. As such reinforcement projects take some years, only innately long–lived seeds may survive in this top soil layer.

The reinforcements of a dyke along river Waal near Heerewaarden (province of Gelderland) occurred between 1980 and 1983. The topsoil layer consists of a rather light sandy clay and was sown with a standard seed mixture of *Festuca rubra*, *Poa pratensis* and non–persistent *Lolium perenne* after the reinforcement. Afterwards the dyke is managed as a hayland. During the project the vegetation in the verges of three small roads fairly rich in species density was partly saved (Fig. 2). The surrounding area of the dyke is extensively used either for agricultural purposes as heavily fertilized and species–poor meadow or orchard or consists of wet moorland in the outer marshes.

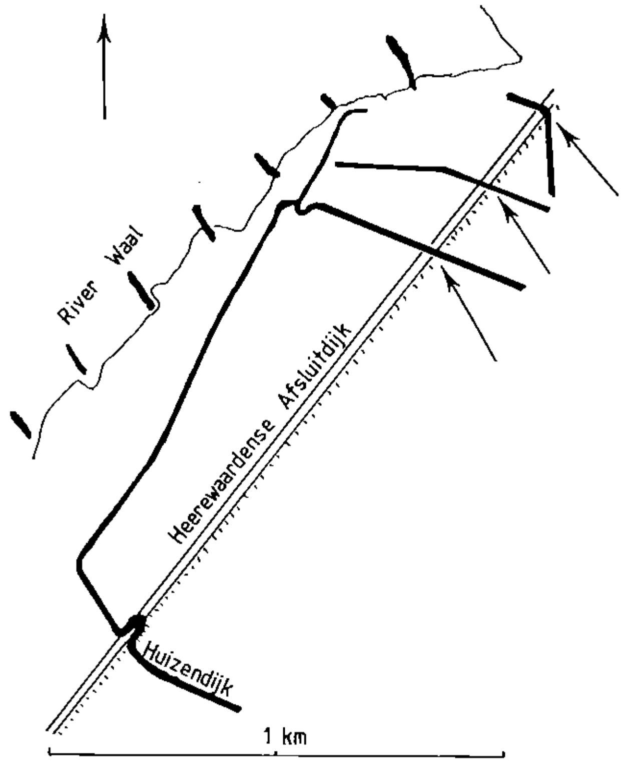

Fig. 2. Map showing the situation at the Heerewaardense Afsluitdijk. Possible sources of seeds were indicated by arrows.

In June 1987 the vegetation of the dyke was surveyed for the distribution of vascular plant species. Although distribution patterns may be partly attributed to differences in abiotic conditions, there is not much reason to ascribe all patterns to these conditions as the vegetation definitely consisted everywhere of a species-rich Arrhenatheretum. Table 3 shows four different types of distribution. Only one species, *Silene pratensis*, could not be categorized properly as it only occurred in the saved road verges and from about 600 m onwards to the Huizendijk. This species may have originated from the verge of the latter dyke.

First of all, it is clear that only a very few species show a gradient from the saved verges (category D), namely 6 out of 85. The existence of categoryD gives support to the hypothesis that this dyke may operate as an 'ecological corridor' for species of this group. Category D obviously shows significant differences compared with the group of species that are found irregularly on small spots here and there on the dyke (category C) and the group of species that occur everywhere (category B)(Chi square-test, P less than 0.001), since the proportion of autochorous species is much larger in the first category and no anemochorous species are found in it at all (Table 3).

Tab. 3. The proportion of species that occurred only in the saved verges (category A), everywhere on the dyke (category B), irregularly on small spots here and there (category C) and only in a part of the dyke from the saved road verges onwards (category D) on Heerewaardense Afsluitdijk in June 1987. All species occurred in the saved verges. Dispersal characteristics are assessed with the aid of FEEKES (1936).

CATEGORY	ANEMOCHORES			AUTOCHORES	REST	TOTAL SPECIES NUMBER
	VERY EFFICIENT	EFFICIENT	LITTLE EFFICIENT			
A	37.5 %	12.5 %	50.0 %	0 %	0 %	8
B 1)	13.3 %	20.0 %	35.6 %	24.4 %	6.7 %	45
C 2)	15.4 %	26.9 %	42.3 %	11.5 %	3.8 %	26
D	0 %	0	0	83.3 %	16.7 %	6

1) of which two species are sown previously.

2) of which *Lolium perenne* is sown previously.

Species of category B and C either may have originated from the saved verges and may have covered the whole range within three or four years, or may have regenerated from the soil seed bank or may have been from adjacent farmland in some common species, e.g. *Dactylis glomerata*.

Probably all six species belonging to category D do have a persistent seed bank (THOMPSON & GRIME 1979, PRIESTLEY et al. 1985, ROBERTS 1986)(Table 4). Three of them are restricted to more or less disturbed microhabitats, but *Lathyrus pratensis* and *Lotus corniculatus* are characteristic for hayland vegetation. Therefore, the results may be puzzling : Why is this pattern found in these species with a long-lived seed bank in many situations ?

Tab. 4. Species that occurred only in a part of the Heerewaardense Afsluitdijk from the saved road verges onwards (category D).

AUTOCHOROUS SPECIES:	ZOOCHOROUS SPECIES:
BRASSICA NAPUS	RUBUS FRUCTICOSUS
LATHYRUS PRATENSIS	
LOTUS CORNICULATUS	
MEDICAGO LUPULINA	
PAPAVER DUBIUM	

Why do these species not behave like other autochorous species with a persistent seed bank that are grouped in category B ?

Although several answers on these questions are possible, a plausible explanation may be the low survival in this dyke e.g. due to heavy predation of specimens in category D. All have rather large, protein-rich seeds that may attract for instance mice, whereas seeds of many autochorous species of category B are rather small and may be insignificant to predators.

'Ecological corridors' for plants once again

There are indications that road verges and river dykes may operate as 'ecological corridors' for plants, if construction and management are appropriate. As the results so far show one must be modest in assessing this role apart from the negative influences as a result of traffic. Many species have evolved features that enable them to recolonize patches after local disturbances, either by having a long range seed dispersibility or by forming an innately persistent seed bank. The latter strategy however may be vulnerable to e.g. attack by predators and fungal infection, and bad storage conditions. If mortality due to local conditions is considerable, species with the latter strategy may also benefit from an 'ecological corridor' (Fig. 3). Moreover especially some grassland and woodland species which do not have an innately good dispersal capacity or a persistent seed bank seem to be vulnerable.

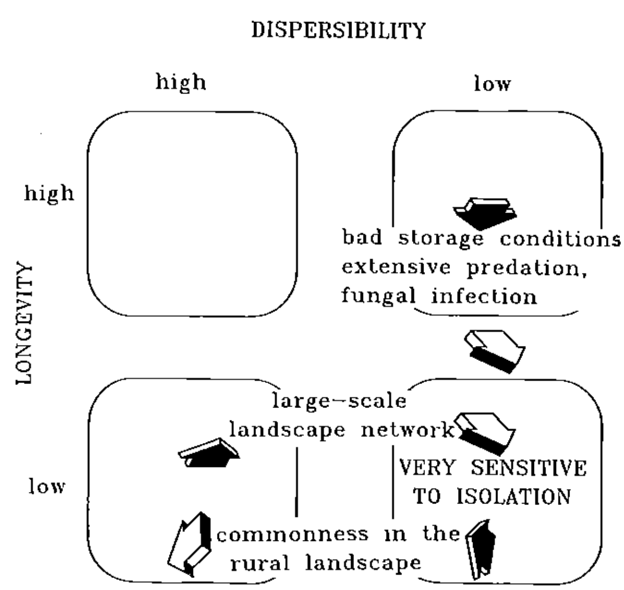

Fig. 3. Factors that may change the position of species in the tentative division into groups of plants based upon maximum dispersibility and maximum innate seed longevity.

For species with a long range dispersibility it is necessary to have an extensive reproduction capacity in order to obtain a sufficient possibility to reach all suitable habitats. Depending on the structure of the landscape and the distances to be covered between natural habitats a further differentiation must be made within the group of relatively good dispersers. In a large–scale network the distances to be bridged may be so large than an'ecological corridor' may be also beneficial for the latter group (Fig. 3). On the other hand species that are common in rural areas may not need 'ecological corridors', as the distances to be covered are commonly insignificant (Fig. 3).

To achieve conditions appropriate for well functioning habitats as well as 'ecological corridors' insight into the requirements of the various species to their environmentis necessary. This knowledge must subsequently be applied to provide favourable environmental conditions, e.g. in the ways of construction and management of road verges and river dykes (e.g. see MELMAN et al. this volume). Research groups in our ministery try to obtain such knowledge among other groups in the Netherlands. The demands in hydrology, nutrient availability and undisturbed space limit the possibility to create conditions necessary for all appropriate ecosystems in these linear landscape elements. For instance the width of many road verges may prevent the colonization of many woodland species and the hydrology and permanent input of nutrients and pollutants from traffic and fertilizer treatment in surrounding farmland do not tolerate the establishment of wet oligotrophic peatland in verges and dykes, maybe with the exception of some parts in the edges of junctions.

It remains however unclear whether the system of 'ecological corridors' will operate as desired. So far all evidence has been gathered from patternbased studies. There still is a great need for evidence obtained from process studies to assess the precise possibilities of road verges and river dykes.

While DARWIN (1859) concluded in his'The origin of species' that "there is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling onaccording the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved", we now have the task to take measures to save this grandeur and beauty in spite of all threats from recent human activity. A good management of linear landscape elements may be one of them.

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CHANGES IN GRASSLAND USE CONSEQUENCES ON LANDSCAPE PATTERNS AND SPIDER DISTRIBUTION

A. ASSELIN

Introduction:

The recent changes in Europeen Common Agricultural policy due to agricultural surplus (quotas for milk, decrease of the price of other products...) are changing agricultural systems at the farm and field level. Among these changes, total or progressive abandonment of less favoured areas are the most obvious in many countries (BRANDT & AGGER , this volume). In France, the notion of less favoured areas is extending from the Mediterraneen and mountain zones to regions with a traditionnally thriving agriculture. Normandy, where our study is being carried out, is an agricultural region based on dairy cows. Dairy products such as butter and wellknown cheeses (camembert), cider and Calvados are produced and have made this region very rich in the past. Permanent grasslands often planted with apple–trees or pear–trees cover up to 85% of agricultural land.

Ecological consequences of changes in grassland management have been studied by many authors (MORRIS 1971; DUFFEY et al, 1974). In "The Pays d'Auge" (Normandy), principal consequences are a decrease of stocking rate on certain grasslands and more arable lands are used to produce maize (*Zea mais*) or cereals. This is a beginning of changes and some grasslands are neglected:

- stopping of mowing ungrazed grass
- stopping of hedgerows, dykes, springs and drains management.

This is not a complete abandonment but a progressive process.

Nowadays, extensive grazing occurs in some farms with very irregular management of grasslands and hedgerows. A complete abandonment is expected at least in farms with important physical constraints.

A– PHYSICAL CONSTRAINTS:

The study area is typical of the Pays d'Auge. It is a plateau made of a calcareous and clayey material. In the upper part, calcium has been washed away. The plateau is cut by valleys with steep slopes. On the slopes, a layer of heavy clay is found under the calcareous clayey material. The abundance of clay creates problems of soil humidity. So grassland is the most appropriate land use.

B– CHANGES IN LANDSCAPE:

The consequences for the landscape of the region are development of patches of bramble (*Rubus fruticosus ssp.*), bracken (*Pteridium aquilinum*) and willow (*Salix sp.*) or rush (*Juncus sp.*) in wet areas. These patches become to be very numerous inside of fields or progress from hedgerows around them (Fig. 1). The landscape changes from a coarse grain (woodlots, grasslands) to a very fine grain landscape (patches of *Rubus, Pteridium, Juncus*,...). Patchy colonisation increases landscape diversity at the scale of few hectares.

Another important consequence for the landscape is the decrease of hedgerow and dyke network management. Hedgerows are not trimmed, so they become wider. From year to year, bramble progresses from hedegrows into fields. Dead elms, very abondant in this region, fall and make breaks in the hedgerow canopy. In this case, Rubus covers the ground till the center of the hedgerow and inhibits growth of any other plant specially forest herbs, so corridor function of the hedgerow for forest species desappears more or less.

C– BIOLOGICAL PATTERNS:

The taxonomic group of Araneae has been chosen as biological material to assess changes at the landscape level. Spiders are usually abondant in any landscape element and have a high position in the trophic chain exclusivelly predators, they feed of insects (80% of their preys)(EDGAR 1969; KAJAK 1971; NYFFELER 1982). Spiders are very sensitive to vegetation structure (DUFFEY 1962; GREENSTONE 1984) like birds which are usually used in landscape studies at a broader scale(BLONDEL 1983; FROCHOT 1987; FULLER et al. 1987; OPDAM et al. 1987). Spiders have to adapt to new environments and DUFFEY (1975) explains : "examples provide some evidence of sensitivity of spider associations to small–scale environment changes and the ability of many species to adapt to new situations or exploit new habitats almost immediatly they are created". In agricultural landscape, ploughing, mowing and grazing effects on spiders communities have been studied by many authors (SOUTHWOOD et al. 1967; DELCHEV et al. 1974; MANSOUR et al. 1983). The colonisation of areas by new species depends on their capacity for dispersal, on the one hand and on the proximity of the different habitats, on the other (HUHTA 1971). Many spider species have developped aerial dispersal behaviour (SOUTHWOOD 1962; YEARGAN 1975; VUGTS et al. 1976). In his studies on colonisation of a tidal habitat separated from the sea by damming, HEYDEMAN (1960, in HUHTA, 1971) shows evidence of dispersal of spiders by land.

Few studies concern the influence of landscape structure on spiders communities. Colonisation of arable fields by spiders coming from neighbour areas has been described(NYFFELER 1982; WEBB et al. 1984; LUCZAK 1986). Forest surrounding a clear–cut area may act as barriers for the dispersion of open–land species (HUHTA 1971). Species richness is more important at the edge of a field or a grassland than at the center (MAELFAIT et al. this volume).

How do spiders react to changes occuring in our landscape?

Sample area and method :

Spiders were sampled in a mosaic (65 ha) of 8 parcels of land (mixed woodlot, deciduous woodlot, mowed grassland, grazed grassland, abandoned grassland) which are separated by hedgerows, tracks or roads. Spiders were sampled by visual search in quadrats of two square meters during 6 months (only cumulated results of February and March 1987 are presented here). 26 sampled areas were chosen: the center of each parcel and in bramble patches, on their edges and in some hedgerows.

In the first year study, the mosaic was chosen as to stay on the same type of soils and it should enable us to:

–understand species exchanges between adjacent areas (woodlot/grassland, hedgerow/abandoned grassland,...)

–understand consequences on spider assemblages of the development of very fine grain landscape elements.

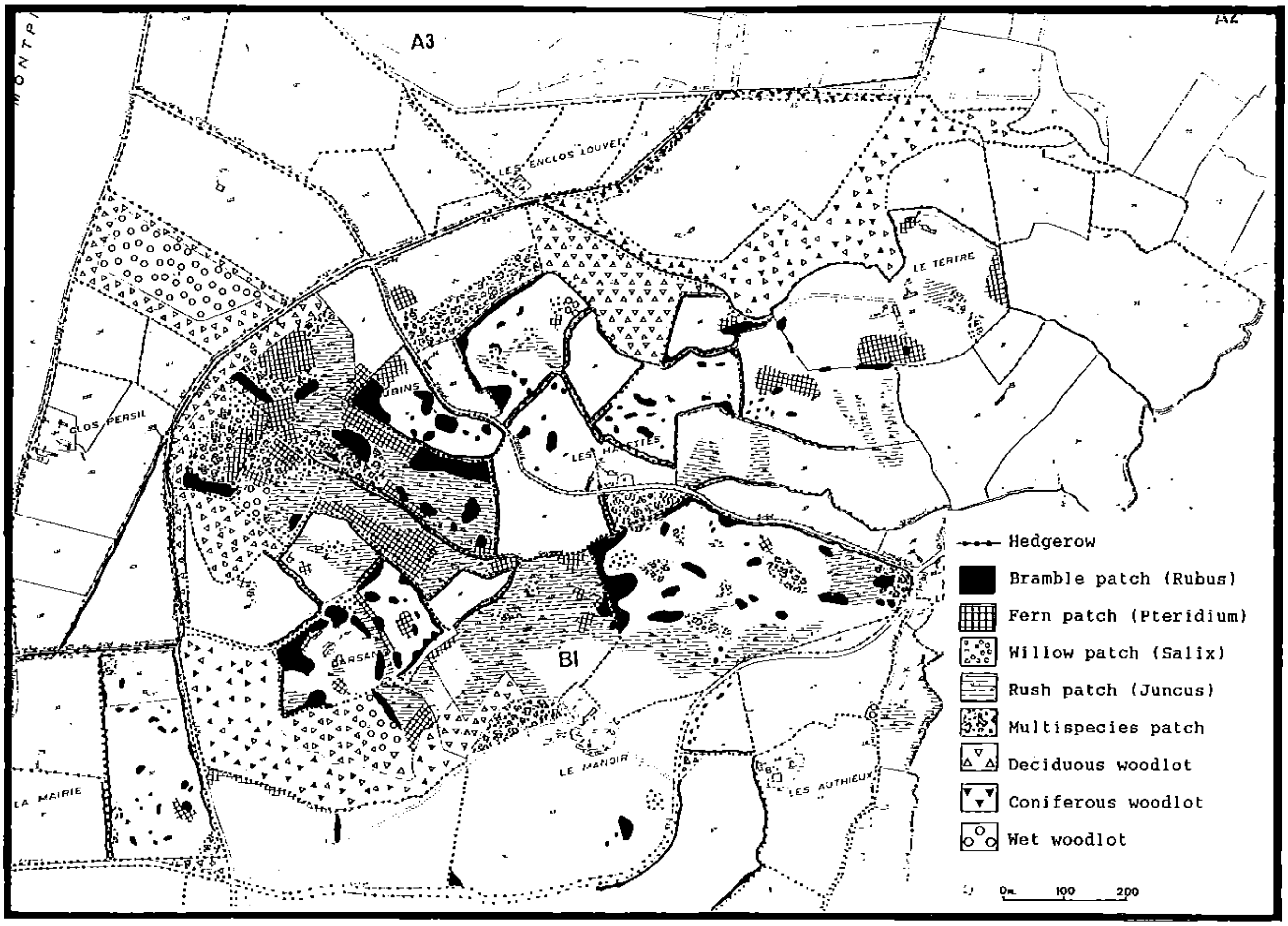

Fig. 1: Landscape map

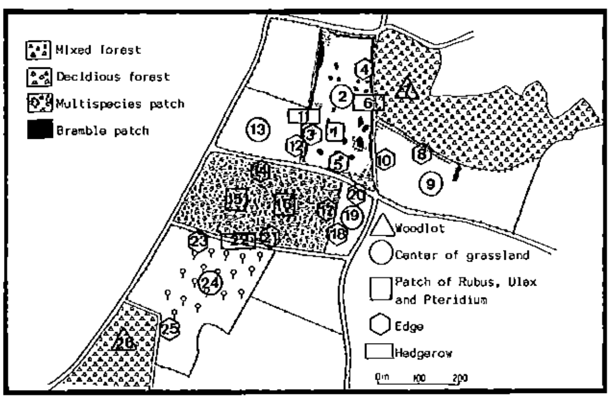

Fig. 2: Sample mosaic

Results:

Correspondance analysis (JAMBU et LEBEAUX 1978) was chosen to analyse relations between sites (the 26 samples) and spiders (69 species)(Fig. 3). This method is appropriate to study environmental gradient (AUSTIN 1985).

On the first axis of the correspondance analysis, grassland samples are isolated from the others : spiders species of grassland (grazed pastures and meadows) are very different from those of woods or oldfields. Determinant factors for axis 1 seems to be the height of vegetation (according to the great sensitivity of spiders to vegetation structure).

On the second axis, two samples (one hedgerow and a grassland edge) are isolated. On the third axis, woodland stations are separated from oldfield stations. Edges samples are gathered at the intersection of axis 1 and 3 (Fig. 3).

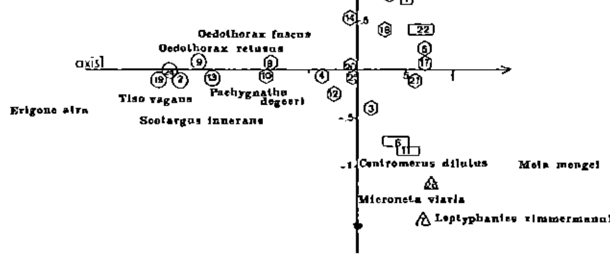

Fig. 3: Samples and species on the plan of axis 1 and 3 of of correspondance analysis.

Interaction among landscape elements :

This preliminary analysis allows us to see examples of neighbourhood effects on species composition:

Species composition of grassland edges number 25 is affected by the contiguous wood number 26 and species composition of the second edge number 23 is affected by the oldfield number 16.

Hedgerow spiders assemblages are influenced by the nature of connected uncultivated elements:

- the woodlot number 7 for the hedgerow number 6 or 11
- the oldfield numbers 15, 16 for the hedgerow number 22.

We assume these effects are due to species movements among landscape elements.

Effects on species richness : (Fig.4)

Species richness increases gradually when samples of the different parts of meadow are added to oneanother. Development of patches of Rubus (due to changes in agricultural practices) affects species richness too.

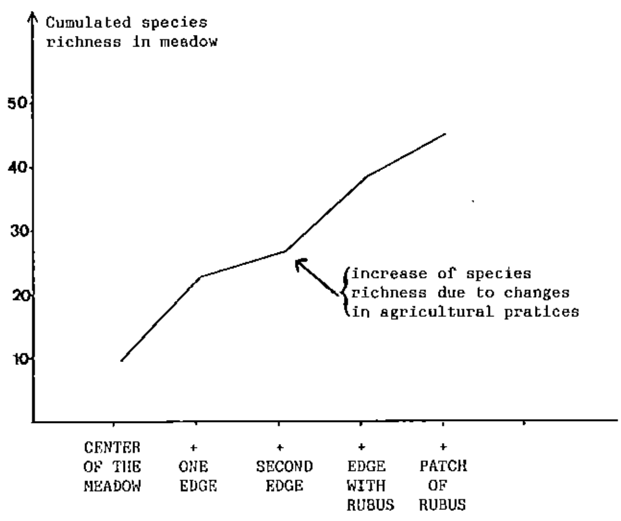

Fig. 4: Effect on species richness

Conclusion :

Spiders are very sensitive to vegetation cover and landscape structure. Contiguous and connected landscape elements affect species composition of grassland edges and hedgerows. Biological functioning (connectivity) is directly relatable to connectedness in this mosaic (BAUDRY & MERRIAM , this volume). Changes in agricultural practices influence species richness.

Discussion – Questions :

Patchy colonisation of bramble, bracken,... increases landscape heterogeneity. We hypothezise that this mosaic landscape illustrates changes in agricultural practices before conversion to another land use or abandonment. This is an intermediate stage. Many questions are araising :

– How will the landscape change in the next few years if agricultural trends are the sames ? What would be the differences with a complete abandonment ?

DUFFEY E. et al (1974) explain :"The mosaic situation of patchy scrub, where there are grassland, edge and woodland species, may persist for variable periods of time especially where the soil differs locally in depth and nutrient status, and where there is interference by man in cutting, burning or by the grazing of domestic animals".

– What is the speed of colonisation by Rubus and Pteridium ? Development of Rubus in hedgerows till the center inhibits corridor effect for forest plant species. How Rubus or Pteridium patches affect colonisation by other species?

– What is the global trend of species richness at landscape level?.

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DYNAMICS, INTERACTIONS AND CONNECTIVITY OF LINEAR ELEMENTS IN RURAL LANDSCAPES OF CENTRAL BELGIUM. PLANNING OPPORTUNITIES.

H. GULINCK, I. VANDEN BERGHE, E. ABTS

Introduction

The interfluvia of the Central Belgian loess region are gently undulating landscapes, essentially cropland, and characterized by a loose network of semi–natural, more or less overgrown benches (steep colluvial taluds) and sunken roads. These linear elements are genetically linked to the topographical structure and to the evolution of the agricultural land structure.

The benches and sunken roads are varied considerably in length, orientation, vegetation cover and physiographic structure. Sunken roads may be envisaged as two opposite steep benches. In the study area, the benches vary in depth and width from a few decimeters to more than 15 m.

Spatially, these elements are part of a complex of superimposed networks of different kind, scale and connectivity. One should consider the total road pattern, the field parcellation, the land use pattern and the topographic structure with associated flow patterns and erosion features.

From a systems point of view, sunken roads and benches are to be considered as parts of an agricultural system (transport), a geomorphological system (relief elements, run–off, erosion and sedimentation) and a biological system (habitats and corridors). It is worthwhile to stress the fact that the concept of connectivity applies to each of these system approaches.

The landscape elements mentioned are threatened by several factors, such as the dutch elm disease, changes in rural transport, field consolidation, and loss of adapted maintenance practices.

This paper gives an overview of the different structures, functions, dynamics and interactions which should be considered in order to obtain a landscape–ecological understanding of sunken roads and benches. This understanding may lead to the development of solutions for the acute problem of erosion, sedimentation and flash–flooding, in such a way that simultaneously an improvement of the agrofunctional and of the biological structure of landscapes is achieved. At the same time it gives an opportunity to make reflections about the possible meanings of connectivity in the practice of landscape planning and management.

Figure 1 depicts the localisation of the study area at two geographical levels. Level A covers the 1:50,000 map sheet n 32 of the national topographic survey (640 km^2), level B is a hydrographic basin of approximately 1.5 km^2. Figure 2 is a map of the main linear features and the general land use.

Landscape evolution

A grid with cells of 0.42 km^2 was laid over the 1908 and 1986 topographic maps of the study area (level A in Fig. 1). Within each square the total number of benches was counted, as well as the number of "active" benches (i.e. in arable land). In a time span of more than half a century, the number of active benches has decreased with 28% on the average, mostly because of changes to urban land–use. Actually there is an average density of 0.5 km/km^2 of benches in the agricultural area. In another study over the same region, the density of sunken roads was equally estimated at 0.5 km/km^2. In contrast with the relative stability of the overall pattern of the major sunken roads and benches, the parcellation has evolved very strongly. Using aerial photographs and field surveys, a comparison of 1947 and1986 could be made for the level B study area. Here, the average parcel size has risen from 0.75 to 3 hectare.

According to interviews with older farmers, there used to be a network of shallow parcel separating furrows. For 1947, the total volume of these furrows can be estimated at about 15 m^3/ha. In 1986 this volume is less than half that figure. Furthermore there were a lot of low benches between parcels, not depicted in the older topographic maps and hardly visible on the older air photos. There were also well maintained diversion ditches within fields. This earlier structure accounted for a limited retention of rainfall, but certainly helped diverting run–off water from scouring erosion gullies. Aerial photo comparison reveals a doubling of the total gully length (gullies deeper and wider that approx. 25 cm) over the same time period.

The land–use itself has not changed substantially. But depletion of organic matter, better weed control and higher mechanic pressure are some of the important factors that have contributed to an increase in soil erosion.

Decay of linear elements

In recent years, a deterioration of the sunken roads and of the taluds is manifest. This decay is essentially erosional : gullying of the road bases, mass movement and ravining of bench slopes. The reasons are manifold and will be discussed briefly.

Most elms, which made up half of the high vegetation in many sunken roads have been killed by the dutch elm disease. Often, the sites of the elms are nowadays subject to severe erosion. Research is under way in order to assess with greater precision the impact of the dutch elm disease.

The changes in agricultural practices have also brought more physical pressure on the linear elements. The general increase in soil erosion has also negatively affected the hollow roads and the benches. Many hollow roads have become deeper by the gullying of their beds, and the access to adjacent fields has become more difficult.

In former times, the benches were subject to a more or less regular coppice or mowing regime, with regular repair of vegetation damage. Nowadays, the maintenance is more irregular, and the methods are rougher (burning, bench cutting by heavy machinery, etc.). In some cases there is a total absence of maintenance, which allows for some trees to grow to an intolerable weight on the steep benches, fertilized by run–off water from the adjacent cropland.

Most of the narrow elements (small furrows and low benches) have disappeared because of the general enlargement of the fields.

Research topics

From these observations, it can be deduced that the landscape ecological study of the linear elements has to focus on three approaches:

a) an agrofunctional approach; b) a biological approach; c) a hydrological and geomorphological approach. In the agrofunctional approach, special attention has to be given to the transport and traffic patterns with which the linear features are spatially associ-

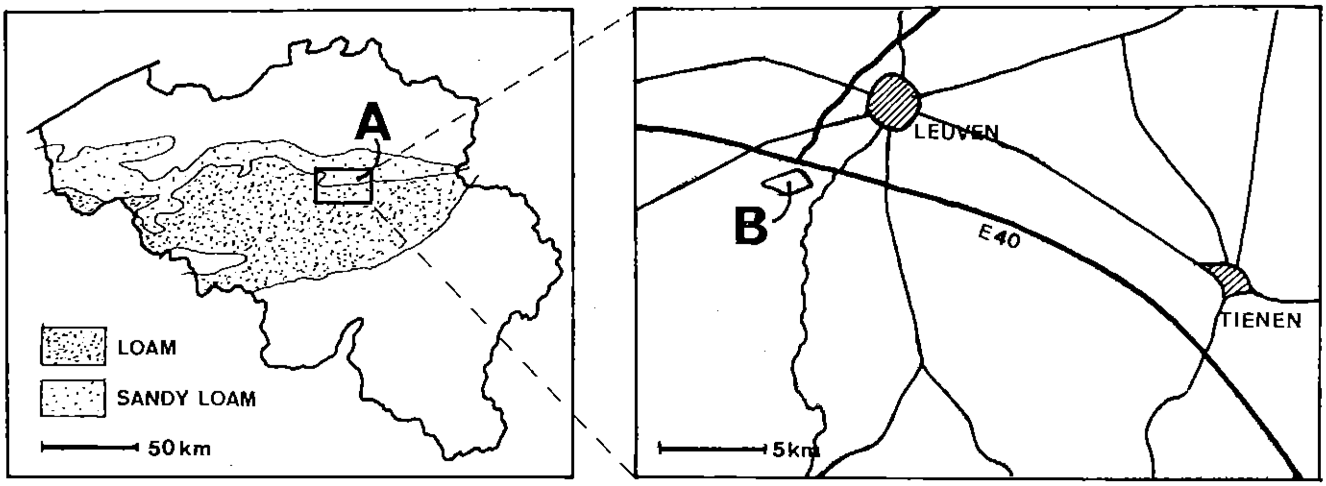

Fig. 1 : The study area (A and B : see text)

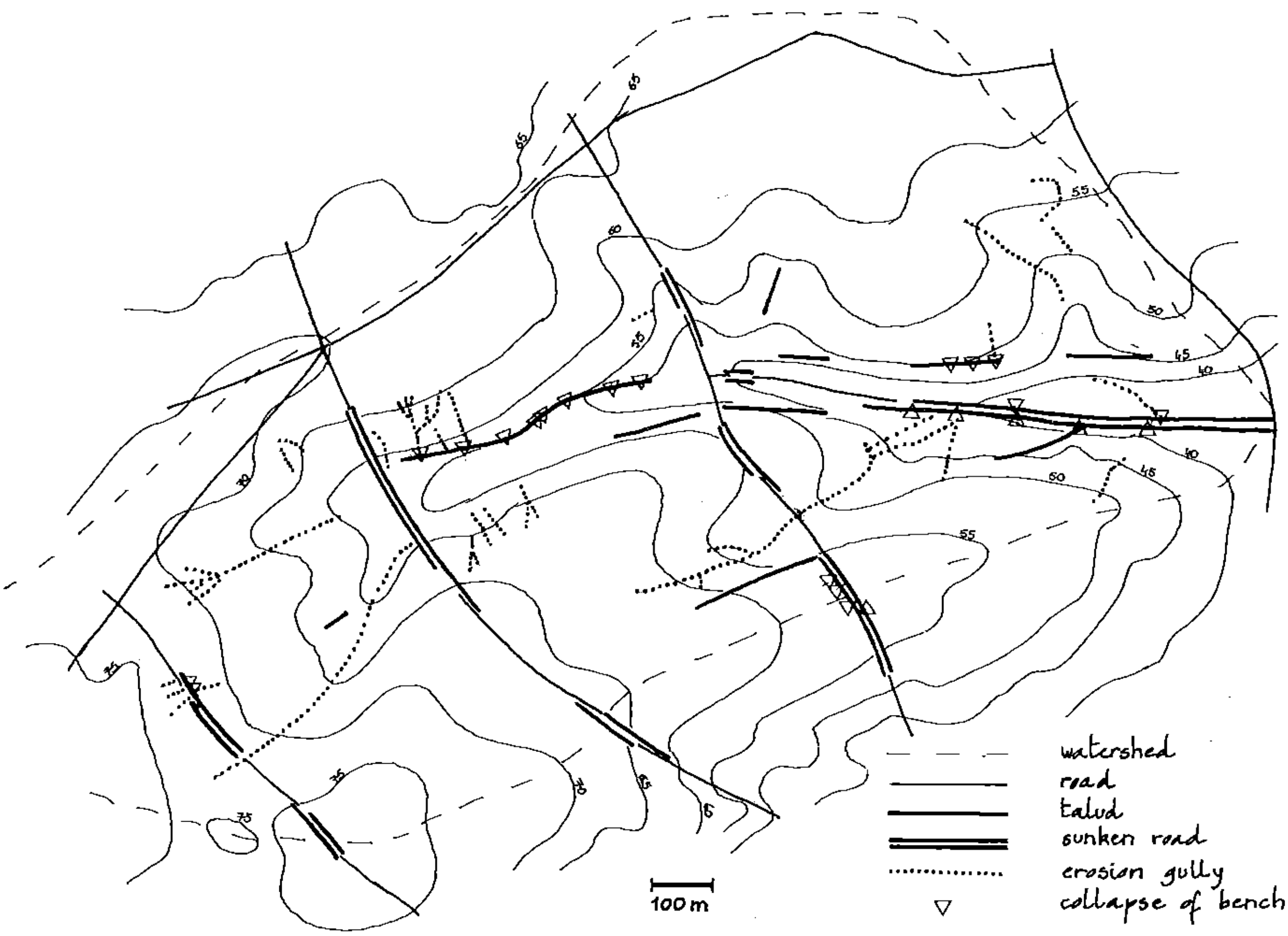

Fig. 2 : Topography, sunken roads, taluds and main decay features in the level B study area

ated. Within our test area, limited information is available so far, but a study is planned in order to assess the impacts of the changing agricultural practices and conditions along these patterns.

In the biological approach, the analysis of the structure and the evolution of the vegetation is necessary. A study of this kind is also envisaged. Furthermore it would be important to study the ecology of the fauna and the role of the linear elements as habitats or corridors. Especially the burrowing species in the benches deserve attention, since the erosion of certain sites may indeed be attributed partly to these species.

Our research has focussed so far on erosion and sedimentation patterns as influenced by linear elements in the landscape. The fallout 137Cs, a result of atomic experiments in the 50ies and 60ies, and of the Chernobyl accident in 1986, can be used as a precise tracer for the movement pattern of the topsoil, since it absorbs tightly on illite clay. A relative increase in 137Cs is an indication for soil sedimentation. So, the impact of linear elements can be measured. At certain places, the vegetated taluds account for the retention of as much as 30 ton of soil material per ha per year (VANDEN BERGHE, et al., 1987). Eventually a spatial model will be developed, incorporating the impacts of not only climatic, edaphic and topographic patterns, but also of the spatial pattern of linear elements and other discontinuities in the landscape.

Landscape Planning

Besides damaging the crops and the topsoil, excess run–off is also responsible for occasional muddy flash–floodings in the valleys. As such, the landscape–ecological consequences of changes in the agricultural uplands escalate into physical, economic and political problems for many municipalities in Central Belgium.

There are different alternative policies thinkable : –A drastic reduction of erosion of the cropland by using alternative (conservation) tillage techniques, or expanding the area of permanent cover (grassland, forest). For economic, political and psychological reasons, such solutions are only possible in the long run, but they deserve attention in the changing agricultural contexts. The impacts of conservation tillage on run–off, infiltration and soil structure have to be carefully investigated, as well as the environmental impacts of the eventual increased use of herbicides.

– Technical solutions in the valleys such as relatively large retention basins. This alternative does by nomeans deal with the causing factors in the interfluvial landscape, and are generally rejected by nature conservationists.

– Solutions which are taking into consideration the landscape structures such as roads, linear elements and pattern of land–use. The solution we propose here are variants of this policy.

In a'minor intervention' proposal, the interferences are restricted as much or as close as possible to the public domain, with minimal interference in the agricultural fields (fig. 3). This proposal is essentially limited to the conservation, strengthening and management of existing structures and to the construction of afew retention basins and dams, distributed at appropriate sites in the landscape. Such a scheme could be realized in a short time.

In a 'major intervention'proposal, a much further elaborated restructuring is envisaged (fig. 4). Here, not only the immediate need of stormwater buffering is envisaged, but also the following objectives, which give a practical example of a possible expansion of the connectivity principle :

– improvement of the agricultural structure through land consolidation and new communication lines (optimization of agricultural connectivity) ;

– establishment of an ecological infrastructure with higher connectivity than the actual one, along the agricultural infrastructure and the surface drainage structure : the hollow roads, benches, old and new road verges, green waterways and extensive land– use patches are parts of a potential new network (connectivity of functions and of different network types);

– creation of a spatial and functional flexibility within the rapidly changing economic and social conditions in agriculture and in rural areas. Similar polyfunctional restructuration proposals have been illustrated by BUREL (1984) for agricultural areas in Brittany.

Conclusion

The overgrown linear elements of the agricultural landscape in the loess covered region of Central Belgium and in similar landscapes elsewhere are subject to different deterioration factors. Instead of dealing directly with their conservation or with the objective of enhancing their connectivity for bio–ecological reasons, it is useful to investigate their total landscape–ecological role. It becomes clear that a landscape–ecological planning asks for a spatial integration of the agricultural, hydrological, geomorphological and biological functions. These functions are spatially expressed as networks of different kind. The urgent problem of soil erosion and flash floodings is an opportunity to develop planning proposals in which these networks can be redesigned and in which the connectivity of landscape elements and networks plays an important role. Doing so, it is possible to keep in balance the roles the different political and social partners (municipalities, farmers,...) have to play and to take into consideration a flexibility in land–use and landscape planning, given the rapid evolutions within agriculture and within rural areas.

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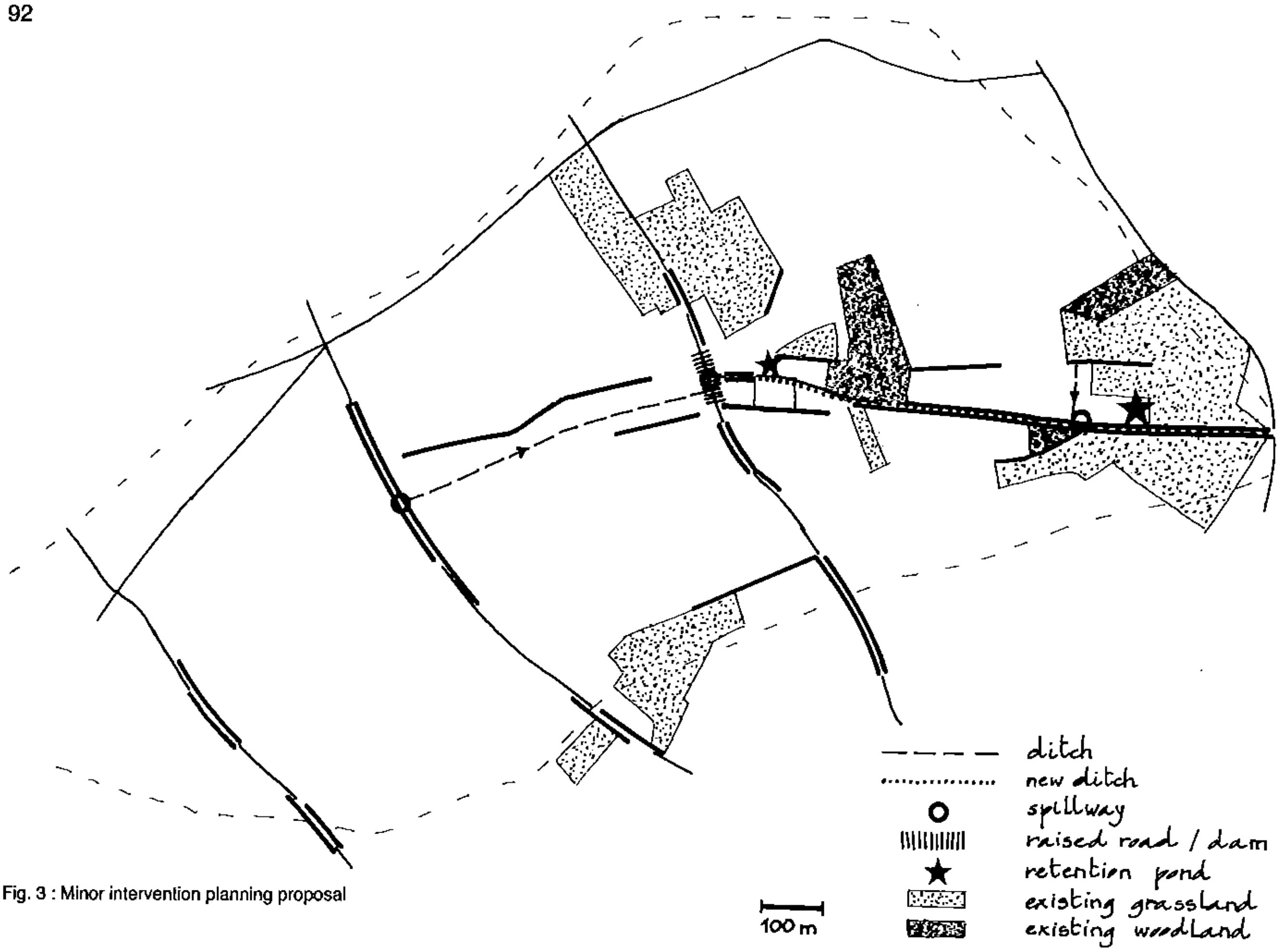


Fig. 3 : Minor intervention planning proposal

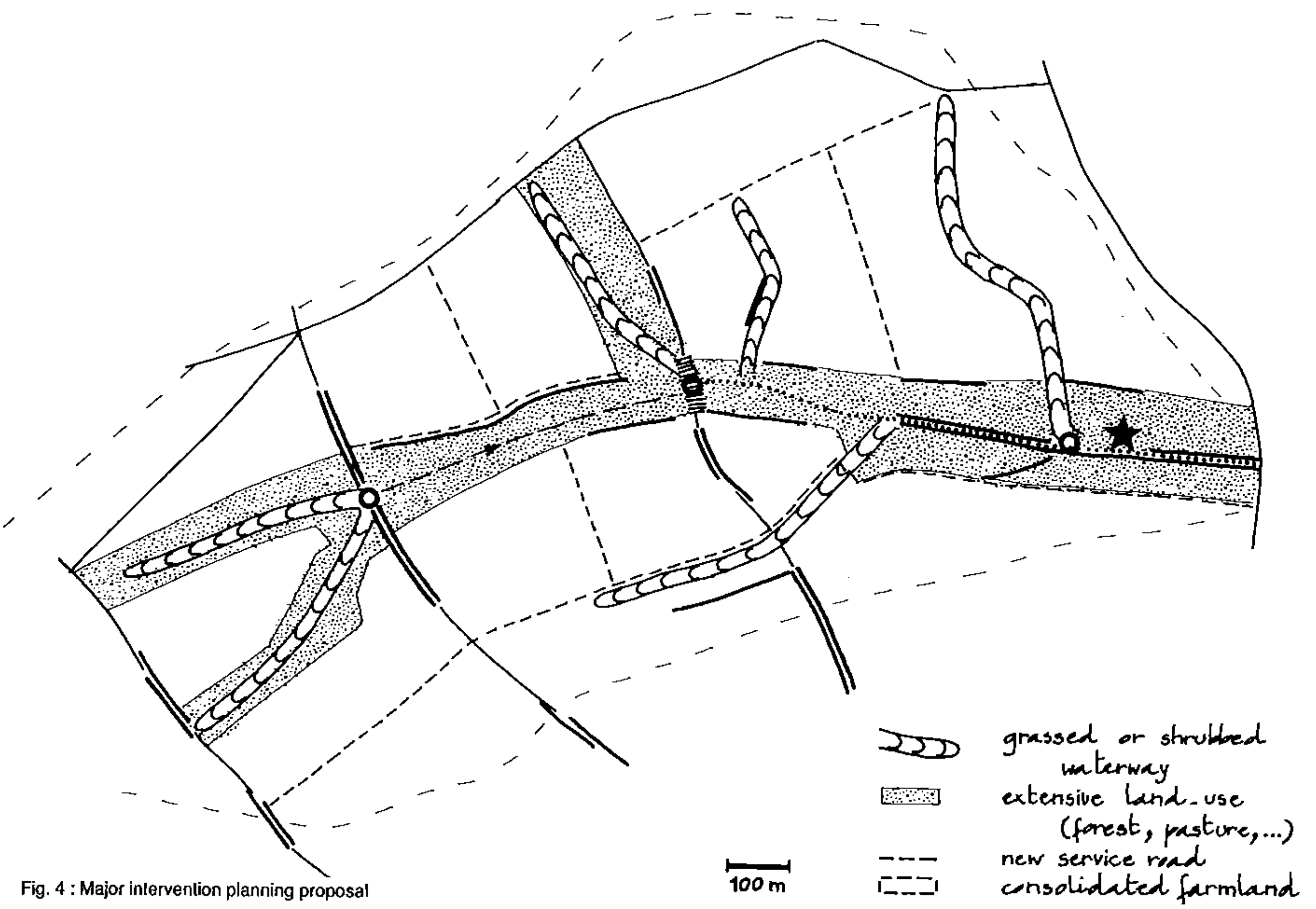


Fig. 4 : Major intervention planning proposal

A METHOD FOR THE DEVELOPMENT OF ECOLOGICAL INFRASTRUCTURE AT SPECIES AND LANDSCAPE LEVEL

A. VAN AMSTEL, B. SCHOORL, H. VAN DE VEEN

INTRODUCTION

For survival of animal and plant species specific habitat requirements must be fulfilled. Animals rely on the availability of food resources, shelter and breeding grounds, and plants require specific abiotic and biotic conditions. For dispersal all species must cross the more or less inhospitable interspace between optimum habitats.

In man-made or man-altered landscapes longterm survival of local populations of terrestrial organisms is dependant on possibilities for dispersion. But most species also use the interspaces as areas for feeding, shelter and breeding. Therefore the total ecological structure has to be taken into account in upgrading of living conditions. This ecological structure has to be in tune with the species requirements.

In a case study it proved to be possible to match the actual qualities and limitations of the landscape with the requirements of a set of selected threatened animal and plant species living in man-altered landscapes. This matching can in theory be done at any spatial scale. It may result in recommendations for upgrading of the ecological infrastructure.

In this study information has been collected on the actual conditions of the land in soil, water and vegetation in a study area of about 50 km, in the eastern part of The Netherlands. Information has also been collected on the historical and actual species distribution. Seventythree threatened but not yet extinct animal and plant species have been selected. For these species autecological information on habitat requirements and dispersion processes has been collected from literature.

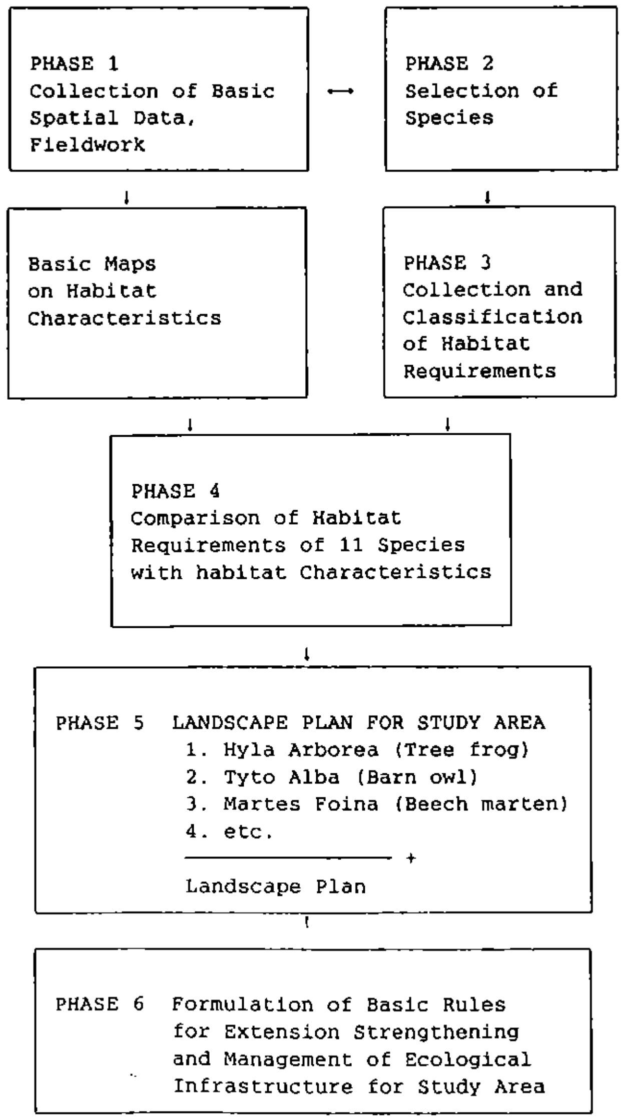
Matching of requirements of species with actual conditions of the land has resulted in a set of maps with locations for upgrading ofecological structure for the 11 most important species. Recommendations for upgrading of the total structure of the study area was another result of the matching procedure.

PURPOSE OF STUDY

In this study the concept of ecological infrastructure is applied at the operational level from a species and landscape perspective. This exercise is based on fieldwork and data from a reallotment scheme "Rossum-Oost" near Denekamp in the east of the Netherlands.

Location
of study area

OUTLINE OF STUDY



PHASE 1: COLLECTION OF BASIC SPATIAL DATA AND FIELDWORK in pilot study area.

Data are collected on:
- Species distribution
- Soil, Water and Nutrient Characteristics
- Habitat Characteristics of Vegetation Cover.

From literature:
Data are collected on
- Existing Knowledge on Study Area

PHASE 2: SELECTION OF SPECIES.

It is impossible to satisfy each species requirements in extension, strengthening and management of ecological infrastructure. But choises have to be made explicitly. Therefore in this study species are selected which are
- rare by international, national and regional standards.
- characteristic for the area.
- indicating special habitat characteristics.
- having crucial roles in ecological processes.

But the developed method is equally suited for the extension and strengthening of ecological infrastructure for other species. Selection is carried out using national and international census data on plants and birds, amphibians and reptiles and handbooks on species distribution.

PHASE 3: A CHECKLIST FOR HABITAT REQUIREMENTS.

A checklist of variables is made for easy structuring of information. For each variable classes are defined for easy comparison with habitat characteristics. For *Hyla arborea* for example this resulted in the given table:

HABITAT REQUIREMENTS OF HYLA ARBOREA (Tree frog)

VARIABLES	CLASSES
Soil	1 (3/5)
Moisture	4
Nutrition status of soil	3-4
Exposition to sun	1
to wind	1
Relief	2-3
Species composition of annuals	3
Cover	2-3
Hight	3-4
Pattern	2
Species composition of bush	1
Cover	2-3
Water dynamics	1
Volume	3-4
Salinity	1
Nutrients	2-3
pH	2-3

SELECTED SPECIES
49 Animal species and 24 Plant species are selected being rare, characteristic or having crucial roles in ecological processes. Habitat requirements of these are collected from literature.

For a selection of 11 of these species PHASE 4 is carried out, resulting in 11 maps of the study area with locations for extension and strengthening of ecological infrastructure and resulting in a landscape plan for the study area.These 11 species are:
- EARTH WORM (*Lumbricus terrestris*)
  Being basic food for many animals.
- WOOD MOUSE (*Apodemus sylvaticus)*
  Being basic food for carnivores.
- *TREE FROG (Hyla arborea*)
  Being threatened.
- BADGER (*Meles meles*)
  Being threatened.
- BARN OWL (*Tylo alba*)
  Being threatened.
- BEECH MARTEN(*Martes foina*)
  Being threatened but spreading.
- ORTOLAN (*Emberiza hortulana*)
  Being near extinction.
- KINGFISHER (*Alcedo atthis*)
  Being threatened and characteristic near brooks.
- OXLIP (Primula elatior)
  Being characteristic in woodlots.
- *PHYTEUMA SPICATUM*
  Being threatened.
- PURPLE HAIRSTREAK (*Quercusia quercus*)
  Being threatened.

PHASE 4: COMPARISON OF HABITATREQUIREMENTS WITH HABITAT CHARACTERISTICS

The collection of basic data resulted in a map of landscape units at a scale of 1:10.000. A soil map and a map of moisture status of soils at a scale of 1:10.000 were already available. From these maps a combined map of moisture and nutrition status of soils was derived. All these maps were used as basic information on habitat characteristics.

Comparison of habitat requirements on the abiotic environment of 11 species with soil map and map on moisture and nutrition status of soils resulted in 11 maps with suitable and unsuitable places for each species.
—Unsuitable areas on abiotic criteria are locations where requirements cannot be met but interventions in soil and moisture can sometimes be carried out to adjust the abiotic environment to the species requirements. Very often, however, these interventions are too expensive. For example soils which totally lack calciumcarbonate cannot be limed for ecological reasons.

Suitable areas were looked at more closely.

Comparison of habitat requirements of 11 species with the landscape unitmap resulted in suitable and unsuitable areas on biotic criteria (as for example vegetation structure).
—Unsuitable areas on biotic criteria are potential locations for extension of ecological infrastructure for that species.
—Suitable areas on biotic criteria are potential locations for strengthening and management of the ecological infrastructure for that species.

PHASE 5: LANDSCAPE PLAN FOR THE STUDY AREA.

Combination of recommendations on 11 species maps resulted in a landscape plan for the study area.

Analysis based on autecological literature learned that surprisingly little conflicting requirements were met.

PHASE 6: FORMULATION OF BASIC RULES FOR EXTENSION, STRENGTHENING AND MANAGEMENT OF ECOLOGICAL INFRASTRUCTURE.

PHASE 1 to 5 resulted in locations for action. In PHASE 6 general recommendations are given for the support of the chosen 11 species for the study area. Potential conflicts with requirements of the total set of selected 49 animal species and 24 plant species were analysed.

CONCLUSIONS

With the method it proved to be possible to select threatened and characteristic species for the pilot study area for which extension and strengthening of ecological infrastruture was necessary.

In the method for strengthening and extension of ecological infrastructure the whole spectrum of ecological requirements of species has been taken into account.

The method resulted in a landscape plan for the pilot study area. This plan stated locations for extension and strengthening of ecological infrastructure for 11 selected species.

Recommendations for technical measures for improving living conditions and dispersion of populations of the selected species have been taken from literature.

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THE SIGNIFICANCE OF PAVED AGRICULTURAL ROADS AS BARRIERS TO GROUND DWELLING ARTHROPODS

H.–J. Mader

1. Introduction

Man–made linear structures like highways, channels or railroad–tracks hamper the movements of small mammals and epigeic arthropods in forest ecosystems (OXLEY et al. 1974, MADER 1979, MADER & PAURITSCH 1981). Additionally, they take a share in the process of growing insularisation of unused and seminatural habitats. In modern agriculture narrow field–tracks are replaced by heavyduty paved agricultural roads. This process is frequently accompanied by the reduction of landscape structures, which have been associated with fields–paths in previous times, such as hedgerows , verges or ditches. Very little is known about the effects of paved agricultural roads on the movements of epigeic arthropods in agroecosystems (HEIDT 1986).

2. Methods

Wolf spiders (Lycosidae) were caught in the field and released on different types of agricultural roads in March to May 1987 near Bonn (West–Germany). The movements of the released animals were record ed and analysed. Before starting the field–experiments, it seemed necessary to study the phototaxis of the test organisms. The light–orientation of the spiders was tested in a darkened laboratory using a single point light source in opposite position (FIG.1). The results show a significant orientation towards the light . Consequently the field experiments had to be conducted with the sun positioned in direction of the road only, thus limiting the experimental time each day to a one–hour periode.

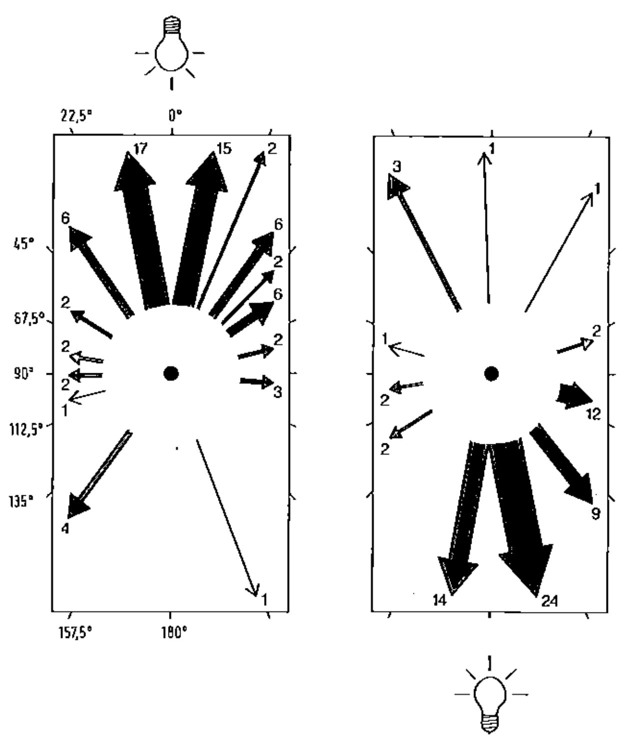

Fig. 1 : Light–orientation of *Lycosa amentata* in a darkened laboratory using single–point light sources. Animals were released in the centre of the test–area. The width of the arrows corresponds to the number of animals reaching the edge of the test–area within a certain segment.

A single animal was released from a black jar with openings at the top and its movements were recorded on a map before starting the next animal. The time was measured from release until the animal reached the verge. The area of observation was limited to 3 m up and down the road. In each test at least 12 animals were caught and released consecutively.

3. Results

3.1 70 Wolf spiders (*Lycosa amentata* (Clerck)) were released on a paved agricultural road of 270 cm width. The animals were set free at a distance of 40 cm from the road verge on both sides of the road. The animals show a significant tendency (= 41.6, $p < 0.01$) to rush to the nearest road–verge in stead of crossing the road or staying on the road (FIG. 2). The average

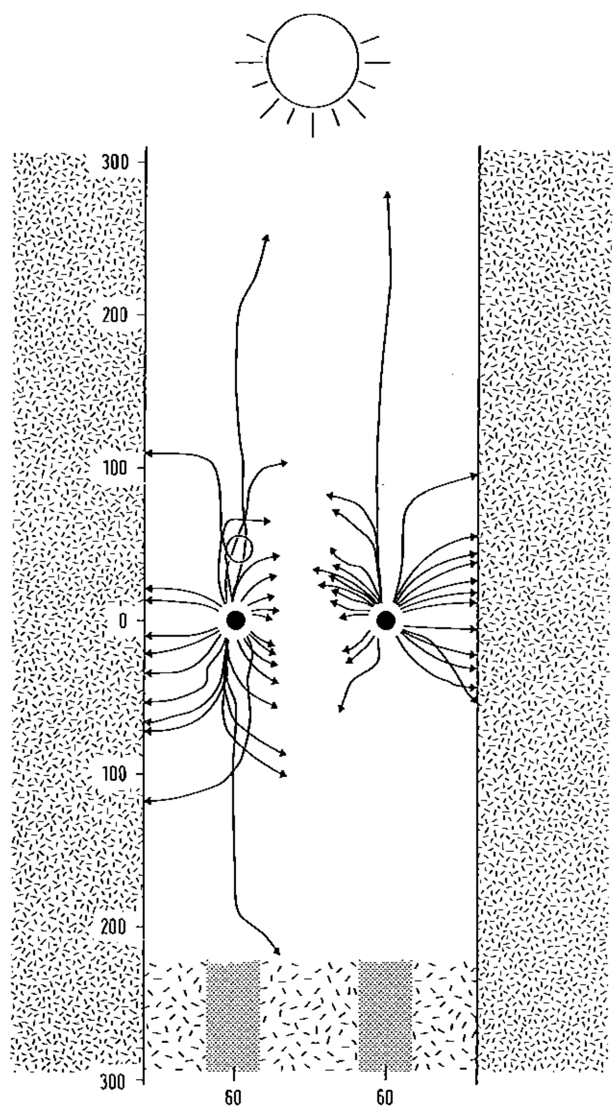

Fig. 2 : Mobility diagram of n = 70 spiders released on a paved agricultural road . 50 % of the animals were released near (40 cm distance) the left roadverge and 50 % near the right road–verge.Arrows indicate the actual movements of the animals.

time from release until the animals reached the verge was 42 sec. Most of this time was spend for initial orientation immediately after release while the animals kept their position motionless.

3.2 Spiders (n=52) released on an unpaved agricultural road with a central green vegetational strip showed no significant attr action towards the nearest road verge. On the contrary, a high percentage of animals rushed to the central vegetational strip (FIG. 3).

3.3 Lycosid spiders inhabiting the verges of an agricultural road driven away from their habitats into the road to a distance of at least 20 cm returned to the roadside vegetation immediately. From a total of 30 experiments not a single specimen forced out of the verge crossed the road (FIG. 4).

3.4 Ground–foraging wolf spiders are easily to be observed in the early spring season, when the vegetation is still low. Men moving through the habitat of a spider population will notice the animals rushing away from the origin of disturbance. In a homogenous situation without agricultural road (control), those animals observed to the right of the advancing disturber will usually move to the right, those on the left side will escape to the left. On a roadverge of 2 m width, parallel to an agricultural road , inhabited by a dense population of *L. amentata* (Clerck) the reaction upon disturbance was tested and compared to the control situation. The directions, the an imals choosed for escape were recorded in the field for each animal observed and pooled into two groups, i.e. the animals observed to the right and the animals observed to the left of the advancing disturber. The animals closer to the agricultural road showed a strong tendency to move towards the source of disturbance, away from the road (FIG.5). This behaviour is in sharp contrast to the control situation. It seems that the animals try to avoid to be driven to the edge of their habitat or even into the agricultural road (see 3.3 above).

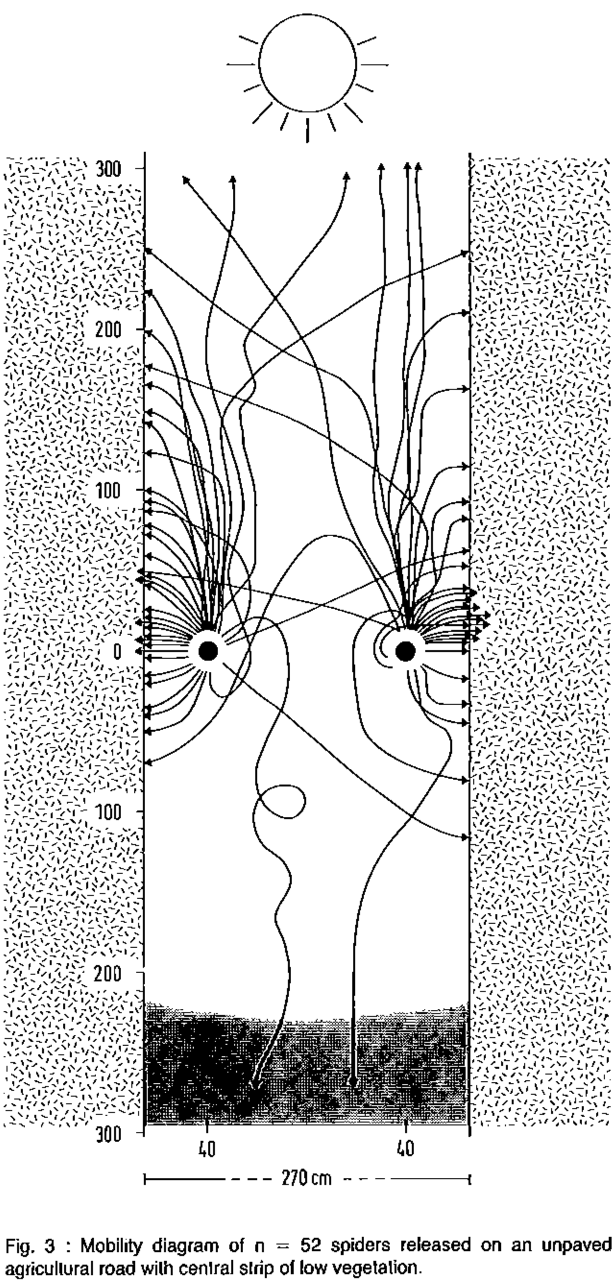

Fig. 3 : Mobility diagram of n = 52 spiders released on an unpaved agricultural road with central strip of low vegetation.

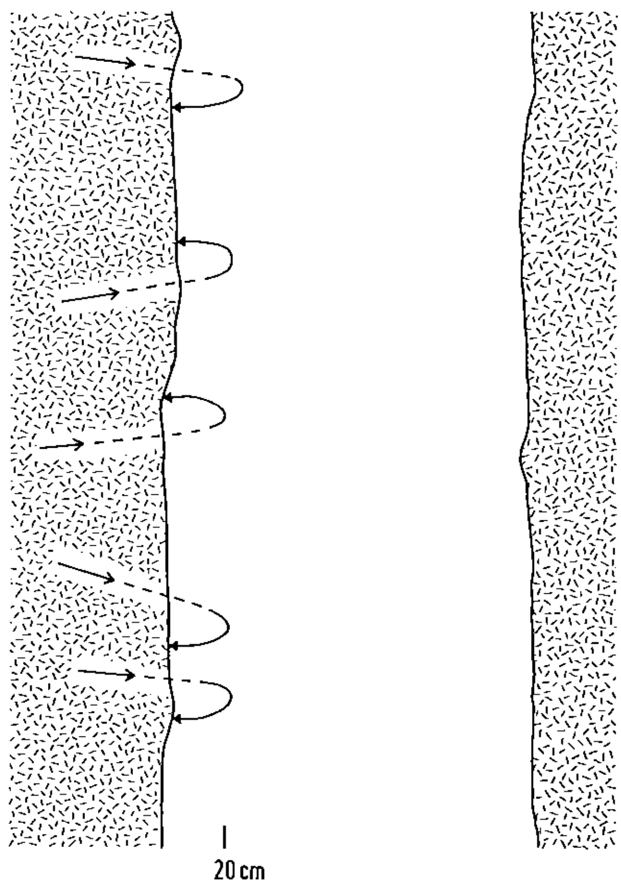

Fig. 4 : Movement of spiders (arrows) driven out of their road–verge habitats into the agricultural road.

4. Discussion and Conclusion

In intensely used agricultural fields, many epigeic arthropods are restricted at least part of their life to small marginal structures such as road verges, field boundaries, hedgerows, or woodlots.

Paved agricultural roads seem to be obstacles to the movement of ground dwelling arthropods in arable landsapes. This may enhance the process of increasing dissection of the agrocoenosis and reduce the possibilities of species to invade the adjacent fields. Very little is known about the influence of predators such as Carabid beetles or Lycosid spiders on prey populations in arable fields.

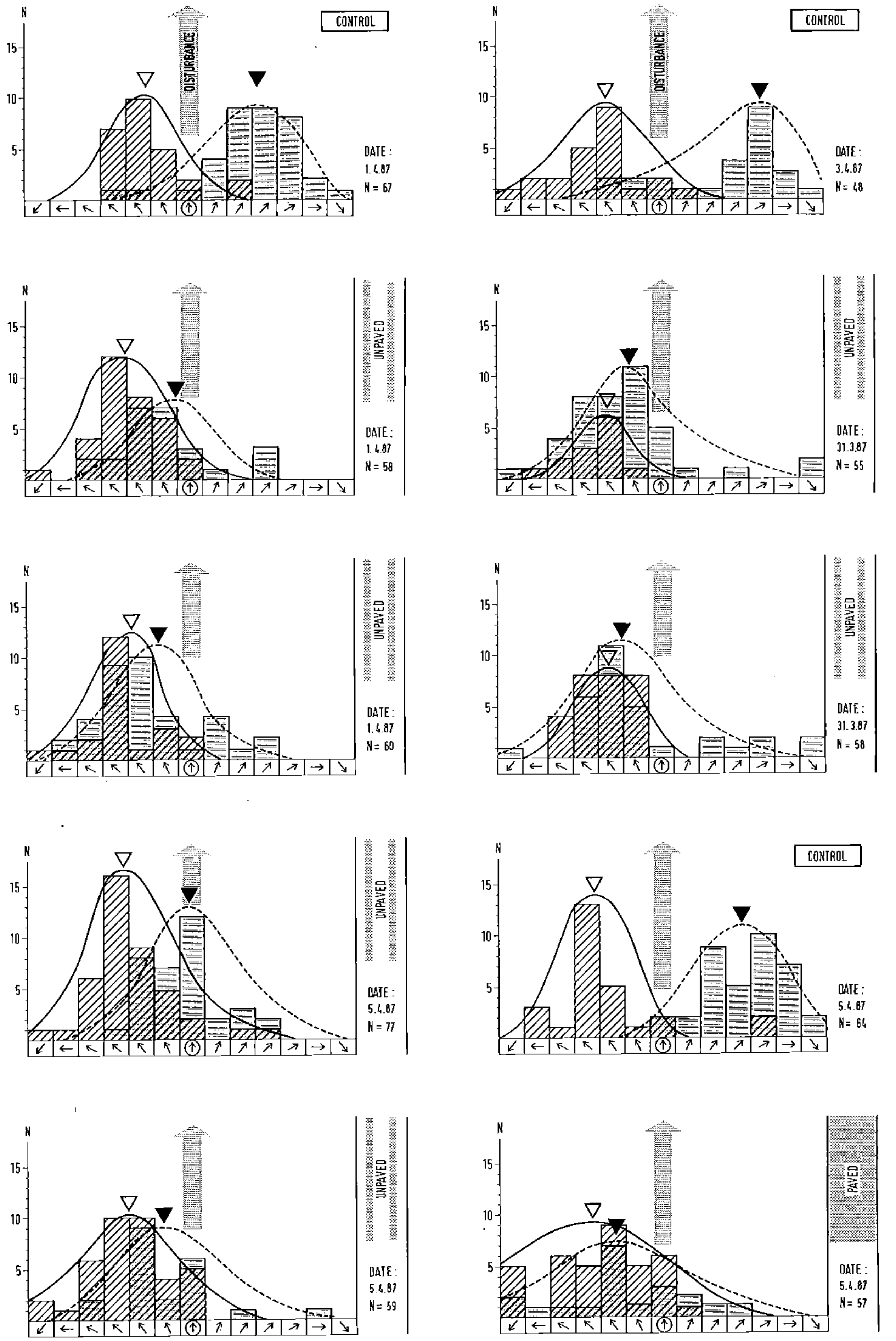

Fig. 5 : Frequency distribution of escape–directions of wolf spiders disturbed in their road–verge habitats by man slowly walking through it.Animals to the left of the disturbance: dashed columns, solid line ; animalslo the right (near the road): dark columns, broken line. Notice dark triangles indicating cating the average escape–direction of the animals close to the road in contrast to the control. Escape–directions Indicated by arrows below the columns.

However, there is evidence that field boundaries serve as reservoirs of predatory arthropods (MADER et al. 1986, MORRIS & WEBB 1987, WRATTEN 1987) and that overwintering polyphagous insects benefit from such landscape structures (SOTHERTON & RANDS 19 87).

Concerne is growing about an overall impoverishment of self–regulation within agro–ecosystems and the possible consequences and longlasting effects of the misuse of agrochemicals. We know that Carabid beetles and Lycosid spiders are good dispersers. This is especially true for field species (Den BOER 1970, RICHTER 1971). Nevertheless, it is obvious, that agricultural roads cannot be neglect ed as barriers against the day to day movements of the terrestrial arthropods in habiting road verges. Planning of agricultural roads and associated field boundaries should include these arguments.

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AN APPROACH TO ECOLOGICAL RESOURCE MANAGEMENT

S.Toch

Conflicts between economic development and natural resource conservation frequently lead to tensions between local development interests and broader collectivevalues. This often results in alienation of local support for resource conservation that may in fact be beneficial to long term community development.

An integrated management approach is needed that addresses local community concerns while maintaining the sustainability of the natural resource base. The utilization of components in working models of resource maintenance can provide a more applicable approach to build upon. As such, certain management strategies in the Ile–de–France or Paris Region are described in order to illustrate an approach that may serve as a bridge between resourcdevelopment interests and conservation objectives.

THE FRAMEWORK

No human population can be expected to adequately consider environmental effects if their resource needs and interests are not sufficiently addressed. No ecosystem can be expected to support human use and settlement if taxed beyond its capacity to sustain itself. Thus, the sustainability of an ecosystem must include the viability of the human population within it, while maintaining the integral natural functions that allow for its survival. Conservation programs need to work with the development interests of the local community and development needs to consider the sustainability of the natural resource base. Conservation and development must be convergent and not conflicting goals.

It could be stated that ecological development is a challenge, a conceptual and operational challenge. Part of this challenge is the management of fluctuating changing and evolving systems that account for ecological functions while maintaining for human resource needs. OLMSTEAD (1970) suggested a systems approach to understanding the viability of an agricultural model and its relationship to its surrounding environment . This concept is demonstrated by a series of overlapping circles representing the connectivity between the individual components of an ecosystem. These include natural, political, social and economic issues.

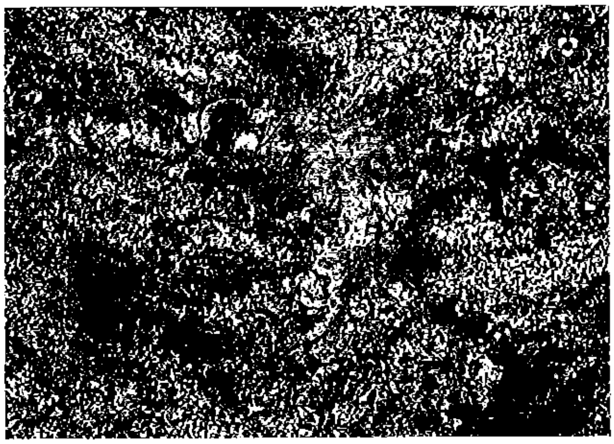
Indicators of ecological balance include air, water,and soil characteristics, as well as the health and quality of the vegetation, and the quantity, diversity and reproductive capability of the fauna. Also included are the maintenance of human basic needs, which include vitality and health, as humans are viewed as a component of the natural ecosystem.

We can benefit from Olmstead's model by identifying indicators of the socio–economic situation, as well. This includes the patterns of settlement in an area, the system through which the rights to use land are recognized, used or transferred and whether the economy is accomodating local, national or international markets. Other indicators may also be utilized as appropriate to the specific situation. By observing the levels of ecological integrity and the systems that influence the socio–economic situation, we can establish a framework for the application of relevent resource management strategies.

THE PROBLEM

The Paris of Ile–de–France Region is a major world metropolitan center with a population of approximately ten million people in 1987. It holds a history of rapid urban growth that has been accompanied by public works projects and new town development. It also contains an ecologically diverse environment thar includes land use transitions between agriculture, forest, wetland and developed areas.

In the early 1960's it was thought that the region's population would grow from 8.4 million in 1962 to a population of 14 million by the year 2000. This urban concentration and related development pressures posed a serious threat to the rural and agricultural communities. This created problems in open space preservation and a displacement people and jobs due to the rapid shifting of the landscape. The consommation of space through rapid urban development and resource utilization continued through 1987 despite a slowing population growth. As Paris is the center of the French population and economy, this rapid urban expansion came to be called the "tache d'huile" (AREEAR Ile–de–France, 1983), a drop of oil easily spread to the surrounding rural communities.



Paris–ile–de–France Region viewed from T.M. Satelite image, IAURIF, Environment and Open Space Division, April 30, 1984

THE RESPONSE

In an attempt to disperse some of the Paris population, efforts began towards decentralizing the French economy. Along with assistance to other French cities to develop economic potential, five new towns were initiated on the outskirts of the Paris agglomeration with an aim towards enhancing economic opportunities there. In addition, due to the diminishing rural landscapes, protection strategies were initiated that could preserve open space.

It should be noted that the development pressures stemmed from an urban population and the problem of diminishing open space has been largely framed in terms of the perception of an urban community that was well represented in the governing process. In order to maintain a balance between the conservation of resources and the problem of urban expansion, the response of thepeople was taken from the "development side", focussing on a population that was not directly dependant on these natural resources for their basic survival. As is generally the case, this population was financially and politically more powerful.

As such, the immediate response of the urban population to the problem of encroaching development was a primary preoccupation in "coping" with growth. Their objectives were to provide a "better" population distribution and improved living conditions in an urban context. In accordance with these objectives rural land was viewed as a "reserve" for urban development (SCHEMA DIRECTEUR (1968–70)).

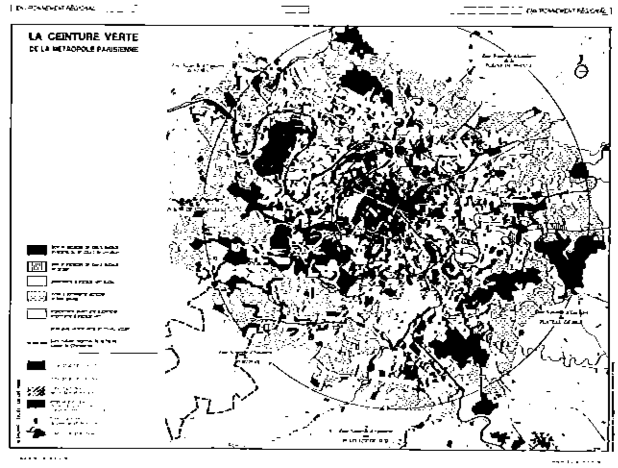
Following the tradition of the French landscape, much of the previously preserved rural areas coincided with sites of historic interest. These traditions included forests protected for hunting purposes. Then; the nobility had secluded hunting grounds where the peasents could not go, now; the poor cannot afford to reside in areas of rural amenity. Accessibility of rural areas was also based on geographic location; the West with Versailles being a traditionally protected landscape, and the East historically housing immigrants and lower class citizens. Building on the value that the French place on historic sites, most of the forests are located in areas once inhabited by royalty.

These urban interests also included a value being placed on an urban "escape", or a place to go to get out of the city. The least expensive management technique to achieve this objective within a reasonable distance was the protection of landscape amenity. This initiated a perceived necessity for a strategy in non–development. Such interests gave rise to a regional policy on Discontinuous Zones (ZNE) in 1974. The main function of these zones was to maintain a discontinous urban development pattern (BRYANT 1986). The objectives were to protect landscape amenities through the integration of complimentary industries such as combining agriculture with forestry, and allowing only for a limited development that was in "harmony" with the natural landscape.

These ZNE objectives provided for recreation in six designated areas surrounding the Paris agglomeration. These zones created a diversity in the urban landscape. Through this integration of space, transition zones were also created providing for wildlife functions that identified hunting and naturalist interests, while creating a break in urban development patterns.

Although "harmonious development" was geared more to the aesthetics of construction endeavors, raising the value of property and maintaining a rural flavor, such an idea could be transferred towards the protection of environmentally sensitive areas ensuring land use management that is related to the functions of the natural cycle. An example might be working with farmers to reduce pesticide use near a water supply, targeting conflicts in land use.

Thus, the interests of the community were identified. The regional strategies stressed amenity in the landscape and an "urban escape" element. The support of the community was employed through identifying relevent community issues in doing so, however, this strategy aided in the preservation of open space areas and agricultural landscapes in the Paris Region. Rather than such areas being perceived only in terms of agricultural production and natural area preservation efforts, the agricultural production and recreation were stressed as methods of management, aiding in an economic maintenance of open space while c functions. Though perhaps not acknowledged by the urban community, such management strategies accounted for the continuation of some important ecological functions.



Green Belt Region with associated planning Strategies IAURIF, 1986

Complimenting the ZNE strategy, other intervention techniques were increasingly emphasized in the Ile–de France. This included the creation of a Green Belt Region that lay between 10–30 km. from the Paris agglomeration. In contrast to earlier strategies, the Green Belt reflected a move towards "managing existing structures rather than coping with growth" (BRYANT 1986). This included landscapes of economic agricultural degeneration and non–agricultural areas such as wooded space.

Its functions were to provide leisure and recreation space, trail facilities, to reduce pollution and to rehabilitate "degenerating" landscapes. This was done through the creation of open green and recreation space, and through a nonprofit agency called the SAFER, deemed federal funds to aid in the protection of agriculture and help local farmers adjust to new economic situations. The proposed long–term agricultural zones included both economically sound and fragile agriculture, with a fragility index based on a combination of intensive urban impacts, difficult markets and fragmented landscape structure. These "fragile" zones were maintained still with the landscape amenity in mind, but attempting to preserve this space also aided in the preservation of a viable agricultural community.

Thus, the Green Belt provided for the conservation of open space accessible to the public, advocating "right to farm" measures, and due to intercommunal boundries, it initiated contractual agreements between towns, regions and the state for the protection of the landscape.The implied flexible boundries of the Green Belt were seen as a major strength as well as the linkage between rural economic interests and the urban recreation focus. Intercommunity cooperation aided in the protection of buffer zones and ecological functions through land use zoning that crossed political boundries. It was clear, however, that ecological problems were not the focus of these planning strategies. Even the economic concerns were not as important as the amenity and recreation interests of a select urban community. Building on these concerns, however, stategies could still be implemented that were capable of addressing other conflicts, as well.

LOCAL INTEGRATION

The philosophy of the French Natural Regional Parks is specifically aimed at producing a balance between natural environmant components and human activities. Established in 1975, these parks are initiated through local interest and represent a regional structure incorporating conservation objectives with rural economic priorities. Local interest are also represented in a charter outlining common priorities. In France there are 21 Natural Regional Parks covering 2.8 million hectares. Many of these parks are situated in mountainous zones, forested areas and areas of rural renovation. (ESPACES RURAUX ET AMENAGEMENT DU TERRITOIRE 1986)

The main objectives of these parks include the protection of nature, the integration of economic development interests and the protection of cultural heritage and values.In France these objectives provide for the protection of rural landscapes through maintenance of the agricultural economy and the establishment of outdoor recreation opportunities. They also can contribute to the protection of environmentally sensitive areas through the establishment of local environment associations as well as providing for the protection of historic/cultural sites through encouraging local markets, tourism development and education programs.

The Natural Regional Park of the Chevreuse Valley is an example of such a local management strategy situated approximately 30 km. Southwest of the Paris agglomeration in the department of Yvelines. Established in response to the expanding new town of Yvelines, it is an example of the local level management process based on the cooperation between 19 different communities. The actual and potential pressures include urban development pressures in scenic valleys, intense recreation use, agricultural development, wetland drainage and landscape amenities. It holds 37000 inhabitants on 25000 hectares, 10000 of which are forested and representing approximately 1000 historic sites and artistic monuments. It is the first French regional park to be placed so close to an urban agglomeration.

The Parc is managed by a syndicate with representitives from all concerned municipalities, the Conseil Gnral en Yvelines, and the Conseil Regional d'Ile-de-France. The governing syndicate is associated with the Green Belt agency,local federation of environmental associations "Friends of the Park", the National Forest Service and professional consultants.

The Parc objectives are based on a local charter and include the protection of the natural environmant with an adaptation to local economic needs. Also stated are the development of the local agricultural economy, the facilitation of public initiation and education and the maintenance of a value placed on the patromony of cultural/historic sites.

These objectives can be transferred to ecological as well as community interests. They provide for public outdoor facilities such as trail and bicycle routes that answer recreation needs while providing an orientation to the natural environment. They also aid in ensuring a viable agricultural economy while protecting rural landscape amenities. Public education is promoted through cultural sites while providing for a tourist economy. In addition natural resource expositions and museums promote natural area education that can provide for a long term interest in the environment. It should be noted that none of these management strategies were legally enforced. Their purpose was to maintain a base that would encourage the protection of open space. The financial incentives that were offered by the region and statewere based on local initiatives in resource protection. In addition, none of these strategies have distinct boundries, encouraging the expansion of land use plans that incorporate open space preservation.

ECOLOGY WITH ECONOMY?

There are few identified examples of strategies that provide a bridge between conservation and development concerns. Practical applications must therefore, build on components of projects that successfully address significant issues. However, in doing so we must be aware of the underlying philosophies specific to each situation, and that certain management strategies may not address actual problems. For example, the French experience may be suitable for a Western approach, but it may not be appropriate to transfer only this perspective into the problems of the developing world. In contrast, however, it is important not to discount the validity of many of the underlying concepts due to perceived differences in ideology of geographic location. Some of these approaches may prove useful in a variety of situations. An example might be in acknowleding the value placed on the preservation of historic sites. Thus, it is important to utilize management strategies appropriate to specific situations while allowing for a general framework that may help to identify relevent factors.

In the Ile-de-France the identified problems were due to the population increase and the related consommation of space. Environmental perception was taken from an urban focus, identifying interests in open space preservation and the maintenance of economic structures under pressure. Population interests were, thus, identified as being related to maintaining the landscape amenity and ensuring an "urban escape".

The system needed to maintain continuety and resilience to the urban pressures. A response was needed that stressed diversity and integration of resources and interests. Utilizing an intertwining approach that identified the connectivity between political, economic, cultural and ecological factors, certain ecological functions could be identified in the applied strategies. The ZNE identified the use of complementary industries in resource management, as well as a development that was in "harmony" with the natural landscape. The Green Belt stressed intercommunity cooperation that did not need to rely on political boundries. Economic viability was also addressed in maintaining links between a viable rural economy and urban interests. The Green Belt built upon existing economic structures and targeted sensitive agricultural areas for economic assistance programs. The Natural Regional Parks provided a structure through which local interest could initiate regional planning strategies that identify community concerns while considering ecological constraints.

Thus, building upon the interests of a given population, certain issues can be addressed that provide for the conservation of the natural environment as well as economic development issues. The applied strategies in this region certainly do not address all of the concerns in either area, and this author does not mean to imply that there should be an end to the search. What is clear, however, is that in order to begin the quest for a sustainable world, one in which environmental integrity is maintained while providing for the economic survival of the human community, we must begin with the little access that we may have into the system, and build upon successful components of applied strategies.

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THE IMPORTANCE OF RESIDUAL BIOTOPES FOR FAUNA AND FLORA

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INTRODUCTION

In 1983, the Research Council of the National Environmental Protection Board (S VN) launched a research programme for a project called "The importance of residual biotopes for fauna and flora". The aim of the research is to analyse the consequences to fauna and flora of the ongoing fragmentation of the natural landscape, which leads to the formation of "residual biotopes". In the research programme the objective is worded in the following way:

- The importance of original biotope mosaic for preserving functional ecosystems.
- The importance of the size of the area of certain biotopes for preserving its biological values.

The results will be used in the establishment of reserves, etc., and also in the formulation of regulations on nature conservation for forestry and agriculture.

The budget for the fiscal year 1986/87 was SEK 2.05 million. About fifteen research scientists at the universities of Lund, Uppsala and Umeå were engaged.

TYPES OF LANDSCAPE STUDIED

Research is focused on three important types of landscape which exhibit biotope fragmentation that poses an acute problem from the viewpoint of nature conservation, namely:

- the South–Swedish deciduous forest and mixed forest landscape;
- the North–Swedish coniferous forest landscape; and
- the traditional agricultural landscape.

The decisive factors in the design of the different sub–projects are stated below:

1. The Swedish deciduous forest landscape

Large coherent areas with deciduous forest being sparse, we have made the assumption that most broad–leaved deciduous forests preserved in the future – at least those classified as natural forests– will occupy fairly small areas, which, also , will be more or less isolated from each other. Therefore, we have primarily directed our iffolts at elucidating the differences – if any – between landscapes with a rich occurence and those with a sparse occurence of broad–leaves deciuous forest stands. Within the sub–project "Fragmentation effects in South–Swedish deciduous forest landscapes" quantitative and qualitative differences in fauna are analysed, both as a consequence of replacing deciduous forest with coniferous forest, and as a function of different sizes of stands. This comparison is made both in and between three types of landscape with varying percentages of deciduous forest.

2. The North–Swedish coniferous forest landscape

Three problems – cf. the overall objective of the project – have been defined within this area:

– first, the area of old forest is decreasing , and this will lead to the fact that in future, virgin forest stands will only exist in reserves, or in patches that can be preserved through regulation–. that is, the significance of the size of the area;

– secondly, the increasing degree of draining will reduce the area of wet forest – that is, the importance of preserving the original biotope mosaic, and

– thirdly, certain successional stages will practically disappear as a consequence of modern efficient fire combating and the fact that nowaday coniferous forests are considered more profitable.

The first two problems above are dealt with in sub–projects that have been going on for two years, while the third issue is treated in a less comprehensive new sub–project.

2.1 The importance of biotope area

Focus within this group of projects has been on high–productive coniferous forests. An important reason for this is that this forest type has often been the object of protective draining and tree species change, and that it is rather expensive to preserve this forest type as its commercial value is high.

We have found that the best way of obtaining knowledge on the effects of the surrounding productive land on forest stands of different sizes, with particular attenti on paid to the surviving capacity of organisms, is conducting large–scale field trials, where stands of different sizes are left when clear–felling.

Thanks to benevolent participation by the Forest Service, such a trial is conducted in coniferous forest near the tree limit on Mount Gardfjället (province of Västerbotten) within the sub–project "Effects of biotope fragmentation in boreal coniferous forests in similar environments".

The studies are base on the assumption that old productive spruce stands are characterized by a typical internal stand dynamics, and one of the questions to be studied is whether this dynamics is changed in small as compared with large stands. A corollary question is wether species that are dependent on this stand dynamics – like those plants that establish themselves on uprooted stumps, in light patches and on old windthrows – can survive in smaller stands (that is, that suitable regeneration niches are formed often enough and in sufficient number for the establishment to be successful). This is, of course, valid only on condition that the whole forest stand is not felled in a storm or subject to other, often largescale catastrophes that cannot be considered in the experimental design.

Within the sub–project "Population dynamics in residual forest biotopes and forest edges", which is carried out in the southern–most part of the boreal area (near the Grimsö Wildlife Research Station) , the breeding success of a number of bird species is studied in stands of different sizes. The objective was to test a model assuming that predation from the surroundings into an isolated stand of a certain type is proportional to the difference in carrying capacity between the stand and its surroundings. The sub–project "Relationship between biotope, landscape composition, area demands and reproductive success", specifically dealing with problems relevant to the preservation of species demanding large areas, comprises field work in the provinces of Uppland and Småland. Black wood–pecker was chosen as the model species, and this bird can also be considered as a key–species as it pecks new nest–holes every year . Thanks to this, there will be breeding opportunities for other hole–nesters (birds and mammals), in this productive land which is generally characterized by a lack of nest–holes.

2.2 Biotope mosaic projects

Within the sub-project "Biotope changes in boreal coniferous forests" the hypothesis is that, in the future productive land, wet forests will constitute the only type of old forest. For this reason it is urgent to shed light on the importance of nature conservation for wet forests, bearing in mind the growing draining practices.

Therefore, the foodchain bilberries – caterpillars – insect-feeding birds (passerines, gallinaceous birds) is studied within the project. The hypothesis is that, owing to the specific light and nutrient conditions in unaffected moist forests the dominating plants will be more attractive to herbivorous insects and hence be very favourable to insect-feeding birds.

2.3 Succession projects

Thanks to the extra funding received in the fiscal year 1986/87 it became possible to start a new project dealing with deciduous tree succession biotopes after forest fire. In the project entitled "The significance of stand size and habitat variation to the fauna of dead wood" the beetle fauna in dead wood was investigated in seven deciduous-tree stands in the province of Hälsingland, all representing late successional stages after forest fire. The results so far show that both the size of the area and the size of the trees are significant to the number of species, and it is also shown that the beetle fauna of these late deciduous tree successions are characterized by a complex beetle community structure with a high species richness whereas the density of individuals is remarkably low.

3. The traditional agricultural landscape

As it is to be exspected that the original, natural, community structures in the agricultural landscape are impacted by increased fertilization and pesticides/herbicides application, we have decided to give priority to sub-projects elucidating the influence of pollinators and seed predators on the reproductive success and survival of plant populations.

This basis for the investigation was to study fragmentation effects in the agricultural landscape, where "residual areas" of many kinds in the arable land constitute "habitat islands" of different sizes. Within all sub-projects, studies will be made both in a traditional agric ultural landscape characterized by a high degree of biotope patchiness, and in a modern, highly productive agricultural landscape with original biotopes.

Within the sub-project "Relationships between the number and size of residual biotopes, species diversity and activity of pollinators and the reproductive success of the flora", carried out mainly in the province of Dalsland, studies of the qualitative and quantitative composition of the pollinator community, and of the reproductive success of some selected flowering plants, are being performed in the two types of agricultural landscape.

Within the sub-project "Gene flow, population structure and biotope fragmentation in two related plant taxa" the degree of isolation in populations of different sizes of an autogamous and an ant-pollinated dry meadow species (*Scleranthus annuus* and *S. perennis*) is investigated. Studying the demographic effects of autogamous fertilization and crossbreeding is an important part of the project. During the fiscal year 1986/87 a sub-project dealing with population genetics of insects (Lepidoptera) was included in the study. Within the project "Survival difficulties in small faunal popu lations" studies are performed of the distribution, mating success, sex ratio, genetic variation and "vitality" of populations of different sizes of two butterfly species, *Parnassius mnemosyne* (province of Blekinge) and *Maculinea alcon* (province of Skåne), which both occur in extremely isolated populations. The occurrence of both the butterflies and their respective host plants having been mapped in the two study areas, there is an extraordinary possibility of investigating the genetic variation both in and between the populations, as well as effects on population dynamics, if any.

FUTURE WORK

The design and scope of the sub-projects are well suited for answering the relevant questions, and activities will proceed in accordance with the present work. However, more emphasis will be put on distribution studies within the framework of some of the existing projects. The distribution capacity of organisms is a decisi ve factor for the colonization of fragmented biotopes and for genetic variation.

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BIOLOGICAL PATTERNS AND STRUCTURAL PATTERNS IN AGRICULTURAL LANDSCAPES

F. BUREL

Rural landscapes, in western France, are characterized by the presense of hedgerows inter connected into a network and connected to uncultivated areas such as woodlots, heathland or old fields. Since 40 years many hedgerows have been removed in order to enlarge fields for modern agricultural practices. A question planners involved in land consolidation operations address to the scientific community is how to design a new landscape in which ecological processes are maintained and which is convenient for modern farming (BUREL1984, BAUDRY & BUREL 1984). Two main research projects (POLLARD et al 1974, INRA et al 1976) dealt with the ecology of hedgerow and adjacent fields but most of the studies have been restricted to one or a few elements and did not take intoaccount the landscape at a planner's scale. The purpose of my research was to evaluate the relationships between landscape structure role and the spatial distribution patterns of four different groups : plants, spiders, carabids and birds.These groups differ by their way of dispersal, their mobility (MCDONNEL & STILES 1983 , THIELE 1977). In this paper I present the results obtained with ground beetles (Carabidae).

Carabids assemblages have been studied in such landscapes by POLLARD (1968), THIELE (1976), RINGBY & NIELSEN (1980) and DEVEAUX (1976) and GEORGE (1978) in France. They all separated the rural zone into three parts :first the fields, second the hedgerow, third a strip in the field . Along the hedgerow except for this strip there was no relationship between hedgerow and field species assemblages, hedgerow ones being characterized by the presence of forest species. I focused my study on those forest species : I looked at which species penetrate from the forest into the rural landscape and how landscape structure influences their spatial distribution.

1 – STUDY AREA

The study area was chosen to be a hedgerow network area attached to a large forest suitable for interior species (FORMAN & GODRON 1985) in which hedgerows are still interconnected. It is localised North–East of a state forest 15 kms East of Rennes (Brittany – France). The forest is composed of two main stands : the first one is a dense iron wood (*Carpinus betulus*) coppice, with no shrub layer, on a wet soil; in the second oak and beech trees (*Quercus pedunculata* and *Fagus sylvatica*) are grown for timber, shrubs (*Viburnum opulus, Rubus fruticosus*) cover 20 % of the surface in the first 100 meters, beyond there are only leaf litter and mosses . The rural area which extends at most 1,5 kilometers from the forest and is 1 kilometer wide, is composed of two farms, fields are mostly meadows : perennial grassland in the wet parts, or biennual fodder; cereal crops are grown in three fields. Trees in hedgerow separating fields and bordering lanes are mainly oak trees pruined along the whole trunk more or less distant from each other depending upon farmer's management. Shrub and herbaceous layers density are determined by the intensity of cattle grazing from adjacent fields, when hedgerows are between two pastures the whole shrubby vegetation may be removed by cows. The row of woody vegetation is on an earthen bank traditionnaly bordered by a ditch which permitted the drainage of the fields. Most of the ditches are no longer efficient, being no more managed.

2 – METHODS

Carabids sampling was done with pitfall traps from April until October 1985 during three days every two weeks. There have been twelve periods of trapping. Sampling design was as follow : two transects of eight traps, 25 meters apart, in the two forest stands, a set of three traps in the center of three fields and 26 sets of three traps, 50 meters apart, along hedgerows . In hedgerows there was one trap on the top of earthen bank, and one on each side, at field level or close to the ditch (Figure 1).

Data were analysed with ordination and clustering methods using computer programs from ADDAD (JAMBU & LEBEAUX 1978).

3 – RESULTS

79 taxa of carabids have been identified (73 at the species level, 6 at the genus level). Traps have been splitted into six groups according to their potential habitat for carabids, as determined by

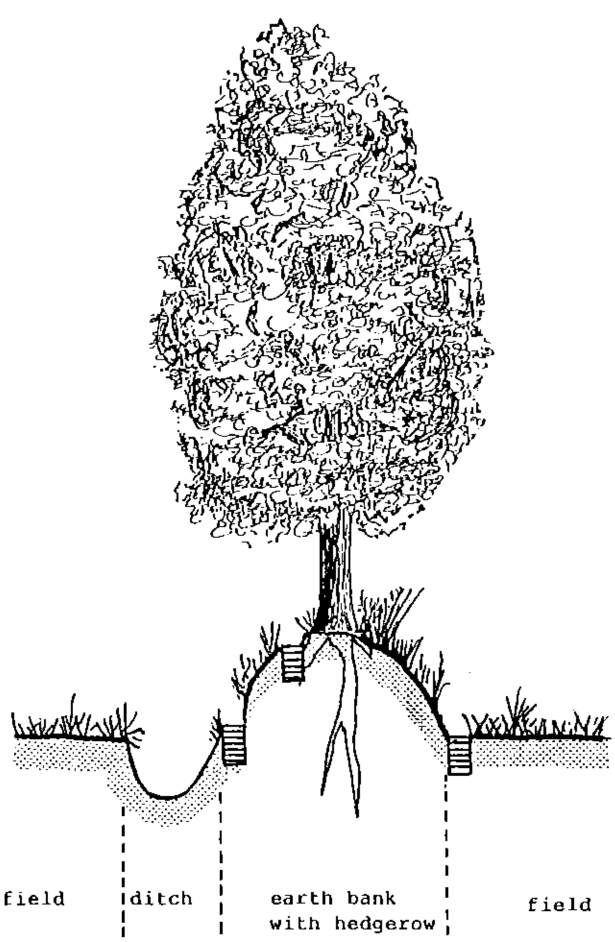

Fig. 1 : Location of Traps in the hedgerows

the litterature (THIELE 1976, GREENSLADE 1964) which underlines the importance of microclimatic conditions : 1 forest, 2 fields, 3 bank top, 4 vegetated bank side, 5 almost bare bank side, 6 lane.

A cluster analysis, on the four first axis of a correspondence analysis has been performed on the data matrix frequency of species x type of habitat, in which the twelve periods of trapping had been lumped together (Table 1). This confirms previous results ; carabids assemblages of the fields are different from those of the hedgerows, which also differ from those of the forest (FIGURE 2).In a single hedgerow, bank top and vegetated sides differ from non vegetated sides ,lanes are isolated.

Tab. : Carabid species frequency per habitat

	Forest	Lane	Top of earthen bank	Vegetated side	Non vegetated side	Field
Nebria breviecollis F.	37	100	78	93	74	100
Poecilus cupreus L.	18	66	50	68	69	100
Chaetocarabus intricatus L.	0	0	35	10	17	0
Abax ater Villers	87	16	21	17	34	0
Agonum lugens Dufts	12	0	28	27	13	0
Amara sp. Bon.	6	83	28	44	65	100
Abax ovalis Dufts	56	16	7	10	8	0
Argutor oblongopunctatus F.	37	0	7	3	0	0
Archicarabus nemoralis Müll.	31	16	0	3	13	0
Abax parallelus Dufts	56	17	7	0	4	33
Agostenus nigricornis F.	6	0	7	10	8	0
Brachinus (brachinidius) sclopeta F.	6	16	14	10	13	33
Diachromus germanus L.	0	33	7	17	8	66
Metallina lampros Hast.	0	66	64	65	43	100
Microlestes sp. Schm.	0	50	0	3	4	33
Nebria salina Frm.	0	0	7	27	8	66
Platysma nigrita F.	0	0	0	17	0	0
Platysma nigrum Schaller	50	0	7	7	4	33
Ophonus (Pseudophonus) rufipes De G.	0	33	7	7	17	66
Philochthus (Megodontus) sp. Steph.	43	0	7	24	8	66
Procustes purpurascens F.	62	0	0	3	4	0
Pterostichus cristatus Duf.	25	0	0	7	0	0
Steropus madidus F.	68	100	85	62	86	66
Syntomus sp. Hope	0	0	14	17	17	100
Stomis (lagurus) vernalis Panz.	0	16	0	17	8	33
Anchomenus dorsalis Pontop.	6	16	0	24	4	66
Anchus ruficornis Goeze	0	0	0	7	4	0
Acupalpus sp. latr.	0	16	0	3	8	33
Agonum mulleri Hast.	0	16	0	3	4	33
Argutor strennus Panz.	12	0	7	13	0	0
Batenus livens Gyll.	43	0	0	0	0	0
Anisodactylus binotatus F.	0	33	0	3	4	100
Asaphidion sp. Gozis	0	0	0	0	4	33
Badister bipustulatus F.	12	0	0	3	8	33
Harpalus affinis Schr.	0	0	14	7	4	66
Hadrocarabus problematicus Hbst.	31	0	7	3	4	33
Carabus granulatus L.	12	0	7	0	0	66
Carabus auratus L.	0	0	21	7	8	33
Loricera pilicornis F.	0	0	0	10	0	33
Platysma anthracinum (Melanius) ill.	0	0	0	10	0	33
Agonum viridicupreum Goëze	0	0	0	0	0	33
Brachinus explodens Dufts	0	33	0	3	0	0
Clivina fossor L.	0	0	7	7	4	66
Notiophilus biguttatus F.	12	0	0	3	0	33
Phyla obtusum Serv.	6	0	0	0	4	0
Percosia equestris Dufts	0	0	0	7	8	0
Trechus quadristriatus Schrank	0	0	21	3	0	33
Trechus tenebrioides Goeze	0	0	7	3	0	0
Parophonus maculicornis Dufts	0	0	0	0	4	0

The same analysis performed on species allowed the recognition of forest species (these which characterised the traps in this particular forest). They were found in the rural area, either on the ground in the first hundred meters out of the forest for all of them, or on bank tops beyond this forest edge for only a few of them.

Computing mutual information (LEGENDRE & LEGENDRE, 1984) between those forest species and vegetation structure in hedgerows shows a significative relation for most of them with a dense herbaceous layer and a not too sparse tree cover.

In a correspondance analysis on the data matrix traps x species, for the rural area only the first axis was defined by two traps in a very wet part of a lane. On the second axis bank tops traps scores were related to distance from the forest (FIGURE 3). Species assemblages of fields and bank sides are independant to that distance. So are these of laneways which are more similar to the forest than ones in a different situation at the same distance.

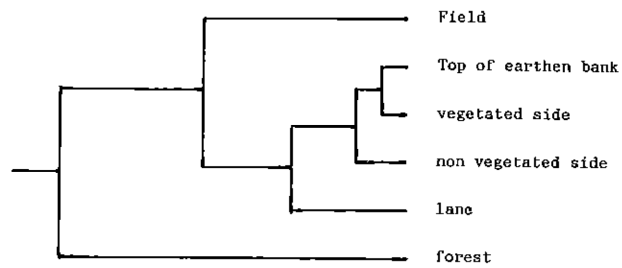

Fig. 2 : Cluster of Carabid habitats

4 – DISCUSSION

Spatial distribution of carabids assemblages in this rural area adjacent to a forest depends upon several levels of organization, from species biological behaviour to landscape design.

All the forest species present do not use hedgerows in the same way, some are strictly forest species only found in the forest or in the first hundred meters out of it, this is the case for *Hadrocarabus problematicus*. Some use hedgerows as forest peninsulas (SIMPSON 1964,MILNE & FORMAN 1986) they are found as far as 600 m from forest edge on bank tops but their abundance decreases as distance increases, one of the "peninsula species"is *Abax ovalis.* The others, actually, use hedgerows as corridors (FORMAN & GODRON 1981), *Abax ater* has been trapped as far as 1,5 km out of the forest. All these species qualified by the litterature (JEANNEL 1941 & 1942 , BONADONA 1971) as forest ones, do not react in the same way to landscape structure.

Corridor role of hedgerow depends upon its structure. Earthen bank over grazed by cattle are not suitable corridors for forest carabids. This corridor function exists only with a dense herbaceous layer and shade provided by woody species.

"Peninsula species" may explain most of the variation in species composition on bank tops within the first kilometer out of the forest. Lanes are of overriding importance for the survival of forest species . Their species composition is close to forest ones and abundance of corridor species in them is higner than in single hedgerows. This has to be related to the particular microclimatic conditions : shade, humidity, decrease of wind velocity, due to the presence of two hedgerows. Lanes are suitable habitats for corridor species and they act as stepstones (MACARTHUR & WILSON 1974) or even new sources in the rural landscape.

As long as such corridors are interconnected and connected to single hedgerows which are suboptimal habitats, forest species will remained in the landscape. They must be carefully maintained in rural management operations such as reallotments . Those networks must be connected to forests which are a large pool of forest species. Density of lanes and suitable hedgerows will determine the density of forest species in the landscape, but from a conservation point of view only a few of them might be enough to maintain them. But changes in species composition in time (DEN BOER 1985) after hedgerow removal need to be assessed to know the level of habitat redundancy that must be kept . In the few suitable habitats present abundance may be anormally high due to sursaturation phenomenon as they are the only refuges left. Figure 5 illustrates some landscapes and the abundance of forest carabids species in them.

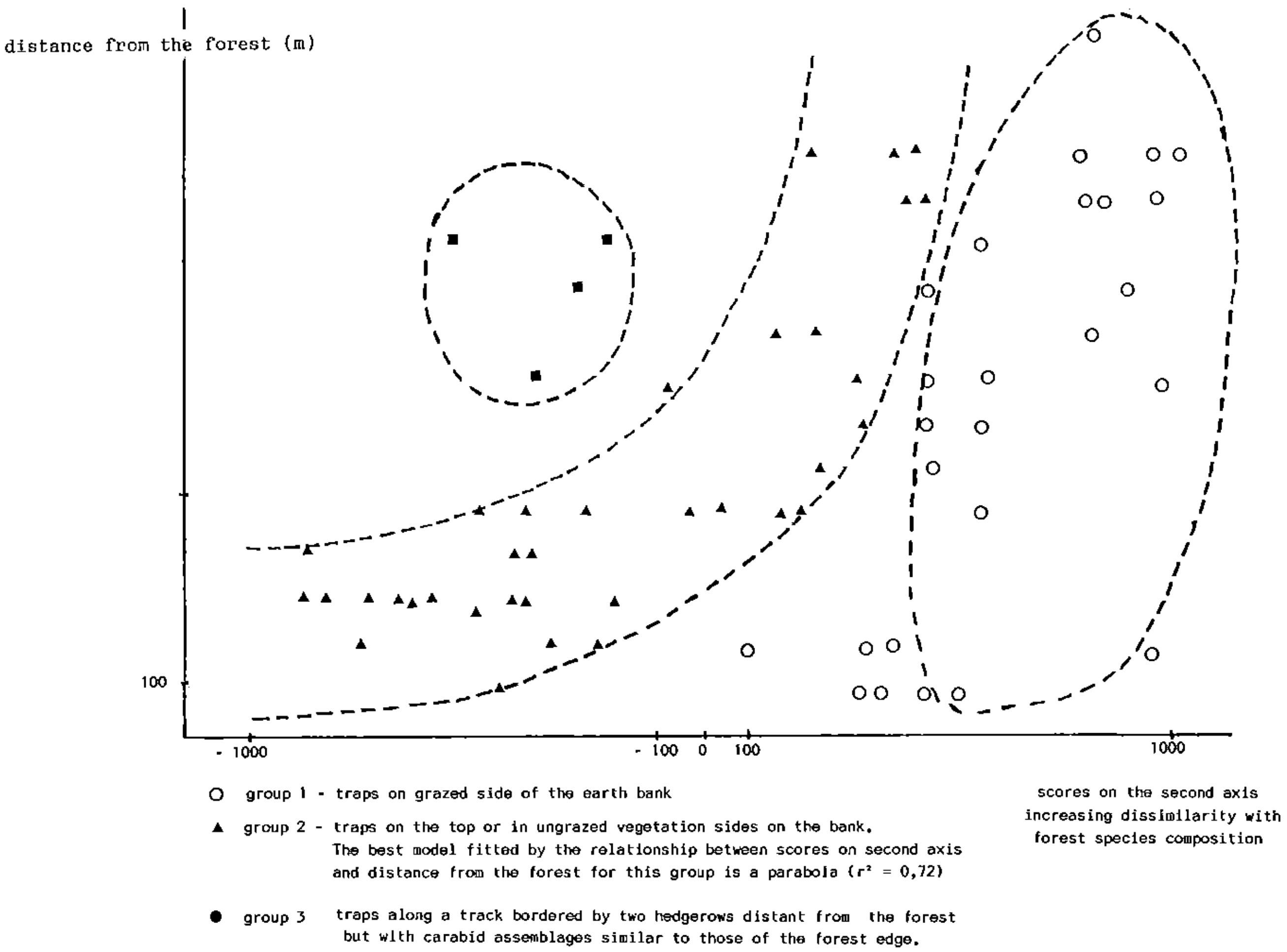

Fig. 3 : Relation between distance from forest and the scores on second axis of the correspondance analysis

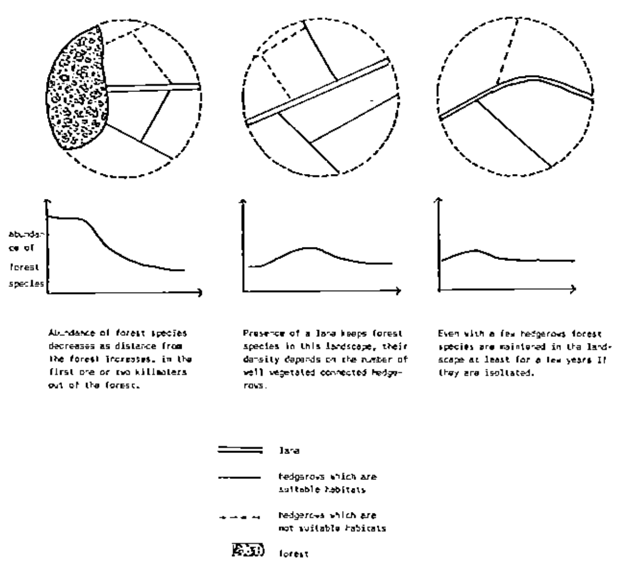

Fig. 4 : Carabids forest species in three different landscapes

CONCLUSION

Dispersal of forest carabid species in the landscape depends for only some of them, the "corridor" ones upon landscape structure. For those species which are poor dispersers (DEN BOER 1970), non flying species, connectivity is similar to connectedness (BAUDRY 1984, MERRIAM 1987, BAUDRY & MERRIAM 1987) between hedgerows. Those hedgerows must have a particular structure and lanes must strengthen forest influence in the rural area. Experiences of capture–recapture will measure the dispersal potentiality of those landscape features which may replace woodlots in intensively used agricultural zones.

For this biological group it has been possible to underline landscape structure influence among other levels of organization . It is a necessary component to maintain biological richness of a landscape and the only level on which, currently a planner act. For other groups and other ecological processes, favorable landscape patterns will differ. Mainly for example for wind and water flows or wind disperse species for which hedgerows act as barriers. For animals which use a larger portion of space such as birds or large mammals, biological patterns will have to be studied at a different spatial scale, size of landscape units for management will be larger.

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DISPERSAL AND PATCH CONNECTIVITY AS SPECIES–SPECIFIC CHARACTERISTICS

L. HANSSON

Connectivity depends both on the landscape composition and certain aspects of the movement patterns of the animals. These latter aspects have to be investigated fairly closely in order to predict the connectivity in a specific landscape.

Some of the first ideas of connectivity were developed with small mammal dynamics in mind (MERRIAM 1984, FAHRIG & MERRIAM 1985, LEVKOVITCH & FAHRIG 1985). Prevalence and extinctions of North American deer mice and chipmunks were successfully examined for landscape effects in south Canadian woodlots in agricultural mosaics. Small mammals may thus show many characteristics which make them suitable for tests of general problems regarding connectivity between landscape elements. One of these characteristics, which has been examined fairly intensively for other reasons, is their dispersal behaviour (e.g. LIDICKER 1975, STENSETH 1983). Dispersal is the movement of an animal from one home range to another, either as young (natal dispersal) or as adult (breeding dispersal).

In order to have a rapid recolonization of a patch with a temporarily extinct population of a certain species, dispersal should occur at or just before the reproduction period, it should include a large proportion of reproductive (possibly pregnant) females and occur on a broad front, through a variety of examine the efficiency of dispersal in these respects for a number of small mammal species which have been studied mainly in southern Sweden.

First it should be made clear that there are great differences between cyclic and non–cyclic small mammal populations. The former increase to pronounced peak densities every three to four years and then decline to very low levels. Non–cyclic populations have peak numbers each year, usually in early autumn. Cyclic populations have been found to show a pronounced presaturation dispersal with healthy, often reproducing, animals in the increase phase and saturation dispersal, where more or less exhausted animals are found, in the peak phase (LIDICKER 1975, STENSETH 1983). Non–cyclic populations instead demonstrate annual dispersal peaks (GARTEN & SMITH 1974, HANSSON 1981).

Most non–cyclic species, such as bank voles and wood mice, show a dispersal peak in early autumn (Fig 1), coinciding with the density peak (HANSSON 1981, 1987). Usually most animals are on the move in September which means that a high mortality will hit the dispersing animals before reproduction starts in April–May next year. However, the mouse *Apodemus flavicollis*, an inhabitant of climax forests, also disperses to a considerable extent in early summer, at the beginning of the reproduction. This is still more usual in the field vole *Microtus agrestis*, a species common to successional stages. This species is often cyclic and then shows the main dispersal before or during peak numbers. The shrew *Sorex araneus* deviates from the small rodents in mainly dispersing during winter (HANSSON 1987, TEGELSTRÖM & HANSSON 1987), i.e., only some months before reproduction starts. Thus, from this aspect *M. agrestis* and to a lesser extent *A. flavicollis* and *S. araneus* may show a rapid recolonization rate due to time of dispersal.

The proportion of reproductive females dispersing during the breeding season constitutes an important component, eliciting recolonization. Generally, the percentage of reproductive females dispersing is less than in resident populations (Fig. 2) but there are exceptions; *M. agrestis* females, even pregnant, frequently disperse during the summer orpopulation increase and the same

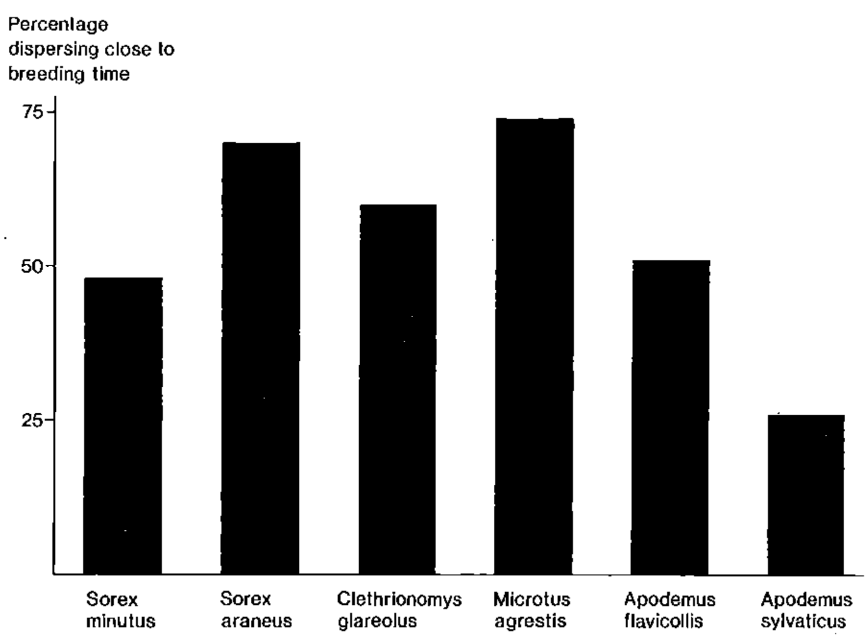

Fig. 1. Proportion of dispersing non–cyclic small mammals on the move outside, the annual density peak in south Sweden, i.e. dispersing during December–August. These dispersers face relatively low mortality and good colonization prospects. Recalculated from HANSSON (1981).

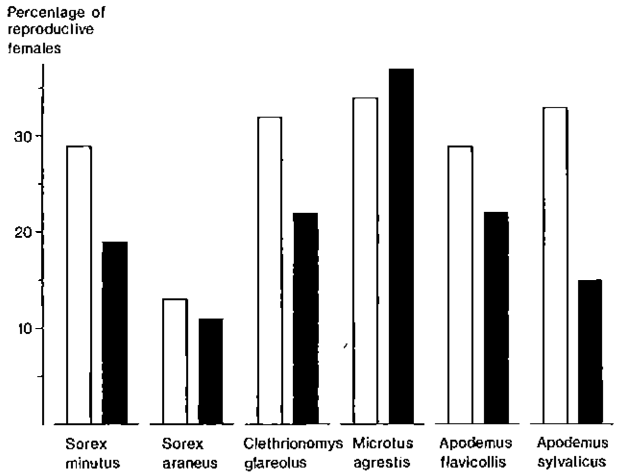

Fig. 2. Proportions of resproductive adult females among resident (white) and dispersing (black) animals. Recalculated from HANSSON (1981).

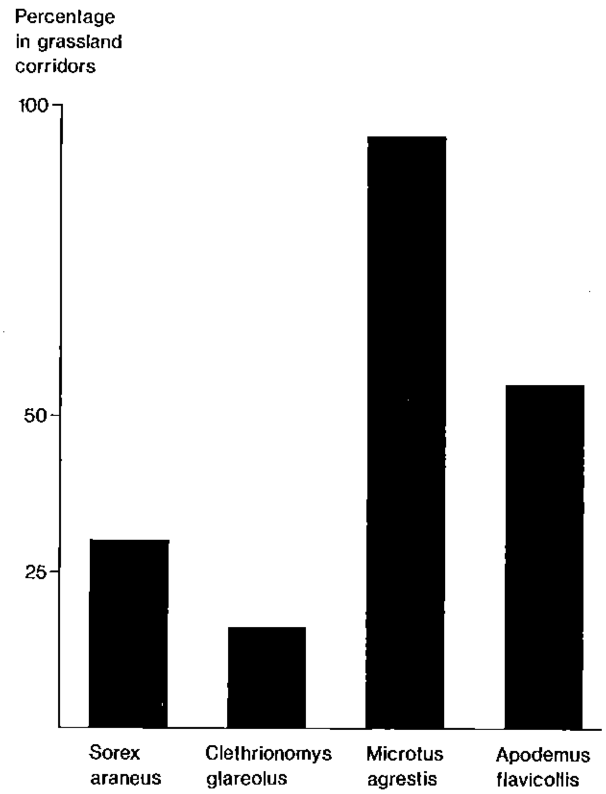

Fig. 3. Proportions of dispersinganimals (no/m) moving at grassland corridors in relation to those moving insideforest in a forest landscape in south-central Sweden. Recalculated from HANSSON (1987).

applies to another small rodent species from successional stages, the water vole *Arvicola terrestris* (STODDART 1970). The latter two species should be at an advantage in recolonization due to rapid production of offspring.

Many species disperse along restricted corridors of sheltering vegetation, e.g. the generally clumsy voles, while other small mammals move more on a broad front through several habitats (Fig 3). Generally, folivorous small rodents (e.g. voles and lemmings) may be more sensitive to predation and appear more cryptic while granivorous–insectivorous species such as mice and shrews are adapted to pursue widely distributed food (seeds, insects) and also move in unsheltered terrain during dispersal (HANSSON 1987). This may even include water, frozen or not (HANSKI 1986, TEGELSTRÖM & HANSSON 1987). Thus, the latter types of animals should more easily recolonize isolated habitat patches in landscapes dominated by less suitable vegetation.

There are at least two Scandinavian examples where dispersal characteristics seem to affect the persistence and dynamics of local populations. The first one is *A. flavicollis* which shows outbreak numbers, but no cycles, after rich beech and oak mast years. During such outbreak years there is a pronounced dispersal from old closed woods to minor woodlots within agricultural fields, often with oak and beech (HANSSON 1981). The dispersal during outbreak years is later in the season than in normal years and generally culminates at the end of the reproductive season. Dispersing and resident animals both show high mortality over winter and consistently there are no *A. flavicollis* which survive to the following spring in the small woodlots(HOFFMEYER & HANSSON 1974, HANSSON 1981).

The second example comes from clearcuts in northern coniferous forests. These grassy, open habitats are inhabited by both bank and field voles. The bank vole *Clethrionomys glareolus* is also common inside the forests which forms the matrix between the generally distant clearcuts. Thus, *C. glareolus* may easily disperse inside forest. *M. agrestis*, although often dispersing as pregnant females, has to rely on clearcut corridors or on a very slow dispersal through the forests. In the cyclic vole populations *C. glareolus* reaches peak numbers on clearcuts far ahead of *M. agrestis* (e.g. LARSSON & HANSSON 1986) and this is at least partly due to slow recolonization rates. *M. agrestis* is an important forest pest (LARSSON 1975) and close or interconnected clearcuts may aggrevate this problem (LARSSON & HANSSON 1986, cf. also HANSSON 1977).

At least three factors may thus interact in various ways to produce a certain dispersal rate. When combined with various compositions of the landscape, there will be a large number of possible outcomes. Connectivity may thus seem to be very specific to species and localities.However, any mature science should produce generalizations. It might be possible to see if various animal "strategies" or types of animals show different dispersal rates and if these animal types live in some characteristic landscape. As a start, it is obvious that animals adapted to temporary grasslands, such as *M. agrestis* and *A. terrestris*, show high and efficient dispersal, e.g. by pregnant females, in sheltered environments. Also cyclic populations may show efficient colonization with their presaturation dispersal. Animals from climax forests should not be expected to disperse until really necessary and *A. flavicollis*, for example, may demonstrate inefficient saturation dispersal at outbreaks. Further such generalizations should be sought, if possible on community level, and tested and then integrated into general or mean dispersal abilities ofanimals (and plants!) from various characteristic landscapes.

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THE ARTHROPOD COMMUNITY OF THE EDGE OF AN INTENSIVELY GRAZED PASTURE

J.–P. Maelfait, K. Desender & R. De Keer

Introduction

Within the framework of applied biological research quite some investigations focused on the possible role of field boundaries as overwintering sites for arthropod predators of crops and that in view of the possible ability of these animals to limit or to control pest outbreaks (e.g. DESENDER 1982, GORNY 1968, 1971, RYSZKOWSKI & KARG 1976, SOTHERTON 1984, 1985, THIELE 1977).

A lot of (landscape) ecological research was carried out on the woody boundaries of farmland (hedgerows; e.g. FORMAN & BAUDRY 1984, FUCHS 1969, SOTHERTON et al. 1981, THIELE 1964, TISCHLER 1958, VAN EMDEN 1965).

Only very few investigations however so far dealt with the untrampled grassy border zones of pastures (DESENDER et al. 1981, D'HULSTER & DESENDER 1982). The purpose of this contribution is to present results showing the landscape ecological importance of a non woody border zone of an intensively grazed pasture.

Material and Methods

Since 1979 an intensively grazed pasture of 100 x 500 m in the vicinity of Ghent (Belgium) is studied for what concerns its soil fauna (MAELFAIT et al. 1986). A drainage ditch runs along one of the long sides of the pasture. Between the ditch and the pasture and along a fence is a narrow zone (0.5 m of width) which is only partly grazed and not trampled. The dominant grass of the pasture is perennial ryegrass (*Lolium perenne*) with a ground coverage of some 90%. Dominant grasses of the edge are: *Festuca rubra, Holcus lanatus, Anthoxanthum odoratum, Festuca pratensis*; herbs that occur are: *Achillea millefolia, Anthriscus sylvestris, Heracleum sphondyleum, Rumex acetosa, Stellaria graminea.* Herafter the difference in composition between the spider and beetle communities of that pasture and the zone along its fence as well as the migrations between them are discussed.

Quadrat sampling was performed in the pasture and in the border zone at approximately monthly intervals during 1979 and 1980. On each occasion sampling units with a diameter of 10 cm and a depth of 15 cm were taken, 30 in the border zone and 120 in the pasture. These samples were sorted manually in the laboratory, then extracted for three days in Tullgren funnels and finally sorted by hand a second time.

Results and discussion

Maximal densities during winter for spiders, Staphylinid and Carabid beetles respectively reached about 250, 1100 and 900 inividuals per square meter. In table 1, 2 and 3 we give the percentual abundance per species of the adult spiders, Staphylinid beetles (except for Aleocharinae) and Carabid beetlis. Only species representing at least 5% of the total abundance for the respective groups in at least one of the sites are mentioned. Also listed are the total number of species for the three taxonomic groups. Especially in view of the much larger sampling effort in the pasture, the difference in species richness between both sites is striking. For each taxonomical group, the densities in the pasture and its boundary are depicted (figs. 1–6) for the two most abundant species in the pasture.

Erigone atra and *Oedothorax fuscus* are obviously the two dominant spider species in the pasture (table 1). *O. fuscus* is also very abundant in the border, where *E. atra* is rare. Species only occurring in the border zone (*M. fuscipes, R. lividus, M. herbigradus*) are usually found in litter and detritus and are often recorded for woodland habitats. For the two most abundant spider species (figs. 1 and 2) densities are highest by the end of summer when the overwintering generation reaches maturity. Synchronically with a decrease of the numbers of adults of *O. fuscus* in the pasture, there is an increase of that species in the border. This increase can be interpreted as being caused by animals seeking shelter for winter conditions. The same holds true for many beetle species(see further). This phenomenon does not seem to occur in *Erigone atra*. This species shows a pronounced aeronautic dispersal during autumn and winter. It has also been obwerved to overwinter in the pasture itself, where inividuals have been found in soil crevices, mole–holes and holes of earthworms during cold weather spells.

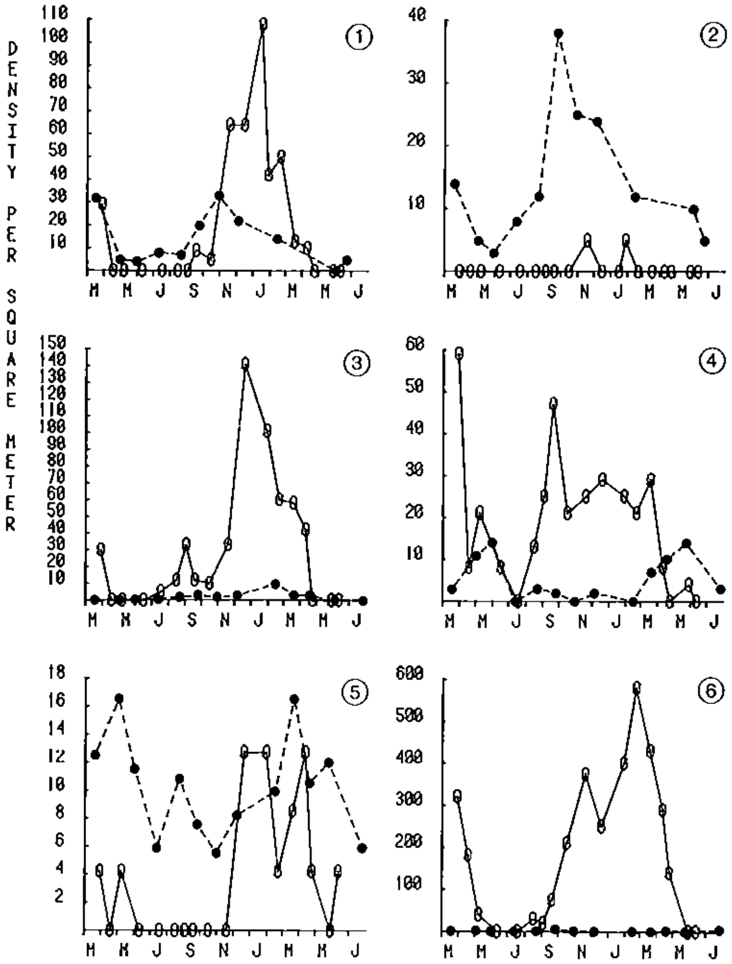
Tab. 1. Percentual abundance of the most abundant spider species (› 5%) present in the quadrat samples (1979, 1980).

	pasture	border zone
Erigone atra	39 %	3 %
Oedothorax fuscus	37 %	40 %
Bathyphantes gracilis	9 %	1 %
Erigone dentipalpis	9 %	1 %
Pachygnatha degeeri	1 %	6 %
Monocephalus fuscipes	0.3 %	16 %
Robertus lividus	-	6 %
Micrargus herbigradus	-	6 %
Total number of species	12	33

Philonthus varius is the most dominant Staphylinid species in the pasture followed by *Oxytelus rugosus, Platystethus arenarius* and *Philonthus fuscipennis* (table 2). As already shown for spider species again it is obvious that according to the species the importance of the edge zone is quite different. *Platystethus arenarius* for example is nearly absenet in the edge. The reason for this is probably that this species is coprophagous and therefore hibernates in the pasture itself close to cattle droppings. In *Philonthus varius* (fig.3) on the other hand density curves for both sites are inverse and indicate seasonal biotope alternation with hibernation

Tab. 2. Percentual abundance of the most abundant Staphylinid beetles (› 5%) present in the quadrat samples (1979, 1980).

	pasture	border zone
Philonthus varius	21 %	8 %
Oxytelus rugosus	11 %	9 %
Platystethus arenarius	11 %	0.1 %
Philonthus fuscipennis	10 %	4 %
Xantholinus longiventris	8 %	1 %
Tachyporus chrysomelinus	5 %	12 %
Tachinus rufipes	4 %	7 %
Trogophloeus elongatulus	1 %	17 %
Tachyporus hypnorum	1 %	9 %
Tachyporus nitidulus	1 %	6 %
Total number of species	33	61



legend : figs. 1–6. Densities in pasture (full symbols) and in border zone(open symbols) for (1) *Oedothorax fuscus*, (2) *Erigone atra*, (3) *Philonthus varius*, (4) *Oxytelus rugosus*, (5) *Clivina fossor*, (6) *Pterostichus vernalis*.

occuring in the edge. *Oxytelus rugosus* (fig.4) shows the same density course in the edge and the pasture, however with higher abundances in the edge. Species which are almost restricted to the edge zone (e.g. *Trogophloeus elongatulus, Tachypours hypnorum* and *T. nitidulus*) are known to prefer crop fields or habitats with a high amount of litter.

In Carabid beetles finally (table 3) *Clivina fossor* is the most abundant species in the pasture. It also occurs in the edge zone (fig.5) but in low numbers and that in contrast to the extremely high abundances of *Pterostichus vernalis* there (fig.6). Except for *Clivina fossor* and *Pterostichus strenuus* the other mentioned

Tab. 3. Percentual abundance of the most abundant Carabid beetles (› 5%) present in the quadral samples (1979, 1980).

	pasture	border zone
Clivina fossor	36 %	1 %
Pterostichus vernalis	19 %	58 %
Pterostichus strenuus	15 %	4 %
Bembidion properans	16 %	7 %
Bembidion lampros	6 %	10 %
Agonum dorsale	1 %	11 %
Total number of species	18	42

species practically all show seasonal biotope alternation and hibernate in the edge zone. These species all are known as adult hibernators, reproducing during spring in the pasture.

The shelter function of the edge zone can be demonstrated by means of recorded temperature extremes from January until April (DESENDER et al. 1981). In the edge the temperature extremes are reduced, especially the minimum values are higher. These differences could be the result of the standing crop, the presence or absence of litter and the development of the sod layer (resulting in different ground structure). Measurements have proven that the development of the sod layer and the amount of litter are indeed much higher in the edge zone as compared to the pasture. The border zone, where no trampling occurs, thus offers many invertebrates an aerated temperature buffered hibernation site.

The results given above show the seasonal migration of athropods between two ecosystems: an intensively grazed pasture and a zone of untrampled grassy vegetation along its fence. Such a verge thus not only contributes to the overall richness of the arthropod fauna of a cultivated countryside. Besides containing a number of species being restricted in their occurrence to such not to heavily disturbed zones, it also serves as an overwintering site for arthropods of the pasture itself. It therefore enlarges the survival probability of some of the arthropod species of the pasture and contributes to the faunal diversity of the pasture ecosystem.

We conclude that our data strongly suggest that such non woody margins of grassland should be fully taken into consideration during the process of landscape planning.

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RECONSTRUCTION OF THE LIFETIME TRACK OF BUTTERFLIES: POTENCY AND LIMITATIONS OF THE MRR–METHOD

J.CHR. BOTH

Introduction

Discussions on "connectivity" of the landscape rest on the population concept: more or less isolated populations are connected by "ecological infrastructure" and on the other hand, populations are isolated from each other by landscape elements that hinder organism movement and thus act as a barrier.

It is the magnitude of the "normal" movement of the individuals during their lifetime (the "lifetime track" according to BAKER 1979) that determines the extensiveness of the population. So knowledge of the ecology of organism (c.q. animal) movement is a prerequisite of discussions on "connectivity" and "ecological infrastructure".

Estimations of the length of the lifetime track of butterfly species are often based on the mark–release– recapture–method (MRR–method). Butterflies are individually recognizable marked and the distance between the most distant capture points (the range, R) is used as parameter characterizing the "mobility" of the species concerned (e.g. SHREEVE 1981 and ARNOLD 1983). However, as often stated (e.g. BAKER 1984) the measured magnitude of R is strongly dependent on the extensiveness of the observation area. If the observation area is smaller than the home range of the butterflies, the estimated parameter value is not a realistic charcteristic of the butterfly species, but rather a reflection of the dimensions of the observation area! Only if the species' home range is smaller than the observation area, the MRR–method can give a reliable estimate of the length of t he species' lifetime track.

Movement parameters

One can escape the mentioned limitations of the MRR–method by simulating the range expansion, using estimations of the "movement parameters" (1) steplength and (2) area restrictedness. Steplength is defined as the mean distance moved in one day's p eriod. Area restrictedness is measured as the frequency distribution of direction deviations between pairs of successive movements.

Figure 1 shows the measured and the simulated range expansion of female *Maniola jurtina* in a 5 ha large observation area (the riverdune grassland "Junner Koeland West" in the Dutc h province of Overijssel). If the butterflies had been marked regularly over the area and if the marked individuals would be recaptured everywhere in the area w ith equal chance, the mean distance between place of marking and place of recapture would be 150–160 m. As expected the measured range of *M. jurtina* levels off at this independently calculated level. So this value of 150–160 m is not so much a property of the species as well as a consequence of the dimensions of the observation area! The range expansion simulated on the base of the two mentioned movement parameters is a better approximation of reality. As expected simulation within a limited observation area results in a range expansion similar to the observed one.

Characterizing the movement pattern of butterfy species

Butterfly species (sexes distingguished) can be characterized according to the value of the two mentioned movement parameters.

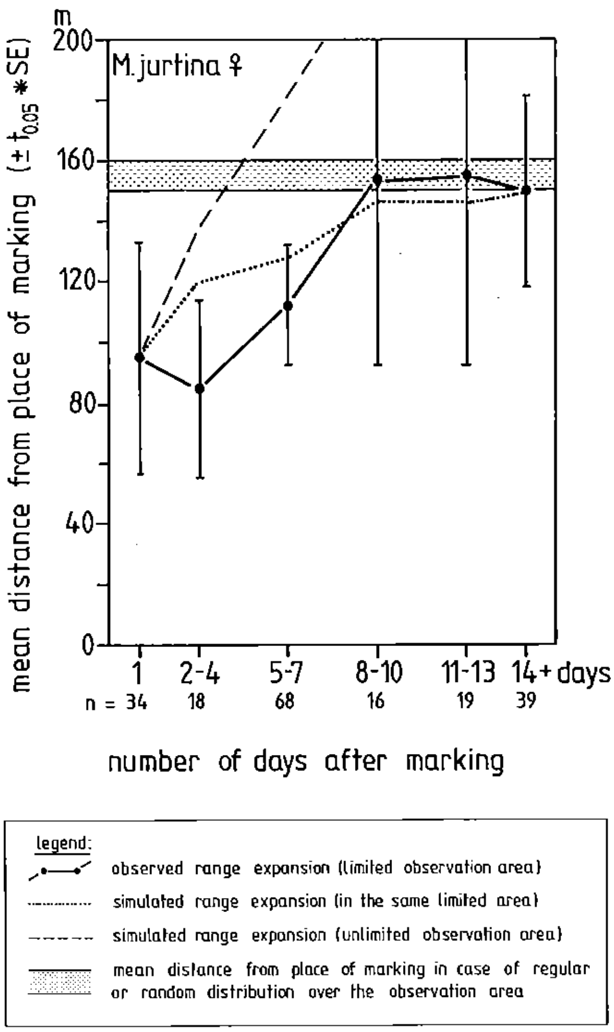

Fig. 1. Observed and simulated increase of the distance from place of marking in relation to the "age" of the marked butterfly.

Figure 2 shows the position of *Maniola jurtina* together with two other common species of the "Junner Koeland West", namely *Lycaena phlaeas* and *Heodes tityrus*. The position of the latter species is still tentative.

A returning movement pattern with a short steplength (e.g. male *H. tityrus*) results in a relatively short lifetime track. On the other hand, a more wandering movement pattern combined with a longer steplength (e.g. female *M. jurtina*) produces a much longer lifetime track. Furthermore the figure shows that the same length of lifetime track may result from different combinations of the movement parameters. Compare for instance female *L. phlaeas* and female *H. tityrus*.

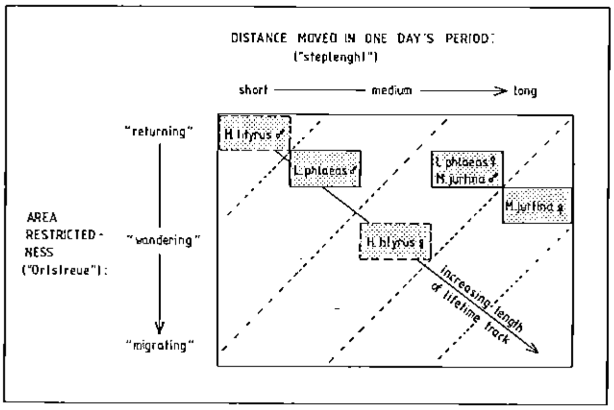

Fig. 2. Characterization of the movement pattern of the investigated butterfly species (sexes distinguished) according to the values of the two movement parameters "steplength" and "area restrictedness".

Conclusion

It is possible to gain insight in the length of the lifetime track of butterfly species by means of the MRR–method, even if the species' home range is larger than the observation area. In that case the range expansion should be simulated on the base of the values of the movement parameters "steplength" and "area restrictedness", as estimated by the MRR–method.

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ISOLATION RELATED DECLINE OF THE BUTTERFLY *HEODES TITYRUS* (PONTOPPIDAN 1763) IN THE NETHERLANDS

J.CHR. BOTH

Introduction

Long-term conservation of a species (or better: preservation of an evolving line) cannot be realised by merely establishing and preserving some favourable habitat patches containing "interaction groups" of individuals of the threatened species. Extinction of "interaction groups" is a common and natural phenomenon and a "metapopulation" can only persist via interpatch migration which offsetslocal extinction (a.o. DEN BOER 1979, WILCOX et al. 1985).

In the present paper former and recent distribution patterns of the butterfly *Heodes tityrus* (Pontoppidan, 1763) in the Netherlands are compared, using data gathered in the framework of the Dutch Butterfly Mapping Scheme (GERAEDTS, 1986). As this species is rather vulnerable to the vagaries of the climate and as the dispersal capacities are rather limited (BINK, pers. comm.), formerly inhabited patches which were also highly isolated will have a lower chance to be still occupied at present than less isolated patches.

Some notes on the ecology of *Heodes tityrus*

H. tityrus is a butterfly species that thrives in a countryside with short, flowery vegetation: (poor) grassland, heath and moor. The caterpillar's footplants (*Rumex acetosa* und *R. acetosella*) are still very common nowadays. In the Netherlands there are two – and sometimes three–generations in one year (GERAEDTS, 1986). *H. tityrus* is susceptible to climatological variation, which is expressed in the great difference in population size from year to year. This susceptibility is caused by the small degree of intrapopulation variation in speed of sub-adult development and in moment of emerging of the adults. Consequently a period of bad (cold, rainy) weather may endanger the reproduction of an entire population (BINK, pers. comm.).

The decline of *H. tityrus* in the Netherlands is described by GERAEDTS (1986). The shrinking of the distribution area has not evolved in the normal way, which means: withdrawal toward the center of the distribution area in south-eastern direction The opposite occured: the species has disappeared in the south and maintained itself in the north-east. The areas that have the highest atmospheric SO_2-concentration. That is the reason why it is supposed that the decline of *H. tityrus* has been caused in some way or another by "acid rain".

Measuring the degree of isolation: the immigration index (Im)

The "degree of isolation" will be used in this paper as a synonym of the immigration rate of DIAMOND (1979). The more immigrants arrive at a habitat patch (in a unit of time), the less the degree of isolation of the habitat patch will be. In this paper a "habitat patch" is defined as a square block of 5 by 5 kms in which *H. tityrus* has been recorded at least once. A block is the unit of inventory of the Dutch Butterfly Mapping Scheme. The Amersfoort co-ordinates of the south-western angular point of a block end in a 0 or a 5. Obviously the delimitation of the habitat patches is completely arbitrarily. However, the dimensions of a block correspond more or less with the lenght of the lifetime track of *H. tityrus* in a suitable area.

As the degree of isolation is assumed synonymous with the number of immigrants that arreve at the block, the following "immigration index" (Im) was developed as a measure of isolation:

$$Im = \sum_{d=1}^{65} (N_d/B_d) * S^d$$

where:

d = rounded distance (in units of 5 km) from the center of a block to the center of the block for which Im is calculated ("target block");
N_d = total number of blocks with records at distance d from the "target block";
B_d = total number of blocks at distance d from the target block;
S = "survival" per 5 km migration

If the degree of isolation of a block is estimated according to the formula mentioned above, it is supposed that the target block receives immigrants from all other blocks of the area (c.q. the Netherlands). The emigrants that leave a "source block" are assumed equally to disperse in all directions and consequently only a fraction $1/B_d$ will be directed towards the target block at distance d. It is supposed that during migration there is an exponential decrease of numbers with distance: in each unit of distance (5 km) only a fraction S is assumed to survive. In this paper N_d was estimated as the number of blocks at distance d from the target block with at least one observation of *H. tityrus*. Consequently N_d will be maximally B_d, the total number of blocks at distance d. For a given distance d the quotient N_d/B_d (see the formula above) will have 1.0 as a maximum and well in the case that all blocks at that distance produced at least one observation. For the parameter S a value of 0.56 was chosen arbitrarily. With this value of S the presence of observations in blocks at a distance of more than 25 kms from the target block does hardly influence the magnitude of the immigration-index of that target block.

Distribution data

Distribution data were extracted from the data-base of the Dutch Butterfly Mapping Scheme (system 1032 on the VAX-8600 of the Agricultural University Wageningen).

Two recording periods were considered: a former period which ends in 1979 and a recent period which covers the years 1980-1985. The location of a record is given as the Amersfoort-coordinates of the south-western angular point of a 5 x 5 kms block. Some of the records from the former period might be located in the wrong block. It concerns records which localities were characterized only by the name of the municipality. However, all records from the recent period are located in the right blocks.

Recent presence in relation to original degree of isolation

The distribution pattern in the period before 1980 has been compared with the distribution pattern in the period 1980-1985 (fig. 1).

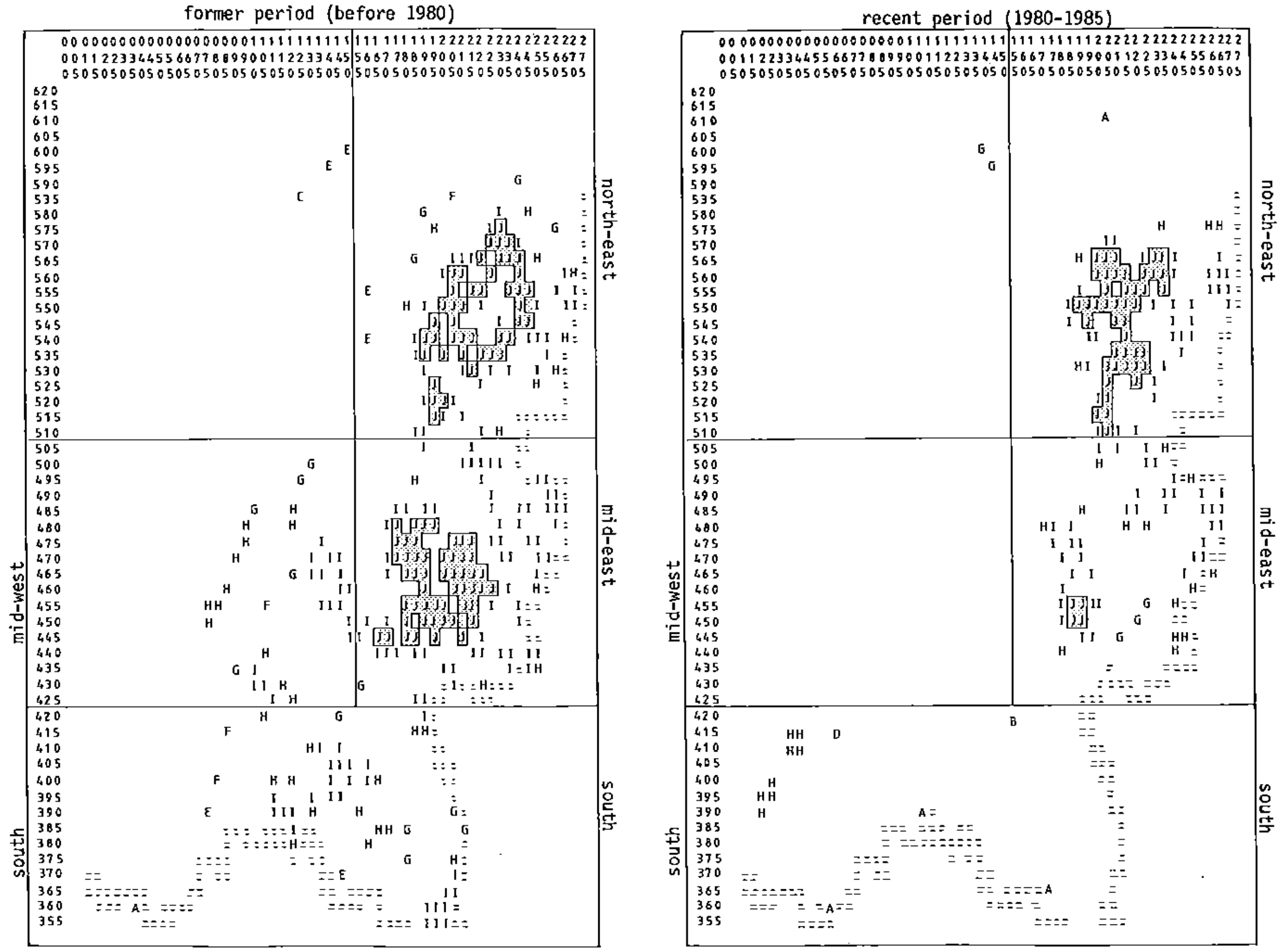

Fig. 1. Former (before 1980) and recent (1980–1985) distribution patterns of *Heodes tityrus* in the Netherlands (excluding the southern part of the province of Zuid–Limburg). The grid cells are indicated by Amersfoort–coordinates of the south–western angular–point. The alphabetic characters (A–J) indicate the degree of isolation, as measured by the immigration index (Im). The blocks with the highest values of Im (class J), i.e. the blocks with the lowest degree of isolation, are outlined and shaded. Frontier blocks without records of *H. tityrus* are indicated by a =–sign. The four regions are separated by straight lines.

In the former period *H. tityrus* was observed (at least once) in 305 blocks, excluding the blocks of Zuid–Limburg. In 77 of these blocks the species was also recorded in the recent period. The (fraction) presence, abbreviated by the symbol P, consequently amounts to 0.25. The mean (original) value of the immigration–index of the blocks with recent presence is 37% higher than the mean (original) value of the immigration–index of the blocks in which *H. tityrus* is absent in the recent period.

Fig. 2 shows the increase in presence with increasing original Im: a monotonously increasing P. The blocks with an original immigration–index falling in class H or less nowadays lack *H. tityrus* almost completely. More than 20% of the blocks with an occurence in the former period had such a low value of Im. On the contrary, the fraction presence of the blocks with a high original immigration–index (class J) is above the mean, namely 0.42. More than 30% of the 305 blocks with formerly occurence of *H. tityrus* fell in this category. The remaining (almost) 50% of the blocks had an intermediate value of Im (class I) and likewise shows an average P–value.

Regional variation in presence

The decline of *H. tityrus* in the Netherlands shows a remarkable regional variation. In the north–eastern part of the country the species has maintained itself rather well, while it has disappeared almost completely in the western and southern regions. It may be questioned if this regional variation in decline can be attributed to variation in original degree of isolation, as measured by means of the immigration–index.

Table 1 shows the values of P that would be expected in the different regions if the national relationship (fig. 2) would hold in all regions in the same way. In the north–east the presence is much higher than expected on the ground of the degree of isolation of the blocks. In the mid–west and the south on the other hand, the observed presence is too low. Apparently the regional differences in original degree of isolation do not entirely account for the observed differences in presence between the regions.

Two (not necessarily nutually exclusive) explanations come into the picture.

First of all the deterioration of the habitat of *H. tityrus* in the midwest and south may be more pronounced than in the north–east. Deterioration may have been caused by air–pollution (GERAEDTS, 1986). The second explanation may be found in the inadequacy of Im as a measure of the degree of isolation. I–blocks in the north–east may in fact be less isolated than I–blocks in the south and mid–west. Im–values were calculated without reckoning with the number of observations in the source blocks. The

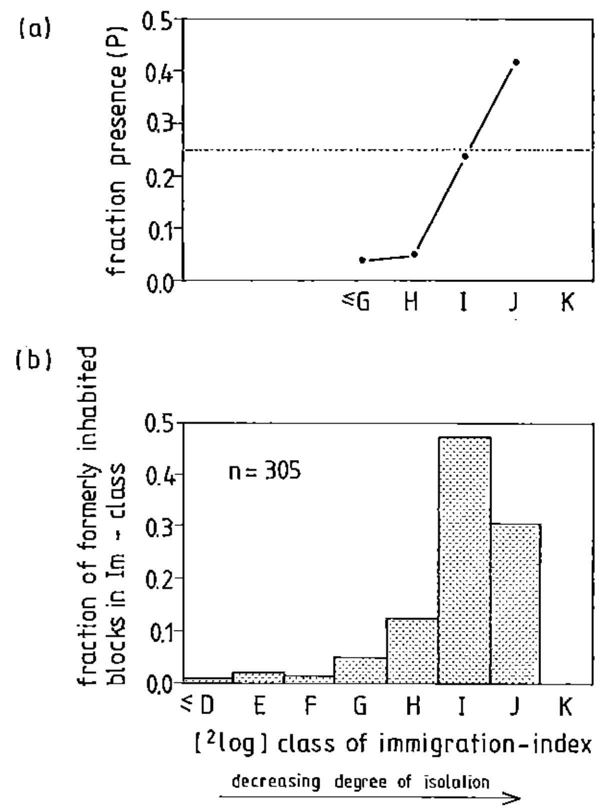

Fig. 2. (a) Fraction presence (P) of *Heodes tityrus* in formerly inhabited blocks in relation to the original value of the immigration–index of that blocks. Dotted line: the P of all blocks together (0.25). (b) Frequency distribution of the original values of Im of the 305 formerly inhabited blocks (see Fig. 1).

I–blocks in the north–east are for the greater part situated at the margin of the large core of J–blocks (fig. 1). The sources of immigrants of these I–blocks may be much larger than the immigrant–sources of the I–blocks in the mid–west and south. Differences in "connectivity" of the landscape may also play a role. The landscape in the north–east may be more inviting for migrating butterflies than the landscape in other parts of the country. Further research is needed in order to decide which explanation suits best.

Conclusions

The recent presence of *H. tityrus* in formerly inhabited 5 x 5 kms blocks increases with decreasing original degree of isolation as measured by the immigration–index.

This isolation dependent presence however does not completely account for the regional variation in decline of *H. tityrus*: the recent presence of blocks with a certain degree of isolation in the northeastern region is much higher than in the midwest and south. It is not known if (a) the immigration–index does not measure the degree of isolation properly and/or (b) the habitat of *H. tityrus* has deteriorated in the northeast in a lesser degree than in the other parts of the country.

Acknowledgements

Mr. J.G. van der Made and ir. M. Tax supplied the distribution data and commented the distribution maps. Drs. F.A. Bink made valuable marginal notes to an earlier draft of the fig. 1. He also focussed the attention on some essential aspects of the ecology of *H. tityrus*.

Tab. 1. Observed and expected presence of *Heodes tityrus* in the four regions of the Netherlands (see Fig. 1). The expectednumber of blocks was calculated by multiplying the number of blocks of each class of Im with the Im–class specific P as holding on national scale (see Fig. 2a).

region:	observed presence (P):	expected presence (P):
north-east	46 / 95 = 0.52	27.5 / 95 = 0.29
mid-east	31 /120 = 0.26	36.8 / 120 = 0.31
mid-west	0 / 36 = 0.00	5.1 / 36 = 0.14
south	0 / 51 = 0.00	7.4 / 51 = 0.15

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INTERACTION BETWEEN WATER BODIES WITHIN THE FIOODPLAINS OF LARGE RIVERS : FUNCTION AND DEVELOPMENT OF CONNECTIVITY

C. Amoros & A.L. Roux

Alluvial floodplains of large rivers generally appear as networks of more or less interconnected waterbodies (Fig. 1). Within this aquatic network, several kinds of biotopes can be distinguished (e.g. main stream; lotic side arms, deadarms, oxbow lakes), which result from the displacement of these channels according to the dynamics, i.e. the processes of erosion,transport and sedimentation (LEOPOLD et al. 1964 ; SCHUMM 1977).

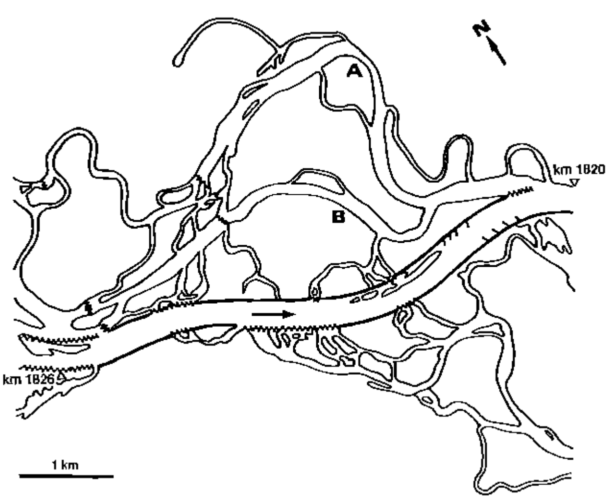

Fig. 1 : The water network within a reach of the Danube floodplain near Baka(river km. 1826–1830) modified from VRANOVSKY 1985); the main stream is channelized for navigation and the side arms blocked at their upstream end by submersible embankments; A and B are the sampling stations used by Vranovsky to compare the zooplanktion biomass.

Although the floodplain areas of large rivers had decreased markedly over the last two centuries (because of navigation improvements, flood control management etc.), even in the industrialized countries,the former channels represent an important part of the fluvial network. For example, within the Czechoslovakian–Hungarian reach of the Danube River, between river Km 25 and 35, oxbow lakes and the dead arms represent 26% (92 ha) of the water surface (BRAVARD 1986).

The lentic ecosystems of the alluvial floodplain have been integrated in the concept of river system (BOTNARIUC 1967 ; HYNES 1970) according to their relationship with the main stream. For example, ROTSCHEIN (1973), RICHARDOT–COULET et al. (1982) and WELOMMME (1985) have focused on the exchanges between these water bodies and the main stream. More recently, MINSHALL et al. (1985) have recognized the importance of their inputs within the river continuum concept.

Some of these water–bodies are permanently connected to the main stream at their two ends (the lotic side arms), some are connected only by their downstream end (the dead arms and backwaters), some are completely isolated from the main stream except during floods (the cutoff channels and oxbow lakes).

Based mainly on previous data obtained from other studies, which in general had different objectives than those addressed here, the present paper focuses on the ecological implications of the different levels of connectivity as well as the temporal changes thereof, either natural or man–made. Although the aquatic ecosystems of the alluvial plain are also connected to terrestrial and underground ecosystems, this paper addresses only on the production and exchanges of organisms between the permanent superficial water bodies.

1 – Comparisons of the biomass between side arms and main stream

In order to assess the interactions between the different water bodies of the floodplain in relation to their connectivity, it is necessary to evaluate the contribution of each part of the network. Examples can be taken in zooplankton and fish populations

1.1 – Zooplankton

It is well known that zooplankton develop more efficiently in standing than running waters. BOTHAR (1968) has compared the Cladoceran and Copepod populations of the main channel of the Danube River (riv. km. 1668) and a water–body connected to the river only during high water and floods : in July, 2 weeks after the return of normal discharge, the zooplankton abundance in the side–arm was 200 times higher than in the main channel (1192 vs 5.9 ind. l^{-1}). As well the zooplankton biomass in Danube side arms connected permanently at their downstream end, VRANOVSKY (1974, 1975) has measured 7500–6000 mg.m^{-3} (wet weight) in the Baka side arm (riv. km. 1821), 10430 mg.m^{-3} in the Zofin side arm (riv. km. 1836) and only 500–430 mg. m^{-3} in the main stream (ratios : 1:15, 1:14 and 1:22).

1.2 – Fishes

It is also well known that the ichthyomass (or standing stock) of secondary channels of backwaters connected to the main channel for most of the year is higher than that of the main river. In their detailed studies, Holcik et al. (HOLCIK & BASIL 1973, 1976 ; HOLCIK et al. 1981) indicate the following estimates for the Danube River, between the mouth of the Morava and Ipel Rivers (Tab. 1).

In the same section of the Danube, the overall annual production is about 748 metric tons of fish, of which about 140 tons occur in the main channels and about 608 tons in the side arms.

Tab. 1 : Ichthyomass in the main channel and in the backwaters of the Danube River between the mouth of the Morava and Ipel Rivers (mean values 1961–1972). From HOLINCK et al. 1981.

	Main channel	Backwaters	Ratio
Ichthyomass (kg.ha^{-1})	35	371	1:11
Total ichthyomass (10^3kg)	278	1157	1:4
Area (ha)	7937	3114	1:0,4

Fish production is correlated with the extent of side–arms and backwaters. According to RICHARDSON (1921 in GUILLORY 1979), in the Illinois River, an average of fish yeld of 199 kg.ha^{-1} in a section with about 83% backwaters and 78 kg.ha^{-1} in a section with only 63% backwaters.

It can thus be said that the production of large alluvial rivers is strongly correlated to the connectivity of their different water–bodies.

2 – Organism drift from side arms towards the main stream

Since their biotopes are connected to the main stream, planktonic organisms, some benthic invertebrates as well as juvenile fishes may be washed away by increasing flows, thus providing increased amounts of food for main–stream organisms.

2.1 – Zooplankton

These microscopic, weak–swimming organisms can be easily swept along by the minimum of current. In a side arm of the Danube River, blocked at its up stream end by a submersible embankment (riv. km. 1482), BOTHAR (1981) found 10833 ind.m^{-3} (average of the Crustacean populations) during July–August–September 1976 when the side arm was only connected downstream. During the same period, the planktonic Crustacean averaged only 323 ind.m^{-3} (1:34) at about 500 m downstream the junction. During high water in June, the side arm was connected at both upstream and downstream ends, thus the planktonic organisms were washed away mostly by the current; they were 3 116 ind.m^{-3} in the side arm and 1875 ind.m^{-3} in the main stream (1:1.6)

2.2 – Macroinvertebrates

The invertebrates living on the bottom, among the aquatic vegetation and swimming in the lentic backwaters and the dead arms are often washed away by increasing flows, thus constituting an important part of drift in large rivers. On the Upper Mississippi River, ECKBLAD et al. (1984) have carried out, at two study sites (ca.mile 671 and ca. mile 663), comparisons between organism drift coming from backwaters and the drift in the main channel, 1:3 and 1:8 respectively. This was confirmed by SHEAFFER & NICKUM (1986a) on the Mississippi River (between miles 556 and 552), the macro–invertebrates occurring within 3 backwater systems and within the main channel upstream and downstream the connections. In the main channel of the Upper Rhine River (ca. riv. km. 27), CELLOT & BOURNAUD (1986,1987) have collected invertebrates from drift and from benthos along a cross profile (5 sampling points), in September when the river discharge was around 400m^3.s^{-1} and in the beginning of October, just after an increase to 630 m^3.s^{-1} (Tab. 2). They have shown that the increasing flow has

Tab. 2 : Comparison of the number of *Asellus aquaticus* (Crustacea) per sample within the drift and the benthos of the Upper Rhne River before (September) and just after (October) a discharge increase (from CELLOT & BOURNAUD 1986, 1987).

	September					October				
Sites	A	B	C	D	E	A	B	C	D	E
Drift	0	1	0	1	0	21	?	262	299	25
Benthos	0	0	0	1	0	3	4	29	52	80

washed away invertebrates species such as *Asellus aquaticus* that are usually scarce in the main channel and characteristic of the lentic dead arms

2.3 – Larvae and juvenile fishes

SHEAFFER & NICKUM (1986b) recently studied larval and juvenile fishes near the mouths of backwater complexes of the Mississipi River : 2 in the main channel 800 m upstream and 800 m downstream from the backwater confluences, and one in the backwaters about 300 m from the confluence (Tab. 3). Overall, more larvae were captured in the backwaters than in the main channel habitats, indicating that backwaters are more productive. In the main channel, densities were greater downstream from the mouths of the backwaters than upstream; possibly indicating that

Tab. 3 : Relative abundance (N.100 m^{-3}) of larval and juvenile fishes collected in 3 backwater habitats associated with the backwater confluence in the Mississippi River (from SCHAEFFER & NICKUM 1986b).

	Sites in relation to backwaters		
	Upstream	Backwater	Downstream
Larvae	60.4	179.7	170.9
Juveniles	15.3	181.5	22.9

1/ larval fish drifted out the backwater areas

2/waters rich in nutrients or zooplankton that drain into the main channel create productive downstream sites, which may be used as nursery areas.

Juveniles are more abundant in the backwater areas than in the main channel ecosystems because these areas, analogous to the littoral zone of lakes(KITCHELL et al. 1977) are more productive (ELLIS et al. 1979) and are more intensively utilized than are the lotic channels (COPP & PENAZ in press). COPP (1987) found backwaters and oxbows to contain the highest biomass values for juveniles (up to 200g.m^{-2}), whereas the lotic channels presented among the lowest values (the highest at 57.6 g.m^{-2}). The migration of some fishes during their larval period results in higher densities and biomasses in the backwater areas close to the main channel, where larval migrators such as *Gobio gobio* (COPP & CELLOT, submitted) may account for a significant portion (up to 50%) of the fry community (COPP 1987 ;COPP, submitted).

3 – Effects of connectivity on former channels ecosystems

Depending on the degree of connectivity, the main channel has various degrees of influence on the aquatic ecosystems of the floodplain. Biomass of zooplankton, benthic invertebrates and fishes, as well as the organic content of the surficial sediment will be used to demonstrate such influence.

3.1 – Zooplankton

In 2 Danube side arms at Baka (riv. km. 1826–1820), VRANOVSKY (1985) has measured a smaller zooplankton biomass in the side arms supplied directly by the main channel (Fig. 1B) than in those that are more isolated (Fig. 1 A) (respectively 2015 and 2995 mg.m^{-3} of Protozoa + Rotifera + Crustacea in the average of 18 estimations in 1977 and 1978 with $P<0.01$).

3.2 – Benthic invertebrates

On the Upper Mississippi River, NEUSWANGER et al. (1982) have compared two side channels during mean discharge (June, July and August 1978), one was connected only at its upstream and dowstream end (pool20) and the other was connected only at its downstream end. For this comparison, they used two kinds of benthic invertebrates: a) a set of species living in the bottom sediment (= Herpobenthos) which includes *Hexagenia* larvae(Ephemeroptera), Chironomidae larvae and Oligochaeta ; b) a set of species living on solid substrates (= Haptobenthos which consists of Odonata larvae, Ephemeroptera larvae, Trichoptera larvae and some Chironomidae larvae). The biomass of the species living in the bottom sediment was higher in the side arm connected only at its downstream end (Tab. 4), whereas the flowrate occurring in the side arm connected at its two ends led to a higher biomass of species living on solid substrates.

Tab. 4 : Average biomass (mg.m^{-2}) of benthic invertebrates occuring in two Upper Mississippi sidearms in relation to their different connectivity (compiled from data of NEUSWANGER et al. 1982).

Study sites	Herpobenthos	Haptobenthos
Side arm connected up- and downstream	1960	7880
Side arm connected only at downstream	5040	636

3.3 – Fishes

In two water bodies of the Rhine River, KIECKHAFER (1977) indicated that the fish catch in a water body connected to the main channel was higher than the fish catch of an adjacent oxbow lake completely isolated from the main stream, (respectively 524 kg.ha^{-1}and 321 kg.ha^{-1}). On the upper Rhine River, COPP (1987) found fish reproduction to be much less intensive (species richness, density, biomass) in oxbows well isolated from the main river than in those closer to the main stream.

3.4 – Organic content of the surficial sediments

Within 4 sectors of the Upper Rhine River (ca. riv. km. 94,88, 68 and 30), ROSTAN et al. (1987) used the organic content of the surficial sediments as a record of ecosystem metabolism, thus integrating the seasonal and annual fluctuations. The organic load was evaluated by the Organic Sediment Index of BALLINGER & MC KEE (1971), which is the product of the organic carbon and nitrogen concentrations expressed as percentages of the dry weight sediment. The C.N. Index increases from the main stream and the lotic side arms connected at their two ends (0.01 – 0.10) towards the most distant oxbow lakes that are completely isolated (2.30 – 11.23); within the dead–arms connected only by their downstream end the index appears as an increasing gradient from the open end to the blocked end.

Not surprisingly, those channels in greater contact with the main flow contain less organic matter in their superficial sediments (Fig. 2). However(based on data from these 61 sites) no significant difference occurs between the dead arms permanently connected at their downstream end (Fig. 2C) and those connected only during spates (Fig. 2D). Indeed these "isolated" former braided channels may be closer topographically to the main stream than some other dead arms, which are up to 1500 m away from their downstream

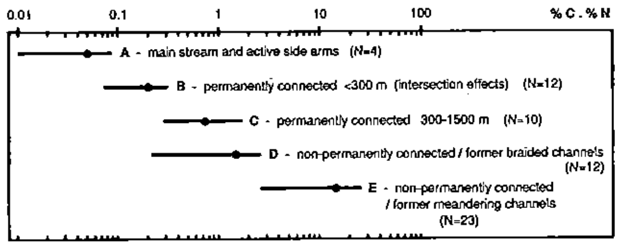

Fig. 2 : The organic matter in the surficial sediments of water bodies, within 4 reaches of the Rhine floodplain in the relation to their connectivity : A = the main stream and the side arms connected at up – and downstream ends; B + C = the former channels permanently connected downstreams, B = stations localised at less than 300m from the confluence and C = stations localised at more than 300m; D = former braided channels isolated from the main channel except during spates; E = former meandering channels isolated from the main channel except during spates (compiled from data of ROSTAN et al. 1987).

connection ; in such cases, one must also consider the flood frequency, i.e. the duration of the temporary connection. The isolated former meandering channels are significantly different from the isolated former braids for two reasons : a) they are generally more distant from the main stream and are separated by levees, which constitute a topographic obstacle to water overflows ; and b) according to their developmental pattern, they are more homeostatic than the isolated former braided channels (ROSTAN et al. 1987).

4 – Effects of the duration of the connection

As was suggested by the organic content of the former braided channels, the duration of a temporary connection within a bioyear timescale may influence floodplain ecosystems. This could be emphasized by examples concerning zooplankton, zoobenthos and fishes.

4.1 – Zooplankton and zoobenthos

The decrease of the current speed of short–term interruptions of the flow in side arms studied by VRANOVSKY (1972) within the Czechoslovak–Hungarian reach of the Danube River, showed little or no influence on the zooplankton. However, during autumnal decrease in discharge, which lasts 3 months, zooplankton abundance in backwaters increased conspicuously in comparison with zooplankton abundance in the main stream. The same influence was observed by BOTHAR (1972) in anotherDanube side arm (riv. km. 1669) which was connected at its two ends only during high water and flooding (Tab. 5) : the zooplankton abundance increased conspicuously according to the duration of the disconnection ; the zoobenthos showed the same pattern at a lesser extent.

Tab. 5 : Average abundance (ind.m^{-2}) of zooplankton (Cladocerans + Copepods) and zoobenthos (Chironomids + Oligochets) occuring in a Danube side arm in relation to the duration of its disconnection (compiled from data of BOTHAR 1972).

Disconnection duration (weeks)	23	6	13 + 3 + 2
Period (months)	Aug.-Jan.	Mar.-June	Sept.-Feb.
Zooplankton	1558	23	579
Zoobenthos	11549	5622	4063

4.2 – Fishes

Flooding is a crucial event for the reproduction of many species of fishes in alluvial large rivers, and consequently for fish production in these areas, there is a high correlation between the annual fish productions and the duration of flooding. Over a 38–year period on the Middle Danube River (Fig.3), the level of fish yield depended on the extent and the duration of the flood in days (STANKOVIC & JANKOVIC, 1971). The fluctuations of fish yield ranged roughly between less than 500 t when the flood lasts only 20 days and more than 1500 t when the flood lasted 200 days. Increases in the biomass estimates did not occur only during the years of high water levels but also the following years. For the Middle Danube River, every increase of the average annual water level by 1 cm instigates a yield increase about 500 kg during the corresponding year and of about 300 kg the following years (HOLCIK et al. 1981).

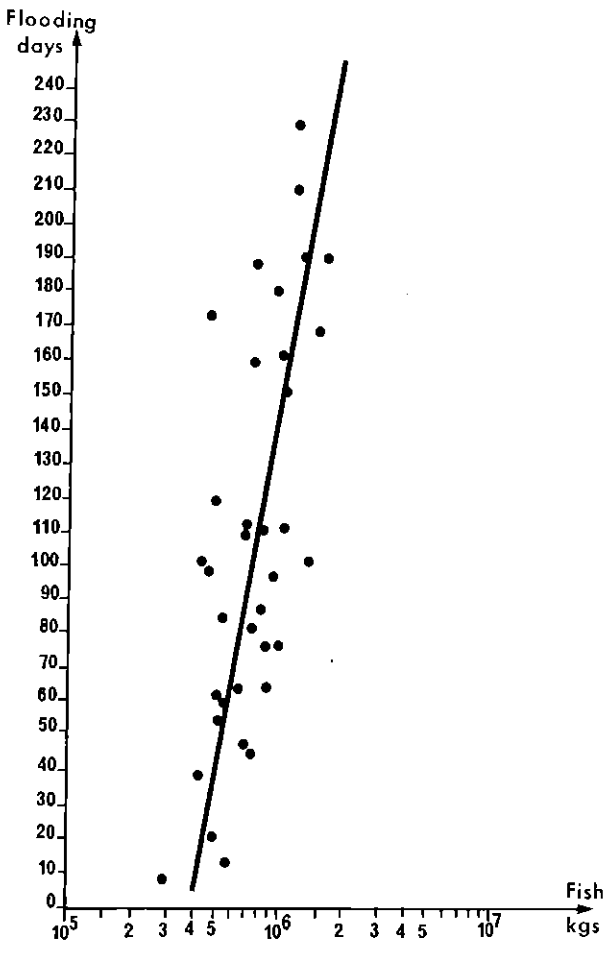

Fig. 3 : The annual fish yield in relation to the duration of the flood in the Middle Danube River, over a 38–year period (from STANKOVIC & JANKOVIC 1971).

A reduction in the area flooded (i.e. its connectivity) by embankments, channelization, regulation dams, etc., induces drastic effects on fish populations. For example, in a reach of the Missouri River, regulation resulted in a loss of nearly 60% of the area inundated, accompanied by a nearly 6–fold decline in the fish yield (WHITLEY & CAMPBELL 1974). Another example, after the 1968 closure of the Kainji dam on the Niger River, the reduction of flooded area and other disturbances to flood cycle had the im mediate effect of reducing fish catches by up to 50% (WELCOMME 1986).

5 – Effects of changes in connectivity

Within decennial timescale, the connectivity of the aquatic network may change as the result of natural processes and human impacts. The disturbance that occurs at the connection between the different channels induces alluvial deposition, which results in the formation of alluvial plugs. They are rapidly colonized by riparian plants, which slow down the water flow and thus accelerate the isolation of the former channels (positive feed–back). Therefore, the different connectivities, the effect of which having been exhibited above, result partly from the development of this natural process, which lead to a progressive decrease in the overall connectivity, as flood–control and navigation embankments conspicuously reduce the connectivity of aquatic network.

Within the Roumanian Danube floodplain, NEGREA & NEGREA(1975) have studied the Crapina and Jijila backwater systems during two periods; the first in 1956–1957, and the second in 1966–1967 after the Jijila systems has been disconnected by an embankment. Despite a slight overall increase of the biomass resulting from eutrophication, their results (Tab. 6) demonstrate a marked increase of Cladoceran biomass in the Jijila backwater after its isolation. Planktonic species predominate within the connected backwater (low abundance andgreat species number) whereas phytophilous Cladocerans (few species with great abundance) predominate within the isolated backwater, which become overgrown by aquatic plants.

Tab. 6 : Average biomass (mg.m^{-3}) of Cladocerans (Crustacea) within two backwater systems in the Danube floodplainbefore and after the embankment and isolation of the Jijila arm (from NEGREA and NEGREA 1975).

Study areas	1956-57	1966-67	ratios
Crapina	27.9	166.0	1 : 6
Jijila	51.6	4904.0	1 : 95

Conclusions

Within the aquatic networks of alluvial floodplains, the zooplankton bio–mass of the former channels increases with decreasing connectivity. As for the fishes and benthic invertebrates, the results are more complex because qualitative differences may be as great as the quantitative ones. In any case, when their biotopes are connected to the main stream, planktonic organisms, some benthic invertebrates as well as larval and juvenile fishes may be exported to the main stream , thus providing an important amount of food for river organisms.

In large alluvial rivers, water bodies of the floodplain are of vital importance as :

1/ reproduction sites for many fish species,

2/ food production centres for fishes, supplying both the floodplainand the main channel itself with food organisms,

3/ refuges during high water, thus providing shelder for fishes against strong currents, 4/ refuges in the case of heavy pollution in the main channel ; for example, during the years with the heaviest pollution load on the Rhine (in the60's) the side arms served as refuges during the spells of lethal and/ or critical water variables, and it was once more the case during the recent heavy pollution of the Rhine coming from Switzerland,

5/ centres from which the depopulated areas of the river may be restocked.

Because of fluctuation in water level the connectivity of the floodplain may not be measured by a simple distance between two landscape elements;the distance (horizontal spatial dimension), the topography (vertical spatial dimension) and the duration and/or frequency of the connection (temporal dimension within bioyear) must be considered simultaneously.

Within the larger temporal dimension, the connectivity of the aquatic network decreases naturally by alluvial deposition, which leads to the progressive isolation of former channels. The ecological successions that develop within these biotopes increase their isolation. However, the erosive processes of the fluvial dynamics may destroy ancient fluvial landforms, thereby constructing new landforms. In this way, fluvial dynamics may rejuvenate parts of the aquatic network and compensate the natural reduction of the connectivity. Usually, human action, namely embankments, reduce the connectivity and in addition prevent natural rejuvenation, being that lateral erosion of the river is impeded. Consequently, the rejuvenation processes of fluvial dynamics, as well as the connection of former channels, must be considered in the management of large river systems.

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THE MAINTENANCE OF ROAD VERGES AS POSSIBLE 'ECOLOGICAL CORRIDORS' OF GRASSLAND PLANTS

P.J.M. MELMAN, H.J. VERKAAR & H. HEEMSBERGEN

Abstract

There is evidence that grazy road verge vegetation may operate as an 'ecological corridor' for plants. In order to obtain knowledge on the maintenance required for such a possible functioning the effects of mowing regime, soil substrate and shading on vegetation performance were studied. It was found that mowing and subsequent removal of the hay once or twice a year tended to affect positively species diversitv and preservation of some rare species. A decrease of the level of above-ground production resulted in high species diversity depending on soil substrate. Abundant planting of trees and shrubs however had unfavourable effects.

Introduction

There is a growing interest in the maintenance of linear landscape elements, say road verges. There are indications that road verges among other linear landscape elements may operate as 'ecological corridorš for the migration of species through rather hostile surroundings apart from their possibility to provide a suitable habitat for rare species. Notably some grassland species may benefit from such corridors (VERKAAR, this volume). The aim of this study is to find out which mowing regime is most appropriate to grazy road verge vegetation performance (species diversity, occurrence of rare species, maintenance of the original features of the landscape, avoidance of local disturbance) given a certain soil substrate (clay or sand) and exposure to shade or full sun.

Materials and methods

In 1982 two study areas were selected. One consisted of a verge on rather unfertile, sandy soil along motorway A1, near Voorthuizen, partly shaded by a plantation of oak and birch. Another study area was choosen in a relatively broad verge on rather fertile, clayey soil along motorway A15, near Tiel, partly shaded by a plantation of tall poplar trees and shrubs of hawthorn and alder. Both verges were laid out in the sixties and early seventies and were managed as haylands by mowing twice per year.

In each study area five permanent plots, 10 m x 25 m (Tiel) and 10 m x 30 m (Voorthuizen) in size, were established in the shade and another five in unshaded conditions. Five regimes were selected : 1. mowing twice per year (June and September), 2. annual mowing in June, 3. annual mowingin September, 4.mowing every second year (June), and 5. no mowing. After mowing the hay was subsequently removed.

In June and September each year vegetation composition has been recorded. In June of each year standing crop has been measured by cutting 1 m x 1 m of the vegetation at a height of 3 to 5 cm above soil surface. Plant material was subsequently dried at 70°C for three days and weighed.

Results and discussion

In general some clear trends could be observed, although up to 1986 only a part of them were already statistically significant. Therefore in some cases it is still unclear whether differences between plots are either due to yearly fluctuations or due to developments caused by the experimental conditions.

If mowing practice was abandoned in unshaded plots with sandy soil (regime 5), the species diversity declined and grasses became dominant (Fig. 1). As was described by WELLS (1980), these grasses form a dense mat of litter, if mowing is omitted. Then, common species, e.g. *Festuca rubra* and *Agrostis capillaris*, which are known as rather competitive (GRIME 1979), almost exclude other, dicotyledon species.

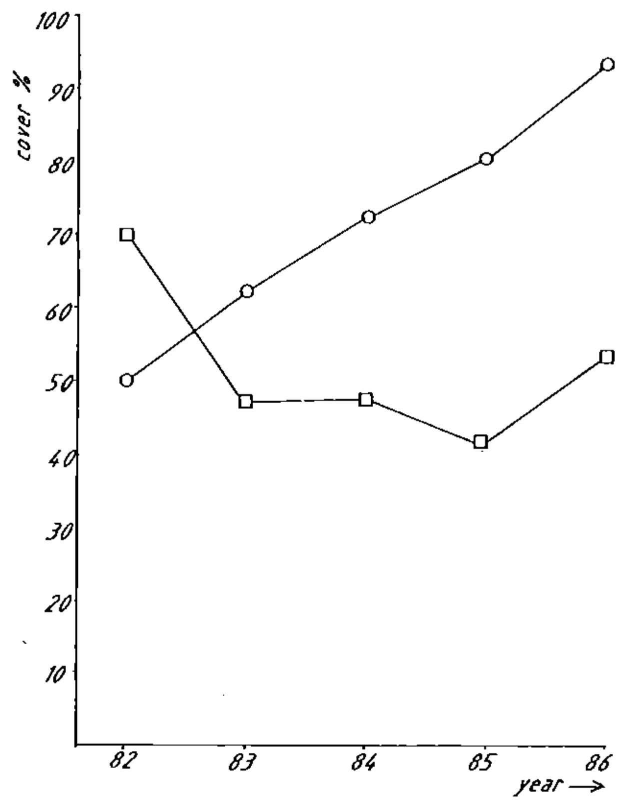

Fig. 1. Cover of graminoid species in unshaded, annually mown (regime 1 to 3) ( ) and unshaded, unmown (regime 5)( ) plots on sandy soil in the course of time.

If road verges however were shaded, the proportion of grasses decreased particularly in clayey soil and dominance of some common herbs, e.g. *Anthriscus sylvestris* and *Heracleum sphondylium* in regimes 1 to 3 and *Phalaris arundinacea* and *Urtica dioica* in regimes 4 and 5, was found. Obviously most grass species in the plots are less tolerant to shade than forbs like *A. sylvestris*.

If all data of a study area were taken together, no significant correlation could be found between standing crop and species richness in the same year on sand and only a weakly significant correlation for the area on clay. On the other hand, standing crop of the previous year was strongly correlated with species diversity in the subsequent year, but this correlation differed between plots on clay and sand (Fig. 2). As most of the road verge plants here were perennials and vegetation density may affect mortality most probably, it is very likely that the survival of plants could be properly

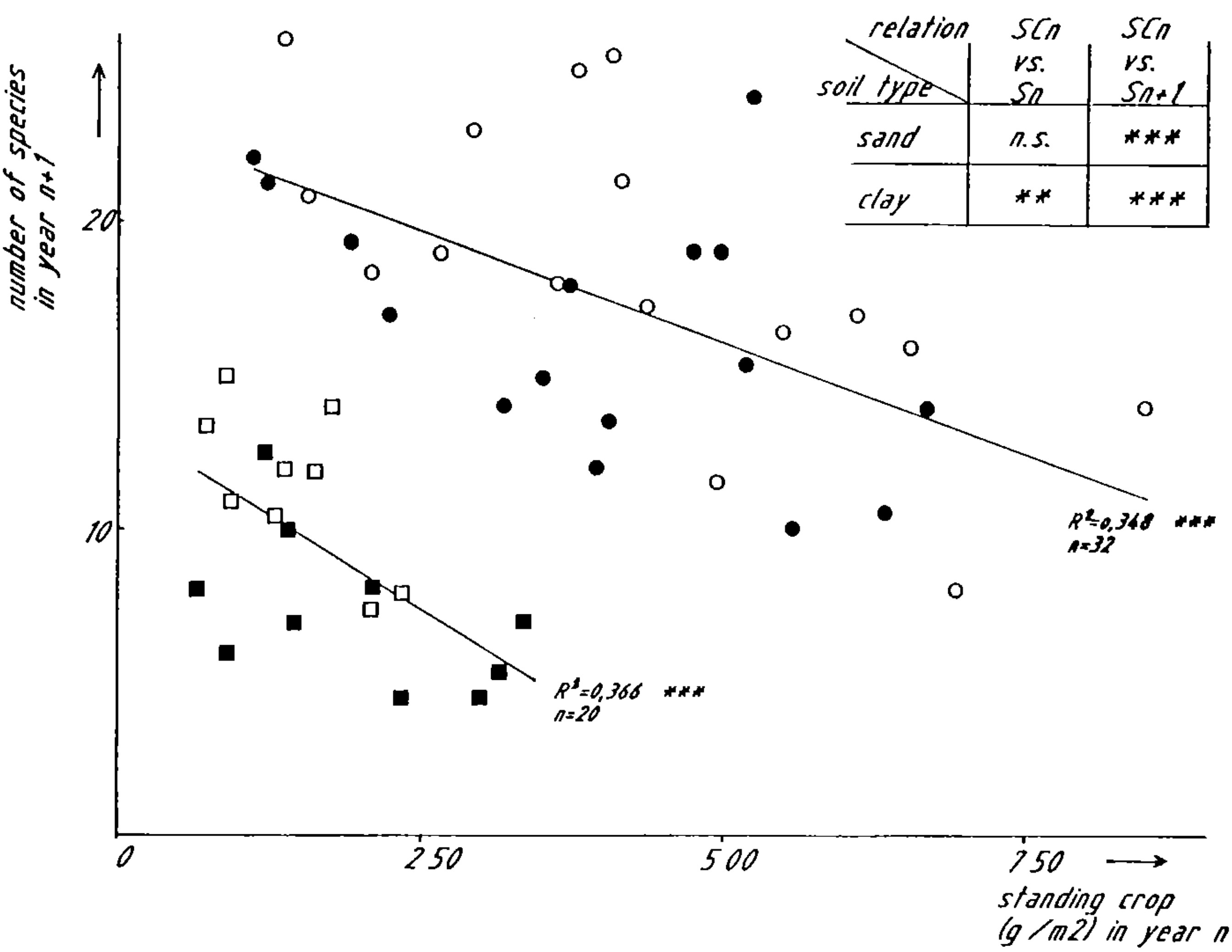

Fig. 2. Relationship between standing crop in year n (SCn) and species number in year n+1 (Sn+1) on clay (dots) and sand (squares). Solid symbols indicate shaded plots, open symbols unshaded plots. The number of data, R square and the significance level are indicated per soil type. Insertion : level of significance of SCn vs. species number in year n (Sn) and vs. Sn+1 on sand and clay.

noticed just in the subsequent year and not in the same year. Clearly a decrease of the level of standing crop resulted in a higher species density. Management regimes should be aimed at such low levels of production, although the level that is favourable to a high species diversity differs on soil substrate.

As GRIME (1979) predicted earlier, a 'corridor'–figure as revealed by AL–MUFTI et al. (1977), is not very likely for herbaceous vegetation which is of recent origin or has been subjected to marked changes in management, because maximum standing crop often varies to such extent that conditions favourable to high species diversity in one year may be followed in the next by the development of large amounts of biomass that tolerates only a few species. As a consequence, GRIME (1979) did not expect any relation between standing crop and species diversity at all. The differences in this correlation may be explained by differences in the current management regimes of road verges between Britain and the Netherlands. In contrast with Britain in the Netherlands many road verges of motorways have been managed suitable to species–rich grassland vegetation for already more than a decade.

In the shaded plots the correlation between standing crop in the previous year and species density in the next was (almost) significant below the level in the unshaded (Fig. 2). Therefore it can be concluded that abundant planting of trees and shrubs had unfavourable effects on vegetation performance in these plots; planting entails shade and a dense mat of litter and as a result of which a decrease in species diversity occurs.

Although some other trends between various regimes became apparent, so far we cannot give a clear view on the effects of e.g. various mowing regimes, and obviously a longer period of study is necessary.

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Nomenclature follows HEUKELS& VAN DER MEIJDEN (1983).

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AN ECOLOGICAL INFRASTRUCTURE FOR THE CENTRAL RIVER AREA IN THE NETHERLANDS

JULIETTE KUIPER

Design with Nature in a landscape planning competition. The landscape structure plan was originally send in by: Juliette Kuiper, G. Parlevliet and C. van Baarsel. – Second price ex aequo. Ideas and proposals were invited for the submission of a long term landscape structure plan which is to serve as a guide for short term planning.

The size: The Central river area is about 100 x 50 km. The plan is originally presented at scale 1:100.000.

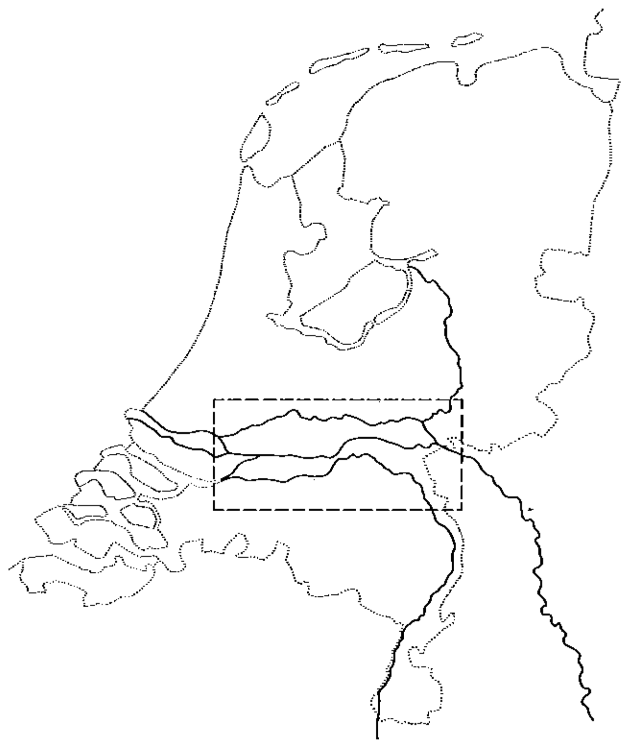

fig.1 Study area

ECOLOGICAL PROBLEMS

One important problem in the Netherlands is the intensity of agriculture use. There is no place left for nature development. Protected nature areas and scattered habitat patches in the cultivated landscape tend to become more and more isolated. As a result there is a continuing decrease in the number of existing species of plants and animals. Secondly, the migration possibilities become critical in the River area. The expansion of urban areas, for example, if unchecked, tends towards absolute barriers in migration corridors for a large number of river– and floodplain oriented organisms.

THE OBJECTIVE

To create a landscape structure plan serving as a blue print for future development of the Central River area: based on landscape–ecological as well as landscape–architectural principles, foreseeing further development of urbanization, agriculture, outdoor recreation and extraction of minerals.

METHOD

In recent years new landscape–ecological theories have been published based on the so–called "Island Theory". In this plan some of these theories are transformed into design principles, leading to a concept for an ecological infrastructure. Migration corridors are created or preserved for 3 types of present ecosystems at the national, regional and the local scale. The situation of the migration corridors is based on landscape ecological as well as landscape architectural principles. The landscape–ecological infrastructure is the base of this planning process. How ecological and architectural principles fit together at 3 different scale levels is shown in a diagram.

INVENTORY

Biesbosch and Old Rhine Streams are two important wetland– and meadowbird nature reserves, sources for many species on regional scale.

LANDSCAPE ECOLOGICAL INFRASTRUCTURE CONCEPT

(fig 4,5 en 6)
LANDSCAPE STRUCTURE PLAN

fig. 7

DRY SANDY AREAS

enlarge the settlements, intersected with afforestation on gradients

RIVERCLAY AREA

Levees
–agriculture to be intensified–linear plantations to be extended
–settlements to be enlarged on nodes of infrastructure
Black swamp– and peat soils
–existing grassland use to becontinued
–new extractionlakes to be concentrated with an eye on waterrecreation
Floodplains
–natural development along Rhine and Waal
–recreation development along Maas and Rhine

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DIAGRAM

Landscape ecological design principles

National level: (see fig.3)
To preserve migration corridors for riveroriented species, via rivers and wet grasslands, between source and sea. To counteract urban development interfering with these corridors.

Regional level:
To "Create" migration corridors for 3 ecosystems:
1 To preserve the large wet grassland–areas for meadowbirds (see fig.4).
2 To extend along river floodplains and brooks the wetland communities between "Biesbosch" and Old Rhine streams (fig5)
–To extend Reed, holm and fleedwood where possible.
–To extend innerdike wetlands as steppingstones along the Waal, where in the floodplains wetlands are not wanted because of meadowbirds.
3 To create corridors for woodland communities on drier land (see fig. 6).
–To extend woods on the gradient from sand to clay between the settlements in behalf of gradient species.
–To connect scattered woodlots in the Riverarea with main woodlands in the Sandy area by plantations.
–To create new woodlots on dry spots along the rivers (ca.30 ha.). fig. 5 and fig. 6 together create relations between Sandy areas and River area.

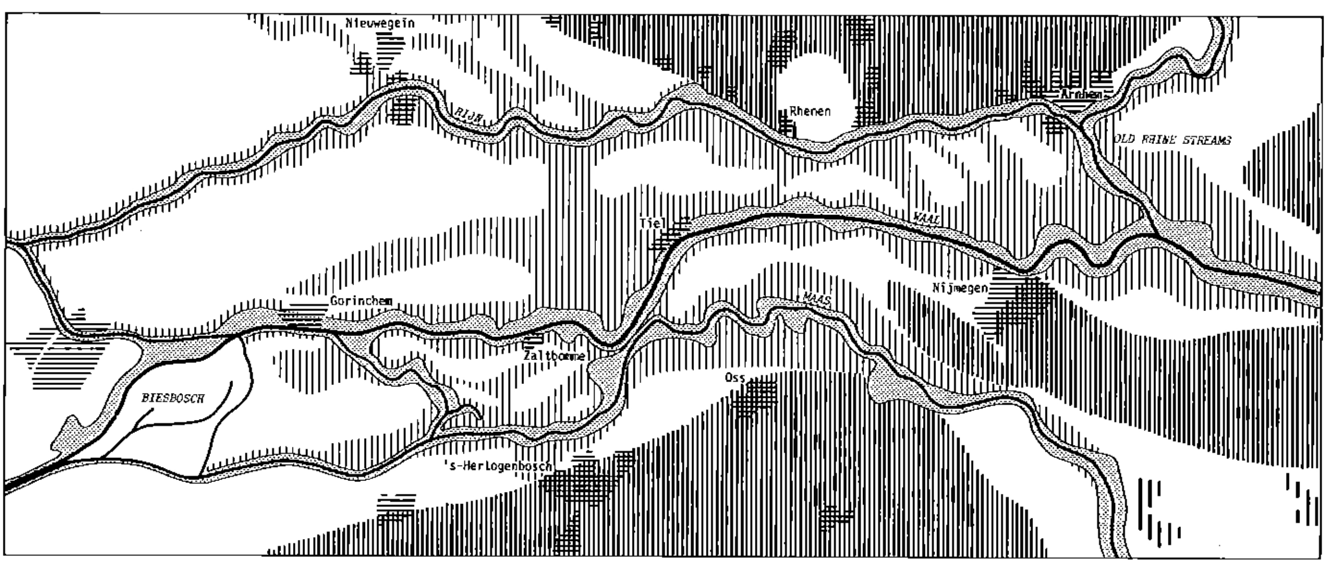
Local level:
To create corridors, for example for the Badger (see fig. 7).

Landscape architectural design principles

National level (see fig. 3)
To accentuate the difference between agricultural use and openness of the Riverarea versus urbanization and large grained density in Sandy areas.

Regional level:
1 To preserve the chain of large open spacesin the west, decreasing in size eastward (see fig. 4).
2 To accentuate the directions of rivers and brooks (see fig.3)
–To accentuate the identity of thedifferent rivers, according to their functions and features.
–To increase variation in openness along the Waal.
–To add, in a symmetrical way more woodlots innerdike along the Waal.
3 To accentuate visual variety (see fig. 6).
–To accentuate the edges of the Sandy area in contrast to the openness of the River area.
–To accentuate the fine grained density of the levees with linear plantations.
–To create new dots in contrast with linear riverlines.

Local level:
To accentuate different local patterns (see fig. 7).



DRY SANDY AREA
- built–up areas
- woodlands and brooks

RIVERCLAY AREA
- fertile levee; with a great variety of intensive agrarian crops and scattered woodlots
- black swamp– and peat soils; with wet grassland areas and meadow birds
- riverfloodplains; with wet hayfields (meadowbirds) and little wetland communities of Reed, holm and fleedwood and scattered deep lakes by the extraction of sand

fig.2 Soil land use and main ecosystems

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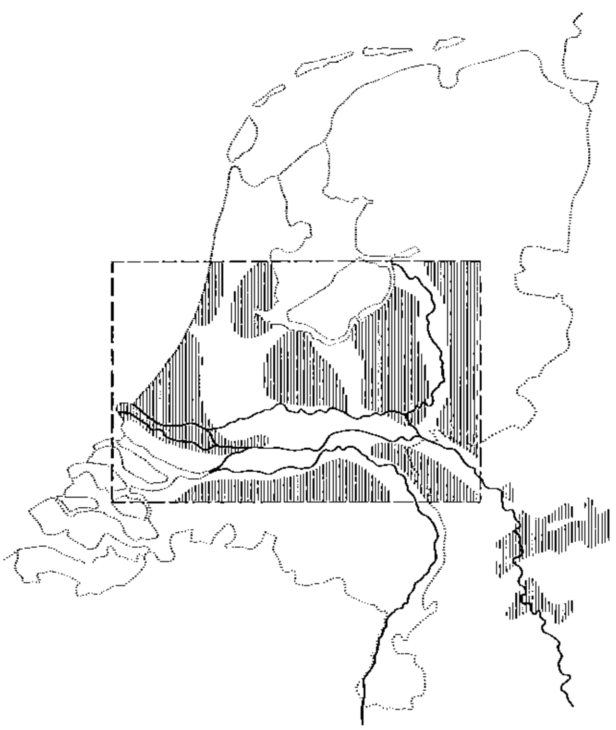
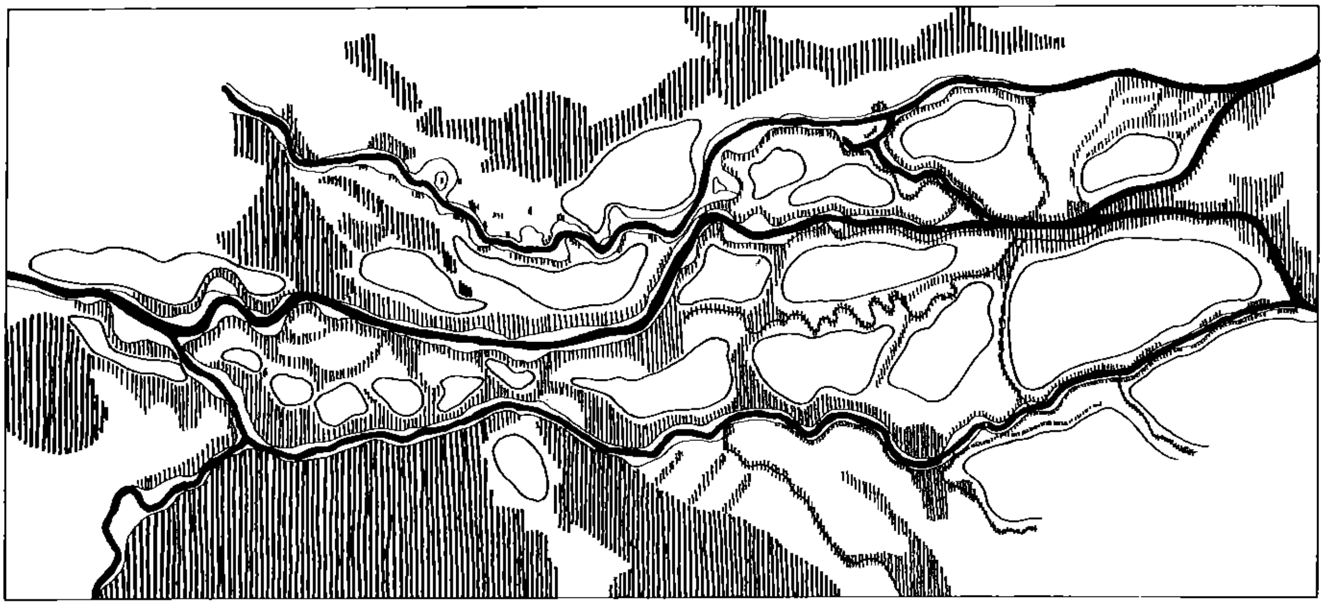


fig 3 L.E.I. National level



open grassland areas, corridors for meadowbirds

dense large grained areas

line grained variety in density

fig 4 L.E.I.Regional level

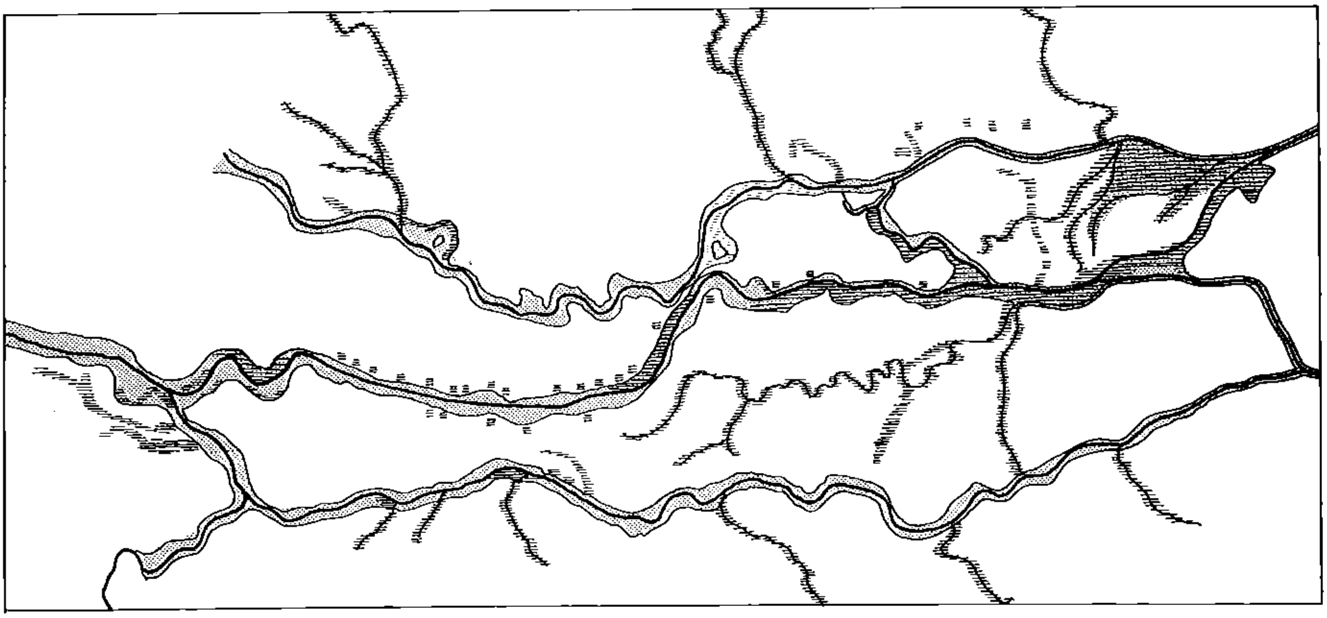


fig 5 L.E.I. Regional level

wetland– and aquatic communities
meadowbirds

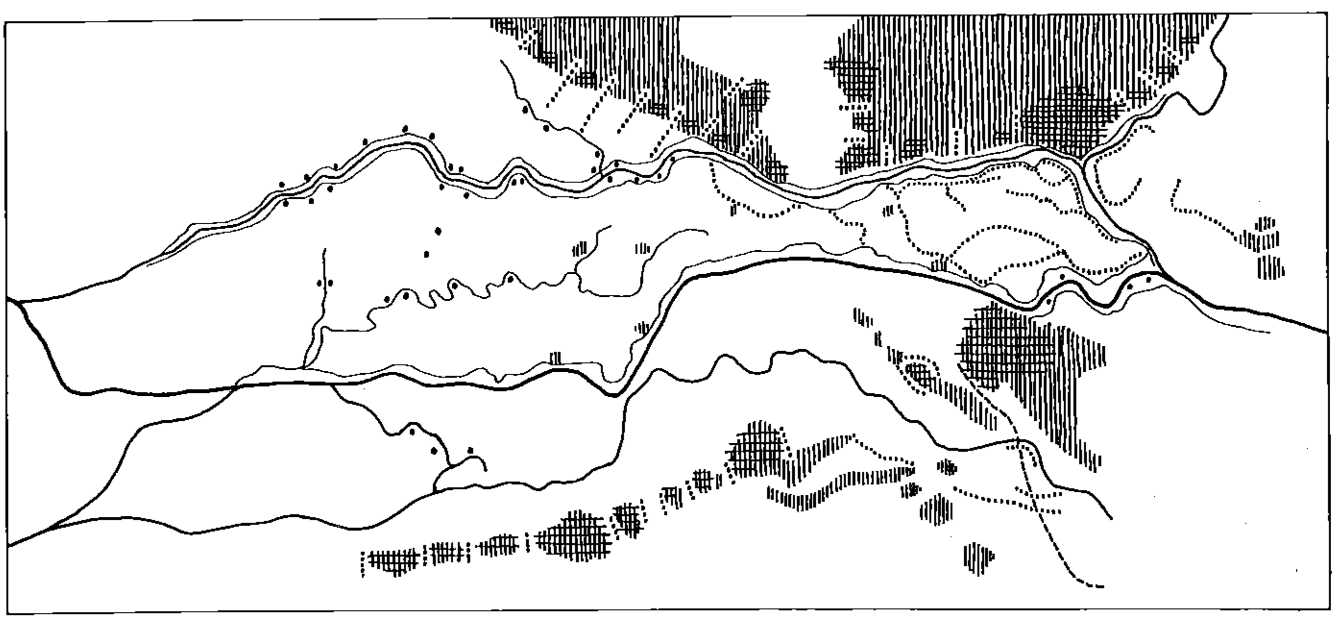


fig 6 L.E.I. Regional level

woodland communities on drier land
settlements
created plantation
new woodlots

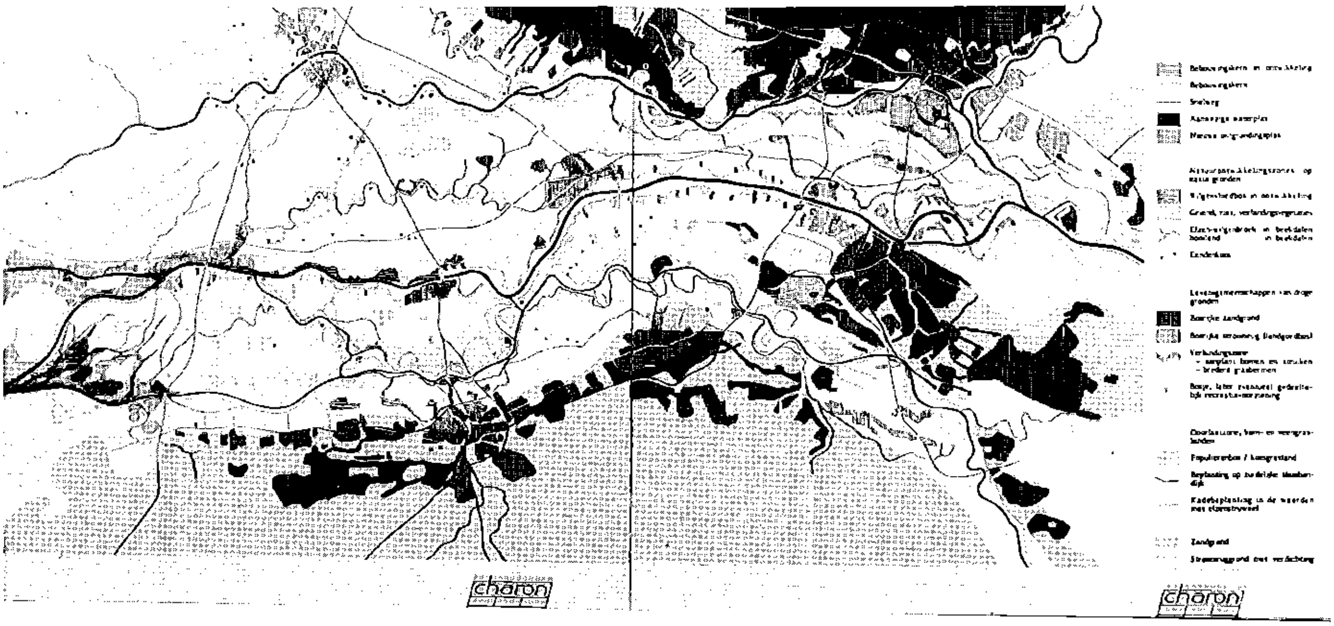


fig 7 LANDSCAPE STRUCTURE PLAN

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THE FUTURE LANDSCAPE OF THE RIVER AA

R. PLANTEIJDT, R.H.G. JONGMAN and K. KERKSTRA

Aim of the study

In many parts of the Netherlands moisture and wet nature is seriously threatened by desiccation, eutrophication and isolation. Much of this threatened nature is a remnant of former extensive wet parts of brook and small river systems. Aim of this study is to indicate environmental circumstances that avoid further desiccation and eutrophication and improve spatial connectivity for the river Aa (Weerijs). Because of incompatibility of the Dutch and Belgium data emphasis is laid on the Dutch part of the river basin.

Present situation

The river Aa is a small lowland river in the west part of the Dutch province North Brabant (Figure 1). It originates from the Dutch-–Belgium border area north of Antwerp and streams in Northern direction. Untill 1900 the upstream parts of the riverbasin consisted mainly of heathlands and bogs. Dominant vegetation types were Erica heathlands (Erica tetralix), Alder woods (Alnus glutinosa), Gale shrubs (Myrica gale) and Reedlands (Phragmites australis). Most of it is now brought under cultivation and is well drained. Streams are enlarged, the drainage pattern has been increased and most part of the system is regulated. The main land use now is agriculture, merely dairy farming and tree nursery in the Dutch part of the river basin and dairy farming and cattle raising in the Belgium part. Moisture and wet nature areas are restricted to a small number of terrains; they are scattered and isolated.

The second problem is caused by the discharge pattern. The layer of phreatic water is rather shallow (Figure 2). Due to this in combination with stream regulation and improved drainage the discharge has become irregular and water deficit can easily occur in dry periods. In the period April–August when potential evapotranspiration exceeds precipitation the small nature reserves are endangered by desiccation. Besides also agricultural water shortage occurs in dry periods(RIJKSWATERSTAAT 1985).

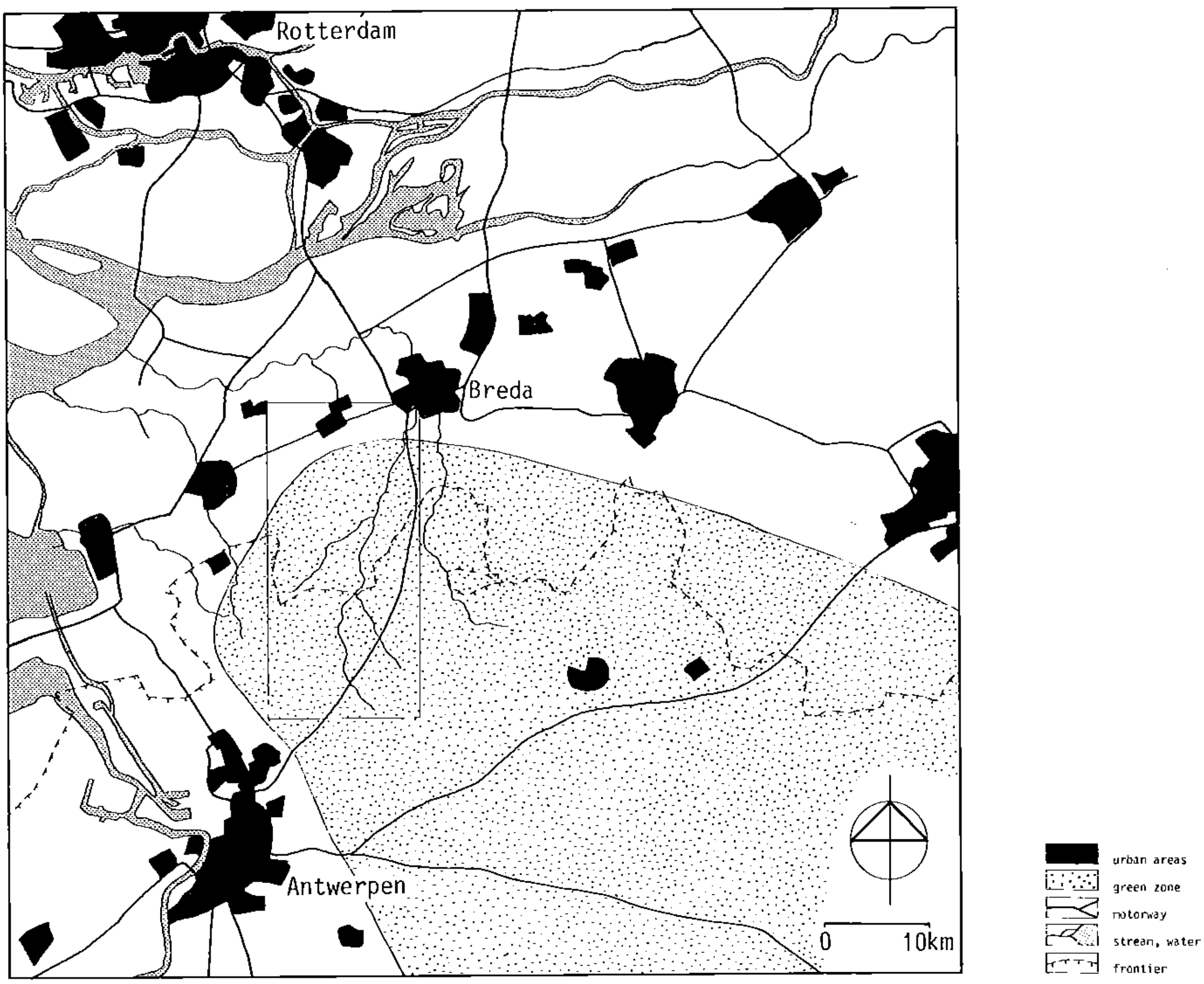

Fig. 1 : Study area

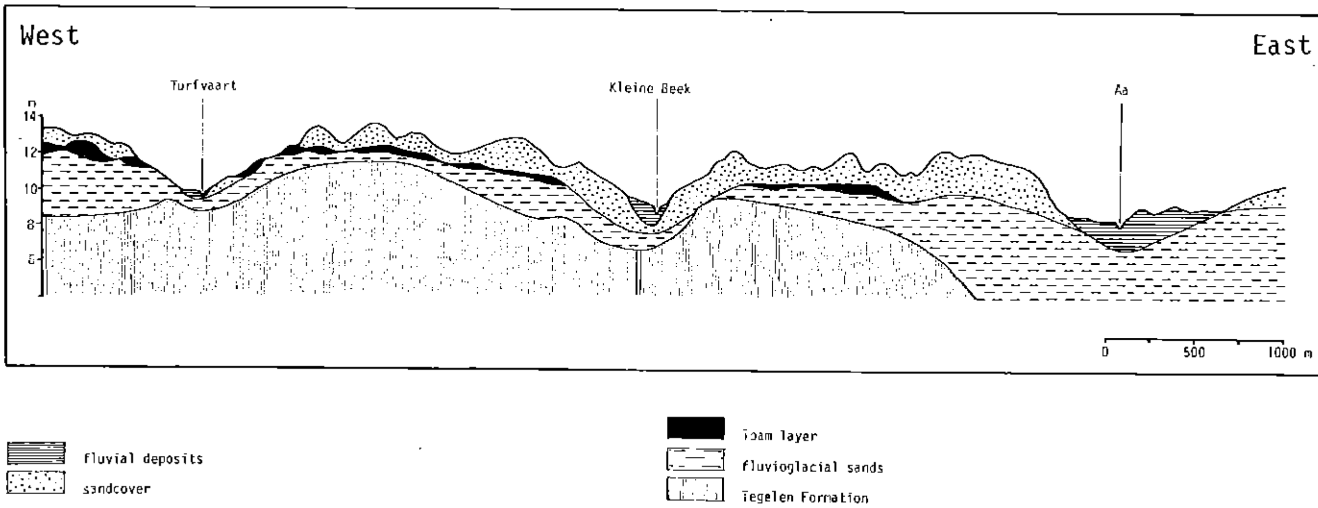

Fig. : 2 East–West section through the study area

Most of the moisture nature areas are oligothrophic or mesotthrophic. Therefore eutrophication is the third problem for the conservation of these natural terrains. The problem is caused by intensive farming, resulting in among others the application of large amounts of manure, of wich much is transported via groundwater into the river system. There it affects the ecological processes (SCHELLEKENS 1981).

Problem solutions

Possibilities to solve the problems concerning isolation and water management depend largely on the possibilities to steer developments in other forms of landuse. Hydrology of the catchment is the main proces to be analysed. From the discharge after high precipitation (storm) it can be concluded that water retention is low. Water retention can be improved by heigtening the weirs to diminish the direct runoff.

For the natural terrains hydrological bufferzones are calculated to be a zone of 200 to 250 m (KEMMERS 1982). This solution, however, will have only minor results. Much more effects are to be expected from reestablishing marshes retention basins and reedlands and alder woods. Possible locations can be found in the seepage areas along the brooks (Figure 3).

Extensivation of agricultural landuse, in combination with water filtering by helophytes (DUEL and SARIS 1986) can diminish eutrophication. The combination of extensivation, filtering by helophytes and bufferzones can improve the living conditions in the brook system by increased shading and taking up nutrients from the water.

Connectivity between moisture nature areas is wanted only if the water quality is improved. Therefore connectivity can only be favoured through corridors, created by heigtening up the weirs in combination with the creation of helophytes filters and improved living conditions in the brook system. Enlargement of mesotrophic moisture nature areas (retention basins) is possible, because most are situated in the seepage area of the river system.

Landscape plan

Two landscape plans are developed, a so–called short term plan and a so–called long term plan (Figure 4). The former consists of minor changes in land use and river management. The latter contains solutions that make substantial land use changes necessary and can therefore be considered as a second phase in landscape planning.

Small scale water retention is achieved by heightening up the weirs and constructing new ones. Hydrological bufferzones will diminish the influence of the agricultural land use.

In the long term plan improved connectivity is achieved in combination with large scale water retention. The weirs are heightened up and the water retention area is enlarged. A large area along the upper course of the Turfvaart will be wetland. A natural swamp vegetation can develop here. The Turfvaart is the section of the river system containing most of the wet natural vegetation now and the heightening of the weirs will improve their mutual connectivity.

Water storage is also realized in the middle course of the Kleine beek.An area of 250 ha. of reedland, storing 25 cm of extra water (500 000 m3), can improve the discharge of the brook by making it more regular and the reedland can improve the water quality by filtering. It is possible to maintain a river discharge of 1 l/sec during a 3 months dry period.

Riverside planting is planned for reestablishing natural stream environment and as ecological corridors, improving connectivity.

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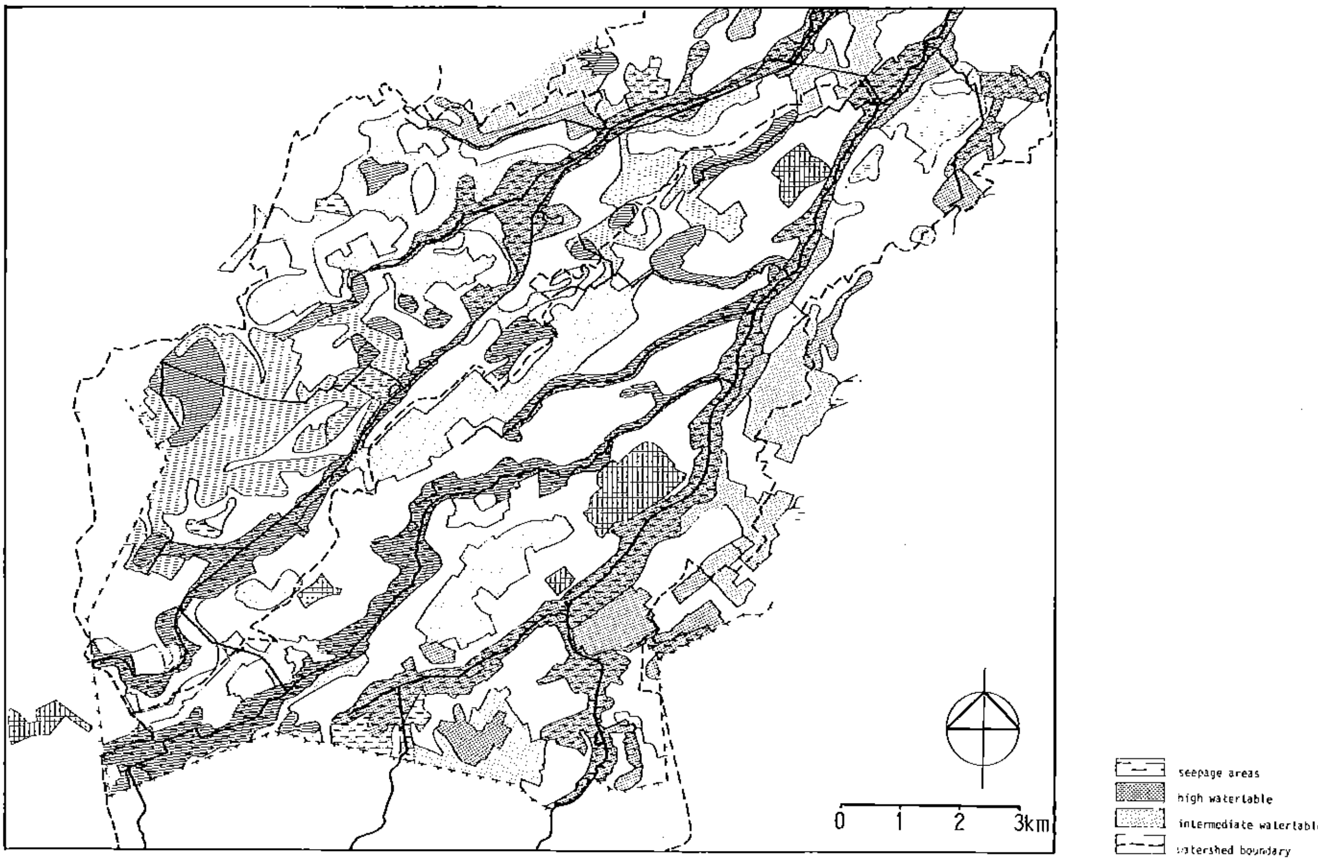


Fig. : 3 Hydrology

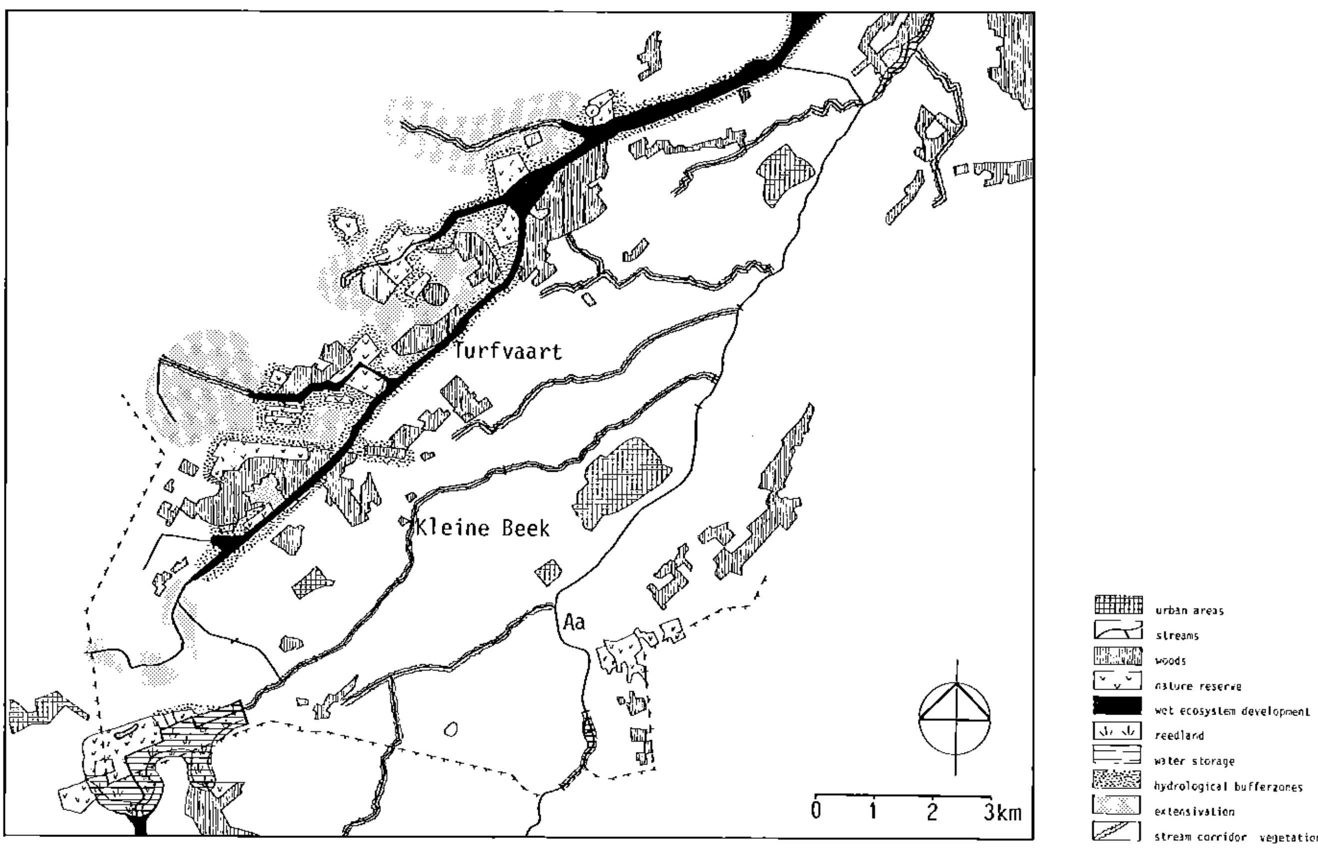


Fig. : 4 Long term plan

THE APPLICATION OF ARTIFICIAL WETLANDS BASED ON FUNCTIONAL NETWORKS IN THE NETHERLANDS

H. Duel & F. Saris

INTRODUCTION

In the Netherlands, many watersystems have become eutrophicated during the last 20 years (VW & VROM 1985). As a consequence the biological equilibrium of the water systems has been disturbed. The ecological changes due to the eutrophication of surface waters have caused a permanent domination of blue-algae. The ability of wetlands to remove pollutants from surface water can become an important item within the scope of future landscape planning and nature conservation. Several possibilities for application of artificial wetlands in the Netherlands are described in this paper (figure 1).

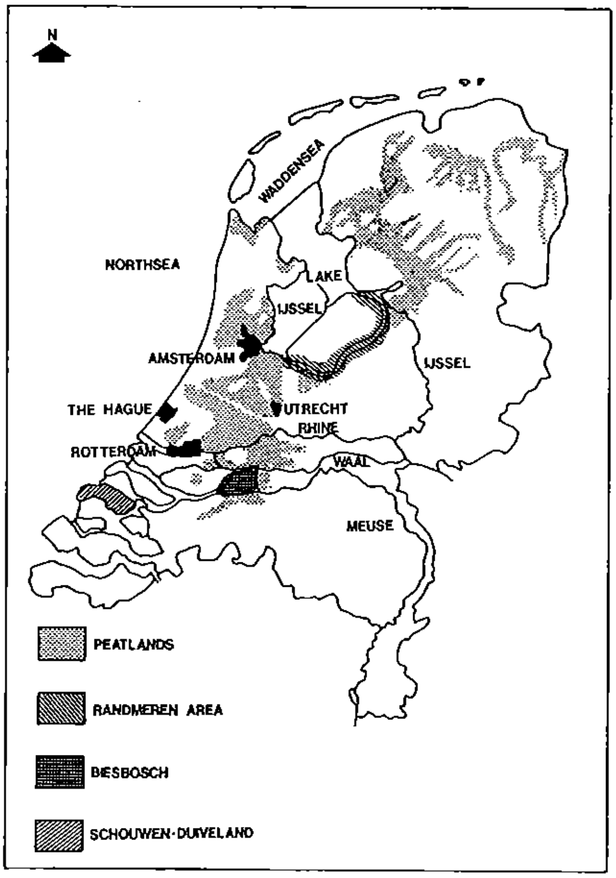


Fig. 1. Locations for the application of artifical wetlands

WETLANDS AND THE PURIFICATION OF WATER

The main mechanisms of wetlands purification are (DUEL & SARIS 1986):

- uptake of nutrients by macrophytes
- adsorption at peat and clay particles
- micro-biological transformation into atmospheric compounds (such as denitrification)
- chemical precipitation reactions
- sedimentation of particles (organic and anorganic)

The hydraulic loading of the (artificial) wetlands has a large impact on the removal efficiency (figure 2). With a hydraulic loading less than 200-300 m^3/ha/year, the removal of pollutants by wetlands is most efficient. As the loading rate is increased, the efficiency of nutrient removal declines rapidly. Also the nutrient loading of the

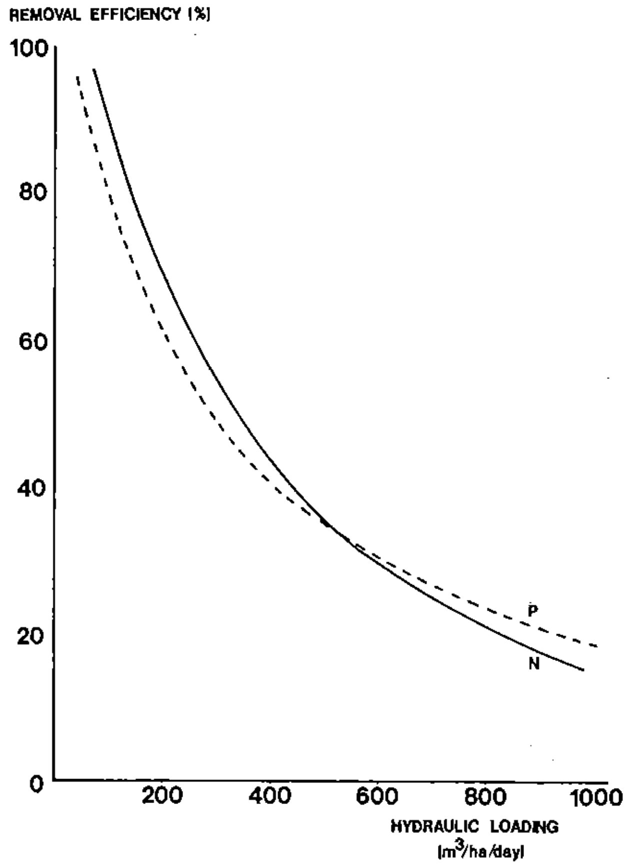


Fig. 2. The removal efficiency of watewater N and P by wetlands at different hydraulic loading rates (after DUEL 1986).

wetlands has a large impact on the removal efficiency (figure 3). At low nutrient loading rates, wetlands have the capacity to remove a high percentage of the nutrients applied. Besides the removal capacity of wetlands depends on a number of soil factors, including adsorption capacity, C/N ratio, aeration of the soil (DUEL 1986, DUEL & SARIS1986, VERHOUVEN 1985, RICHARDSON & NICHOLS 1985).

WETLANDS AND THE DEVELOPMENT OF ECOSYSTEMS

The mechanism of purification of surface water by wetlands can be used for obtaining or conservation of ecosystems which depend on mesotrophic water. Vegetation types of mesothrophic waters such as water soldier (*Stratiotes aloides*) vegetations are rare in the Netherlands. Wetlands, often in combination of adjacent areas, can

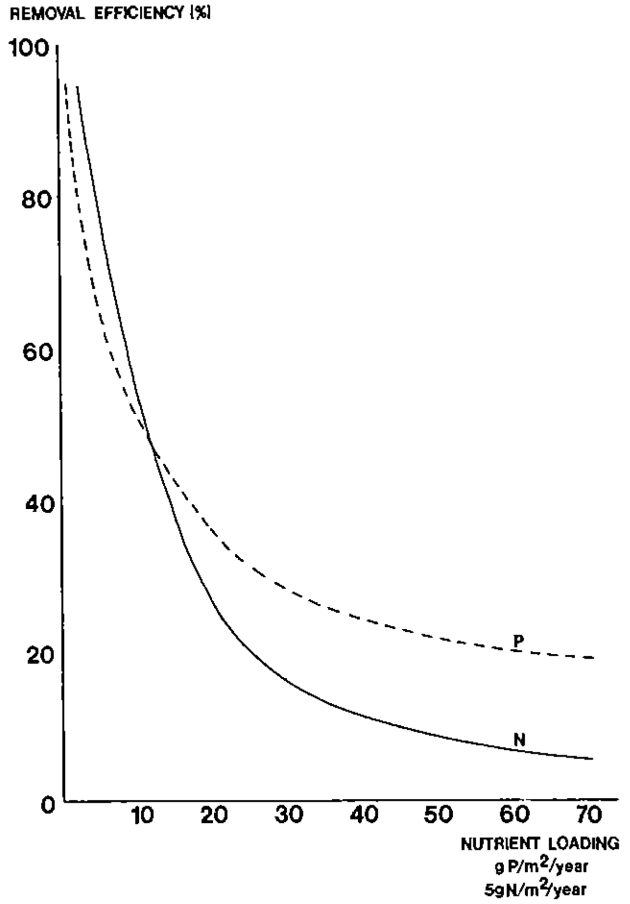


Fig. 3. The removal efficiency of watewater N and P by wetlands at different nutrient loading rates (afterNICHOLS 1983).

provide the necessairy life requiests of food, shelter, protection from predators, breeding and nesting for wildlife (mammals, birds, fishes, reptiles and amphibians). For instance, wetlands are habitat sites of breeding birds, which are rare in the Netherlands (table 1). The otter (*Lutra lutra*) and the water shrew (*Neomys fodiens*) are still the only indigenous mammals living in wetlands (FISELIER 1987). The creation of artificial wetlands for the treatment of eutrophic surface water may increase the ecological quality of the water systems and adjacent areas.

APPLICATION OF ARTIFICIAL WETLANDS IN AGRICULTURAL PEATLANDS

The peatlands in the western part of the Netherlands (figure 1) are agricultural landscape with many water bodies: lakes, rivers, canals, ditches and mesothrophic fens. These elements have become eutrophicated mainly by the discharge of municipal waste waters and runoff of fertilized farming-land (BELTMAN et al. 1986, MEULEMAN 1987). Water purification by artificial wetlands is a method to decline the N and P concentrations in surface water. Moreover vegetation types of mesotrophic waters can develop in a cultivated landscape. A ecological network of corridors and patches (figure 4) will increase the ecological quality of the agricultural peatlands.

APPLICATION OF ARTIFICIAL WETLANDS IN THE RANDMEREN AREA

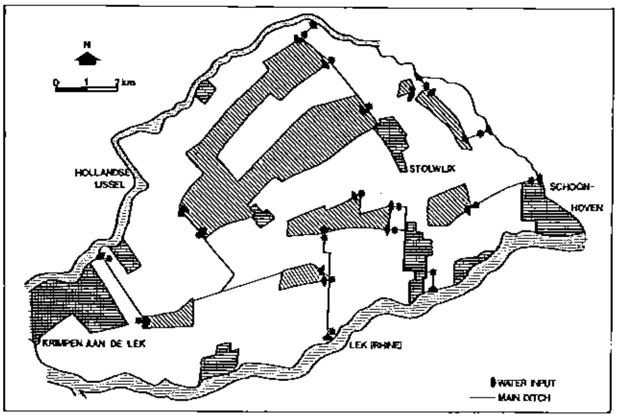
The Randmeren area consists of several eutrophic lakes. In the eutrophic lakes, the littoral vegetation has almost disappeard, which for instance caused a dramatic decrease of the habitat of the predator-fish northern pike (*Esox lucius*) (HOSPER et al. 1987). In order to tackle the eutrophication, artificial wetlands are applied for purification of recrational and municipal waste water (figure 5). Also a feasibility study has been carried out to create wetlands in the lakes and in the mouth of eutrophic rivers (FISELIER 1987).

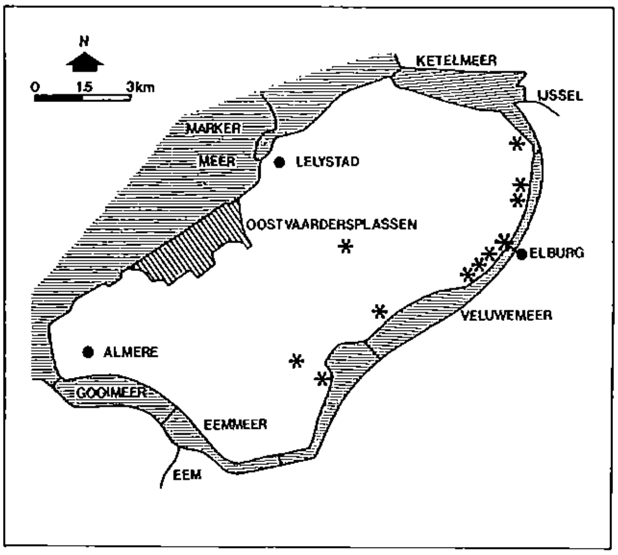
APPLICATION OF ARTIFICIAL WETLANDS FOR THE DRINKING WATER SUPPLY

Eutrophic water from the river Meuse is used for the drinking water supply of the city of Rotterdam. In the former fresh water tidal area of the Biesbosch the river water is let into 3 large reservoirs with a total storage volume of 48,6 million m^3 (figure 6). A fourth reservoir will be constructed when the future development of the water demand and the water quality makes it necessary.From a nature conservation point of view the construction of another water reservoir in the wetland area should be avoided. In stead of water

Tab. 1. Some bird species in wetlands vegetated with *Phragmites, Scirpus* and *Carex* in the Netherlands. Some of them are red-data species, with a relatively large population size in the Netherlands.

Birds			
Botaurus stellaris	Bittern	Cirsus aegruginosus	Marsh Harrier
Ixobrychus minutus	Little Bittern	Cirsud cyanus	Hen Harrier
Ardea purpurea	Purple Heron	Circus pygargys	Montagu's Harrier
Platalea Leucorodia	Spoonbill	Panurus biarmicus	Bearded Reedling
Anser anser	Greylag Goose	Locustella naevia	Grasshopper Warbler
Aythya ferina	Pochard	Locustella luscinioides	Savi's Warbler
Rallus aqauaticus	Water Rail	Acrocephalus arundinaceus	Great Reed Warbler
Porzeana porzana	Spotted Crake	Acrocephalus schoenoboenus	Sedghe Warbler
Porzana pusilla	Baillon's Crake	Acreocephalus scirpaceus	Reed Warbler
Chlidonias niger	Black Tern		





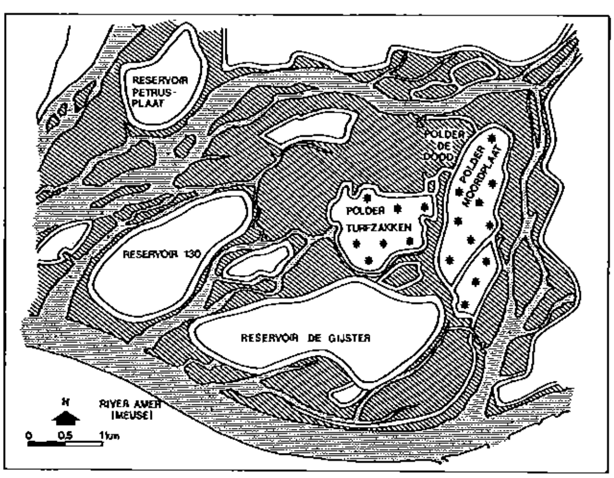


Fig. 4. The location of artifical wetlands to decline the nutrient input of natural wetland ecosystems in the Krimpenerwaard (after MEULEMAN 1987).

Fig. 5. The location of artifical wetlands for the purification of recreational and municipal wastewater in Randmeren area (modified after GREINER & BUTIJN 1985).

Fig. 6. Natural wetlands and water reservois in the Brabantse Biesbosch.

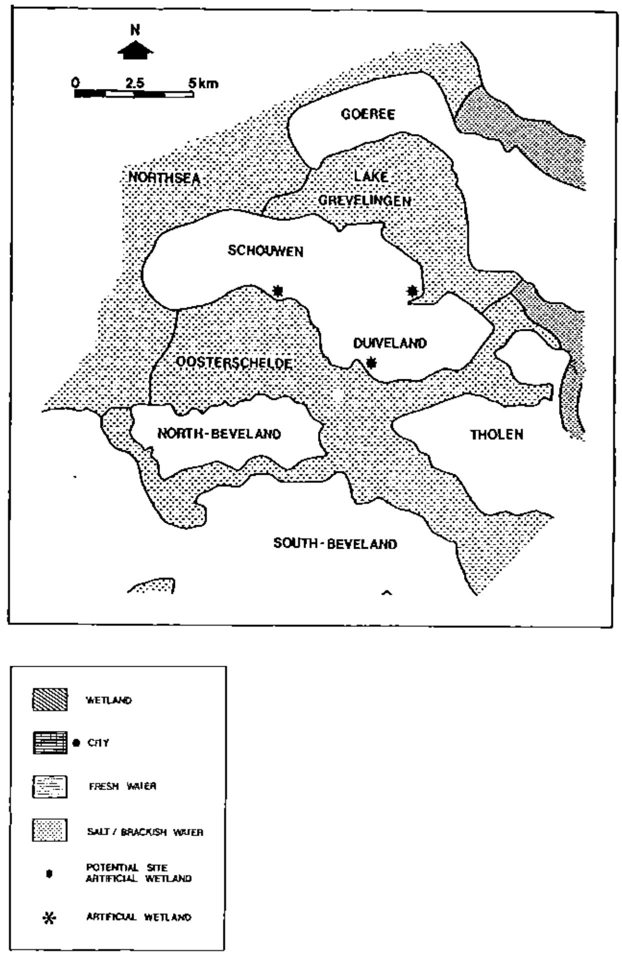


Fig. 7. Application of artifical wetlands for fresh water supply Schouwen--Duiveland.

reservoir, artificial wetlands can be used for the purification of river water for the drinking water supply (DUEL 1986, DUEL & SARIS 1986).

APPLICATION OF ARTIFICIAL WETLANDS FOR FRESH WATER SUPPLY

Schouwen–Duiveland is surrounded by salt water (figure 7). During the winter the nett gain of fresh water by rainfall on the island is pumped out into the salt waters. In the summer there is a shortage of fresh water in the cultivated lands. Retention of the surplus of local rainfall in artificial wetlands offers prospects to safeguard the fresh water supply and to develop wetland ecosystems.

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THE DESIGN AND IMPLEMENTATION OF AN ECOLOGICAL INFRASTRUCTURE IN THE REGIONAL PLAN SOUTH LIMBURG

H.F. GROEN

1. Introduction

In previous contributions much attention has been paid to the theoretical concepts, which underly the aim at connectivity in landscape ecology. In the Netherlands, as in other countries, much energy is invested to work out concepts of habitat networks and to research the validity of these networks.

This article handles briefly with the design and implementation of an ecological infrastructure in the Regional Plan South Limburg (1).

In the Regional Plan South Limburg the regional government gives a description of its policy at the spatial developments in the region South Limburg. It is the result of an analysis and linking up between claims and developing possibilities of a multitude of land utilization types.

Research is carried out to discover the problems and (im−)possibilities in agriculture, landscape, recreation, nature and forestry in South Limburg. For practical reasons the rest of this article only deals with nature with special attention to the concept of an ecological infrastructure. The following subjects will be discussed:

- general characteristics of South Limburg
- the functions of an ecological infrastructure
- the design of an ecological infrastructure
- the implementation of the ecological infrastructure in the Regional Plan South Limburg.

2. General characteristics of South Limburg

South Limburg is the most southern region of the Netherlands. In the west and the south it is surrounded by Belgium and in the east by the Federal Republic of Germany (figure 2). South Limburg can be classified as the second most densely populated region in the Netherlands.

Within the Netherlands South Limburg has an unique geomorphology because of tectonic activity of the Ardennen−Massif and incision and eroding activity of the river Maas and its tributary streams.

The originally flat landscape ist cut up in small table−lands, partly steep hills, hilly countries and valleys with or without rivers or streams.

It is because of this geomorphology and human activity in the past decades that South Limburg suffers by problems with water conservation and soil erosion.

These problems are dominantly caused by the removal of some sixty percent of the terracettes in the past fifty years and the transformation off grasslands into arable land on the hill slopes.

As nature is concerned, a lot of problems and threats have to be faced. Most problems are linked with mankind and are known for many countries all over the world:

- the fertilization of the environment with nitrogen and phosphate
- the pollution of water and soils with heavy metals
- drainage operations
- construction and planning of roads
- recreation
- removal of small landscape elements like terracettes and pools
- intensified agricultural land use
- mining of marl, clay, gravel and silversand.

As a result extensive parts of the rural areas have lost their significance for nature and caused the isolation of nature−reserves and populations of animals like the badger.

3. The ecological infrastructure

Definition:

I consider an ecological infrastructure as "a connected system of nature− reserves, woods and small landscape−elements like streams, pools, terracettes, woodlots and hedgerows".

An ecological infrastructure ought to fulfill more ecological functions at the same time. We can distinguish habitat−functions and dispersal−functions.

Habitat−functions point out the fact that a given woodlot or pool can provide a given animal a place to stay during a part of its life or an ideal home to several generations of a population.

Dispersal−functions focus at the temporal relationships between different areas. A given wood or nature−reserve can act as a source from which migration occurs of individuals or species towards the surrounding areas.

The exchange of individuals between populations of different areas is necessary to maintain this possibility of migration is a point of great concern.

The definition makes clear that to my opinion an ecological infrastructure contains a variety of elements. I think this is one of the most essential characteristics of an ecological infrastructure especially for regions as South Limburg. A good mixture of different kinds of landscape elements is important because most animals use different habitats in summer, spring and winter. Frogs often inhibernate in woods or woodlots, while pools are essential for the reproduction.

The badger needs woods, shrubs or woodlots to dig a hole and raise youngs, but to eat earth−worms moist grasslands have to be inreach. The exchange of animals between different areas offers also migrating possibilities to plants (zoochorie).

It is clear that the function(s) of a given woodlot in an ecological infrastructure might change with the species we are referring to, and the season of the year. Evenso it is clear that an ecological infrastructure has to contain a variety of habitats with small distances between them. It is important to keep this dynamic aspect in mind. It also stands for the opinion of some scientists that it is impossible to design an ecological infrastructure unless everthing is considered to be a part of the ecological infrastructure.

In the next chapter a brief account will be given on the design of an ecological infrastructure for South Limburg on a scale 1 to 50,000.

4. The design of the ecological infrastructure of South Limburg.

The problems with which nature is confronted are mentioned before. To solve these problems knowledge of the existence, distribution and requirements of species is essential. For the region South Limburg the following information is assembled:

- the pattern and character of the vegetation

- the distribution of some key-species of animals
- the developing possibilities.

Vegetation.

In 1984 and 1985 a vegetation survey is carried out on scale 1to 25000. This survey in combination with a land-use survey in 1983 covered about 100% of the rural and agricultural area. The key of the begetation survey enclosed some 150 vegetation types (GROEN and CORTENRAAD 1988: Vegetatiekartering Zuid-Limburg 1:25000; in prep.)

Fauna

There was no opportunity to carry out a fauna survey. Fortunately many data have recently been collected in South Limburg by amateurs and scientific researchers.

It was possible to get an overall picture on the distribution of some key species:

- amphibians (in pools or per km^2)
- reptiles (km^2)
- hamster (holes per km^2)
- badger (holes) and
- bats (guarries with inhibernating bats).

Developing-possibilities.

In 1984 a soil-survey of South Limburg was carried out by the University of Amsterdam to complete the map on scale 1to 50,000 (DE WAAL 1984). With this soil map, the knowledge of the physical and chemical properties of the soil types and the actual influence of surface- and groundwater a map was constructed giving the potentials of areas for vegetation types by matching the specific vegetation-requirements with the abiotic features. In this way the theoretical developing-possibility of vegetation types on a given soil is approximated. As a control a correlation-analysis is carried out on the present occurence of animals and vegetation types on soil types. (GROEN 1988: De ecologische infrastructuur van Zuid-Limburg; in prep.).

The design

With the badger, as an example out of a more complex design procedure, an species-specific demonstration will be given of the sequence of steps resulting ultimately in the ecological infrastructure of South Limburg 1:50,000. Within the Netherlands South Limburg has become one of the last bastions for the badger.In 1960, 1970 and 1980 surveys were made of the badger holes (WIERTZ & VINK 1983). In most cases it was possible to indicate whether a hole was inactive, active or was used to raise young badgers. The first step in order to analyse the situation of the badger home-ranges (figure 1). An approximation of the home-ranges was achieved by adding a circle with a radius of 0,5 kilometer to every hole present in 1980. The area of these home-ranges, about 78 ha, is within the range found by CHEESEMAN e.o. (1981) in south-west England (22-75 ha), KRUUK & PARISH (1982) in Scotland (67-309 ha) and Harris (1982) in a suburb of Bristol (31-81 ha).

These approximated home-ranges have been linked to each other and analysed with regard to the reported use of the holes by the badger in 1980, the availability of fouraging areas, the location of roads, villages or cities. This resulted in a set of area-specific problems. In some places the holes had become inactive because the holes were isolated through marl-pits or roads from fouraging-areas or other populations of the badger. At several sites it was observed that suitable fouraging areas had been destroyed. In the

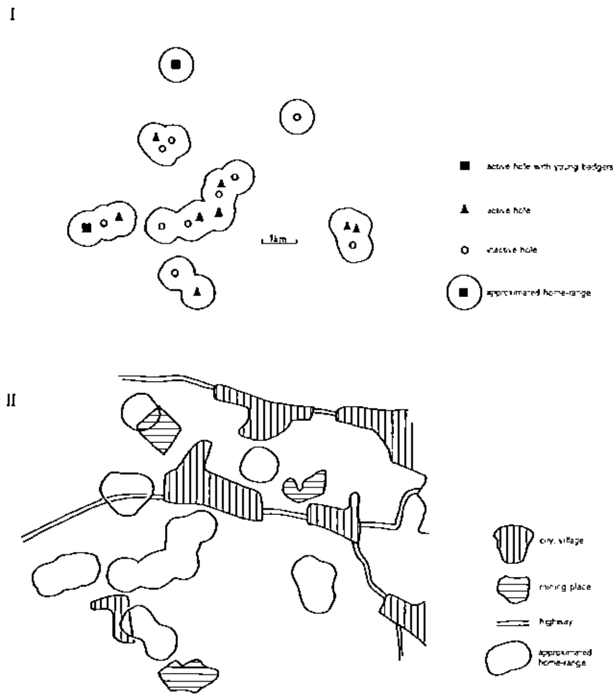


Figure 1.

Analysis of the land suitability for the badger

I. An approximation of the home range of a badger population in a given hole is achieved by adding a circle with a radius of 0,5 kilometer to every hole present in 1980 (ca. 78 ha.).

II. An example of the spatial analysis of the land suitability. The pattern of home ranges linked with the pattern of cities, villages, mining places and highways shows the occurrence of isolation and the need of a wildtunnel.

Fig. 1. Analysis of land suitability for the badger

second step for every sub-region an indication is given of

- the habitat and dispersal functions it has to fulfill for the badger and
- the activities to be taken in order to solve the problems and to realise the adjudge functions in favour of the badger.

For this treatment I used the so called physiographic map which is based on both the geomorphological map and the soil map. The same procedure has been carried out for the other fauna species and the vegetation with special attention to the developing possibilities.

Finally for every physiographic subregion a listing was made of

- the functions the subregion fulfills for vegetation and fauna and
- the desirable activities to be taken because of these functions or to solve problems.

In the whole procedure special attention is given to the ecological relations between neighbouring regions.

Whenever it was necessary more detail is put within a physiographic subregion.

Figure 2 gives the visual reflection of the functions adjedged to the several subregions and can be considered as the ecological infrastructure on scale 1 to 50,000. Of course the map is only useful in combination with the for every subregion specific listing of desired activities. This map is not the same as a nature-value map. In more detail a secondary connecting area may contain very important nature-reserves or living places of rare and protected species.

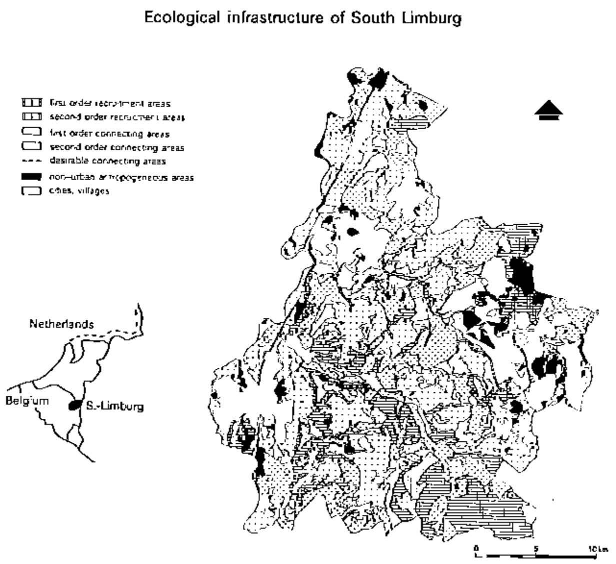


figure 2.

The ecological infrastructure of South Limburg

The recruitment areas are characterised by a high density and diversity of nature and might act as sources of immigration of animals (and plants). The connecting areas have a lower density and diversity of nature, but play an important role in order to make migration between recruitment areas possible. In detail the ecological infrastructure is a connected system of naturereserves, woods, rivelets, pools, hedgerows, woodlots etc.

Fig. 2. The ecological infrastructure of South Limburg

Referring to the definition of an ecological infrastructure the primary and secondary recruitment areas and the primary connecting areas together have to be a connected system of nature reserves, woods and small landscape–elements. In the recruitment areas the nature–reserves and woods play a more dominant role in comparison with the primary connecting areas.

5. The implementation of the ecological infrastructure in the Regional Plan South Limburg.

In the rural areas of South Limburg the physiographic map was used to analyse the qualities and requirements of the agriculture, landscape, forestry, recreation, water and soil management and natur for every subregion. Within the Netherlands it is unique that all the concerned parties have used one common methodology and one basic map to present and compare the results and claims to each other.

This enables to link up all these investigations and seek for the best appropriate solution in every subregion. The map of the Regional Plan South Limburg gives the visual reflection of the developing policy of the government. This map strongly resembles the map of the ecological infrastructure because it has played a central role in the weighing between several mutual exclusive claims.

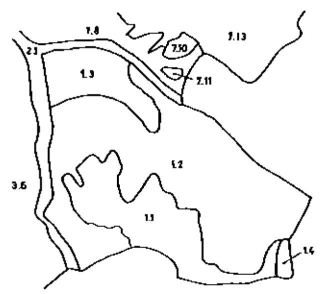
I will finish with the presentation of the policy according to the Regional Plan South Limburg for a little part of South Limburg (figure 3).

Every subregion has an unique code.

For every subregion the combination of cooperating functions are indicated. Function now stands for agriculture, forestry, landscape, recreation and nature.

Finally some desired activities in each subregion are given. In consultation with the local authorities more detail and quantities

I



II

			Subregions			
			1.1.	1.2.	1.3.	1.4.
F	Agriculture	1			x	
U	Agriculture	2		x		
N	Nature	1	x	x		x
C	Nature	2			x	
T	Recreation	1		x		x
I	Recreation	2	x		x	
O	Landscape	1	x	x	x	x
N	Landscape	2				
S	Forestry		x			x

III

	Subregions			
	1.1.	1.2.	1.3.	1.4.
Desired activities:				
Construction of a wild wildtunnel			x	
Removal of paths	x			
Protective zones for nature reserves		x		
Planting of woodlots		x	x	
Planting of hedgerows		x		
Construction of pools		x	x	
Succession to natural wood	x			
and other desired activities	x	x	x	x

figure 3.

The implementation of the ecological infrastructure in the Regionale Plan South Limburg

I A part of the map of the Regional Plan with the indication of the subregions (118 subregions over 17 regions)

II Every subregion is given a certain combination of desired coexisting functions for instands:
nature 1: policy directed to maintenance and development of a high density and diversity of nature
nature 2: policy directed to maintenance of the nature present.

III To adjudge the general policy for every subregion an unique listing of desired activities is indicated in the Regional Plan.

Fig. 3. The implementation of the ecological infrastructure in the Regionale Plan South Limburg

can be given to every given activity. Realisation of the activities is possible because the Regional Plan is a leading framework in the planning of land consolidation–projects and Local Plans.

It is obvious that the effort to maintain or develop an ecological infrastructure just as started. In the future most attention will be paid to the virtual implementation of the presented infrastructure and to the extension of the infrastructure to the surrounding regions and countries. In this it is interesting to mention that recently a start is made to cooperate with German researchers and planners to develop an international ecological infrastructure.

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EVOLUTION OF THE SPATIAL STRUCTURE OF THE HEDGEROWS IN THE HOUTLAND (NW–BELGIUM)

A. BRAEKEVELT

1. Location of the study area

The "Houtland", situated in NW–Belgium, is a subregion of the Northern Flanders'sandy region. It has a flat relief (generally 5–25 m) with exception of some low hills (50 m).

Several small brooks are streaming through this region.The area is characterized by a typical closed agrarian landscape originating from the Middle Ages. One of the main features of this traditional cultural landscape is a dense network of hedgerows, which forms a special type of "bocage"–landscape. The French call it "le bocage flamand". Willows are typical for the borders of the parcels,and hedges often surround the farms. For this project, only a part of the Houtland (within the administrative borders of the province of Western Flanders) has been surveyed: "Het Westvlaamse Houtland" (fig.1). This area (450 km²) consists of more than 3 municipalities and only one town : Bruges,situated in the north.

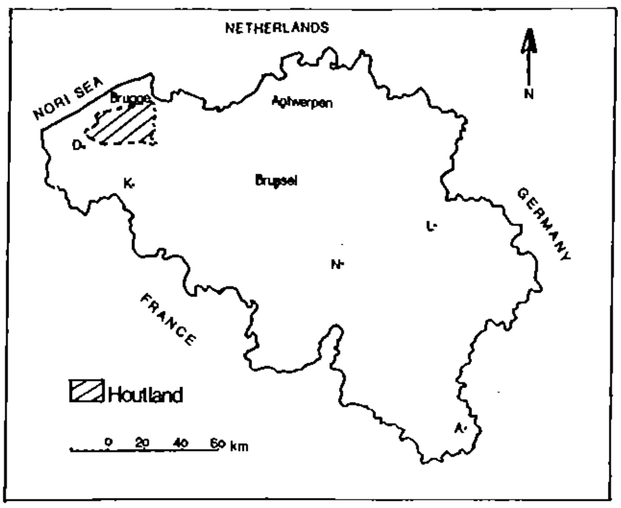

Fig.1: Location of the study area

2. Aim of the study

The Houtland has always been considered as an entity in regional-geographical studies because of its, as already mentioned,very closed and tight network of hedgerows. Nevertheless, those particular landscape elements have never been the subject of a detailed study. In this time of accelerating evolution,even the Houtland hasn't been out of the influence of suburbanization and scale enlargement in agriculture. Those processes led to the gradually disappearance of the hedgerows. In this article, only the planting around parcels is considered, because this particular type was found to have changed the most in our study area. Our attention also affects the structural, and not the vegetative aspects, because the old topographical maps are vegetatively too less differentiated.

The first question we want to answer, is how these changes touched the "identity" of the Houtland. Therefore the spatial structure of the hedgerows has to be systematically described (by means of network analysis : see methodology)in order to know the kind of structural changes in space and time. By this the degree of destruction of the hedgerows since the end of the former century can be known .

It is also possible, by analyzing the different types of connecting hedgerows, to construct an ecological database. Finally we're interested in the detection of human and physical factors which have stimulated or opposed the disappearance of the hedgerows (esp. willows).

3. Methodology

3.1. Sampling

A tritemporal (end 19thcentury,1966–1969,1986) inventory and classification (according to length and height) took place in different sample areas (30), with each a surface of 1 km². The sample areas were taken out of the different physical–geographical landscape units of the study area by means of a stratified random sampling design in order to discover any correlation between hedgerows and soil condition.

The comparison between the spatial structures at the different points of time, was made by means of analyses of topographical maps(scale 1/20000,1/25000) and fieldwork in 1986. This is illustrated by fig. 2. We chose for a cartographical presentation with a gradation in the visual "closing effect" of the hedgerows.

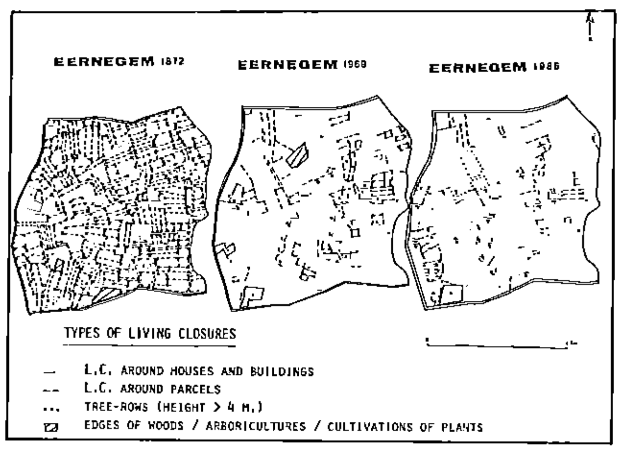

Fig.2: Example of the tritemporal inventarisation of the hedgerows in the Houtland

3.2 Network analysis

a. General

Network analysis is associated with "graph theory", in which only three types of basic structures are identified: paths, trees and circuits. Basic properties of any network are the number of points or vertices (v),lines or edges (e) and separate subgraphs (p).

The connectivity is measured by the cyclomatic number and the –index. The former gives the amount of basic circuits, the latter indicates the ratio of the number of edges to the maximum number of edges given the number of vertices.

In addition to this general type of network analysis, the length of the edges is measured to have an idea of the evolution of the density of the hedgerows.

b. Specific

A differentiation is made between different types of connecting hedgerows: +,T,L,O,W−type. These types make it possible to evaluate the degree of destruction and they also have an importance for ecological studies: it has been demonstrated that the biotic flux varies according to the type of connection (FORMAN & BAUDRY 1984 p. 11).

4. Results

4.1. Evolution of the spatial structure

4.1.1. Density

The density of the length of the hedgerows varied between 13000 m/km^2 and 24000 m/km^2 at the end of the 19th century. It decreased with 60 % in 1966−1969 and with more than 80 % in 1986.

The density of the number of edges and the number of vertices decreased in the same way and was typical for dryer sandy Bhs−soils. Finally, fig.3 gives an example of an overview of the evolution of some variables used in the network analysis. All values at the end of the 19th century are used as a kind of "zero−index" to make a comparison possible. The increase of isolated edges and isolated willows at the corner of the parcels of different landowners is typical for the last ten years.

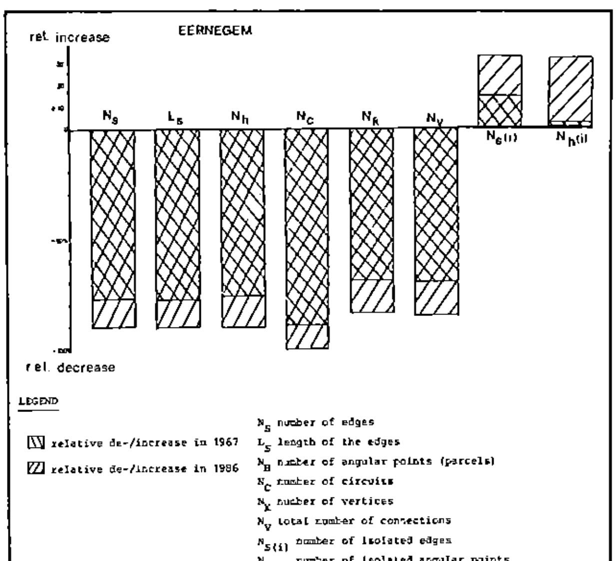

Fig.3: Example of the evolution of the variables concerning the spatial structure of the hedgerows

4.1.2. Connectedness

The way the hedgerows were connected to each other didn't change a lot during the last hundred years. Considering the whole study area, the −index varied from maximum 0.51 around 1872 to maximum 0.37 in 1986.

However, the number of connections generally decreased with more than 75 %. This trend is mainly caused by the disappearance of a lot of "T"−connections on lowland with a clay substratum on less than 1.2m depth. This "T"−type often lost one edge, so it was transformed in an "L"−type. Considering the "T"−type as representative for a well−structured landscape (BAUDRY & BUREL 1985 p. 92), we can conclude that the "Houtland" − even at the end of the former century − was scarcely characterized by this landscape ecological measure.

The number of "L"−connections which ranged between 20 and 40 % at the end of the 19th century, diminished by 'only' 30−40 %. The decrease of the number of these types of connection was associated with an increase of open−field or open−street connections ("O"−type) with more than 50 %, mainly on drier sandy soils. The destruction already started at the turn of the former century. This illustrates very well the decline of the spatial structure of the hedgerow− network.

It is also important to know that the "wood−connections", which are also landscape ecological important types of connection, had completely disappeared in the sixties. In 1872 they still formed maximum 10 % of the total number of connections.

4.2. Physical and human factors

Since we didn't want to confine us to a pure descriptive analysis, we also examined which physical and human factors have stimulated or opposed the disappearance of hedgerows. The results are illustrated by fig. 4.

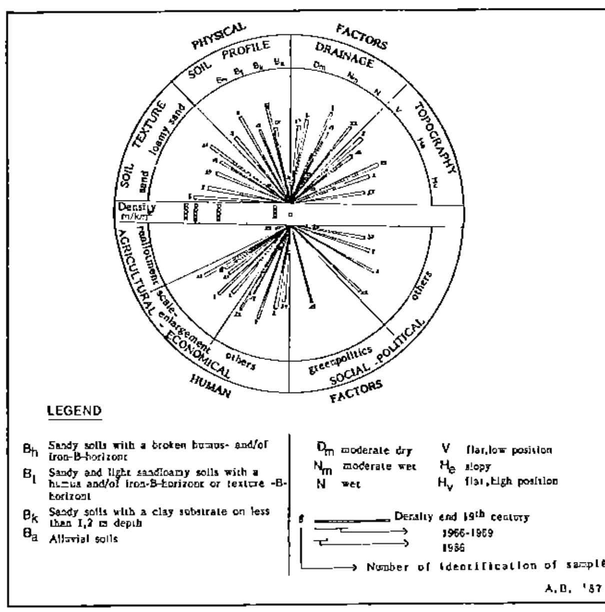

Fig.4: Influence of some physical and human factors on the evolution of the hedgerows

a. Physical factors

Soil profile and drainage seem to have more influence on the density of hedgerows than soil texture : (loamy) sand. Until the sixties, a strong correlation could be found between hedgerows and wetter sandy soils with a clay substratum on less than 1.2 m depth.

On steeper slopes, relatively less hedgerows disappeared than on the more gentle slopes. However the remaining of these edges has little to do with the anti−erosive role they could play, because esp. edges perpendicular to the isohypses were kept.

b. Human factors

At the end of the 19th century hedgerows were mostly surrounding arable land. With the increase of the percentage of grassland in the land use at the cost of arable land (the former varied from 5% to 35%, the latter from 80% to 40% between the end of the former century and 1966–69), hedgerows around arable land disappeared. The main reason for this disappearance is the loss of their function such as limitation and hedging in of parcels. This is due to the rise and the better efficiency of barbed wire as enclosure of the grassland, the enlargement of the parcels and the still increasing rationalization in agriculture. Maximum 50% of the edges is still corresponding with the full border of a parcel.

During the last decade reallotment and regularization works of brooks have taken place. We've found that neither of them is responsible for the enormous removal of the hedgerows (fig.5). Reallotment seems to be carried out in areas with a low density of hedgerows.

This process of clearing away is somewhat opposed by a recent regulation concerning the protection of the environment (esp. timber–felling prohibition) in some municipalities. There is a strong positive correlation between the enactment of this regulation and the amount of hedgerows that still exist. Nevertheless, this timber–felling prohibition is ordered at a moment that the spatial structure of the hedgerows has mainly been destructed. It will neither be efficient if the farmers don't derive any profit of it. A landscape ecological and political planning, that already exists in the Netherlands, could be very useful for the future remaining of the hedgerow– network in the Houtland.

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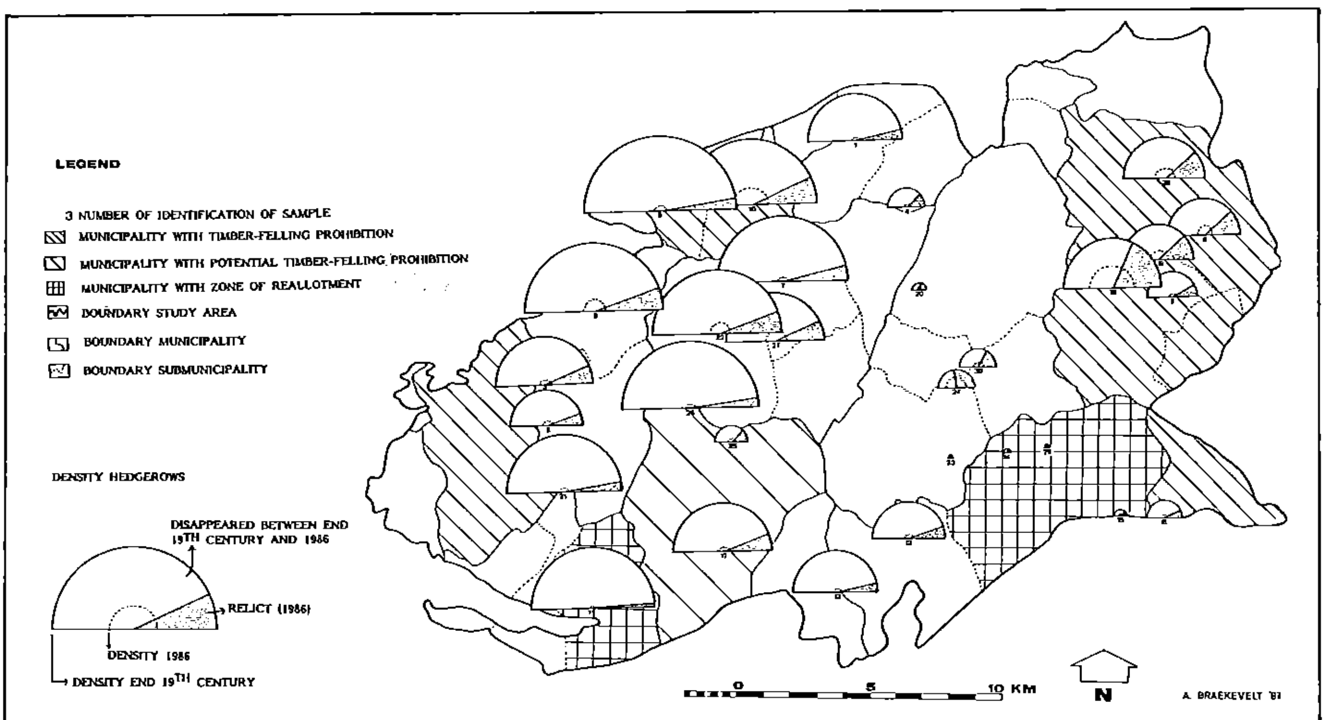

Fig.5: Evolution of the density of the hedgerows in the Houtland (end 19th century – 1986)

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DITCH BANKS IN THE WESTERN NETHERLANDS AS CONNECTIVITY STRUCTURE

Th.C.P. Melman, P.H.M.A. Clausman & A.J. van Strien

Introduction

The peat–polder landscape is one of the most characteristic features of the Dutch Lowlands. Long and narrow grassland parcels, embedded in a fine network of shallow ditches, windmills and sparsely scattered groves, these are the elements of a sketch of Holland.

In the Netherlands the nature conservational value of the peat–polder landscape as a whole is not appreciated highly. This low appreciation is induced by at least two circumstances. The first point is its local commonness: the grassland polders are simply everywhere in the Netherlands.The second point is the strong influence of man, which in itself would lower the nature–value of the landscape. Both aspects might be considered in another context. In the first place it appears that in international respect the peat–polder landscape is rather rare: in north–west Europe, some similar regions of a limited area only occur in Germany and England (fig. 1). The relevance of this is reflected by the occurrence of several species wich are very common in the peat district, but rather rare in European view, e.g. bird species like *Limosa limosa* and *Anas clypeata* (VAN DIJK 1983) but also plant species like *Stratiotes aloides* and *Lychnis flos–cuculi* (see CLAUSMAN & VAN WIJNGAARDEN 1984).

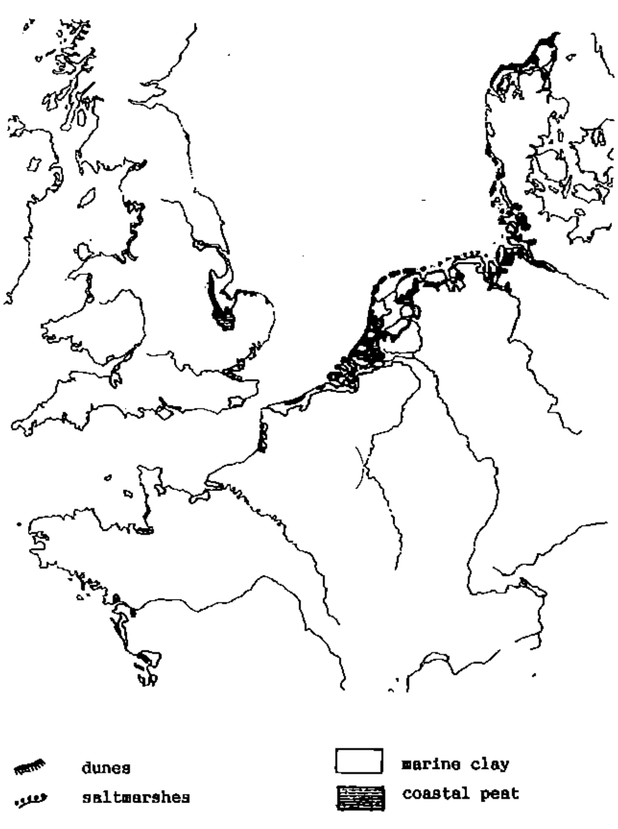

Fig. 1. Distribution of characteristic elements of flat coastal (sedimentary) deposits in north–west Europe.

In the second place, the reclamation of the peat–bog landscape never extinguished all original natural elements. Today's vegetation, for example, still holds remainings of the original fen, side by side with the footprints of human occupation and cultivation. In some respects it is just the interaction between nature and human activities which gave a surplus value to the region; the occurrence of several high valued species, birds as well as plants is promoted by human influence. Some elements of the peat–district, for example meadow birds a nutrient–poor grasslands, have been recognized as important natural elements since a long time. Reserves, enabling specific forms of management, have been established for their preservation.

More recently also attention is given to the natural qualities of the area in agricultural use (e.g. VAN DER WEIJDEN et al. 1984). Reasons for this broader approach are:

1. a great proportion of the populations to be preserved is to be found outside the nature reserves;
2. opinions altered about which species are valuable to conserve; it appeared that local and international rareness may differ strikingly, leading to a revaluation of species (CLAUSMAN en VAN WIJNGAARDEN 1984);
3. the conception that for an effective nature conservation reserves have to be connected by a so–calledecological infrastructure (see DEKKER & KNAAPEN 1986), is gaining ground (MINIST. VROM 1986);
4. combining nature–conservation with present–day farming creates a partnership between man and nature, which may be regarded as valuable in itself and may yield a firmer societal basis for durable preservation of nature (DE GROOT, in press).

From conservational point of view in the agricultural used grassland, the ditches and ditch banks comprise the most valuable vegetation (CLAUSMAN & VAN WIJNGAARDEN 1984). The parcels are strongly dominated by human cultivation; spontaneous vegetation is left only scarcely. Intensification of agriculture during the last decennia levelled down the species–richness of these parcels as well as the differentiation between them. This differentiation on itself was the result of a long–lasting divergence in agricultural type of use (e.g. DE BAKKER & VAN DEN BERG 1982; DE VRIES 1953; WESTHOFF et al. 1971).

The vegetation studies

In the Province of South–Holland several studies are being performed, concerning the nature conservational problems of the vegetation in the agricultural used area. These studies enclose a general survey of the vegetation, and an inquiry into the possibilities for nature conservation and –development of the vegetation of ditch banks. There are several reasons to pay attention to the potency of ditch banks for nature conservation.

1. High actual nature–value. Compared to other elements of the grasslands, ditch banks have a rich, diverse vegetation (CLAUSMAN & VAN WIJNGAARDEN 1984). The average number of plant species is 30 to 35, versus 10 to 15 species in the adjacent grassland parcels (MELMAN et al. 1986).
2. Minor importance for dairy–farming. Ditch banks literally and figurally have a marginal position in the agriculture: the margins yield crops of lesser quality, and their inclination and poor bearing capacity prohibit intensive exploitation.

3. Weak relation between the diversity of ditch bank vegetation and the exploitation intensity on the adjacent grassland (MELMAN et al. 1986); species–rich ditch banks may border intensive used, monotonous parcels. Though this weak relation might be a kind of artefact because of a retarded reaction of ditch banks to the agricultural intensification, it was an eye–opener for nature–aimed ditch bank management.
4. The success of other studies which focus on the possibilities of linear elements for nature conservation, for example the research of ZONDERWIJK (1979) in the Netherlands concerning road banks and the research in Nordrhein–Westfalen (see WOLFF–STRAUB 1985) concerning the borders of arable fields.

Notwithstanding these favourable prospects, some points are to be mentioned which threaten the nature–value of ditch banks.

1. The deterioration of the ditch bank vegetation during the last decade. Repeating the survey of the vegetation of the peat–polder district of South–Holland after a period of eight years, it appeared that many species in the ditch bank vegetation decreased (CLAUSMAN & GROEN 1987). With this deterioration species were involved like *Caltha palustris, Lythrum salicaria* and *Lychnis flos–cuculi*. It must be noticed that however the decrease of the ditch bank vegetation was less serious than that of the parcels, as one could expect from the above mentioned results.
2. Further intensification of landuse due to "super–tax". It has been noticed that, as a consequence of the super–tax on the surplus milk production, the utilization of own land (roughage production) is intensified in order to minimize the purchase of concentrates (VAN DER GIESSEN 1987). There is a risk that this intensification will affect the ditch bank vegetation.

From this findings it was concluded that a special ditch bank programme had to be develloped to conserve the characteristic vegetation of the ditch banks of the peat–polder district. The main question to be answered is: is it possible to maintain and to develop rich ditch bank vegetations in areas with normal agricultural use? In order to lay the foundations for the design of such a programme two studies are being performed: a describing analytical and an experimental study.

The describing–analytical study

An extensive inquiry is made to qualify and to quantify the factors determining the floristic richness and nature–value of the vegetation of ditchbanks. Some 300 places, differing in management and in some physical properties, were mutually compared. By means of analysis of variance the relevance of eight factors was assessed. In total 50–60% of the variance of the diversity was explained. Amongst others, the following results were obtained:

1. ditch banks of heavily manured parcels contain on average less species than ditch banks of more temperate manured parcels (fig. 2); the explained variation is about 15%. In general it seems that – correcting for other involved factors – the influence of manuring becomes clearly noticable in the ditch banks when the gift on the parcel is more than 200 kg N/ha/yr (VAN STIEHN et al. in prep. a).
2. banks of ditches cleaned each year contain less species than those of ditches cleaned every two or three years (fig. 2); explained variation is about 15% (VAN STRIEN 1986 et al. in prep. b).

Also some evidence is furnished that intensive grazing and trampling of cattle has a negative influence on the nature–value of the banks. These results indicate that intensification of dairy farming,

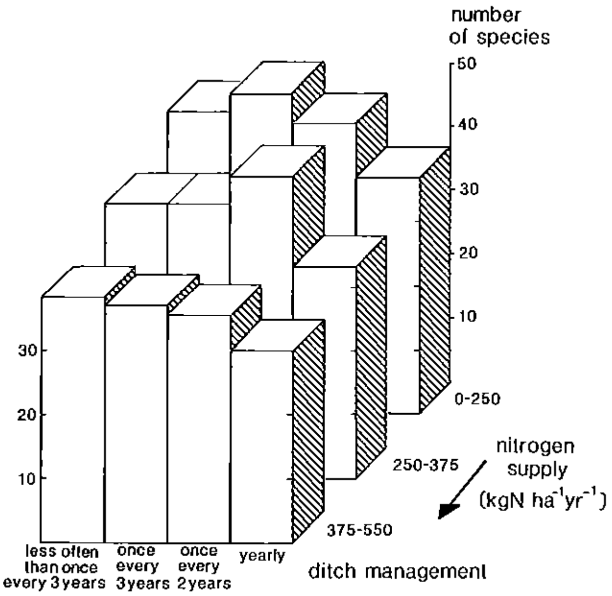

Fig. 2. Avarage number of plant species on the banks of ditches cleaned with different frequency, and with different nitrogen supply.

as it is performed during the last decennia and still is coming about, will at last also influence the vegetation of the ditch banks, notwithstanding their seemingly independence to the adjacent parcels as mentioned above.

The experimental study

From 1986 onwards an experimental field research on ditch banks is being performed. The aim is not only to know the right ecological conditions and how they can be manipulated, but also how such conditions can be fitted into the current practice of agricultural management.

In the study eight locations are arranged, scattered over the province of South–Holland, comprising about 8 km of ditch banks. Several factors are being varied over lengths of ca. 70m, and the development of the vegetation will be recorded over a period of 3 to 4 years. The grounds are put at disposal by governamental departments and by private land farmers. Financial support for fitting up the locations is provided for the greater part by the Department of Country–planning.

In total, five ecological factors are manipulated, one factor concerning the design of the ditch bank profile and four factors concerning the management of the ditch bank vegetation, i.e. the manuring, mowing and grazing regime of the banks, and the deposit of the ditch cleaning material. The four management factors that were varied only regard the ditch banks itself. The management on the adjacent parcels is left to the farmer.

Manipulating the shape of the embankment, a kind of terrace is con–structed, the terrace being about 10 cm above the water level of the ditch (see fig. 3a), thus creating a broader transitional stage between the ditch and the grassland parcel. It was presumed that this would provide more opportunities for several species to survive, and also that the management of the bank would be more easily kept distinct from the parcel. Besides terraces, also steep and gradual sloped embankments have been reconstructed, creating the same bare starting–point as a basis for comparison. Also non–disturbed embankments were taken up in the study. Distributed over the different profile–types 14 different "management configurations" were designed.

At the onset of the study one of the problematic aspects was the short period available (3 or 4 seasons). Would the vegetation development be fast enough to obtain meaningful results?

The experiences up till now are surprisingly positive. In the first growing season a very rapid colonisation of the freshly–cutted, bare ditch banks was established. The terraces, digged out in March (fig. 3a), were overgrown to such an extent in August, that is was hardly noticable that digging activities had taken place recently (fig. 3b).

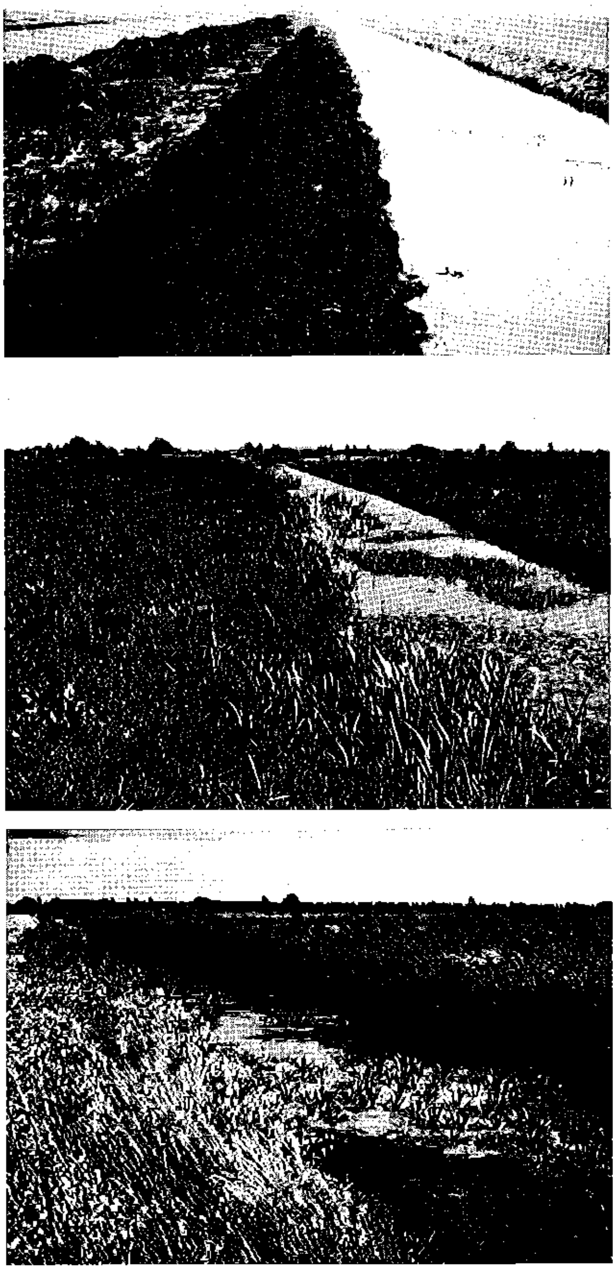

Fig. 3. Three stages in the development of a terrace talus. a) freshly cut, March 1986; b) first growing season after mowing, with *Ranunculus sceleratus* and *Juncus spp.* as dominant species, August 1986; c) second growing season with *Lychnis flos–cuculi* flowering in great numbers, June 1987.

Moreover, the number of species on the cut terraces was already then equal to the number on the undisturbed ditch banks. Also the spectra of species of both talus–categories were similar to each other. Important differences between the categories existed only in relative abundance of species.

In the second growing season a differentiation between the various configurations of management was observable. Since a detailed review of the results is not possible yet, we only present a qualitative description of the most conspicuous phenomena. On the terraced ditch banks a considerable increase of the plant-species, characteristic for marshy land is established. Some terraced ditch banks, not manured and without deposit of ditch cleaning material, delivered a spectacular show of *Lychnis flos–cuculi*, flowering in great numbers (fig. 3 c). This contrasted with nearby ditch banks, cut out with a normal (steep) profile, manured and with deposit of ditch cleaning material.

Since the study is not finished yet, definite conclusions cannot be presented. Nevertheless, the results obtained up till now offer interesting perspectives for nature–aimed management of ditch banks (and ditches) in an agricultural used area. Moreover, bottlenecks concerning the fitting–in of nature–aimed ditch bank management in dairy–farming, which run across regularly, do not seem to be unsolvable (see MELMAN & UDO DE HAES 1987).

The connecting properties of ditch banks

Apart from the possibilities of ditch banks (and ditches) for the survival of the original fen vegetation by means of its abiotic properties, also the spatial properties make the system of ditch banks and ditches in the peat–polder landscape a potentially powerful ecological instrument. Reclaiming the peat–bog district, a very intensive network of ditches (and ditch banks) was constructed. On average the parcels have a width of ca. 30m. This means a length of ca. 30 km ditch and thus 60 km ditch bank in every square km (fig. 4)!

It is interesting to know whether this system functions as a connectivity–structure, i.e. a structure which enables organisms to pass alongto reach vacant niches.

The connecting properties of ditch banks may be distincted at least in two directions. The first connecting direction is from ditch to parcel and v.v.. Species which disappeared from the parcels because of the agricultural intensification, might survive in the ditch banks, where the conditions are more favourable. Ditch banks would function like a refuge, as RUTHSATZ and HABER (1981) already noticed. When re–introducing a favourable management on the parcels, these species might re–enter the parcel from the ditch bank. Some evidence is furnished about this refuge character of the ditch banks. When data of before 1950 (after KRUIJNE et al. 1967) are compared with those of the present–day vegetation, it appears indeed that of the 63 species generally occurring in the former–day parcels (i.e. frequency of occurring › 10%), only 30 (47%) remained general in the present–day parcels and 45 (71%) in the present–days ditch banks (MELMAN et al. 1986). It deals with species like *Caltha palustris*, *Lychnis flos–cuculi* and *Carex nigra*; ditch banks are like a storehouse for highly valued grassland species.

The second connecting direction is length ways the ditch banks. Now it is important to know the conducting properties of this ribbon–shaped structure: how fast can species migrate along this structure? For anemochore species (e.g. *Senecio congestus, Cirsium palustre*) the ribbon–shaped structure of the niches will be

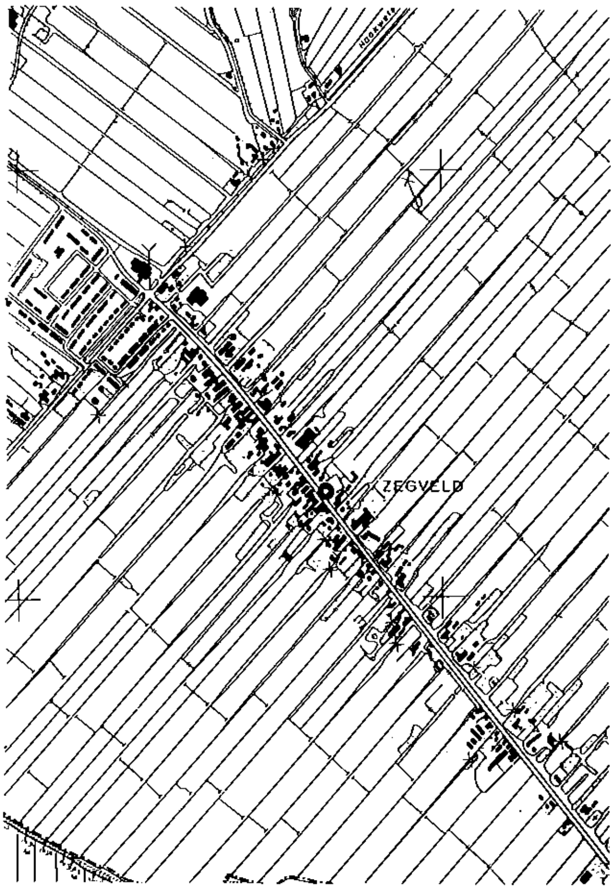

Fig. 4. Aeral view of a characteristic part of the peat–polder landscape of the western Netherlands, with the network of ditches (and ditch banks).

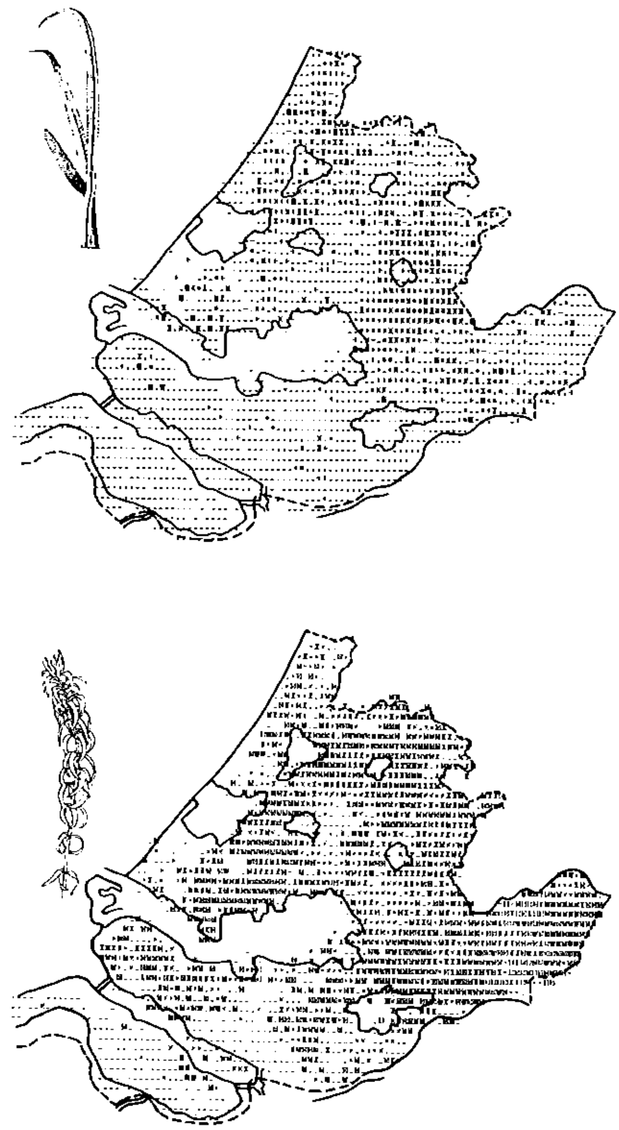

Fig. 5. Distribution pattern of two neophytes in the Province of South–Holland, demonstrating the conducting properties of the network of ditches; a) *Acorus calamus* and b) *Elodea nuttallii*.

less relevant. For species with another dispersal mechanism, the linear character is probably more important.

Illustrative examples of the conducting properties of the network structure of ditchesand ditch banks are represented by the scatter–pattern of some neophytes, newcomers in the Netherlands, spreading themselves from one or few locations into the peat–district, e.g. *Acorus calamus* (fig. 5a), which was naturalized before 1500 (WESTHOFF et al. 1970).

Far more spectacular, however, is the history of *Elodea nuttallii*. This species was introduced in Holland in 1941 (WESTHOFF et al. 1970), and conquered a great part of the ditches in the peat–district in less than half an age (fig. 5b)!

It is now the point to investigate wether this conducting potential can also be made operational for ditch bank species with high nature–value.

Connectability with agricultural practice

Besides attention for ecological processes, in the experimental study also much attention is paid to the fitting in of nature–aimed ditch bank management in current agricultural practice. Adaptations are pursued, propitious for nature as well as for animal–husbandry, creating a harmonious and stable association between both interests. Some aspects seem to be promising.

1. Sparing of the ditch banks while fertilizing. Measuring the spreading characteristics of several current strewer–types, it appeared that, on a medium–sized farm (25 ha) each year a quantity of fertilizer worth about 500,– is wasted in ditches and ditch banks (MELMAN & VAN DER LINDEN 1987a). The development of technical–supplies to control the fertilizing of borders may be prosperous for both interests.
2. Excluding ditch banks from grazing. The deterioration of the vegetation of ditch banks is partly ascribed to intensification of the grazing. Trampling down of the ditch banks is also negative for the agricultural practice; to prevent this damage some farmers fence off from their own. Thus, fencing off ditch banks might also be prosperous for both interests.

When the results of the studies point out that ditch banks offer an attractive perspective for conserving and developing nature in the agricultural landscape, they may be a substantial contribution to finding a way out of problems between dairy farming and nature–conservation. This controversy sometimes is too furious. If this is the case, ditch banks, also in metaphorical sense, may be conceived as connectivity structure: between farmers and nature-conservationists.

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LANDSCAPE PLANNING AND ECOLOGICAL INFRASTRUCTURE: THE RANDSTAD STUDY

W.B.HARMS, J.P. KNAAPEN

1. Introduction

In landscape ecological research two main approaches for landscape planning can be distinguished: the topological approach and the chorological approach. In the topological approach, attention is focused on the 'vertical' relations in the ecosystem: relations between soil, groundwater level and plant and animal communities. This kind of research gives information on suitablility of a site for different landuse types and on its value for nature conservation. In landscape planning, the topological approach leads to a plan that is usually based on the landscape pattern.

The chorological approach focuses attention on the 'horizontal' interactions between ecosystems in the landscape (ZONNEVELD 1985). Characteristic of this approach is the identification of the spatial effect of abiotic, biotic and anthropic factors. In this sense, landscape planning takes the landscape structure into account. Comprehensive landscape planning should be based on both approaches.

As regards the chorological approach: in the last decade the biotic interrelations between ecosystems have received increasing attention. Many studies were done on the effects of area and isolation on animal species. This has led to the concept of ecological infrastructure. However, the question is whether there is a need for such a new concept in landscape planning. And, secondly, if such a concept is justified, whether this concept is operational for landscape planning.

The splitting up of the landscape by all kinds of human activities inevitably leads to isolated and too small habitats for many species and consequently to a decrease of the species concerned (see e.g. OPDAM et al. 1984, 1985; MERRIAM 1984; CONNOR & MCCOY 1979; MADER 1979; GOTTFRIED 1979). Therefore it seems useful to examine the meaning of connectivity in landscape planning as a strategy for nature development and habitat construction in fragmented landscapes.

To examine the second question, pertaining to the applicability of the concept, a specific problem was studied: the allocation of new forests in the western part of the Netherlands, the Randstad.

2. Ecological infrastructure

Before going into the methods and results of the study itself, the biotic relations between ecosystems will be discussed in more detail. The ecological infrastructure of a species is defined as the complex of spatial ecological conditions that favours the survival of that species. More practically, these conditions relate to the effects of area and spatial isolation or connectivity. Connectivity and isolation are considered to be complementary units of the same variable. The following different functions of ecological infrastructure and their associated levels in time scale and spatial scale can be distinguished. Each function has a connectivity aspect and an areal aspect.

The first function is the DISPERSAL FUNCTION of ecological infrastructure. This function concerns the impact of spatial ecological factors on the distribution pattern of a species. The connectivity aspect is a suitable patch beyond the existing distribution area can only be colonized if there is sufficient connection with the edge of the distribution area. The areal aspect of this function is: colonization can only be successful if the new habitat is large enough to sustain a founding population.

The second function of ecological infrastructure is the PERSISTENCE FUNCTION, which relates biotic factors to population dynamics. The connectivity aspect of this function reflects the necessety of connection with neighbouring populations to ensure the interchange of individuals in order to compensate for possible local extinction. The areal aspect concerns the size of the habitat, which has to be large enough to accommodate a certain number of individuals in order to stabilize population fluctuations during several generations.

The third function of ecological infrastructure is called the HOME-RANGE FUNCTION. This refers to the individuals of a particular species. The suitability of a habitat for an organism has a qualitative aspect and a quantitative aspect. The home−range function pertains to the latter, the spatial conditions of a habitat. The connectivity aspect of this function concerns the connections between parts of a fragmented habitat. The areal aspect refers to the total area of the home−range of the individual.

In all three functions, connectivity and area have an additional effect on the survival probability of populations and individuals, and to a certain degree they are interchangeable: a larger area means less need for connection, and vice versa. In each of these three functions of ecological infrastructure the emphasis is on the chorological aspect (the spatial conditions for species survival). The topological aspect in landscape ecology is covered by the term "habitat" sensu stricto (the qualitative conditions). Habitat and ecological infrastructure are, in this sense, complementary terms.

3. The Randstad study

The Randstad is the area encompassing the four biggest cities of The Netherlands: Amsterdam, The Hague, Rotterdam and Utrecht. An outline plan has been developed for the urban afforestation of the Randstad; the so−called Randstad Green Structure plan (NOTA RUIMTELIJK KADER RANDSTADGROENSTRUCTUUR 1985). This plan entails the development of about 10.000 ha of forests and recreation areas within the next 15 years. The Randstad Green Structure plan is based on the following considerations: Firstly, green areas in and near the towns are threatened in many ways and have to be reconstructed and enlarged. Secondly, the recreational amenities of the green areas have to be improved. Thirdly, forests will have to be planted as part of the policy to increase the share of domestic timber on the home market from 8% to 25%.

From the point of view of lanscape ecology, these future forests could be considered as a favourable network for the dispersal and persistence of forest species. The National Physical Planning Agency requested the Dorschkamp research institute to check the three functions of ecological infrastructure for various species and locations.To do this, a spatial computer model (DISPERS) was developed, using the MAP2 Geographical Information System (TOMLIN 1983; VAN DEN BERG et al. 1985), to predict the probability of colonization and of persistence of species in suitable habitat patches (e.g. deciduous woodlands) of variable size in various locations in the Randstad. In this paper. however, only the probability of colonization (i.e.the dispersal function) will be discussed.

4. The probability of colonization

Apart from the quality of the habitat, the probability of colonization of the new forests depends on several factors (HARMS & OPDAM, in press).

In the first place, the existence of a source population is required. Large areas with high densities of forest species are assumed to function as source areas for dispersing individuals. However, species with a declining population are unlikely to expand their ranges and colonize remote patches.So regional population trends must also be taken into account.

Other possible factors determining the probability of colonization are the distance of the new forest from the source area, the dispersal capacity of the species and the landscape's resistance to the dispersal of wood–dwelling species. The latter, the dispersal resistance of the landscape,is the relative degree to which the landscape favours the dispersal of organisms of a certain species.

Seven ecological groups of forest species were considered (fig.1).

ECOLOGICAL GROUPS OF SPECIES

Stage of stand development:	BIRDS	MAMMALS	BUTTERFLIES
YOUNG	Prunella modularis Sylvia curruca Sylvia borin Hippolais icterina	Capreolus capreolus	Polygonia c-album Anthocharis cardamines Araschnia levana
TIMBER	Oriolus oriolus Phoenicurus phoenicurus Fringilla coelebs Dendrocopos major	Sciurus vulgaris	
MATURE	Strix aluco Parus palustris Sitta europaea Dendrocopus minor	Nyctalus noctula	

Fig. 1. The ecological groups of species.

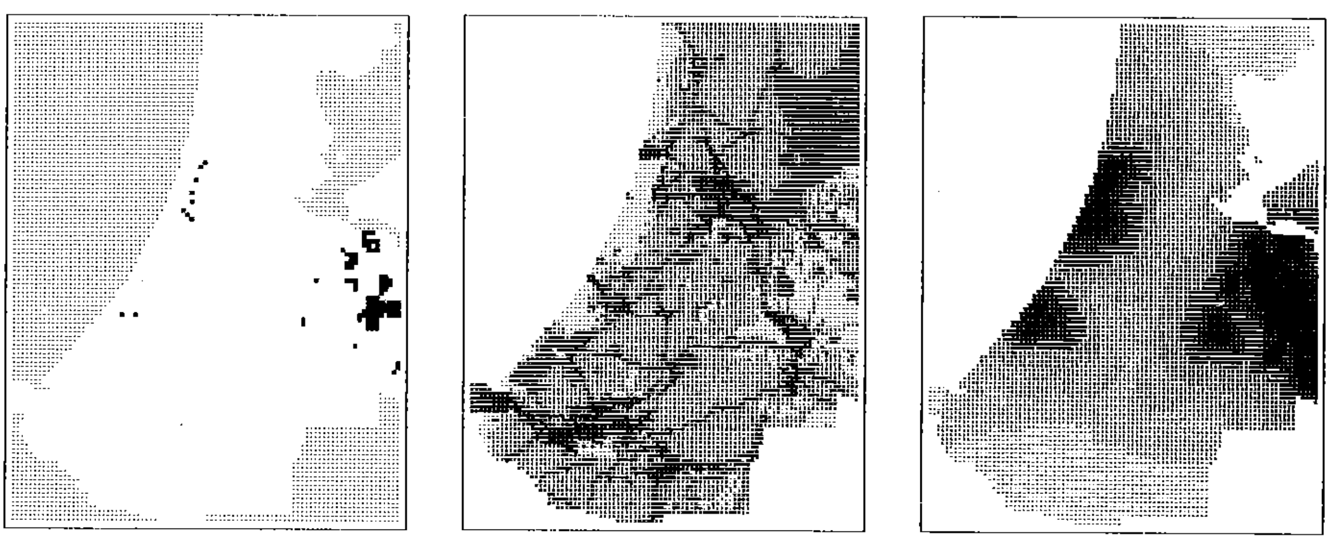
Each group consists of one or more species that prefer a similar habitat. Three groups of bird species associated with different stages in forest stand development were distinguished. Areas with a sufficient frequency and density of at least three of the four characteristic species were designated as source areas. These were mapped on a 1 km^2 grid. Distribution data on three mammals (roedeer, red squirrel and a bat species) according to the same stages in stand development were also gathered. The seventh group consisted of butterfly species of forests and forest edges. These butterfly species are not common, but they are expanding their range.

A simple spatial simulation model was used to determine the colonization probability of the Randstad area. The model (DISPERS) simulates the dispersal from the source area to as yet unpopulated areas with suitable habitats.

The dispersal rate is dependent on the resistance values of the landscape. The scaling of the dispersal resistance is largely based on assumptions about the relative preference of forest species for various landscape elements. The density of woody vegetation is considered to be a good measure of this landscape resistance. This is based partly on research (OPDAM et al. 1984; VAN DORP & OPDAM 1987), partly on experienced professional judgement.

The method can be illustrated by presenting data on the group of bird species of old mature deciduous forest: Nuthatch (*Sitta europaea*), Marsh tit (*Parus palustris*), Lesser spotted woodpecker (*Dendrocopus minor*) and Tawny owl (*Strix aluco*) (fig.2a). Most of the source areas are located in the dune strip and on the push moraine ridge. Others are old estates along the small rivers. Figure 2b shows the landscape's dispersal resistance for this group of bird species. On the map, the dispersal resistance value is expressed in four ordinal classes, but in the simulation more classes were used. The third map (fig. 2c) illustrates the results of the dispersal simulation, i.e. an accessibility map of the Randstad. Four zones of relative accessibility are shown, which again is a simplification of the simulation results. It must be emphasized that the accessibility is expressed in a relative time scale and not in concrete time units.

In figure 3 the results of the dispersal simulation of three groups (birds of young forest stands, birds of old mature forest stands and the Red Squirrel) are compared. For the two groups of bird species the same landscape resistance has been used. Whereas the distribution of source areas of the squirrel is comparable with those of the bird species of old mature forests, the landscape resistance



a b c

Fig. 2. Dispersal simulation of birds of old mature forests: fig. a. source areas, fig. b. landscape resistance (relative values; the intensity of shading indicates the resistancevalue), fig. c. relative zoning of accessibility (the intensity of shading indicates the accessibility).

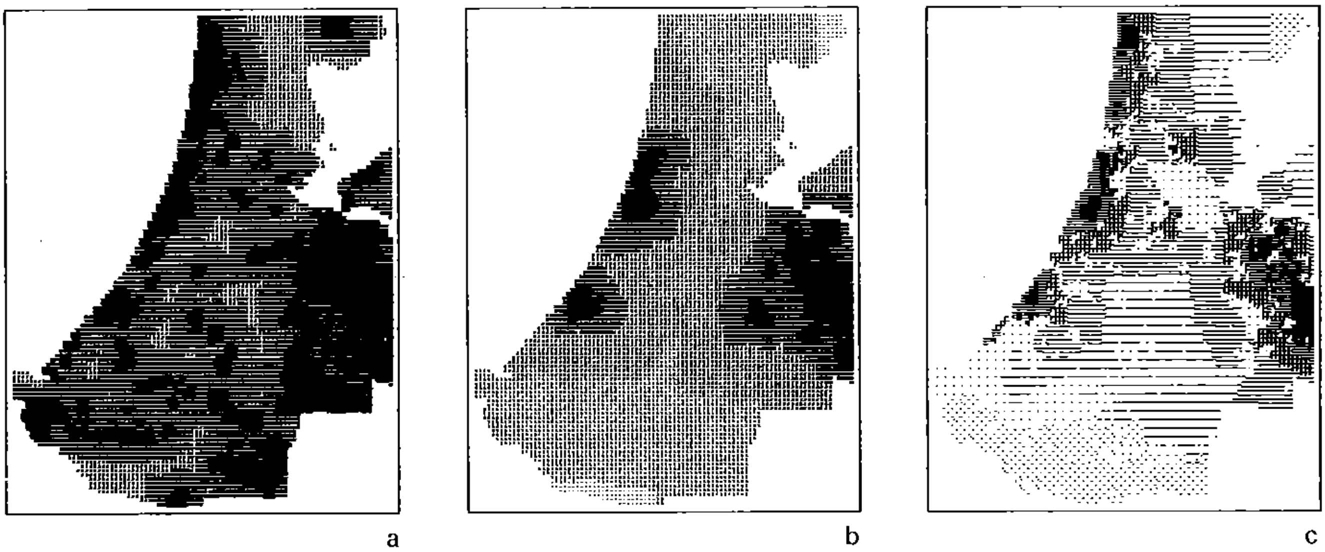


Fig. 3. Relative accessibility of birds of young forest stands (a), birds of mature forest stands (b) and Red Squirrel (c) (the intensity of shading indicates the accessibility).

for these two species groups differs. In these simulations it is clear that the frequent occurrence of the birds in young stands dominates in the pattern of accessibility, whereas in the other two maps the distance from the source areas and the barriers in the landscape are the main factors determining the accessibility (though differently and not comparably, because of the different assumptions in resistance values per ecological group).

Superimposing the locations of the planned forests on the accessibility maps gives the relative probability of colonization of the forests. In figure 4 accessibility map of the bird species of mature forests (the Nuthatch group) is compared with the forest localities proposed in the Randstad Green Structure outline plan (fig.5a).

Locations near Rotterdam show a poor colonization chance, because of the absenceof a nearby source area and because of the high resistance of the landscape. Locations near Utrecht illustrate a better accessibility.

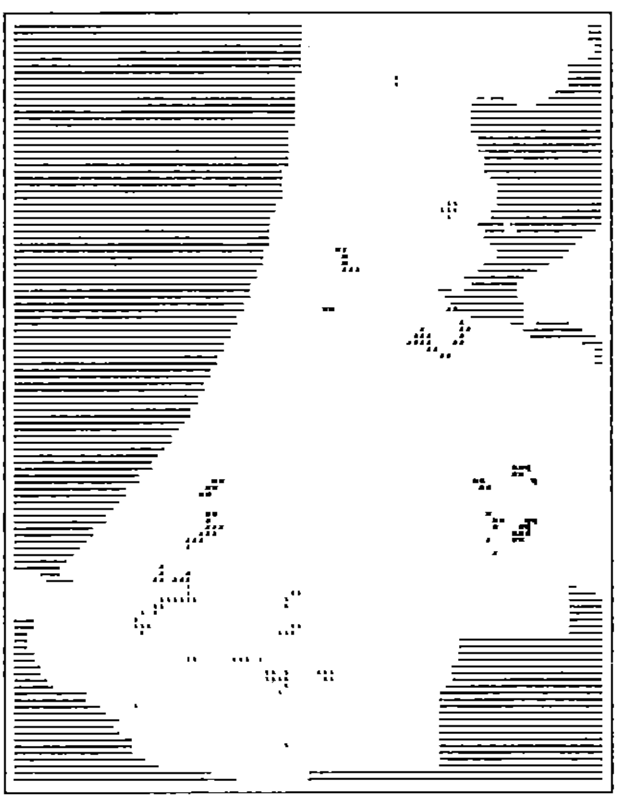


Fig. 4. The probability of colonization for birds of mature forest stands by superimposing the planned forest locations (fig. 5a) on the accessibility map (fig. 3b).

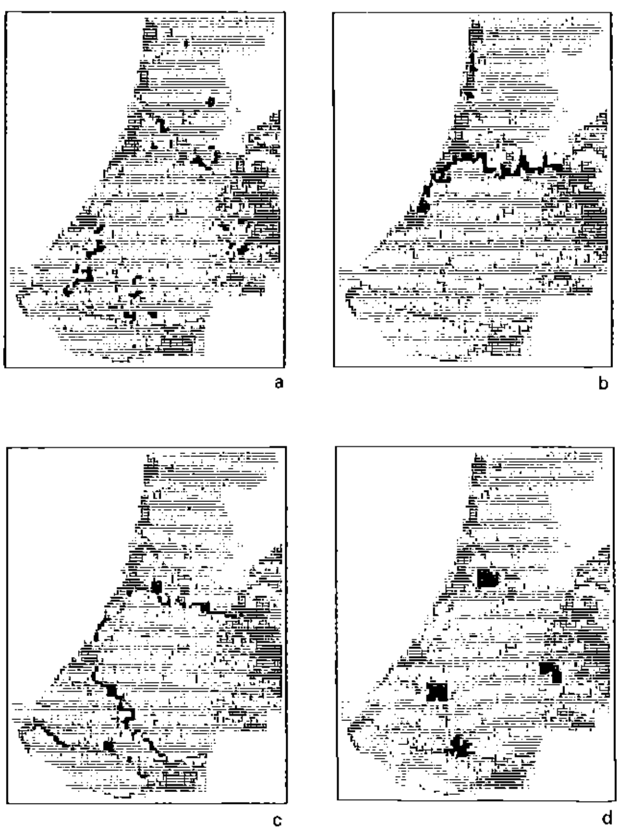


Fig. 5. Forest distributions: fig. a, locations proposed by the Randstad Greenstructure plan fig. b, 'connection', fig. c, 'triple connection', fig. d, 'concentration'.

5. Forest distribution alternatives

In order to improve overall accessibility, alternative forest distributions were developed. The ecological groups differ in their distribution and in the dispersal resistance they experience in a certain landscape. Therefore it was expected that different ecological groups would require different forest distributions. By means of the DISPERS model it can be evaluated to what extent these alternatives improve accessibility. Figure 5 shows three distribution alternatives together with the forest distribution proposed in the Randstad Green Structure Plan. The alternatives are based on two approaches for improving the accessibility: reduction of the landscape resistance, and reallocation of the forests.

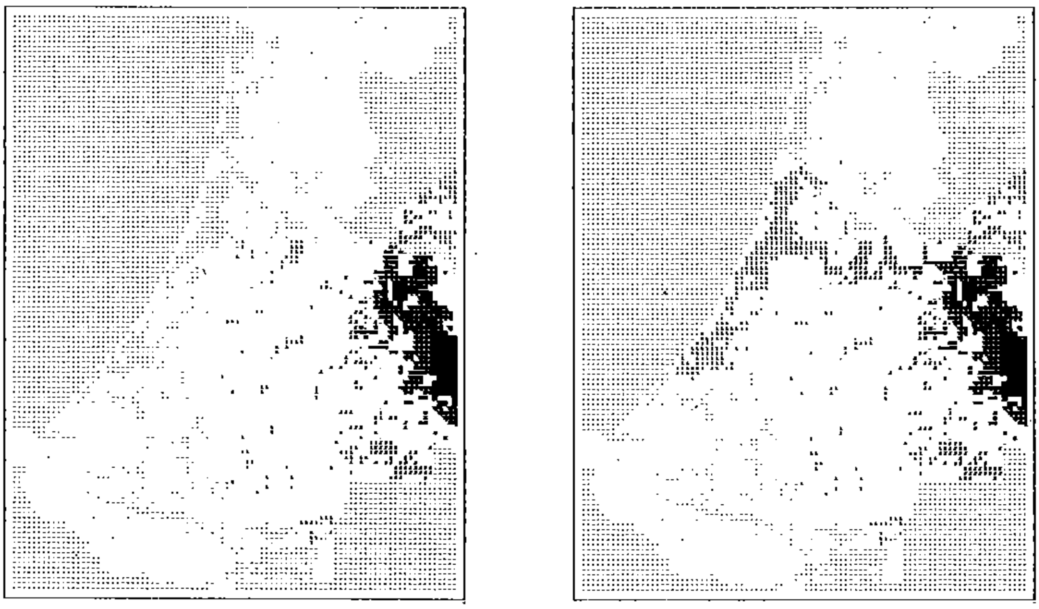
Consider, for instance, the impact of alternative 'connection' (fig. 5b) on the accessibility for the Red Squirrel. To show the impact properly a hypothetical question is considered: what is the accessibility of the existing fo.ests for red squirrels coming from the eastern part of the Randstad only? The distribution alternative 'connection' requires a zone of new forest taking account of the existing roads, buildings etc.

Figure 6 illustrates that such a corridor could be successful for the squirrel, in spite of the existing barriers.

Another example is given in figure 7: the improved accessibility of new forests in the neighbourhood of Amsterdam, by comparing the impact of an other distribution alternative 'triple connection' (fig. 5c) and the Randstad Green Structure plan (fig. 5a) on birds of old mature forests (the Nuthatch group). A slight reallocation of forests and a well-fitted corridor substantially improve the accessibility.

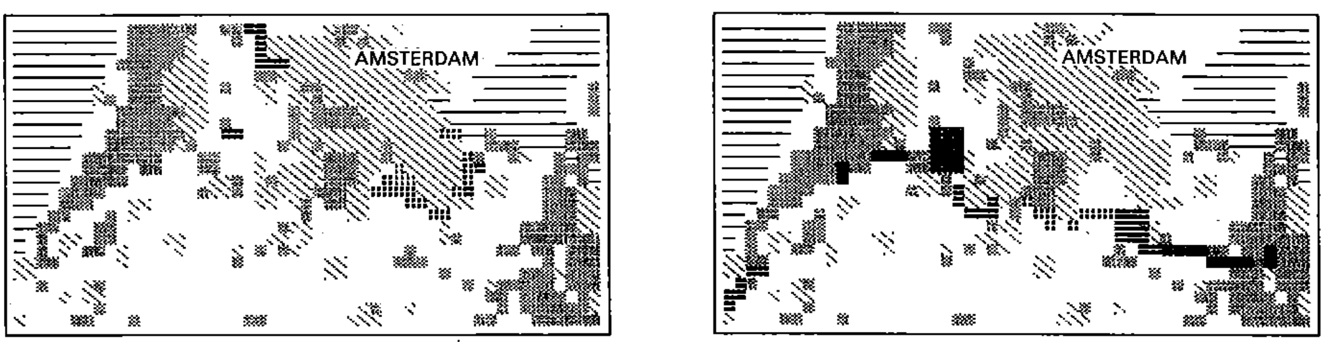
6. Discussion

The method described could be a tool for landscape planning and decision-making. By means of the model DISPERS the accessibility of existing and future landscape elements can be assessed and weak or strong spots in the ecological infrastructure of the landscape can be discovered. Therefore the method could be used



a b

Fig. 6. Relative accessibility of existing forests for Red Squirrel in the hypothetical situation distribution concentrated in the eastern part of the study area only (the intensity of shading indicates the accessibility of the existing forests): fig. a, without 'connection', fig. b, with 'connection'.



a b

Fig. 7. Window plot of colonization probability of birds of mature forest stands in the neighbourhood of Amsterdam (the intensity of shading indicates the colonization probability): fig. a, locations proposed by the Randstad Green-structue plan, fig. b. locations of 'triple connection'.

for both design and evaluation of landscape plans and for connectivity analysis of existing landscapes.

However, it must be emphasized that application of this model is still liable to a number of restrictions. At the moment the major problem is the scarcity of data needed to estimate the resistance of the landscape to the different migrating organisms. The validity of the model should be tested by comparing the results of the simulations with the actual distribution pattern of the species concerned, with monitoring data on range expansion, and with data on population turnover in landscapes with scattered woods. For the present, the method should be considered as an aid in choosing the best localities for urban afforestation, rather than as a tool to provide the exact probability of colonization.

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LANDSCAPE–ECOLOGICAL MAPPING OF THE 'RANDSTAD'–AREA, THE NETHERLANDS

A.A. de Veer & R.W. de Waal

Introduction

At present a landscape–ecological mapping project is being carried out by the National Agency of Physical Planning (The Hague), the Centre of Environmental Studies of the University of Leiden, and the Soil Survey Institute (Wageningen).

Basic data concerning abiotic and biotic components of the landscape are being stored in a 1 km^2 grid system. Maps to be made on a scale of 1 : 250 000 include the following information: A) basic data; B) sensitivity assessment; C) significance from a nature conservation viewpoint; D) vulnerability assessment (combination of B and C).

At the end of 1987, a series of maps of the Randstad area (approx. 3500 km^2) will be completed. This article will show two examples belonging to the objective A, and one to the other objectives (B, C and D). The area displayed in the figure is about 750 km^2 in size; it is situated in the surroundings of Gouda, northeast of Rotterdam. Figure 1 shows the topography of the Gouda area.

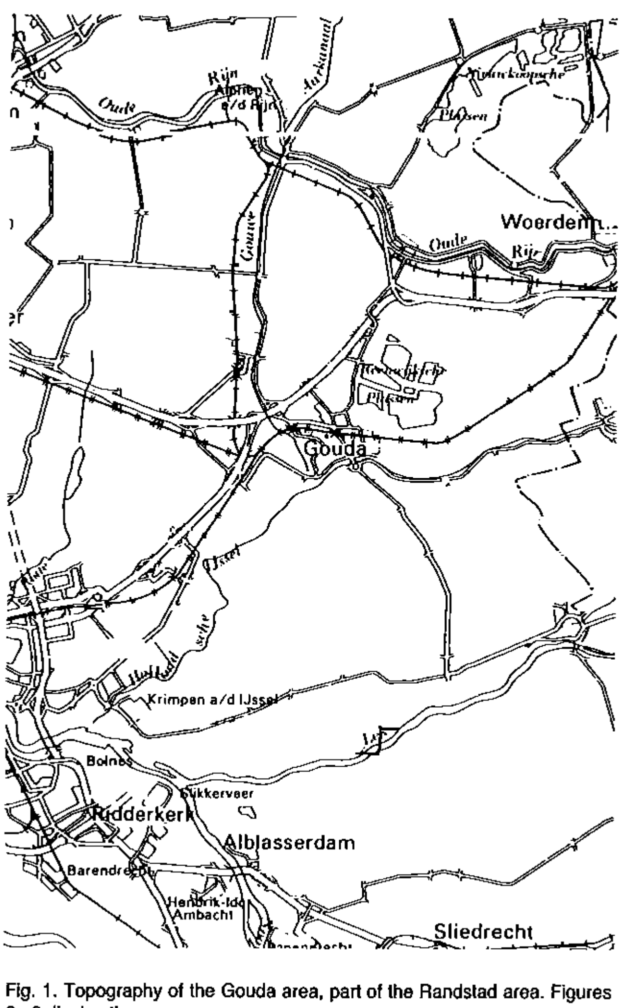

Fig. 1. Topography of the Gouda area, part of the Randstad area. Figures 2–6 display the same area.

Basic data

The basic data have been stored on two levels:

- the component level;
- the landscape level (so–called geotopes).

Abiotic components include soil, water–table class, geomorphology, ground and surface water relations. Figure 2 displays the dominating soil units in the Gouda area.

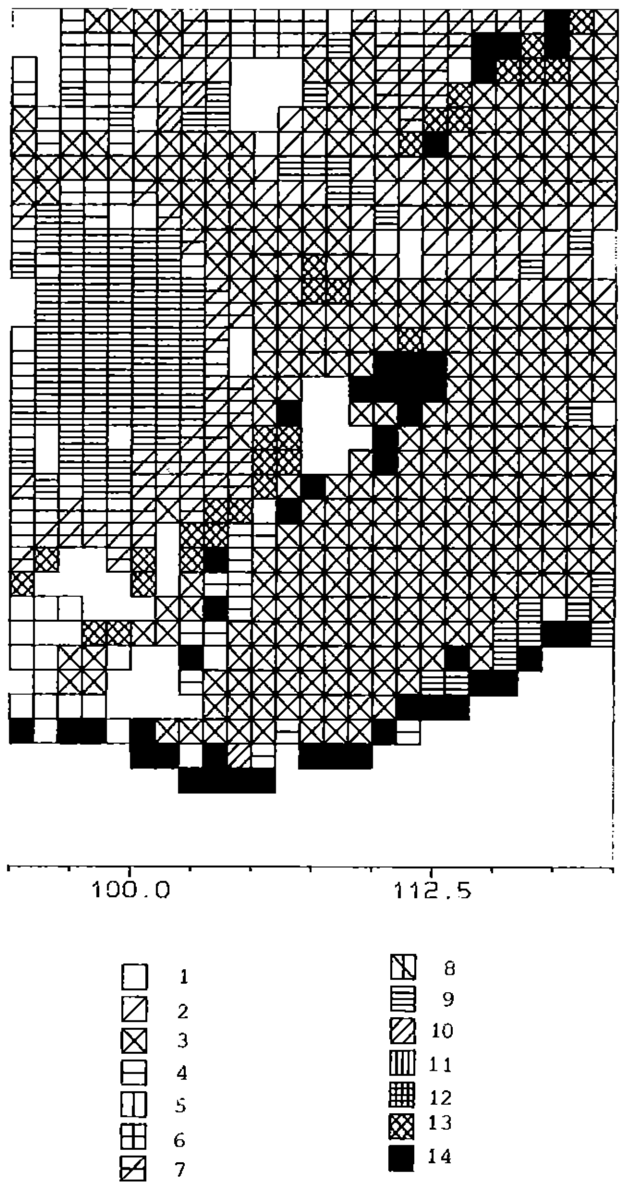

Fig. 2. Soil map. Meaning of codes: 1 = anthropogenic soil; 2 = non–calcareous riverclay soil; 3 = disturbed peat soil; 4 = non–calcareous marine clay soil; 7 = peaty marine clay soil; 9 = calcareous marine clay soil; 10 = calcareous riverclay soil; 13 = undisturbed peat soil; 14 = open water; 5,6,8,11,12 = do not occur in the Gouda area.

Biotic components considered are land use, vegetation, and different fauna groups.

Landscape units or geotopes are based on three groups of differentiating criteria: hydrological regions (infiltration and seepage areas, type of groundwater), generalized geomorphology and vegetation structure. In the legend geotopes are further described as to characteristics of abiotic and biotic patterns and processes. Figure 3 shows the Geotope Map of the Gouda area.

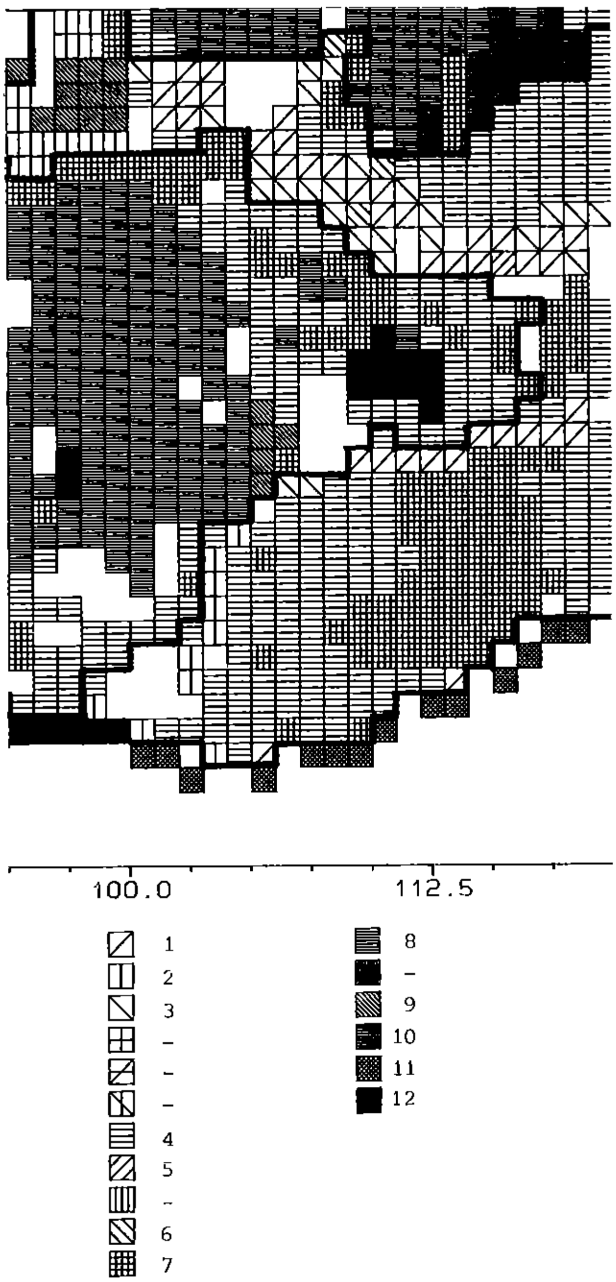

Fig. 3. Geotope Map. Heavy lines indicate boundaries of hydrological regions (reclaimed lake region in the west and north; river foreland region in the very south; river levee and lowland region in the remaining part). Meaning of codes: 1 = levee, pasture; 2 = marine marsh, pasture; 3 = basin, pasture; 4 = backswamp, pasture or arable land; 5 = levee, woodland; 6 = basin, coppice or semi-natural pasture; 7 = backswamp, heterogeneous land use; 8 = reclaimed lake, arable land or heterogeneous land use; 9 = creek ridge and marsh, pasture or heterogeneous land use; 10 = partly dug-out backswamp, coppice or open water; 11 = river foreland, pasture or coppice; 12 = open water.

Sensitivity, significance and vulnerability assessment

Figures 4, 5 and 6 show a series of maps, intended for application in physical-planning problems. Figure 4 gives the sensitivity of the soil to a drawdown of the water-table. Criteria used in the classification program for this map are soil texture, water-table class, and organic-matter content. Figure 5 displays the internal diversity of the soil, automatically derived from the number of mapping units per grid cell. The higher the diversity, the more important the cell is for nature conservation or development. In Figure 6, sensitiviy and significance are combined in a vulnerability map, displaying areas that are sensitive to drawdown of the water-table and that are at the same time significant from the viewpoint of nature conservation. For technical and principal reasons Figure 6 is more than an 'addition' of Figures 4 and 5, although a certain coincidence may be seen between the mapping areas on the different figures.

Connectivity

Connectivity plays a role in several analyses and maps of the Randstad area. A major part of the Gouda sub-area consists of

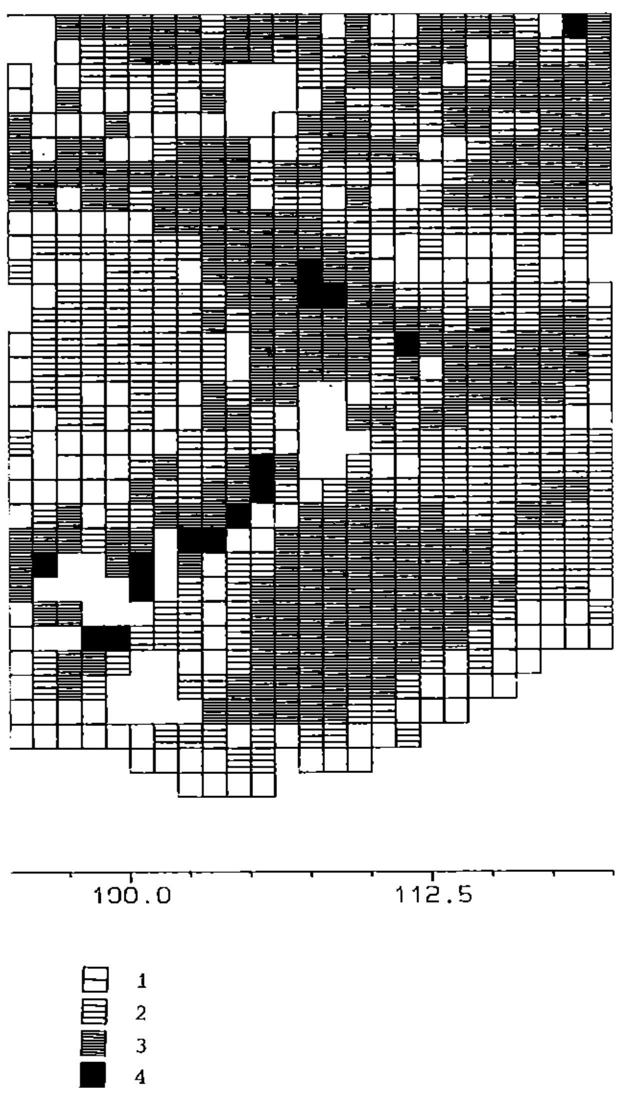

Fig. 4. Sensitivity map of soil to drawdown of the water-table. The darker the cross-hatching, the more sensitive the soil is.

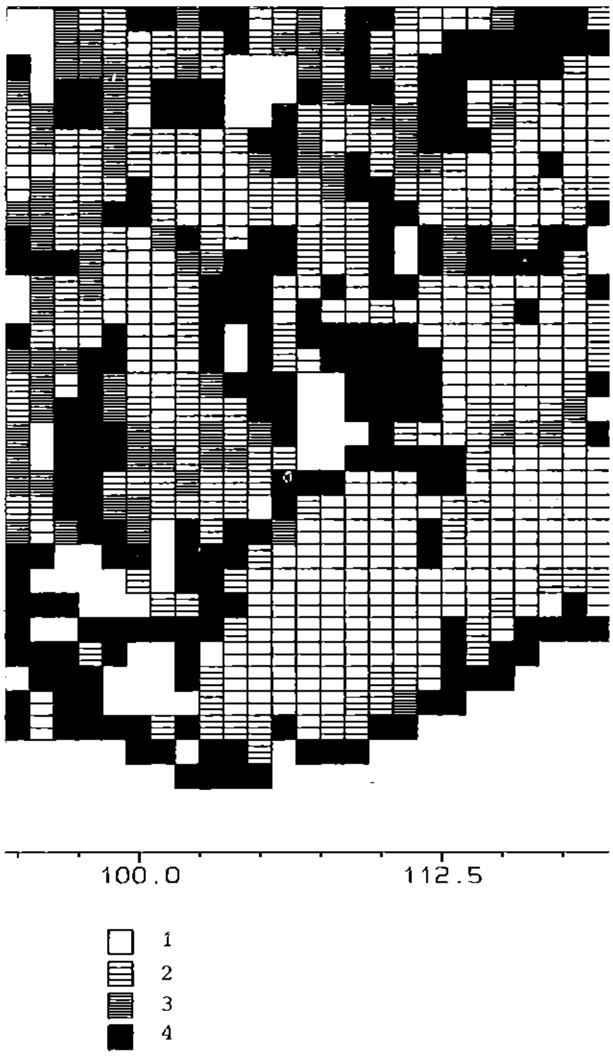

Fig. 5. Soil diversity map. The darker the cross–hatching, the number of unique soil units is.

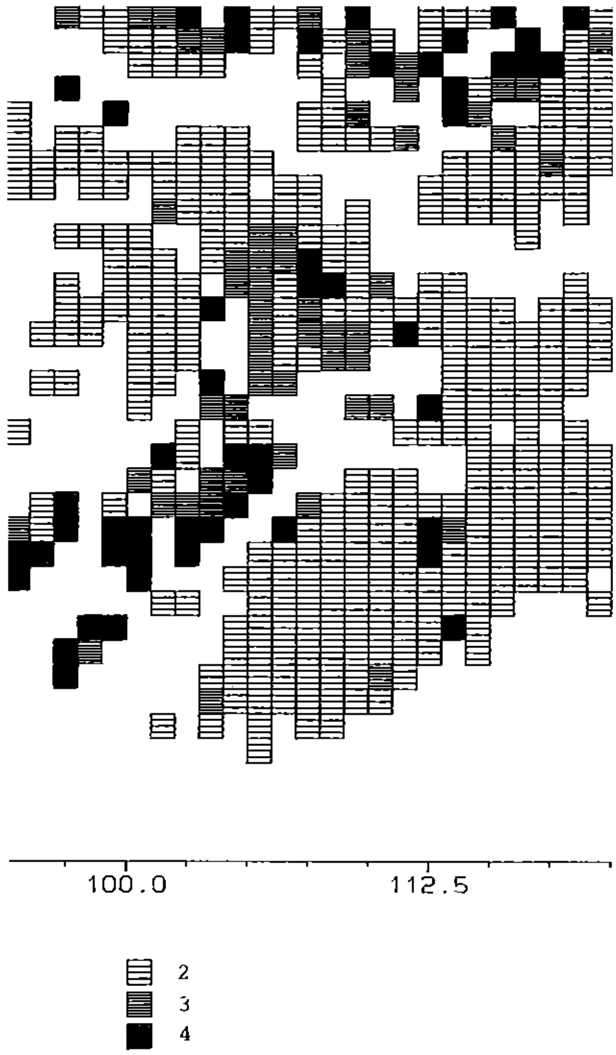

Fig. 6. Vulnerability of soil to drawdown of the water–table. The darker the cross–hatching, the more vulnerable the soil is. Vulnerable means sensitive and valuable from the viewpoint of nature conservation (see text). The lowest class is not displayed.

open pealy 'islands' surrounded by clayey levees with a denser pattern of vegetation (and building) elements, including narrow 'green elements'. If urbanization has not proceeded to far, these belts may serve as corridors for migrating organisms. This pattern of characteristic landscape types can be derived from the Geotope Map (Figure 3).

Connectivity is also influenced by ground and surface water relations between different landscape types. The extended legend of the Geotope Map (not in the caption of Figure 3) gives information about these relations. Together with other environmental factors, these relations determine type and quality of different vegetation elements. Drawdown of the water–table disturbs these relations (e.g. by affecting seepage–indicating species), and thus the landscape itself. This will be illustrated on the Geotope Vulnerability Map.

Generally speaking, landcape data are better suited to connectivity analysis than component data, especially when horizontal landscape–ecological relations are taken into account.

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IMPROVING CONNECTIVITY BY MANAGING AND MAINTENANCE OF SMALL LANDSCAPE ELEMENTS; A DUTCH EXPERIENCE.

B.J. LOCHT AND P.H. GROOTEN

INTRODUCTION

The Dutch landscape is subject to reat urban pressure. This manifests itself in infrastructural increase, land consolidation activities, extension of industrial areas, etc.

At the end of the sixties and the beginning of the seventies, an important movement of volunteers in nature conservation focussed attention on the maintainance of small landscape elements. First emphasis was laid on pollard–trees. These so called "pollarding groeps" (knotgroepen) were very important in the western part of the country, a very urbanised region. The very same groups, because of dedicating their spare time to nature and landscape conservation activities, contributed to a change in mentality concerning this matter. As a consequence they make people aware of the necessity of the management and the maintenance of the landscape elements for flora, fauna and man.

Authorities picked up the signal given by the volunteers and gave evidence of understanding what led to different measures, one of which was to stimulate the foundation of provincial bureaus to coordinate voluntary work. These bureaus were subsidized by the provincial authorities and the ministry of agriculture.

History

Unemployment

In the province of Limburg things went a little different. The closing of the coalmines in the mid–seventies brought considerable unemployment (40,000 unemployed).

Several reinforcement schemes were set up for the southern part of Limburg. In that context job–creation plans were drafted, financially supported by the government.

After a succesfull pilot–project of one year the IKL–Foundation (IKL = Instandhouding Kleine Landschapselementen i.e. preservation of small landscape elements) could start with 79 employees. Its main objective was the preservation of small landscape elements.

The financial support comes from the ministry of agriculture and the province of Limburg, where as the municipalities and the landowners contribute "in kind", i.e. that they supply the fencing and plant material or even manpower.

So, instead of being a small bureau with the purpose of stimulating and coordinating volunteers in landscape management, IKL became a real organisation with a business–like set–up.

IKL–Foundation

In october 1982 the IKL–Foundation started with the execution of her work: the managing and maintenance of the small landscape features in Limburg. This southern most province of the Netherlands (2,200 km²) is build up by a northern, flat and sandy area, whereas the south is hilly and covered by loess. The river Meuse runs through it from the South to the North and is accompanied by clayey riverterraces (fig. 1). These rather great geographic variety on a short distance, makes the landscape very diversified, which is visible among other things in ther great scale of elements present in the rural landscape such as different types of hedges, (rows of) pollard trees, sunkenlanes, wooded or grazy escarpments (graften), small woodlots, isolated trees, ponds, pools, fens, and so on.

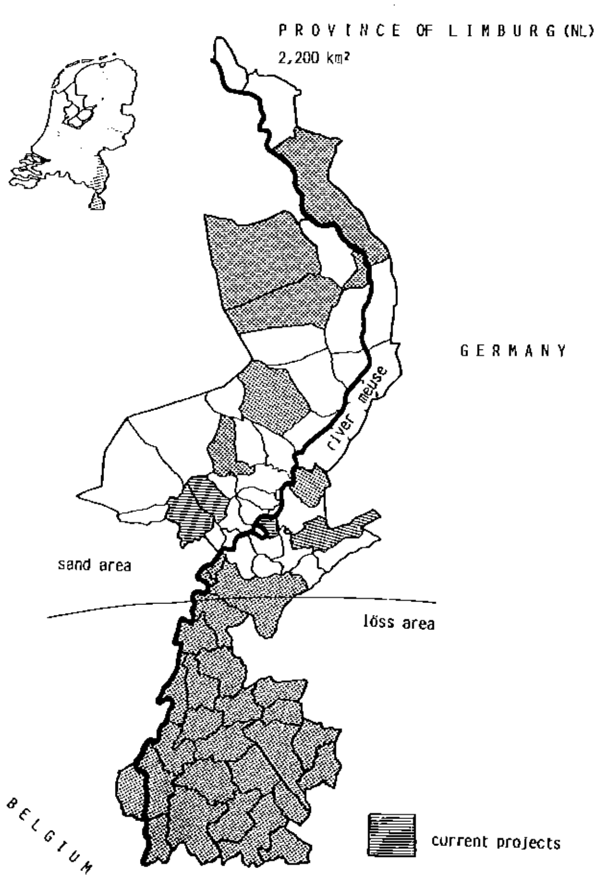

Fig. 1 Location of the IKL–projects

Losing functions

During the last few decades most of the landscape elements are menaced by disappearence. The main reason for this evolution is mostly the loss of their original, agricultural functions: production of timber and fire–wood, boundery, etc.

Recent developments in agriculture such as mechanisation, landconsolidation and over–manuring, but planological and infra–structural expansion too, pose a new threat which accelerates the decline.

Changes

In spite of the loss of their original agricultural functions, the elements remain important for the functioning of the landscapes, even or just for the modern farming.

So, hedges or other linear elements protect the soil from erosion processes by wind and/or water.

As a windscreen they still offer protection for crop and live–stock. But in addition, the small landscape elements have acquired additional functions since their existence over centuries have had a diversifying influence on the floral and faunal populations of the landscape. So, linear elements constitute dwelling habitats, nest and hiding places, food territory an migration routes, amidst intensive and hostile agrarian landscapes. They increase connectivity possibilities in the landscape and so constitute or contribute to an ecological infrastructure. For man too, small landscape features are important. They heighten the recreational value and perception of the environment.

ORGANISATION

In short we will point out the way the IKL–Foundation realise the execution of management and maintenance of the landscape elements.

Planning

The projects concern mostly the territory of one municipality, because the local authorities are the most appropriate level to work on. After a qualitative and quantitative inventory of the elements, a management plan based on these data is drafted.

This plan contains briefly the following items: management guidelines for the elements, results of the inventory, landscape description, legal and planological aspects, procedure of the plan, manpower needed for execution, estimation of the time–laps necessary and finally the financial consequences of the plan. The whole is completed with maps.

Once drafted the plan has to be approved by several authorities: muncipality, the Foundation's Board and at last the Ministry of agriculture.

Execution

Emphasis of the Foundation's work lies in the first place on clearing maintenace areas and restoring decaying elements. In that way we try to save the still existing structures of habitats. By doing so, at a long notice, the reliques can be used as a starting–point for constructing and planning new elements.

In a later stage work will shift more and more to cyclic maintenance.

Will a management plan be useful for the execution, it has to be worked out in a so called "annual working plan". It describes exactly the elements to be treated, by whom and the way how. Before, a supervisor contacts also the landowners concerned. Only with the agreement of the latter, work can be executed.There is no form of obligation.

Types of elements

As said before, although the total area is relatively limited (2200 km²) the diversity of elements is great. The reason lies in the complexity of the edaphic and topographic conditions.

Table 1 summarizes the major types of elements. Some of which have alimited dispersion area. So the sunken lanes and the escarpments (graften) are restricted to the loess area in the South, wereas the hedgerows on embankments (houtwallen) are characteristic of the sandy area in North. In fact the objective of the IKL is not only to preserve the elements with ecological/biological values, although we emphasize this, historical and recreational aspects are taken into consideration too.

Manpower

The Foundation has 79 emplooyees, 63 of which are in charge of the work in the field. At the moment nine shifts are active in 35 municipalities (fig. 1). A planning team does the inventory and drafts the management and working–plans. The department of Public Relations and Information stimulate landowners, local authorities and volunteers to contribute to the Foundation's work. This is done by publishing leaflets and brochures, organising courses, instruction meeting, exhibitions, lectures, etc.

In order to realize the work IKL–staff alone doesn't suffice. Additional manpower is necessary.This need is met in several ways.

In some cases the local authorities make up the shortage. Sometimes working–experience schemes for unemployed people are set up. In several cases local groups of volunteers are enlisted.

Although in Limburg the contribution of the latter is not as important as e.g. in the West of the Netherlands, or as it is in Great Britain, the work done by these people who spend their spare time on the maintenance of landscape elements, serves as an example for society.

Ways of maintenance

In general the way an element will be treated by the IKL depend on the actual an potential function(s) the elements have in the actual and future landscape. Six functions are mainly taken into consideration: (landscape)ecology, biology, agro–ecology, as the most important ones.

Historical, recreational and production aspects play a role too, when we decide on how to treat an element.

Sometimes it is clear what has to be done, as in the case of pollards or trimmed hedges. But in the case of small woodlots or large hedgerows, where interists often differ or are conflicting, deliberation with and information to the landowner is very important.

Five years of experience have taught us that you often have to come to a compromise, which could suggest that ecological and biological aspects should count less. In fact, there where it should have been the case, this was done to preserve an (or more) element(s). By acting in this way IKL has built up a goodwill which will be important in the long run.

But mostly an element treated well in an ecological point of view seemed to limit or avoid nuisances which arrears could cause to agricultural uses.

By executing the work in phases both in time and in space, IKL tries to limit harmful effects of a concentrated treatment.

Table 1 and figures 2 to 8 summarizes for the several landscape element in Limburg possible kinds of maintenance activities as done by IKL.

SUMMARY AND CONCLUSIONS

What was intially started as a voluntary movement, worked out as a professional organisation by engaging unemployed. The IKL–Foundation has since five years, worked for the preservation of small landscape elements in the southernmost province of the Netherlands, Limburg.

Table I

Landscape elements in Limburg (NL) and their treatment by the IKL-Foundation

small woodland	1,2,5,9	(isolated) tree(s)	(1),4,6,(9)
hedge	(4),7,8,9,10	lanes	6,9
hedgerow (houtwal))	1,2,3	dry/wet-grasland	(9),12
escarpment (graft, knick))	4,5,8		
hollow lane)	9,10	pond, pool)	
		fen)	(4),8,9,11

1, cutting 2, coppicing 3, singling 4, pollarding 5, thinning
6, crown lifting 7, trimming 8, fencing 9, planting 10, restoration
11, digging 12, mowing

Fig. 2 Exemple of maintenanace in phases by a hedgerow

Fig. 3 Another exemple of maintenance in phases. Hedgerow is treated over one half over the whole length

Fig. 4 A wooded escarpment (graft) with maintenance arear. To avoid erosionby trampling of cattle; a fence is needed

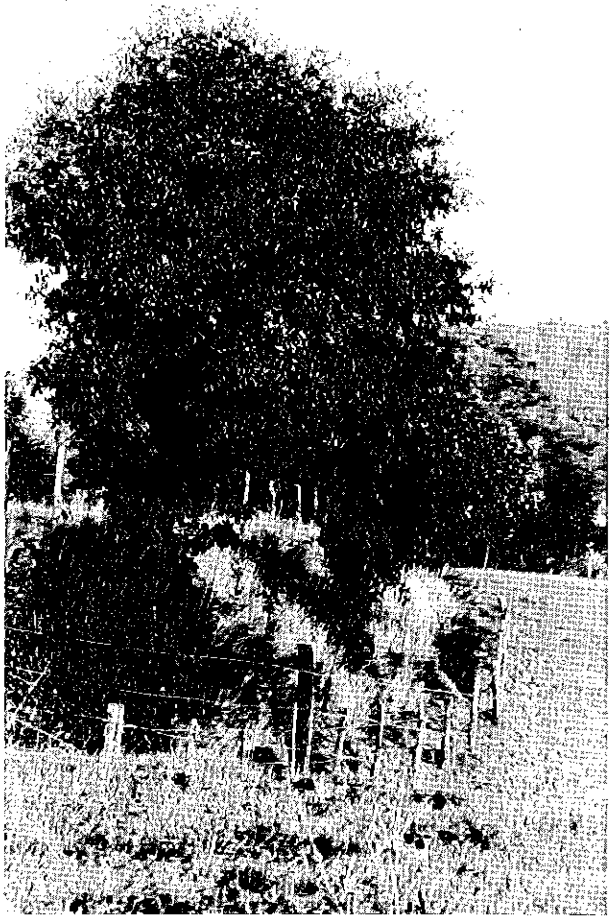

Fig. 5 Escarpment (graft) after treatment by IKL. A new fence is placed and there has been planted.

Fig. 6 Wooded slope of a hollow lane. There is a competition between element and grasland for light, water and nutrition. Fence is in a bad condition. Clearing of the maintenance arear increases the chance of preservation of the element.

Fig. 7 A well maintened hollow lane can accomplish its function for plants and animals

Fig. 8 The digging of new ponds consists an important part of landscape management of the IKL–foundation

Till now more than 400,000 hours have been spent on management and maintenance activities. So, some 100 km of linear elements and 2,500 trees have been treated and nearly 100 ponds have been newly dug.

By planning, the choice of the way of execution is mostly directed by the agricultural demands (claims). This however doesn't in any way mean that landscape–ecological and biological aspects are excluded. On the contrary they can coincide.

The work done by the IKL–Foundation consists in fact in doing the work farmers used to do. Now new developments bring about important changes infarming. As a consequence landscape elements degrade. To pick–up again the maintenance of the elements, taking into account ecological, biological and agricultural aspects, it is necessary to know more about landscape– and agro–ecological principles. The Foundation's work should in fact consist in executing these principles. Therefore a translation–step from ecological models to practical execution guidelines is badly needed.

Or from the scientific level to the application level.

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ECOLOGICAL INFRASTRUCTURE ON A NATIONAL SCALE?

A.J. VAN SELM

Physical planning and nature conservation in the Netherlands are increasingly interested in the concept of "ecological infrastructure". The concept was introduced and elaborated in government policy reports in 1977 and 1981.

Creation of an ecological infrastructure is seen as necessary for as far as possible offsetting the consequences of the isolation of "natural islands" amidst an "ocean of agricultural land". Ideally this structure should enable many species to move from one area to another, thus facilitating the exchange of individuals between different populations of the same species.

The coining of this still rather vague concept generated a lot of research and articles in the Netherlands. It became clear that the design of a national ecologial infrastructure for certain individual species is feasible when enough autecological data are available, e.g. for the badger *(Meles meles)* and the otter (*Lutra Lutra*). Also to designs on a local level for ecological infrastructures that provide for the needs of many different species were developed by order of our national physical planning agency. One of these concerns the area of Rossum in the east of the Netherlands, on which a paper is presented in the poster session part of these proceedings by the Institute for Environmental Studies (1).

The design of an ecological infrastructure for many species for the whole of the Netherlands proved to be much more difficult. The reasons for this are threefold: the problem of the less detailed scale, the enormous amount of data concerning many species, and strategical considerations concerning the relation of nature conservation and development versus agricultural interests. This leads to the situation that publications about this subject (such as this one) ought to be seen as contributions to a discussion about the feasibility of such national structures. In producing these two maps, simplifications and assumptions had to be introduced. The enormous amount of data which can be gathered from existing literature concerning the distribution, habitat requirements and dispersal capacities of may species, has to be reduced to a managable quantity.

This is done by basing the maps only on those species which already have a protected status based on the law on Nature Conservation, which reduces the 32000 species (estimated to be present in the Netherlands – most species are invertebrates and as yet not identified) to some 80 taxa, mostly vertebrates (with the exception of the birds – which are in a different law) and so called higher plants (the Cormophyta). Further, a choice is made for two types of ecological infrastructure each related to a certain type of biotope: one for woods and semi–open areas with woodlots, and one for marshy, river and brook areas. These are in this paper simply designated as the "dry" and the "wet" ecological infrastructure.

The problem of scale is a different one.When designing landscapes or structures aimed at increasing the ecological possibilities for a small area, this can be done on a large map scale (e.g. 1:10.000or 1:25.000). Thus there exists the possibility of relating the data concerning the autecological demands of the species considered to the actual characteristics of that particular area: at least in Holland many types of maps are available on these scales or can be meaningfully used (e.g. soil, groundwater level, geomorphology). When rural reallotment is carried through in a region, generally many data are collected on a very detailed scale (1:10.000).

When designing ecological structures for a whole country, even such a small one as the Netherlands, this is totally different. Coupling of autecological demands of species to the characteristics of sites is no longer possible. Instead of these, maps on these scale have different and interesting properties. The distribution maps on a national scale of the different species groups reveal the particular characteristics of the different parts of the country: some areas are for instance very important for amphibia (e.g. the extreme south, the province of Limburg), others for reptiles (as the central wooded area, the Veluwe, and the high pleistocene plateau in the north). Most interesting and highly alarming is the fact that in the different physical planning plans of the regional authorities these region specific tasks are not identified. With a national ecological plan these different ecological properties of the different regions can be identified, and the regional authorities asked (or charged – but then the Law on Nature Conservation, which is now in revision, will have to provide for this) to preserve the populations of these species on their locations, and for to identify and protect the sites concerned in their physical planning plans and rural reallotment procedures. Furthereon, on a low scale level many plans are made by different institution and private organisations for nature development (as in some regions in Holland we don't have left much to conserve) and the creation of connecting structures (aimed at particular species as the other and the badger, or at connecting hedges etc. in general). As there is virtually no coordination in this field, this leads to the necessity of an overall framework from which the direction and contents for individual plans could be gathered.

The strategic considerations are many. Up until now, the main stream of nature conservation strived for the conservation of all existing nature values at all places where they now occur. It turned out that this high aim is unattainable. Different schools of thought have sprung up since.

One school advocates a strict spatial division between natural areas and the areas in use for other ends (agriculture, roads, built up areas, etc.). Another makes a pledge that nature conservation should aim at species which are not dependent on those (a)biotic conditions which are difficult to preserve in our intensively used country. This concept of a national ecological infrastructure leads to the identification of which species should be preserved in which place. Therefore it necessitates to explicit choices, and this brings rather abstract discussions back to concrete questions.

When this approach to ecological infrastructure on a national scale is coupled with the method for designing an ecological infrastructure on a lower scale level, sketched in an article in these proceedings (2), an interesting perspective opens: identifiable goals, a group of target species for well–defined regions, are chosen departing from a perspective of national interest. These goals can be elaborated on a detailed level, apt for application in planning procedures and e.g. rural reallotment. As a consequence the ecological demands of the chosen target species can be identified and thus fitted in the usual planning procedures: this is not possible with the normal approach of nature conservation, which strives for the integral maintenance of the status quo.

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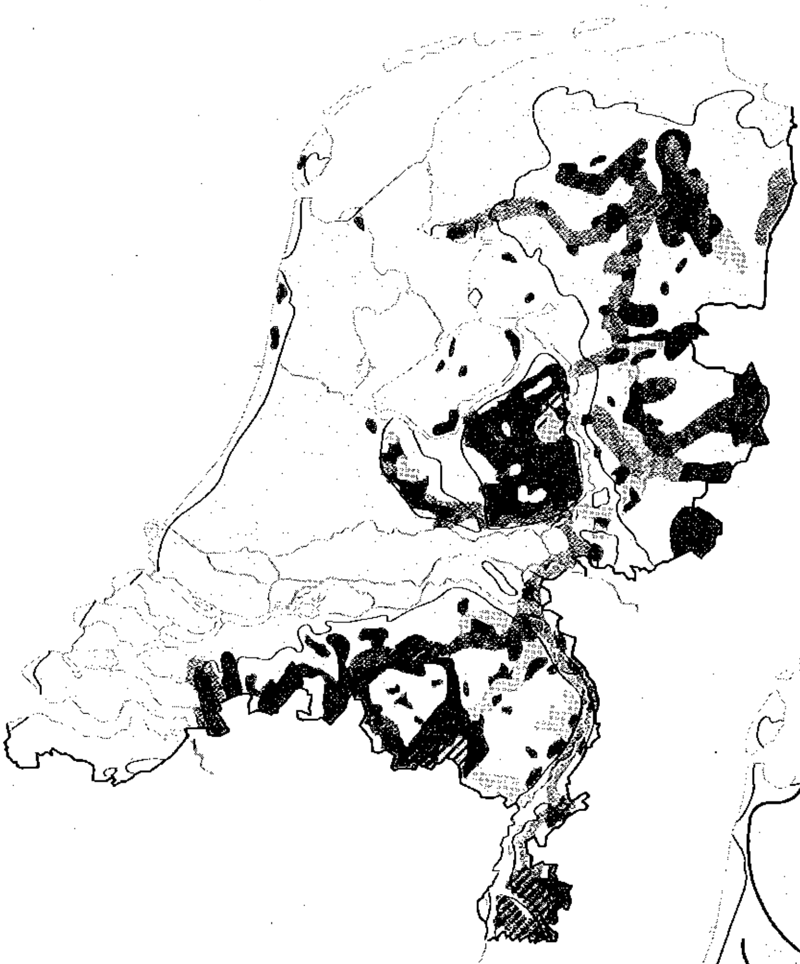

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THE APPLICABILITY OF REMOTE SENSING IN HABITAT NETWORK PLANNING ON A REGIONAL SCALE; A CASE STUDY IN THE PROVINCE OF GRONINGEN, THE NETHERLANDS.

FRANS KLIJN & TOM N. LIGTHART

INTRODUCTION

The landscape in The Netherlands is almost totally manmade. Nature is found in reserves and the like, which cover only 4.4% of the country (situation of 1986). However, the cultivated land has natural values, thanks to small woodlots, hedgerows, waters etcetera.

On a regional scale Provincial Planning Agencies are responsible for the quality of the environment. In the province of Groningen a landscape monitoring project is being implemented to facilitate the early detection of controversial autonomous developments. The monitoring has three major themes:

1. nature and ecological functioning
2. scenery
3. cultural history

A pilot study was carried out for the monitoring project in order to determine the extent to which the use of remote sensing imagery can facilitate the monitoring of the landscape developments. In this paper the attention will be focused on the (elements of) habitat networks.

THE STUDY

Two study areas different in character were selected in which a number of types of images and methods was tested as to accuracy, economy and speed/area ratio.

The area 'Fransum' is characterized by it openess with scattered vertical structure elements as farmyards surrounded by trees. Because of the openess, the quietness and the use as pasture land 'Fransum' is an ideal habitat for meadow–birds. The main threats in this areas are: – the change of pasture land into arable land
- the increase in the density of buildings
- the increase in the density of vertical elements such as trees
- the filling up of ditches

'Grootegast' is the second selected area, longitudinal ridges covered with hedgerows alternated by shallow and open depressions form its special character. The hedgerows are threatened by lack of maintainance and cutting, for the open areas there are the same threats as for 'Fransum'. In the study a Landsat Thematic-Mapper (TM) of 22–08–1984 and black–and–white aerial photographs of different years were used. The scales of these photographs varied from 1:18,000 to 1:6,200. Five main groups of landscape elements were chosen for the mapping:

1. surface water (type, width)
2. land use and infrastructure (roads, etcetera)
3. buildings
4. tree cover characteristic (transparency, vertical structure)
5. relief and geomorphology

The changes in these landscape elements in the study areas were mapped. The detectability of several landscape elements was established.

RESULTS

For monitoring purposes the detectability of the elements has to be high, because in most cases the autonomous developments in the landscape are gradual and include only a small part of the total number of elements. To follow the developments in the degree of connectedness in a landscape the individual elements which are part of the ecological infrastructure must be recognized in the imagery. The extent to which elements contribute to the connectedness differs of course. The differences depend upon the qualities of the element. Concerning a hedgerow its position and the horizontal and vertical structure are important. However with aerial imagery the horizontal structure remains hidden. The changes in the connecting power of a hedgerow system can therefore (if ever) only be traced up to a certain level.

The Thematic Mapper image which was processed to visualize the elements such as hedgerows and ditches to the highest degree possible showed these elements merely partly. Only 50 percent of the afore mentioned existing linear elements could generally be traced. Tracing the hedgerows in the area 'Grootegast' without knowledge of this area more than 30% of the mapped hedgerows were in reality ditches. Apparently the relatively small hedgerows and ditches with their surroundings give a fairly similar spectral image. Enhancing the TM image for one specific element shall reduce the number of mis–interpretations, but only up to a certain level. Mapping of the ditches in the area 'Fransum', in this case with knowledge of the area, resulted in only half the number of the existing ditches.

On the small scale (1:18,000) aerial photographs made by the Dutch Topographical Survey not all the extant narrow linear elements can be recognized. Ditches and hedgerows can be traced with great accuracy on photographs of scales greater than 1:12,000. On these scales the transparency or degreee of uninterruptedness of a hedgerow can be determined. The tree species, a factor important to the connecting power of hedgerows in relation with birds in the 'Grootegast' area (VAN SCHARENBURG 1987) could not substantially be recognized on the used panchromatic photographs. The use of big scale false colour photographs will improve the recognition of species, but is also more expensive. As mentioned before the horizontal structure of a hedgerow remains hidden.

In the study three methods of tracing the changes in the landscape with help of aerial photographs were used:

1. direct
2. indirect
3. semidirect

The comparision of two images of different years of the same area directly with each other is the direct method. The indirect method implies as first step the making of interpretation maps of the images. Next these maps are compared to detect the changes. Comparing an image with an interpretation map of the preceding image and tracking down the changes in this way is called the semidirect method. The interpretation map is after the tracking down updated with the found changes.

The direct method is the fastest (2–4 sq. km/day), but especially when one distinguishes between different classes within an element (i.e. in transparency in a hedgerow) the number of mis-interpretations becomes too large. The indirect method is too time consuming (1–2sq. km/day) to be useful in a monitoring project. The semidirect method is almost as fast as the direct method and leads to less mis-interpretations.

CONCLUSIONS

Despite rapid development in remote sensing imagery(satellites) it has been found that at this moment conventional aerial photography provides the best means for monitoring landscape development at scales relevant for regional planning. The scales of the photographs should be 1:12,000 or greater. The choice of the imagery is mainly determined by the differences in the detectability of linear structure elements between the imagery.

For the monitoring project by the research department of the Provincial Planning Agency of Groningen the semidirect method is the most promissing one. The method provides a data base (basic map) which can be updated every few years and is relatively fast. In view of the relatively slow rate of change in the landscape and the period between the revision of the policy of the province (10 years) it is advisable to take a monitoring period of five years. As only a part of the whole province (less than 10%) can be monitored, due to lack of finance and labour, a stratified technique is recommended.

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ECOLOGICAL BALANCING OF NETWORK STRUCTURES AND LAND USE PATTERNS FOR LAND–CONSOLIDATION BY USING GIS* –TECHNOLOGY

J. SCHALLER, W. HABER

Abstract

Environmental Impact studies and Ecological balancing methods for Land use planning and Land consolidation are gaining more importance in the planning process. The qualitative and quantitative effects of impacts in existing network structures and habitat patterns are fundamental indicators for the evaluation and assessment of planning alternatives. Therefore new mathematical approaches by using Geographical Information Systems (GIS) are necessary.The application of interesting new geographical software tools (NETWORK, TIN = Triangulated Irregular Network) for these issues are shown in a research application for the land consolidation authority in Southern Bavaria.

1. Introduction (from HABER 1987)

Landscape ecology deals with assemblages of ecosystems ocurring in a geographically defined region (=landscape) – principally in the way as ecosystem ecology deals with assemblages of plant and animal species and nonliving environmental agents ocurring at a given site.

Both for landscape and ecosystem ecology, the basic and critical unit is the site or, in ecological terminology, the ecotope. It is a small section of the lithosphere (earth's crust), determined by the local geological situation within the regional climate.

Ecotopes can be considered unique in their particular assemblage of living and non–living components. However, there are similar ecotopes with recurring properties, allowing regognition of ecotope types (ecosystem types) often represented by vegetation units. These types can be classified according to type and intensity of human impact (Table 1 and HABER 1987). Like species diversity in an ecosystem, there is ecotope (–type) diversity in a landscape (cf. TURNER, M.G. 1987).

Ecotopes can also be assembled into regional natural units (RNU, in German "Natürräumliche Einheiten"; KLINK 1973; FINKE 1986; foran U.S. approach see Young et al. 1983) which constitute a third level in the hierarchy of spatial units. They are determined by common geological and geomorphological properties and a typical regional climate. Each RNU has its proper set of ecotopes often forming a characteristic pattern which is also reflected in land–use (KAULE et al. 1979).

2. Land consolidation

The land–use pattern, however, has also been influenced by agricultural traditions, in particular by handling land ownership across generations of farmers. Two types of transferring land resp. farm property to the next generation can be distinguished throughout Europe. One type is bequeathing the whole farm property to one single heir, mostly the eldest son, who, however, was also made responsible to care for his brothers and sisters. The other type was dividing the property equally among all direct heirs. This was often done in the most meticulous way. If a farmer had e.g. four heirs, then the land was not simply divided into four parts, but very often each field or pasture was quartered in order to take possibly different site qualtities into due account. This custom resulted in a land–use pattern characterized by a multitude of tiny parcels of land and thus also in maximum ecological diversity which was often further enhanced by establishing hedgerows and other boundary features between the parcels.

Of course such tiny fields cannot be reasonably cultivated beyond a minimum size, so owners or users were trying to reunite them by acquisition, exchange, lease, marriage etc. in order to reach a "consolidation" of the fields. However, such private measures proved inadequate to ensure effective and economic cultivation of the land, and so the custom of equitable partition resulted in endless quarrels between farmers, eventually forcing the government to take over regulation and distribution of rural land ownership by establishing public "land consolidation" with an own agency based on special legislation.

From its original intentions, public land consolidation (in German "Flurbereinigung", in French "remembrement agricole", in Dutch "ruilver– Naveling") aims at supporting farmers in their effort to achieve the most economical, effective and modern agricultural production. Major measures have been combining dispersed, small parcels of land into large units suitable for big farm machinery, establishing drainage or irrigation schemes, creation of a modern network of agricultural roads, and regulation of streams and ditches. The appearance of the countryside was thoroughly changed. Economically"useless" structures such as hedgerows, tree groups, small streams, ponds, semi–natural grassland, shrubbery etc. disappeared, the land became "clean" and homogenous. However, the more effective land consolidation was, the louder protested conservationists, nature–lovers, recreationists, tourism managers against loss of scenic values, destruction of typical rural features, removal of biotopes or habitats of many plant and animal species. Moreover, increasing environmental damages came to light: soil erosion by wind and water, soil compaction by heavy machines, summer drought in drainage areas. As a first consequence, the Land Consolidation Act was amended in 1976 to include ecological viewpoints and regulations so newer land consolidation schemes became less ecologically harmful or destructive.

In 1983, the Bavarian Land Consolidation Agency charged the Chair of Landscape Ecology of Munich University of Technology to systematically investigate all ecological side– and after–effects of land consolidation and to strike the ecological balance of this important supportive measure for agriculture. The project aims at finding methods for supplementing the traditional economic balancing of land consolidation by ecological balancing, placing particular emphasis on habitats and biotopes of plant and animal species and on ecological connectivity. The methodical approach is site–oriented. All actual ecotopes resp. land–use sites are regarded both as sources and receivers of impacts. This requires a distinction of within–system and between–system impacts. Soil compaction caused by heavy machinery is a within–system impact, but soil erosion is also a between–system impact because the eroded soil going e.g into a stream is an impact on the stream ecosystem.

Of special importance are impacts on landscape composition or physiognomy, caused by land consolidation and also by road construction. Most traffic lanes and road networks act as barriers

* GIS = Geographical Information System

Tab. 1: Ecosystem types and intensity of human impact

Ecosystem types	Human influence	Landuse types	Examples of landuse types
Bio-Ecosystems	Dominance of natural components and biological processes		
1. Natural Ecosystems	without human influence, capable of self-regulation	A8, W8,	bogs and swamps
2. Near-natural Ecosystems	Influenced by man, but similar to 1. - pracitcally not changing after man withdraws. Capable of self-regulation	A1, A2, A4, A6, D1, D7, D8, W2,	Vegetation in water,, natural woodland types
3. Semi-natural Ecosystems	Resulting from human use of 1 and 2, but not (internationally) created, changing after man withdraws. Limited capability of self-regulation; management required.	A7,A11,A13, A14,A16,A17, A20,A21,D5, D6, H1, H3, H11,H12,H13, H21,H22,H31, H31,W1,W30	Vegetation in water-bank areas Herbaceous vegetation Hedgerows, shrub hedges, thickets
4. Agrarian-Forest Ecosystems	Internationally created by man and fully depending on human control and management.		
4.1 with low landuse intensity		D2,D4,D9,D10, D11, D12, D20, H23, R1,S1,S2, S3, S5, W93,	Individual trees,nutrient poor grassland, heath herb-rich meadows,rough pasture, rows of trees and clumps
4.2 with medium landuse intensity		A15, D3, G5, N50, W91, W94, W95, Z10, Z23, Z25, Z32	fertilized grassland, managed forests
4.3 with high landuse intensity		F97, N0, N2, N3, N4, N6, N7, N8, N10, N20, N23, N25, N26, N27, N41, N45, N46, N51,	arable, cropping types
Techno-Ecosystems Examples: Settlements (villages, cities) Traffic systems Industrial areas etc.	Anthropogenic (technical) systems. Dominance of technical structures (artefacts and processes. Intentionally created by man for his industrial, economic or cultural activities. Depending on human control and on surrounding and interspersing biotic ecosystems.	B1, F93, J0, J3, J4, J5, J6, J7, J8, J9, T32	technical infrastructure and settlement types

HABER/SCHALLER 1987

for many animal species and cause fragmentation ("insularization" of contiguous populations (MADER 1979).

Four test areas in Bavaria were selected for this investigation. The available ecological information and data were supplemented by aerial photographs, topographical maps, field work, then computerized and transferred into an electronically operated Geographical Information System (G.I.S.). (For an ecologist, the meanwhile established term "geographical" information system is misleading. As a matter of fact, much of the information is not geographical, but essentially ecological.)

3. GIS technology application in ecological balancing of land consolidation schemes

3.1 General remarks on GIS technology

Increasing complexity of (landscape–)ecological problems, availability of large computerized data bases, and high demands with regard to the quality of research require a growing degree of automation in landscape–ecological planning and research. More conventional work such as design of recreation sites, reclamation of derelict areas, or planning calculations are already being carried out using GIS technology. In the last time, various GIS' are being applied to solve complex ecological problems, where primary consideration is given to the display of a high density of information in form of automated cartographic data with related attributes (SCHALLER 1987).

Fig. 1 depicts the structure of a geographical information system. The nature of the project and the area concerned will determine the choice of the analytical method. Existing information can be added or updated during the course of the project. Data which already exist in digital form like remote sensing data require an appropriate interface to be included in the system. All area–related data can be described and classified according to standard criteria. Data input involves the translation of geometric geographical information into x;y coordinates by manual or automatic digitizing, by use of existing digitized coordinates or image information, or by automatic generation of geometric features by suitable software. Alphanumeric data is usually put in manually. After an interactive "cleaning"process a map–library data base will be created in form of a Geographical Information System. It makes sense to manipulate data in relation to logical spatial units considering the geographical area, the data structure and its classification according to resource or land use variables. As well as statistical and mathematical calculations, the analytical functions of GIS systems include evaluation models, network analysis, linear programming models, overlay analysis, route selection, spatial modelling, surface models and corresponding graphic layouts. Data output can be presented as text, statistics, diagrams, maps or threedimensional graphic presentations. These can be viewed on screen or printed on normal or photographic paper (SCHALLER 1985).

3.2 Ecological balancing as a tool for Environmental Impact Analysis (EIA)

The method of ecological balancing was developed for Environmental Impact Assessments and evaluation of planning alternatives in several research projects:

- Ecological assessment of land consolidation impacts for the Land Consolidation Authority in Bavaria
- Environmental impact of agricultural subsidies on natural resources in a rural area of Bavaria (BACHHUBER et al. 1987)
- Man and Biosphere project 6 "Human impact on high mountain ecosystems" (HABER et al. 1983)

Ecological balancing allows different alternatives of planning, land use or development strategies to be compared and assessed applying several indices derived from the area, related resources and impact data. In a given landscape many processes are taking place. Examples are inputs such as precipitation, solar radiation and outputs such as surface water flow or groundwater recharge. Different model approaches for balancing landscape– ecological processes are sketched in Fig. 2.

In this project approach, models of two different categories are used:

1. Static GIS models – GIS combined with statistical calculations. Results are static thematic maps usually valid only for one point of time.
2. Quasi–dynamic models – Extension of GIS models by introducing quasi–dynamic calculations rendering more points of time. They allow geographical evaluations such as required in re–zoning of planning areas, or calculation of functional spatial units, of networks and cascades. Such models of course do not represent real dynamics; they are derived from transition matrices describing changes of certain features for selected points of time, e.g. land use before and after an ecological change.

These quasi–dynamic models include, besides special spatial ecological analyses, evaluations of interrelationships and changes of energy and matter flows, of species diversity, and of connectivity in landscapes. Calculations and comparisons, however, are related to specific initial conditions or other points in time, and therefore remain static in relation to natural dynamics.

3.3 A case study: Land Consolidation Scheme of Oberhaselbach (Bavaria)

In former land consolidation projects, mainly economical viewpoints were considered. Ecological questions such as size of parcels, species diversity or diverstity of land–use types have not been regarded as relevant problems. Nowadays this has changed and new land consolidation projects are realized applying EIA procedures. The Environmental Impact Assessment is oriented to natural resources such as quality of ground– and surface water, soil quality or soil erosion, local climatical effects and impacts on vegetation and fauna. In addition to these "classical" assessment criteria, integrated ecological parameters such as diversity indices, habitat connectivity and network structure, length of ecotope edges, biological active surfaces and intersection or separation indices have to be taken into account (HABER 1971; FORMAN, GODRON 1984). Of course landscape units such as floodplains, plateaus, and landscape components such als steep slopes, hillsides etc. have to be distinguished and mapped.

The GIS data base for evaluation and assessment comprises natural resource data such as soil types and qualities, groundwater, surface water; topographical data such as contour lines, exposure and slopes, and data on biotic resources. These data are stored in the computer as polygons or linear feature maps. The Subject of environmental impact assessment of land consolidation is the change of land use pattern and land use types in relation to the actual state. The type of impact is coded into a separate data–set and includes information on assemblage of parcels, removal of structures or creation of new structures. The Oberhaselbach project chosen as example for ecological balancing is a current land consolidation. The data base used for the assessment of its planning does not represent the latest updates. Therefore changes in balancing results are possible.

Ecological balancing for different points of time is done with transition matrices describing land use changes in the form of a sequence of different land–use types on the same spatial unit:

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actual state             medium-term change          long-term change
land use type A01  ==>   land use type A03     ==>   land use type A07
                         Balance time point 1        Balance time point 2
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Map 1 and 2 are showing the land use changes for the study area of Oberhaselbach caused by land consolidation. These changes in land use intensity, and in the size of parcels will cause impacts on

Fig. 1 Geographical Information System

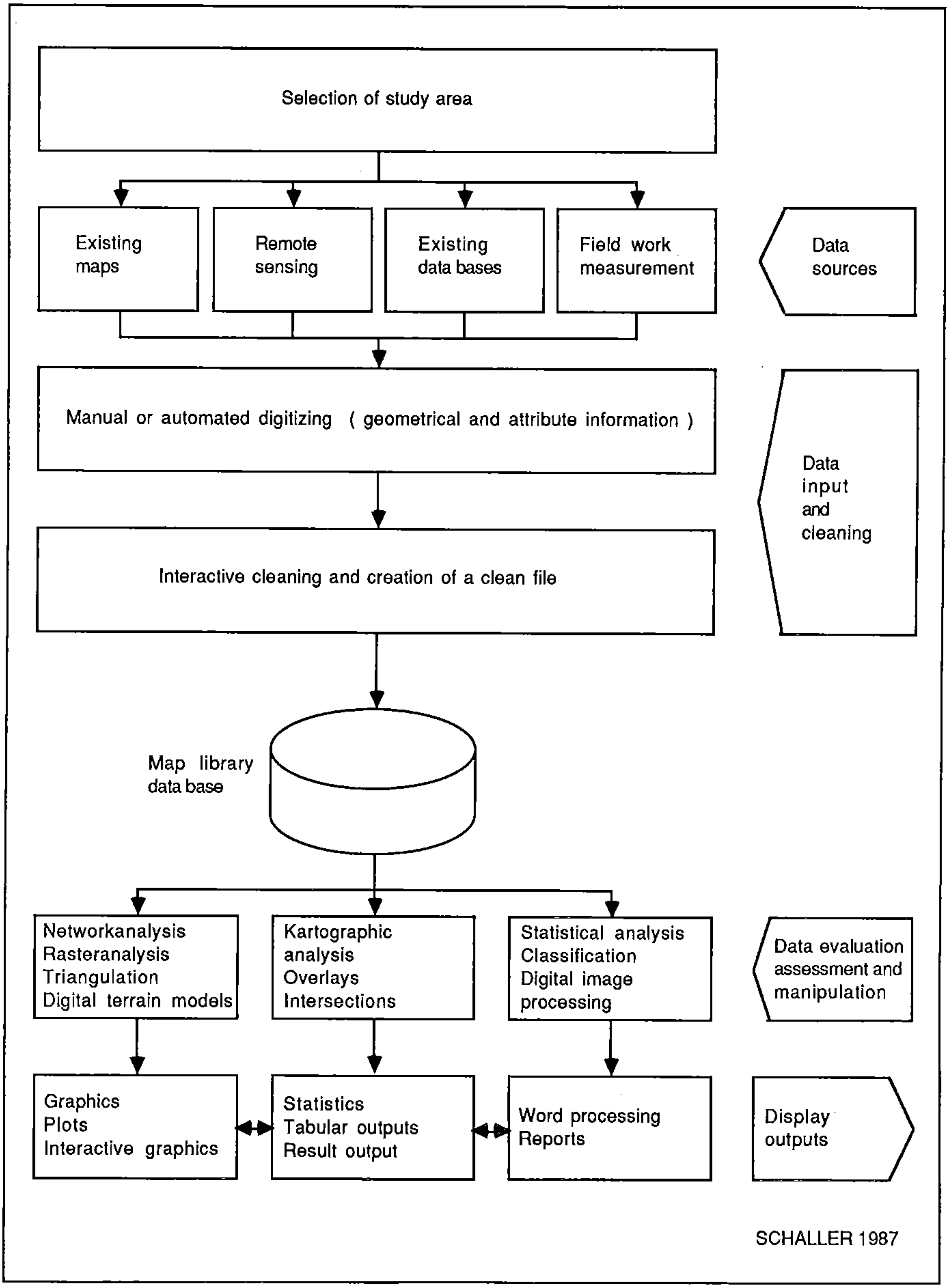

Fig. 2 Reality and Model Approaches

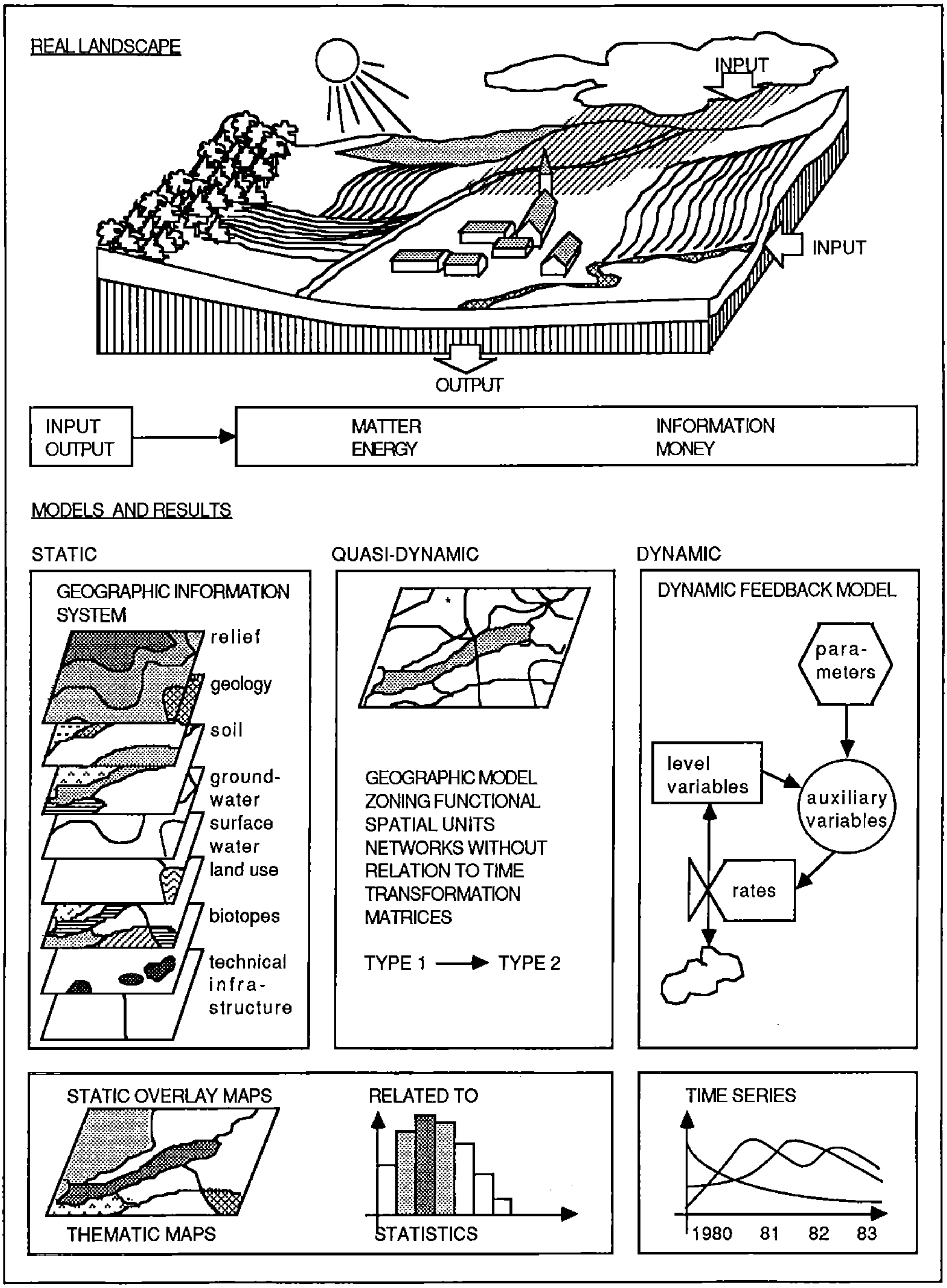

Table 2 : Ecosystem pattern - land consolidation Oberhaselbach

Bio-Ecosystemtype	before land consolidation		after land consolidation		difference before / after	
	area (ha)	%	area (ha)	reference status quo %	area (ha)	%
Natural ecosystems	0,6	0	0,5	0	-0,1	0
Near natural ecosystems	9,9	1	7,4	1	-2,5	0
Semi-natural ecosystems	273,3	28	268,0	27	-5,3	-1
Anthropogenic ecosystems low intensity	27,2	3	4,3	1	-22,9	-2
Anthropogenic ecosystems mediate intensity	103,9	11	65,2	7	-38,7	-4
Anthropogenic ecosystems high intensity	517,6	53	578,3	59	+60,7	+6
Techno-ecosystems	44,8	4	53,6	5	+8,8	+1

Table 3 : Land use border types

Class	Ecosystem type		Neighbour ecosystem type
1	Techno-ecosystems	←→	Others
2	Agrarian-forest ecosystems with high and mediate intensity	←→	Agrarian-forest ecosystems with high and mediate intensity
3	Agrarian-forest ecosystems with high and mediate intensity	←→	Agrarian-forest ecosystems with high and mediate intensity
4	Agrarian-forest ecosystems	←→	Semi-natural ecosystems
5	Semi-natural ecosystems	←→	Semi-natural ecosystems

Table 4 : Assessed land use border types - land consolidation Oberhaselbach

land use border type	before land consolidation		after land consolidation		difference before / after	
	length (km)	%	length (km)	reference status quo %	length (km)	%
1	86,6	31	95,3	34	+8,7	+3
2	86,0	31	63,5	23	-22,5	-8
3	66,3	23	35,0	12	-31,3	-11
4	38,7	14	40,0	14	+1,3	0
5	2,3	1	1,6	1	-0,7	0
	279,9	100	235,4	84	-44,5	-16

natural resources such as groundwater, surface waters, soils, local climate, vegetation and fauna, which have all to be assessed and evaluated to allow ecological balancing of land consolidation. These assessments are strictly site–oriented and can be done for both qualitative and quantitative criteria. In addition to this static, site–dependent approach, more complex characters such as functional ecological units (e.g. watersheds, barriers, buffering zones, cascading and network structures have to be integrated into the evaluation. Typical indicators for integrated assessments have been enumerated above.

Based on the conceptual classification of ecosystem types according to human impacts, different land use and landscape types can be defined as shown in Table 1. The changes of land–use intensity before and after land consolidation are documented in Table 2, where a general loss of natural and semi–natural ecosystem types and of land use types of low impact can be recognized. Another important characteristic to be used in ecological balance sheets is type of boundary between land–use sites or parcels as classified in Table 3. Table 4 shows the impact of land consolidation on this characteristic: boundary types of higher ecological quality are being lost (– 44 %), and replaced, if at all, by artificial boundaries such as fences or straigth ditches.

An approach to more sophisticated problems of ecological balancing than changes of habitat networks of animal species is also possible, and is dis– cussed here with an ecological impact assessment for the fence lizard (Lacerta agilis). Fence lizards utilize different land use types as habitats. They prefer small linear landscape elements like small strips of dry grassland between land parcels, hedgerows etc. Map 3 and 4 show these small, linear landscape elements before and after land consolidation. These changes have a severe impact on the habitat network of the fence lizard.

Land use types and small linear landscape elements can be characterized by zoologists as habitat types with low or high value for the fence lizard or other animals due to the results of fieldwork (BEUTLER,HECKES 1986, Table 5). The assessment of the connectivity value between two habitat types is explained in Table 5 where habitat types with high value get a high connectivity value if they are in near neighbourhood, and decreasing values according to growing distances between them. With the use of Triangulated Irregular Network (TIN) and NETWORK–software (ESRI, 1987) a network of connectivity values can be established using the Geographical Information System (cf. Map 5).

Table 5 : Assessment of habitat values to land use and land cover types for fence lizard

	habitats and linear habitats		linear habitats	
habitat type	code of special type	habitat value	code of special type	habitat value
wetlands	A4 A6 A8 A13 A15 A17 A21	0 0 0 0 1 1 0	A1 A2 A4 A7 A11 A13 A14 A15 A16 A17 A20 A21	0 0 0 1 1 0 1 0 1 1 0 0
grassland	D2 D3 D4 D5 D6 D8 D10 D11	0 0 2 2 2 2 2 1	D1 D3 D4 D6 D9 D10 D11 D12 D20	0 0 2 2 2 2 1 2 0
hedges and thickets	H1 H11 H12 H13 H21 H23	1 2 1 2 1 0	H3 H11 H12 H13 H21 H22 H23 H31	1 2 1 2 1 1 0 0
technical infrastructure	I	0		
arable	N	0		

	habitats and linear habitats		linear habitats	
habitat type	code of special type	habitat value	code of special type	habitat value
woodland and forests	W1 W2 W3 W8 W11 W30 W31 W93 W94 W95	1 1 0 0 0 0 0 1 0 1		
spontaneous vegetation	Z10 Z23 Z25 Z32	1 1 1 1		

0 = no habitat value - no connectivity potential
1 = low habitat value - connectivity function
2 = self-sustaining habitats - very high habitat value

Connectivity value between two habitat types

connectivity types of habitat values	distance from habitat A to B (m)					
	0-10	>10-25	>25-50	>50-100	>100-200	>200
2 - 2	5	4	3	2	1	0
2 - 1 1 - 2	4	3	2	1	0	0
1 - 1	3	2	1	0	0	0

0 = no connectivity
1 = very low connectivity value
2 = low connectivity value
3 = medium connectivity value
4 = high connectivity value
5 = very high connectivity value

BEUTLER 1987

To compare the changes after land consolidation map 6 was computed. The result of this comparison is depicted in Table 6, where the number of segments and their length before and after land consolidation are documented. Of the higher connectivity value classes (3–5), 329 segments and 4,2 % of the length of the habitat network have disappeared.

Another example for quantification of habitat network effects is the intersection of habitat networks by highway constructions. This

Table 6 : Habitat network fence lizard (Lacerta agilis) - land consolidation Oberhaselbach

connectivity value class	actual state		network segments after land consolidation		difference before / after			
	number	length (km)	number	length (km)	number	%	length (km)	%
0 no connectivity value	929	172,8	1172	203,5	+243	+7,7	+30,7	+9,6
1	694	80,0	341	42,1	-353	-11,2	-37,9	-11,9
2	690	46,2	284	18,1	-406	-12,9	-28,1	-8,8
3	443	15,4	150	5,0	-293	-9,3	-10,4	-3,3
4	263	4,3	121	2,0	-142	-4,5	-2,3	-0,7
5	133	0,9	58	0,3	-75	-2,4	-0,6	-0,2
	3152	319,6	2126	271,0	-1026	-32,6	-48,6	-15,2

could be achieved rather easily by introducing the new highway line in digitized form into the existing GIS data base. Using a buffer–overlay procedure, the cutting in pieces of the existing habitat network can be radily demonstrated, and the remaining network segments be displayed as a thematical map; their number can be computed and listed. Using this technology, ecological resp. environmental impact assessments are being both facilitated and speeded up even for complex ecological situations.

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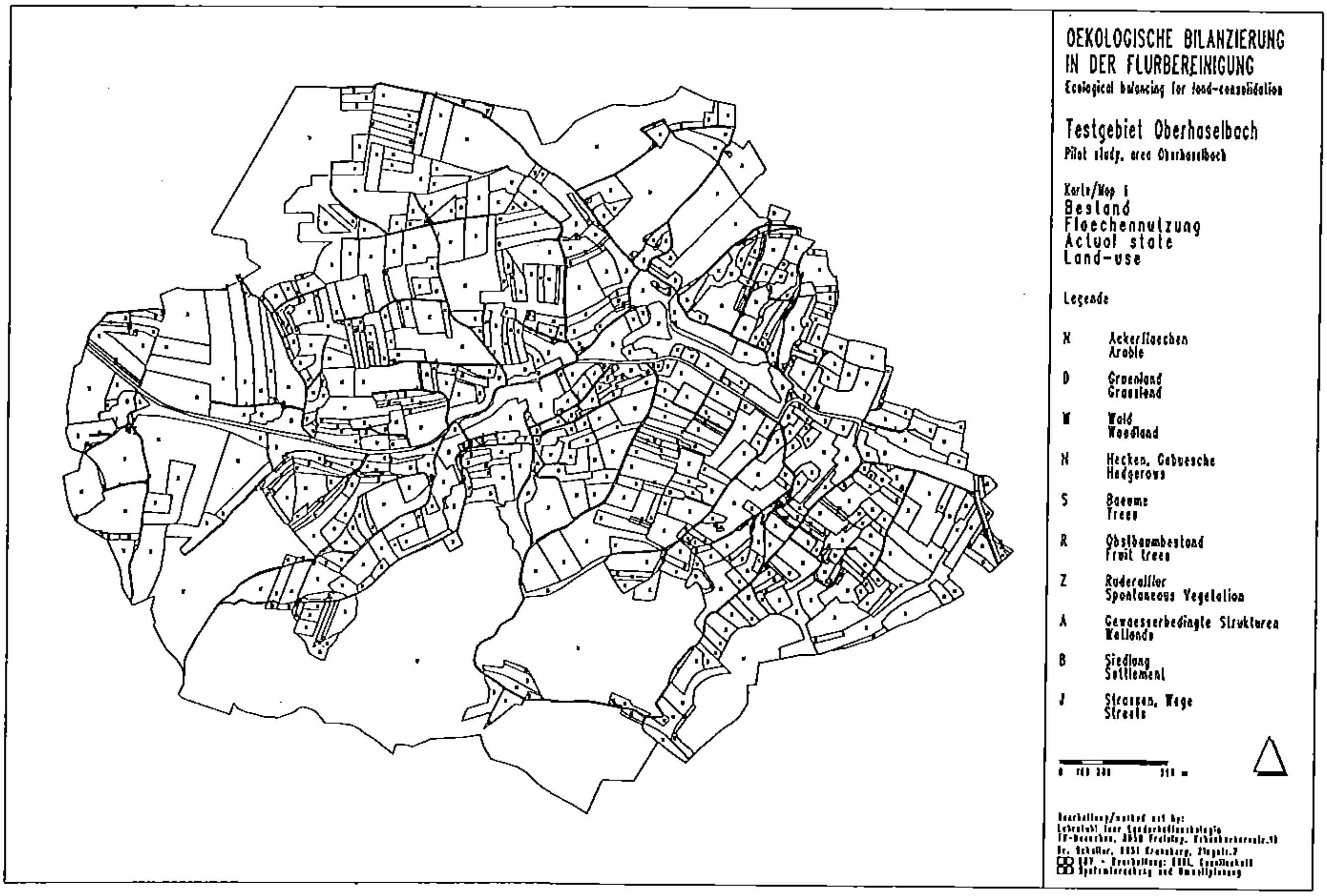
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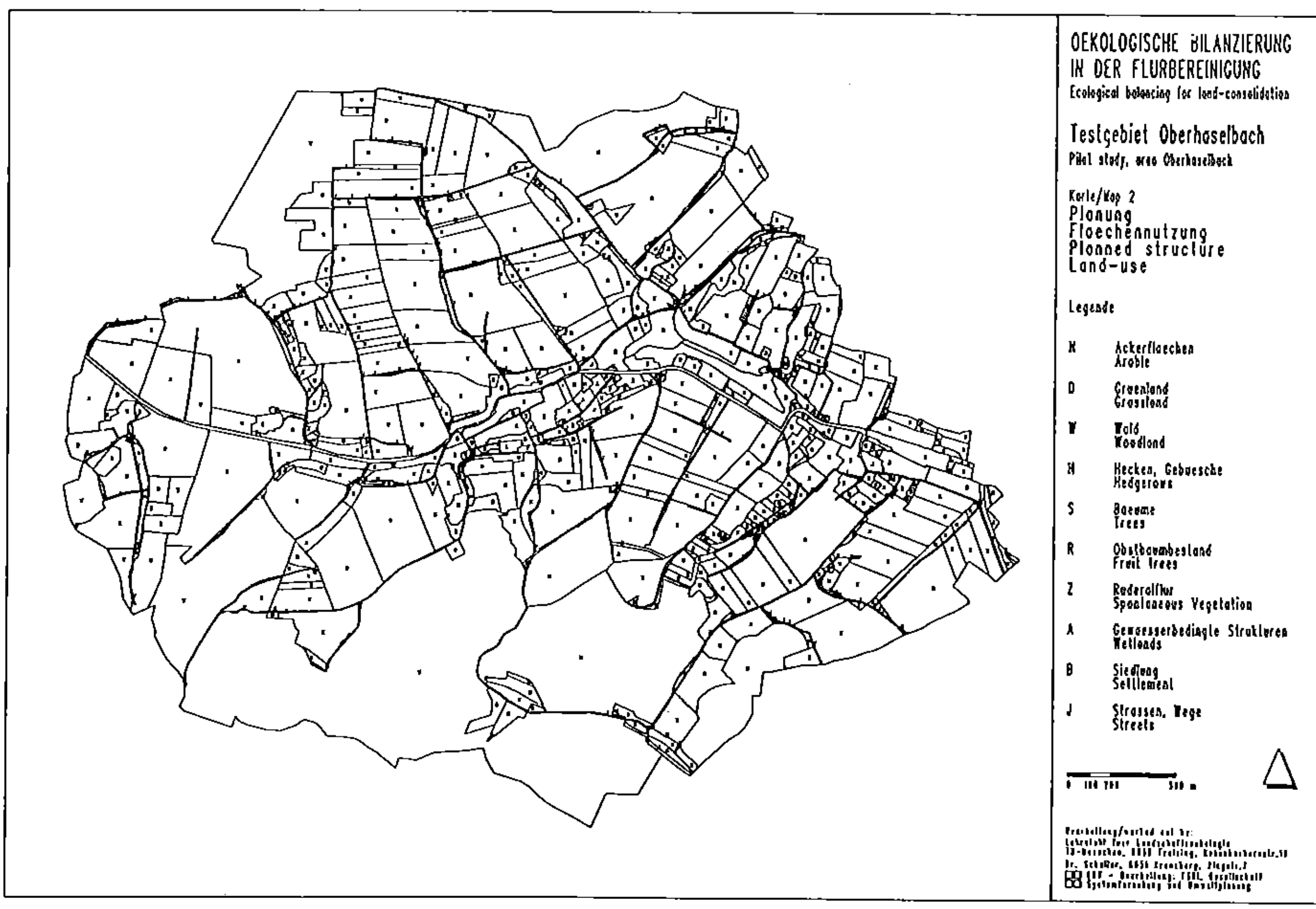
IN DER FLURBEREINIGUNG
Ecological balancing for land-consolidation
Testgebiet Oberhaselbach
Pilot study, area Oberhaselbach
Karte/Map 1
Bestand
Flaechennutzung
Actual state
Land-use
Legende
X Ackerflaechen Arable
D Gruenland Grassland
W Wald Woodland
H Hecken, Gebuesche Hedgerows
S Baeume Trees
R Obstbaumbestand Fruit trees
Z Ruderalflur Spontaneous Vegetation
A Gewaesserbedingte Strukturen Wetlands
B Siedlung Settlement
J Strassen, Wege Streets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Karte/Map 2
Planung
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Planned structure
Land-use
Legende
X Ackerflaechen Arable
D Gruenland Grassland
W Wald Woodland
H Hecken, Gebuesche Hedgerows
S Baeume Trees
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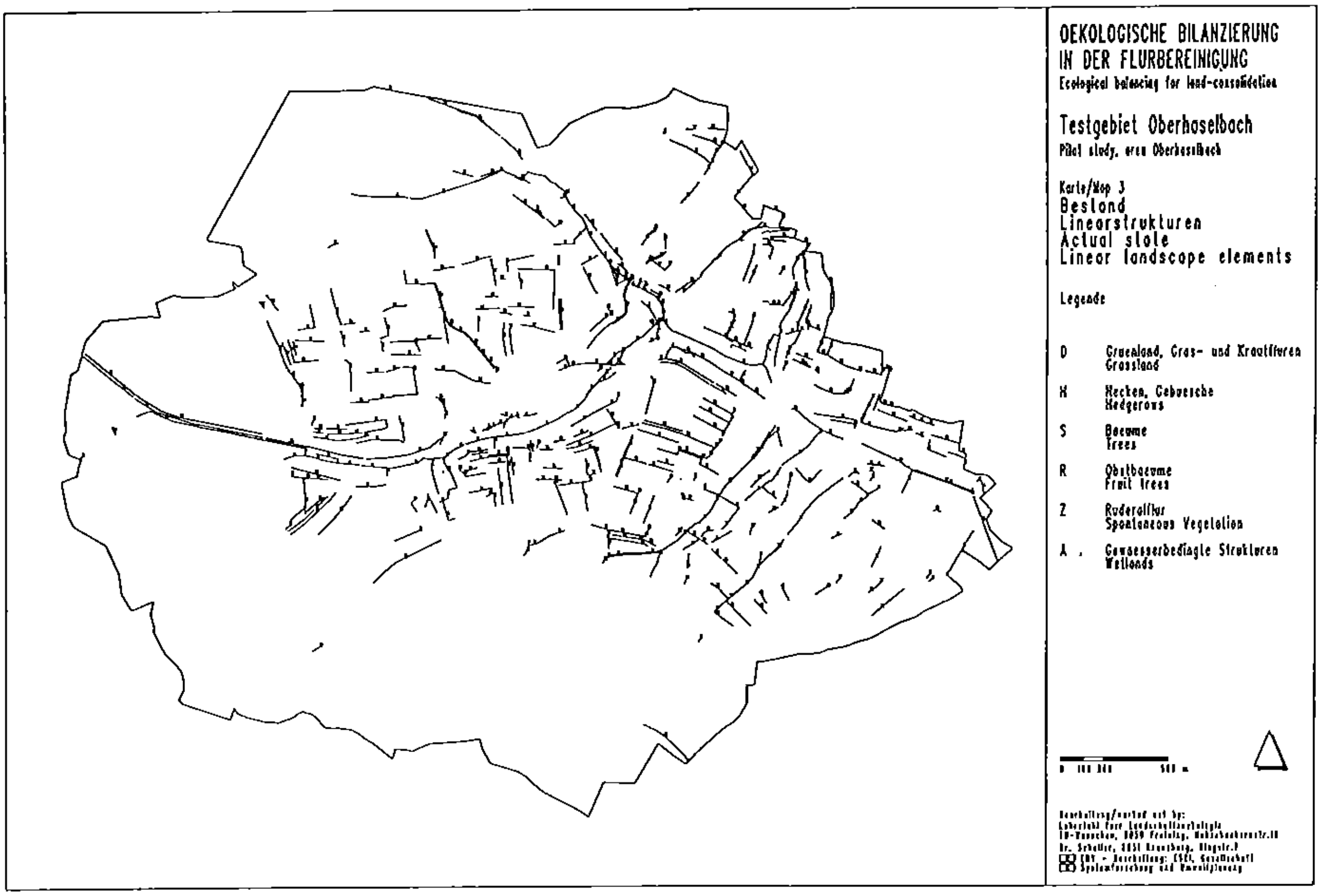
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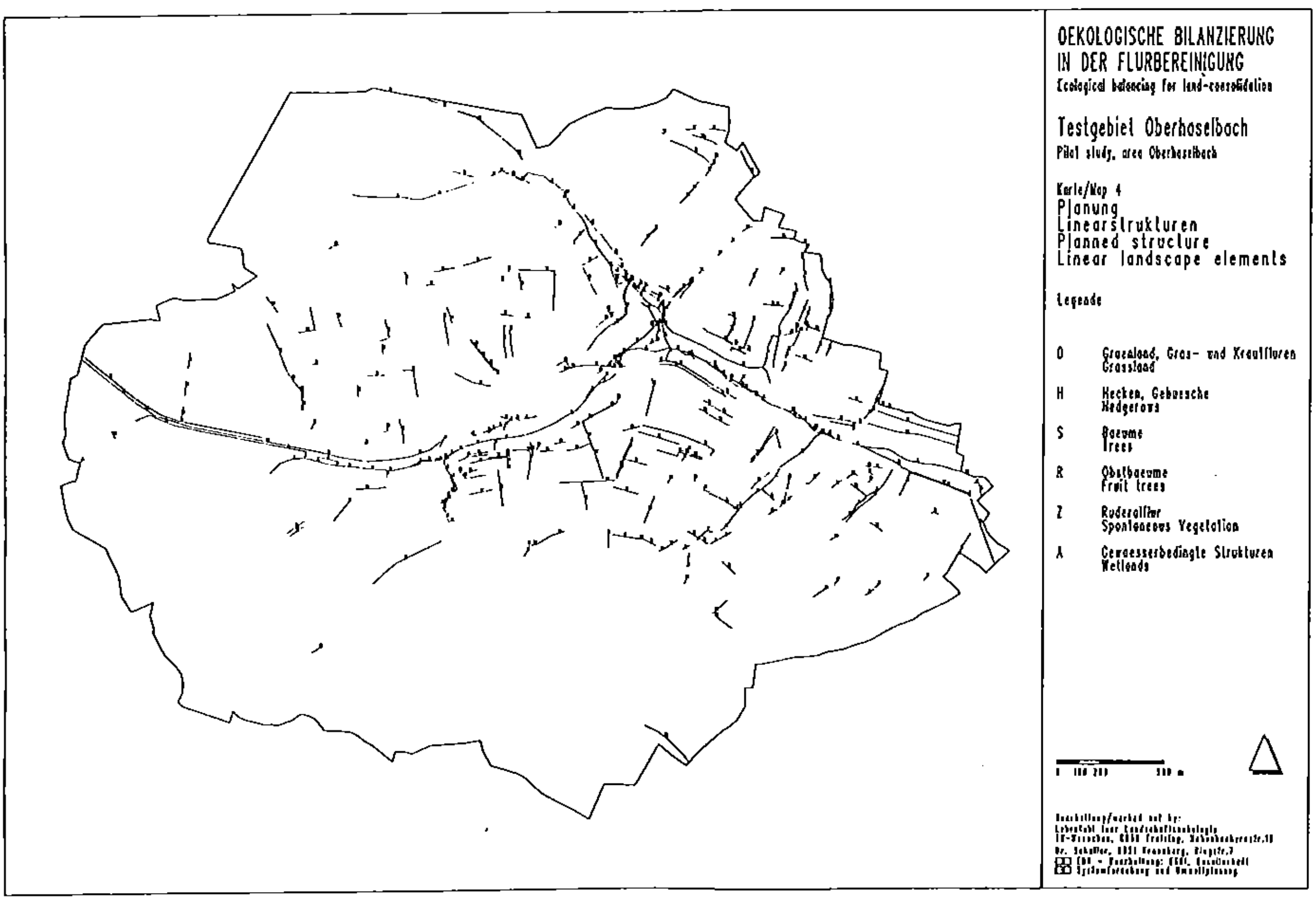
Karte/Map 3
Bestand
Linearstrukturen
Actual state
Linear landscape elements
Legende
D Gruenland, Gras- und Krautfluren
Grassland
H Hecken, Gebuesche
Hedgerows
S Baeume
Trees
R Obstbaeume
Fruit trees
Z Ruderalflur
Spontaneous Vegetation
A Gewaesserbedingte Strukturen
Wetlands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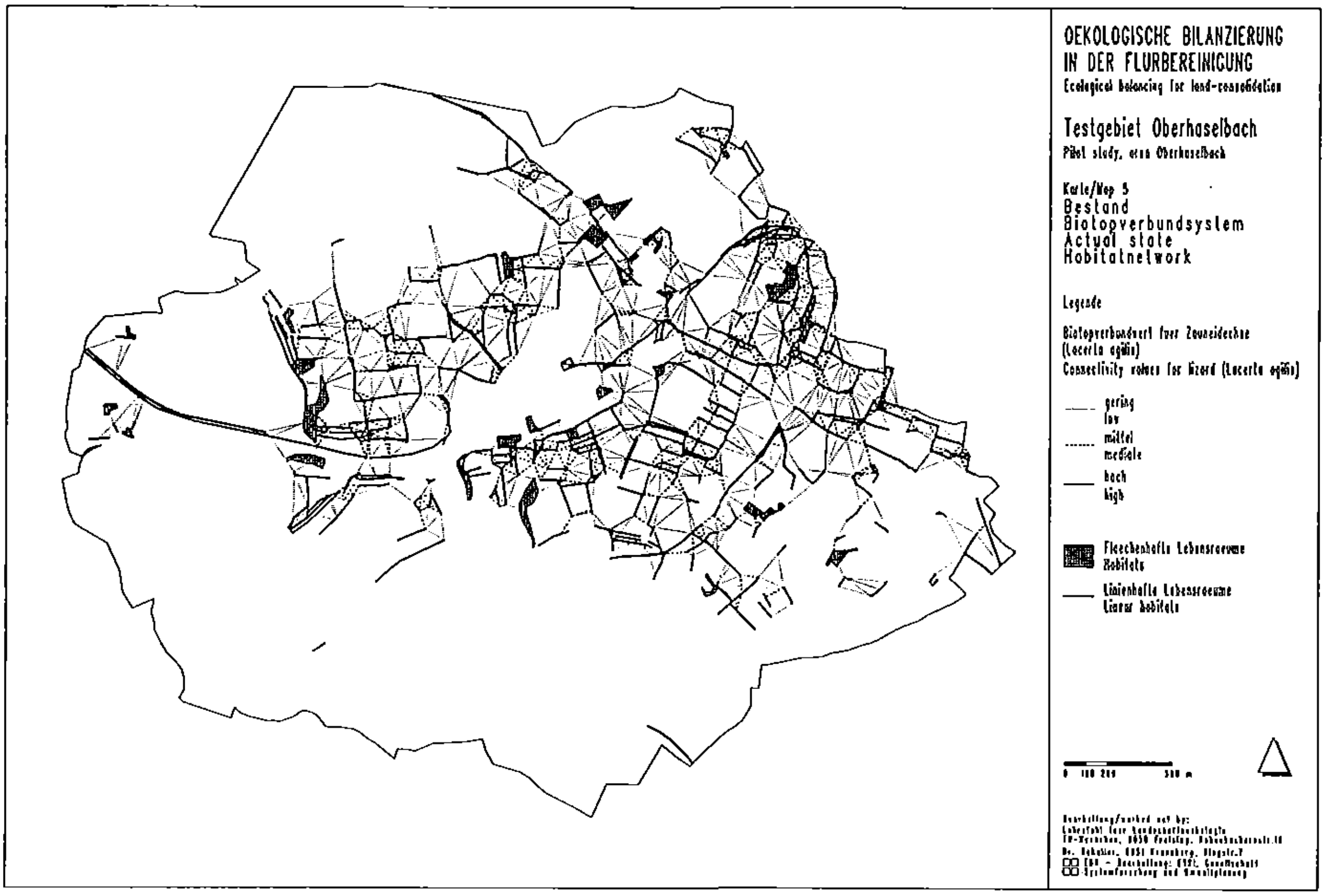
Karte/Map 4
Planung
Linearstrukturen
Planned structure
Linear landscape elements
Legende
D Gruenland, Gras- und Krautfluren
Grassland
H Hecken, Gebuesche
Hedgerows
S Baeume
Trees
R Obstbaeume
Fruit trees
Z Ruderalflur
Spontaneous Vegetation
A Gewaesserbedingte Strukturen
Wetlands


OEKOLOGISCHE BILANZIERUNG
IN DER FLURBEREINIGUNG
Ecological balancing for land-consolidation
Testgebiet Oberhaselbach
Pilot study, area Oberhaselbach
Karte/Map 5
Bestand
Biotopverbundsystem
Actual state
Habitatnetwork
Legende
Biotopverbundwert fuer Zauneidechse
(Lacerta agilis)
Connectivity values for lizard (Lacerta agilis)
gering
low
mittel
mediate
hoch
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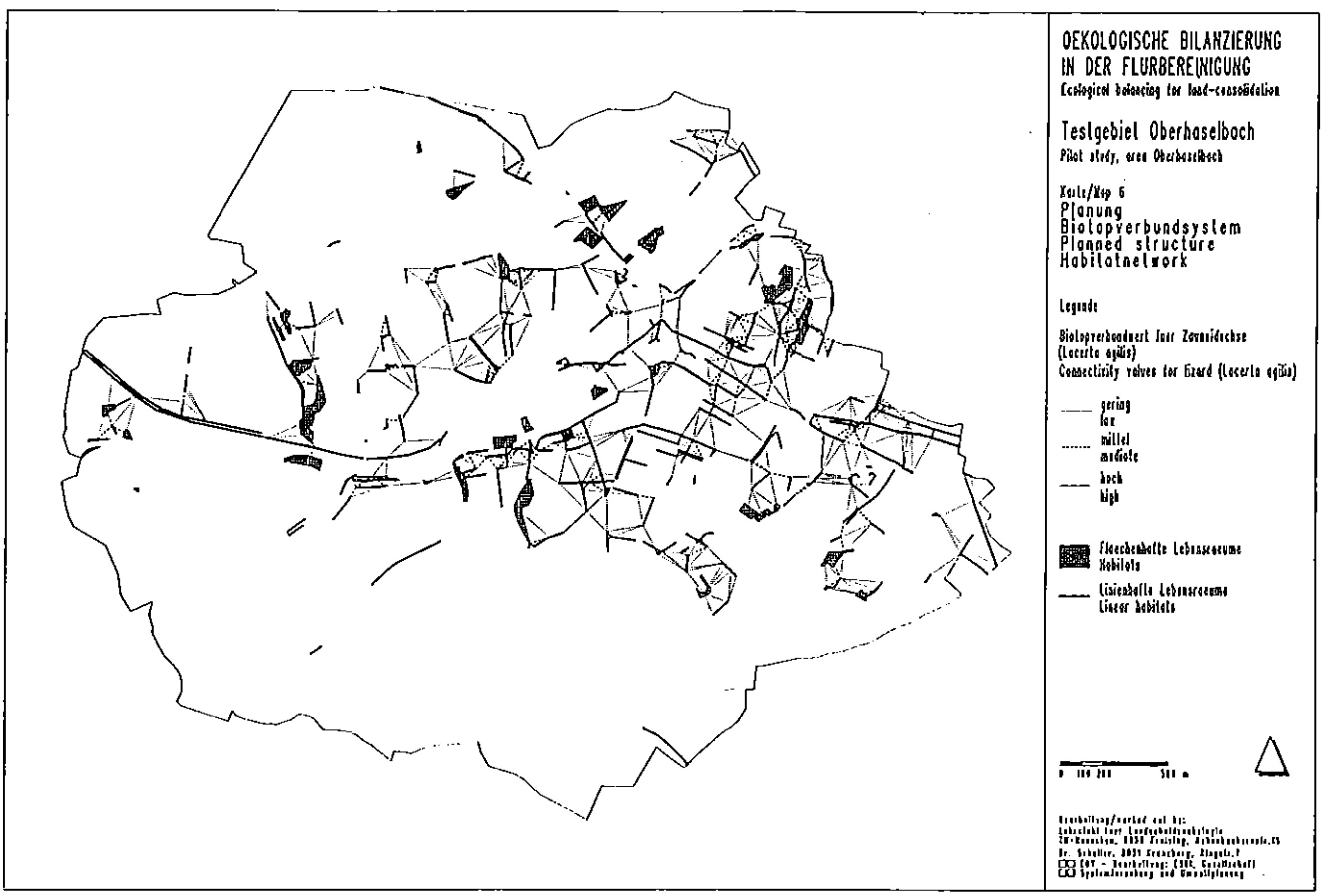
Flaechenhafte Lebensraeume
Habitats
Linienhafte Lebensraeume
Linear habitats


OEKOLOGISCHE BILANZIERUNG
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PLANNING CONCEPTS AND MANAGEMENT STRATEGIES FOR NATURE CONSERVATION IN AGRICU LTURAL REGIONS OF SOUTH WEST GERMANY

D. Bruns

1. INTRODUCTION

Nature conservation in European agricultural landscapes must walk a fine line between European Economic Community politics and scientific know ledge. The landscape planner finds himself in this situation, sandwiched between economic forces motivating the farmer, and implications of the data provided by ecological researchers.

The preservation of wild species of plants and animals in suitable and characteristic habitats is, in West Germany, as in many other countries, required by law. In virgin landscapes, this is accomplished by setting aside specific conservation areas. In an agricultural or urban landscape, the scale on which nature preserves can be declared is insufficient to provide for requirements of many species. Many species are mobile and need wide ranges. Many species are adapted to the dynamic landscape and cannot survive without the human activity in the agrarian habitat.

Conservation strategies in agrarian landscapes must therefore follow two goals;

1) protecting areas for species which exist independently of agrarian perturbation;
2) influencing the manner of agricultural land use to permit survival of perturbation dependent species.

The individual states of the FRG differ somewhat in the way in which they encourage farmers to incorporate conservation into the management of their land. Some programmes which have proved to be useful are listed in table 1.

Tab. 1: CURRENT CONSERVATION PROGRAMMES IN WEST GERMANY

PROGRAMME	EXPLANATION
MARGINAL STRIPS	PROMOTION OF FERTILIZER AND BIOCIDE FREE STRIPS OF AGRICULTURAL LAND, E.G. AT THE EDGE OF FIELDS
CREEK SPONSORSHIP	PROMOTION OF ACTIVIST GROUPS WHO INSTIGATE RESTAURATION OF SMALL STREAMS
WETLANDS	PROMOTION OF LOW INTENSITY USE OF WET MEADOWS, MARSHES,ETC.
GRASSLANDS	PROMOTION OF LOW INTENSITY USE OF DRY OR XERIC MEADOWS AND PASTURES; PROMOTION OF NUTRIENT STRIPPING OF SUCH LANDS
SPECIES	PROTECTION OF SPECIAL SPECIES

Source: Ebel & Hentschel 1987 and own research

There is, at the present time, much overlap in these programmes without sufficient integrated planning. Less spectacular species and ordinary habitat types get much less attention than fields of orchids, or animals for which "corridors" can be traced. Promising ideas for nature conservation planning in agricultural landscapes have been developed in recent years in South Western Germany under the concept of "Biotopvernetzung" or biotope-networks. Efforts began at the level of large state farms and small municipalities (BRUNS et.al.1984, KAULE 1983, LFU 1987). In the meantime larger regions have been examined and planning methods have become more refined (HAAREN et.al., 1984, ROWECK et.al 1987). Methods now allow for the integration of the above mentioned programmes into comprehensive conservation and management schemes for agricultural landscapes.

The further development of these ideas are subsequently described, using an ongoing project in the Western Enz County, an area of approximately 10000 hectares at the Northern edge of the Black Forest (Commissioned by the Enz County government in 1987).

Located close to the Rhine Valley, southern slopes of the Enz County are suitable for wine growing, while other hillsides are used for orchards. On rich loess soils of the low land intensive agriculture dominate the landscape. Limestone hilltops are covered by dry grasslands and woodlots. The grasslands and orchards will be used as examples later on.

2. METHOD

2.1 Basic principles

Landscape is described as a heterogeneous area composed of a cluster of interacting ecosystems (FORMAN & GORDON 1986). For planning purposes the land area of distinctive ecosystems needs to be defined spatially as "biotopes" (TROLL 1966), and the interactions between ecosystems need to be interpreted in functional terms. In agricultural landscapes, the boundaries of biotopes are usually marked by land use. The integrated planning concept applied in the Enz County project is based on the assumption that interactions between ecosystems relate to the physical and ecological similarity of these ecosystems. The focus of the data collection and analysis, and of the planning proposals, is therefore on functional relations hips and similarity between ecosystems (BLAB 1986, KAULE 1986, HEYDEMANN 1986, ROWECK et.al. 1987).

The complexity of ecosystems is such that it is impossible to include all interrelationships in the planning process. Many may not even be known. Species specific programmes may have disadvantages for other species, of which we are unaware. On the other hand, the consideration of large landscape complexes emphasizes ecological interdependence and uses appropriate species only as indicators to demonstrate functional relationships.

The "Biotope Network " can be approached on several levels. Counties can be assessed on a large scale of 1 : 50 000. Small scale relationships requiring detailed local inventory are best clarified on a scale of 1 : 5 000; at this level property lines are incorp orated, which is important later for the determination of necessary conservation measures.

2.2. Inventory

Data collection for the spatial inventory of information is done through the interpretation of scientific maps and aerial photography, and through field work. The criteria and indicators applied in our case study are shown in chart 1. The same criteria are used in the data collection, data analysis, as well as in the proposal phase of the project. Type and acidity of parent rock, nutrient availability and soil moisture, as well as altitude are used as indicator-conditions to describe the physical environment of the study area on a large scale. On a small scale, elements of biotopes may be identified which allow their structural comparism.

Tab. 2 : Functional relationships between ecosystems in agricultural landscapes

Chart 1 : Inventory of indicator–conditions

CRITERIA	INDICATOR-CONDITIONS 1 : 50 000	INDICATOR-CONDITIONS 1 : 5 000
SIMILARITY OF THE PHYSICAL ENVIRONMENT	TYPE OF PARENT ROCK; ACIDITY	NUTRIENT AVAILABILITY } distribution of indicator species
	NUTRIENT AVAILABILITY	SOIL MOISTURE } distribution of indicator species
	SOIL MOISTURE	
	ALTITUDE (CLIMATE CHANGE)	DISTRIBUTION OF LANDSCAPE ELEMENTS
INTENSITY OF HUMAN INFLUENCE	DISTRIBUTION OF AREAS WITH LITTLE OR NO HUMAN INFLUENCE (PHYSICAL ENVIRONMENT DOMINANT)	DISTRIBUTION OF SPECIES INDICATING INTENSITY OF HUMAN INFLUENCE
		TYPE AND INTENSITY OF PRESENT LAND USE
		TYPE OF HISTORIC LAND USE (CA. 1836)
SIMILARITY OF COMMUNITIES		COMPARATIVE QUALITATIVE AND QUANTITATIVE ECOLOGICAL ANALYSIS OF ANIMAL AND PLANT COMMUNITIES ON REPRESENTATIVE AREAS
MOVEMENT AND DISTRIBUTION PATTERNS OF SPECIES	MOVEMENT AND DISTRIBUTION OF BIRDS AND AMPHIBIANS WITH WIDE RANGES IN RELATION TO LANDSCAPE STRUCTURE	MOVEMENT AND DISTRIBUTION OF BUTTERFLIES AND GROUND BEETLES WITH SMALL RANGES IN RELATION TO BIOTOPE STRUCTURE (SAMPLE AREAS IN TRANSECTS)

Chart 2 : Analysis of data base

CRITERIA	ANALYSIS 1 : 50 000	ANALYSIS 1 : 5 000
SIMILARITY OF THE PHYSICAL ENVIRONMENT	DEFINING LANDSCAPE UNITS AS STATISTICAL REFERENCE AREAS WITH CHARACTERISTIC DISTRIBUTIONS OF BIOTOPES	DEFINING LANDSCAPE UNITS OF PHYSICAL AND BIOLOGICAL SIMILARITY AS BIOTOPES WITH CHARACTERISTIC DISTRIBUTIONS OF ELEMENTS AND COMMUNITIES
INTENSITY OF HUMAN INFLUENCE	GRADIENTS OF HUMAN INFLUENCE WITHIN LANDSCAPE UNITS	SPATIAL DISTRIBUTION OF GRADIENTS OF HUMAN INFLUENCE IN BIOTOPES
SIMILARITY OF COMMUNITIES		SPATIAL DISTRIBUTION OF ANIMAL AND PLANT COMMUNITIES
MOVEMENT AND DISTRIBUTION PATTERNS OF SPECIES	SPATIAL DISTRIBUTION OF SPECIES REPRESENTING LONG RANGE RELATIONSHIPS	SPATIAL DISTRIBUTION OF SPECIES REPRESENTING SHORT RANGE RELATIONSHIPS
OVERLAY	DEGREES OF ECOLOGICAL SIMILARITY OF LARGER LANDSCAPE UNITS AND THE FUNCTIONAL RELATIONSHIPS BETWEEN THEM	DEGREES OF ECOLOGICAL SIMILARITY OF BIOTOPES AND THE FUNCTIONAL RELATIONSHIPS BETWEEN THEM

Chart 3 : Proposals for conservation and managment

CRITERIA	PROPOSALS 1 : 50 000	PROPOSALS 1 : 5 000
SIMILARITY OF THE PHYSICAL ENVIRONMENT	PROTECTION OF REPRESENTATIVE EXAMPLES OF BIOTOPES	PROTECTION OF REPRESENTATIVE EXAMPLES OF COMMUNITIES AND BIOTOPES
INTENSITY OF HUMAN INFLUENCE	PROTECTION OF AREAS WITH LITTLE OR NO HUMAN INFLUENCE	RESTORATION OF BIOTOPES ACCORDING TO HISTORICALLY "PROVEN" SUITABILITY
SIMILARITY OF COMMUNITIES		INTEGRATED MANAGEMENT SCHEMES CONSIDERING SPATIAL DISTRIBUTION OF COMMUNITIES
MOVEMENT AND DISTRIBUTION PATTERNS OF SPECIES	PROTECTION OF AREAS WHICH ARE ESSENTIAL IN SUPPORTING LONG RANGE RELATIONSHIPS	INTEGRATED MANAGEMENT SCHEMES CONSIDERING SMALL RANGE RELATIONSHIPS
ENDANGERED SPECIES OR COMMUNITY-TYPES	PROTECTION OF AREAS SUPPORTING ENDANGERED SPECIES OR COMMUNITY TYPES	INTEGRATED MANAGEMENT SCHEMES CONSIDERING ENDANGERED SPECIES OR COMMUNITY TYPES

For example, a land area used as orchards would be identified as one biotope, and the area of adjacent fields would be another. The orchard consists of a number of elements, such as fruit trees, grass, dirt roads, and wood fences. The adjacent fields consist of tilled land and some grassy strips, the grassy strips beeing the only element in common. Orchards and fields are structurally different. However, they may well be based on the same parent rock, have similar soil moisture and climate. What distinguishes them most is the intensity of human influence.

The degree to which the role of the naturally occurring physical environment in forming ècosystems is suppressed by human influence can be measured and mapped by recording indicator species.

Throughout the orchard biotope it is possible to find many plants, for example, which clearly indicate low moisture and low nutrient availability of the soil. The field biotope is void of such plants, except for few species indicating medium acidity. Also in the data collection, representative transects of Enz County are studied in great detail for their species contingent.

Movement and distribution patterns of selected indicator species are noted in relation to pertinent landscape structure. The results of the transects of the Western Enz County are applicable to the entire county as the transect samples all important landscape elements in characteristic combinations, and these combinations are noted during the actual inventory throughout the region. Subsequently random samples are taken to test this extrapolation.

2.3. Analysis of data base

The analysis of the data base is structured in chart 2. Statistical calculations permit definition of similar combinations of elements as biotopes, and clusters of similar conbinations of biotopes as eco-regions or "landscape units" (Figure Landscape units may serve as statistical reference areas, for which average distributions of biotopes are calculated. Within these reference areas, above average, or below average distributions can be shown, as well as typical and a-typical spectrums of biotopes within a region. Similar statistical calculation can be done using the distribution of landscape elements, indicator species, or physical qualities. In an overlay of some or all of the analysis results, it is possible to show gradients of ecological similarity between biotopes, as well as functional relationships between them. Maps are prepared which show the spatial distribution of soil moisture, nutrient availabilty, and other natural factors, contrasting with maps showing the intensity of human influence (Figure 2). From this overlay conclusions may be drawn regarding the sensitivity of biotopes against certain types of land use.

Additionally, the analysis of 150 years old maps shows a landscape picture whose biotope types were more location dependent than today. Large scale, intensive agricultural methods did not exist. This historic analysis leads pragmatically into a discussion of conservation measures, because the interpretation of historic maps makes obvious to any observer which biotopes prevail under conditions of less intensive management. Their suitability has there fore already been proven.

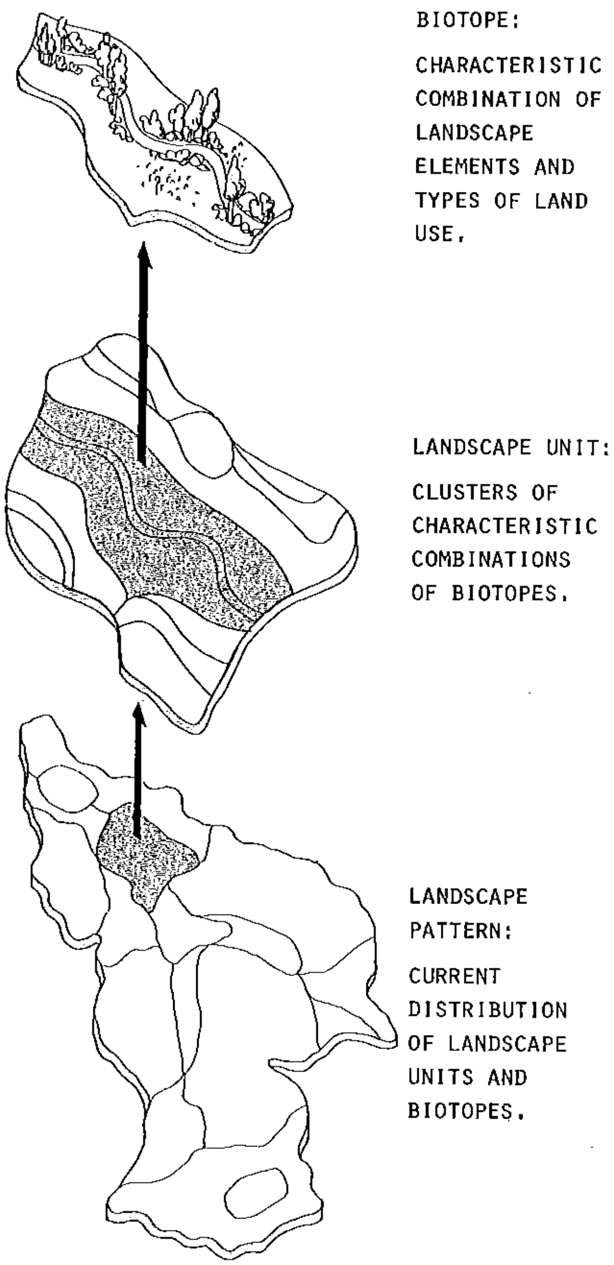

Fig. 1 : Analysis of ecological patterns

3. PROPOSALS FOR CONSERVATION AND MANAGEMENT

3.1. Conservation

Returning to the conservation goals mentioned earlier, the first priority is the protection of species who live independently of agrarian perturbation. The criteria for defining the boundaries of suitable conservation areas are shown in chart 3. Biotopes which are physically and structurally typical of a landscape unit should be protected as representative examples of that region, in order to preserve the typical species spectrums. Areas which support endangerspeciès, or in part support species with long range movement and distribution patters should also be protected.

For example, rivers and their riparian woodland-strips are biotopes which often support endangered species and usually support the long range movement of species. Wet meadows may still exist in the alluvial flood plain. They need to be protected for their number of rare species and as buffer zones for the stream ecosystem. The meadows, however, require specific management if we plan to maintain their present quality.

3.2. Management

Hence, the second goal is influencing the manner of agricultural land use to permit survival of perturbation dependent species. All

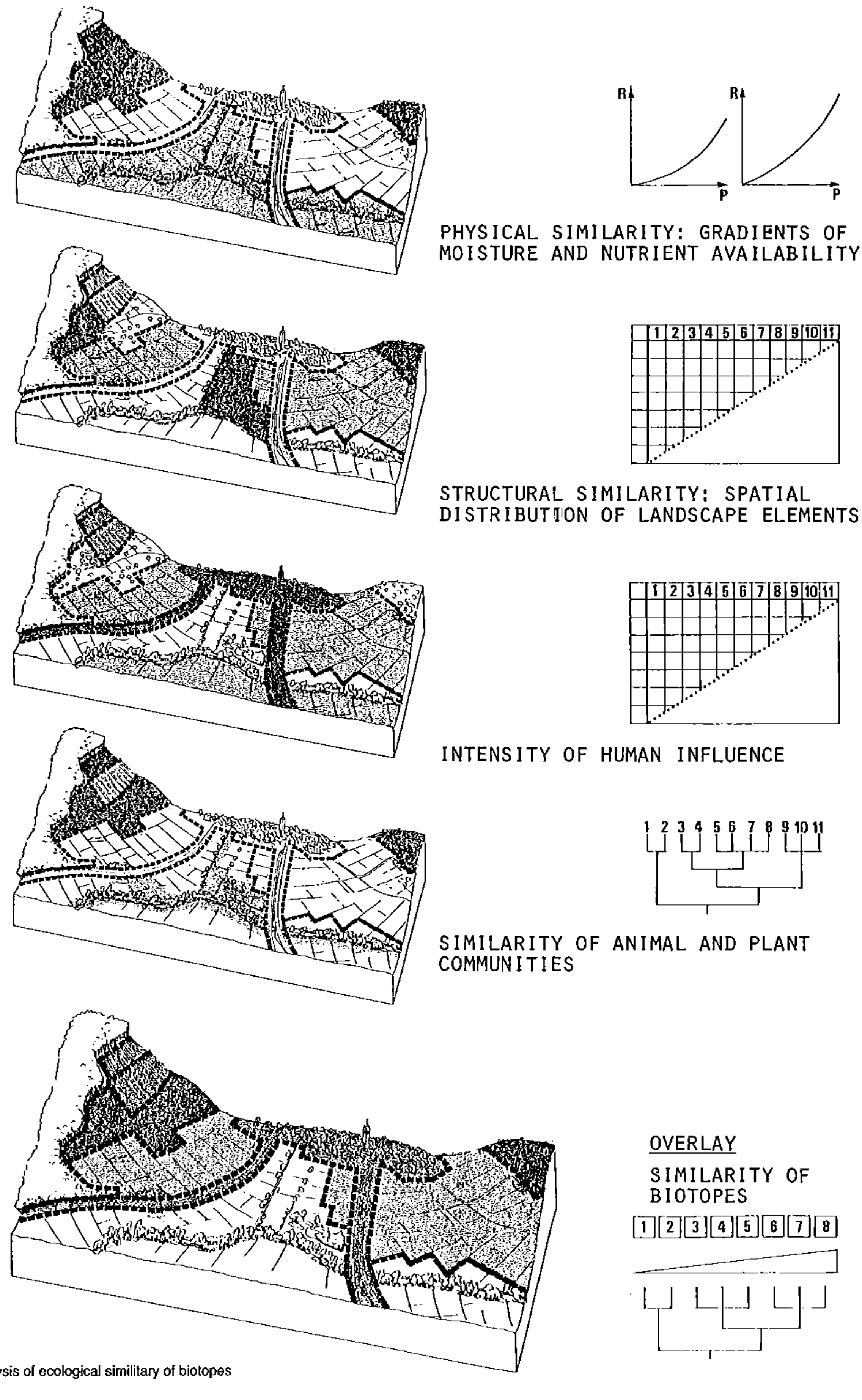

Fig. 2 : Analysis of ecological simillitary of biotopes

land fulfills differing functions as biotopes, so that each area must be analysed separately according to its land use. Proposals stem from a combination of on–site field observations of biotope potential, integrated with theoretical information resulting from the analysis described above. As proposals are made for land areas of the size of biotopes, they provide spatial frames for which specific measures are suggested. The decision of which land management measure to choose is left to the discussion between land owners and a network committee. This committee, in which the planner assumes the role of an advisor, is formed of local politicians and conservationists. It's work commences as soon as the first proposals have been formulated.

Returning to the example of the orchard and grassland biotopes: the orchard has been found essential as breeding habitat for several birds with wide range distribution patters. The orchard contains also grassland which are representative of dry meadow biotopes which typically occur on limestone hilltops of this landscape unit. The grassland can potentially be used for growing grains and many parcels of land have already been converted. The proposal is to maintain the existing orchards and grassland and to restore some of the former meadows, now used as tilled land.

In a first step, the "Network–Committee" approaches the affected landowners and explains the proposals to them. The farmers may suggest that their original plan was to intensify the use of the meadows and that low intensity management would mean a loss. The committee now approaches the state goverment and asks which programmes are available to fund compensation payment for this loss result from conservation management measures. Application procedures for several programms may consequently be initiated, provided the land owners are agreeable.

Our policy of integrating local interest groups and farmers into early design stages ensures that no proposal will appear to be super imposed on the private land owner or the municipality at large. Some research is needed however, to learn about the appropriate degree of public participation (F.LUZ, doctoral diss. in prep.) and education about appropriate land management.

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STUDIES TO DETERMINE THE "POTENTIAL OF BIOTIC REGULATION" AND "IMPAIRMENT OF BIOTIC RESOURCES" IN A REGIONAL PLANNING CONTEXT

ULRICH KIAS

1. Introduction and background

Within the framework of a long–term research project focussing on "Principles and Possibilities of Ecological Planning", a case study is being carried out by the Department of Planning at the Swiss Federal Institute of Technology. This case study in the Rhine Valley of the Grisons attempts to solve methodical and practical problems of ecological planning within a regional planning context.

In Switzerland planning competence is organized in an extremely decentralized way. In most of the 26 cantons there is no landscape planning procedure in an institutionalized sense (a detailed documentation of landscape planning in Switzerland gives SCHUBERT (1982)). So the regional master plans seldom take account of ecological and environmental aspects in a conceptual sense. In most cases you will only find a statement on the status quo of nature reserves and landscape conservation areas. Nothing is said about the quality of biotic resources and the landscape as a whole, and how these should be developed. In consequence the land use plans of local communities seldom deal with ecological or environmental aspects of planning.

On the other hand legal provisions exist, which require better consideration of these aspects within the planning process. But they do not say how this is to be achieved, either from an institutional or from a methodological point of view.

So the main goal of the case study is to develop methodological procedures and helps in this direction, to show what data is required and how this is to be used. At the regional planning level an instrument for documentation and informationis created to permit the analysis and evaluation of environmental quality. With such an instrument, existing environmental impacts can be indicated. In addition it can help, in conjunction with foresighted ecological planning, to allot areas for future land use.

Owing to the complexity of the environmental system, and because impacts on the landscape ecosystem cannot be treated as a whole, a division into subsystems is necessary. Within the case study the following subdivisions, which in general represent human activities and human exploitation of landscape resources, are used:

- Settlement
- Recreation
- Conservation of biotic resources
- Agriculture
- Forestry
- Water management
- Air quality

So much for the background of the following presentation, which will only concern the "conservation of biotic resources" (a more detailed description of the case study is given by TRACHSLER & KIAS (1986); methodological problems of ecological planning are discussed by GFELLER, KIAS & TRACHSLER (1984) and KIAS (1985)).

2. Characterization of the "potential of biotic regulation"

Within the perimeter of the case study about 5% of the area is protected as "landscape conservation zones". Only 0.1% is protected as "nature reserves". Most of the latter comprise relatively small biotopes.

Nature conservation work that is only concentrated on this small part of the overall area of investigation can be compared with a transportation planning agency that only considers those parts of the transport system, which it finds specifically interesting. Based on the assumption that traffic will somehow flow between these parts of the system it ignores the remainder. As you see this is an absurd idea, but it is often reality in the institutional nature conservation.

In the following an overview is given on a methodological approach, which tries to assess the quality of the biotic resources for a whole region, in this case about 130 km².

First of all an inventory is required of the specifically valuable biotopes and parts of the landscape. This resulted for the Grisons Rhine Valley in a list of 139 objects of different size. Each of them is described in detail concerning the type of habitat, the flora and fauna, the land use and the possible impacts by land utilization in the neighbourhood etc. (for more details see JENNY & MUTZNER (1985) and TRACHSLER & KIAS (1986)). The inventory has been entered into the geographic information system for the Rhine valley. It covers about 20% of the area of investigation. Fig. 1 shows a plot of the mapped habitats, differentiated according to their existing and proposed future protection status for a section of the planning region "Rhine valley of the Grisons".

In order to characterize the remaining 80% a land use map has been elaborated, which is shown in fig 2.

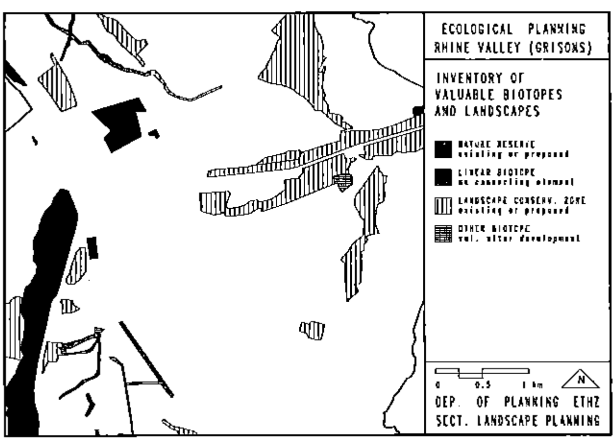

Fig. 1: Inventory of valuable biotopes and landscapes

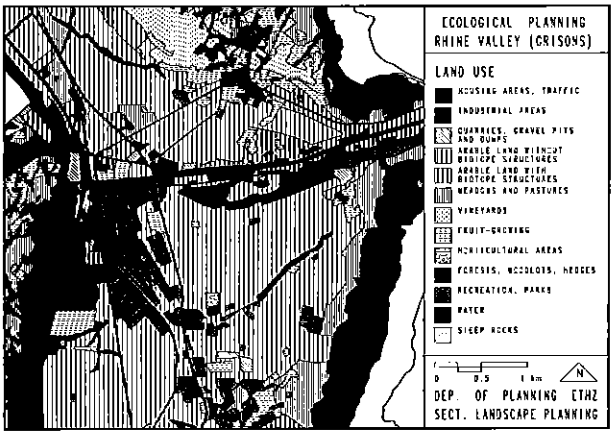

Fig. 2:Land use map (several landuse patterns are shaded the same on this b/w plot; the original map comprises 43 different categories)

To assess this map concerning the "potential of biotic regulation" the concept of hemerobic levels is used, concretely the 7 level scale proposed by BLUME & SUKOPP (Table 1).

Table 1: Degree of human influence on ecosystems according to the concept of hemerobic levels (BLUME & SUKOPP 1976)

ahemerob oligohemerob	natural or nearly natural ecosystems
mesohemerob b-euhemerob a-euhemerob	cultural ecosystems
polyhemerob metahemerob	completely deformed ecosystems

Each land use pattern is classified according to its average hemerobic level. Table 2 shows a selection of land use patterns and their classification.

In a next step the hemerobic levels need to be assessed concerning their influence on the "potential of biotic regulation". According to HAASE (1978) this term means the ability of a spatial entity to maintain and direct or to restore the productivity and efficiency of a natural system. It includes the biotic diversity and complexity as well as the stability of the ecosystem. In order to achieve that the genetic material needed for further development of organic life has to be made available in natural and specifically protected areas. Table 3 shows how this assessment has been done within the described case study.

It is assumed for assessment that the hemerobic level can be used as a primary indicator to characterize the importance of an area concerning the "potential of biotic regulation". Although this may be postulated in general it is not true in every case. In order to regard the specific significance of some landuse patterns a correcting step is necessary.

One example:
Meadows with scattered fruit trees are characterized as b–euhemerob, which would signify a "moderate importance" in the general assessment scheme. Because of their great importance for bird–life this assessment must be corrected to "high importance".

After this is done the next step is to combine the information from the biotope inventory with that of the land use mapping. The result is a map called "Importance concerning the potential of biotic regulation", as it is shown in fig. 3.

Table 2: Characterization of landuse patterns rated according to their typical hemerobic levels

Housing areas:	
Housing (high density)	metahemerob
Housing (medium density)	polyhemerob
Housing (low density)	a-euhemerob
Isolated buildings (incl. courtyards)	a-euhemerob
Industrial areas:	
Industry (high density)	metahemerob
Industry (medium density)	metahemerob
Industry (low density)	polyhemerob
Industrial storage sites	polyhemerob
Supply and disposal areas	polyhemerob
Farmland, fruit-growing, horticulture etc.:	
Arable land without biotope structures	a-euhemerob
Arable land with biotope structures	b-euhem./a-euhem.
Intensivly cultivated meadows	b-euhemerob
Extensive grassland (pastures)	mesohemerob
Viticultural areas (vineyards)	a-euhemerob
Intensive commercial fruitgrowing	a-euhemerob
Orchards	b-euhemerob
Scattered fruit trees	b-euhemerob
Horticultural areas	a-euhemerob
Hothouses	polyhemerob
Forest / Woodland:	
Dense forest	mesohem./b-euhem.
Open forest	mesohemerob
Woodlots and hedges	mesohemerob
Bushes	oligohemerob
Recreational areas:	
Public gardens and parks	b-euhemerob
Camping sites	polyhemerob
Sports grounds	a-euhemerob
Transportation:	
Highways	metahemerob
Main roads	metahemerob
Railways	polyhemerob

Table 3: Assessment of hemerobic levels according to their significance for the "potential of biotic regulation"

Hemerobic level	Assessment (value)
ahemerob	indispensible (6)
oligohemerob	very high importance (5)
mesohemerob	high importance (4)
b-euhemerob	moderate importance (3)
a-euhemerob	slight importance (2)
polyhemerob	no importance (1)
metahemerob	no importance (1)

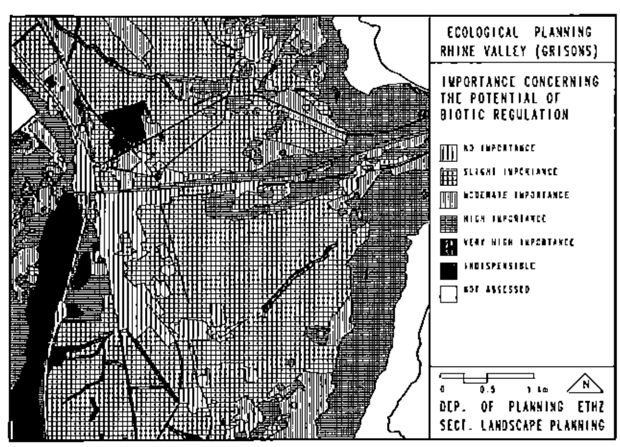

Fig. 3: Importance of spatial entities concerning the "potential of biotic regulation"

Because the data are stored in a computer they can easily be analyzed and balanced concerning different spatial entities. It has been done for the17 local communities within the planning region, each differentiated into the intensively cultivated valley and the more extensively cultivated hillsides.

This allows comparison of the local communities concerning their "biotic quality", as documented in fig. 4. This spatial analysis is completed by an automated procedure to analyze the land use map concerning the length of edges along which a high species diversity may be expected. These are, for example, edges of forests or woodlots and hedgerows. Fig. 5 shows the distribution of these linear structures for a section of the planning region while the diagrams in fig. 6 document the perimeter lengths for all 17 local communities.

It may be objected to this procedure on the grounds that it is not very sophisticated in the sense of ecosystem research. On the other hand its very simplicity and transparency is an advantage, because one goal of the case study is to use research work as a catalyst to initiate a regional planning process that implements aspects of ecological planning. Therefore it is carried out in close cooperation with the regional planning authority. As a consequence of the decentralized planning system in Switzerland already mentioned these people are not planning professionals but do this work on an honorary basis. To have a chance of acceptance and realization the methodical approach had to be very simple and transparent so as to be understandable to non-biologists and non-planners as well.

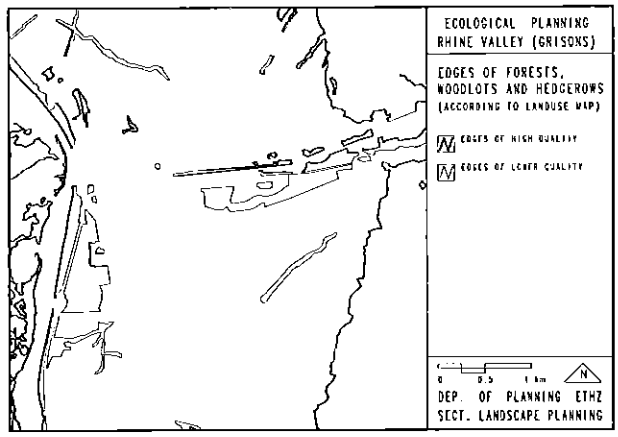

Fig. 5: Edges of forests, woodlots and hedgerows

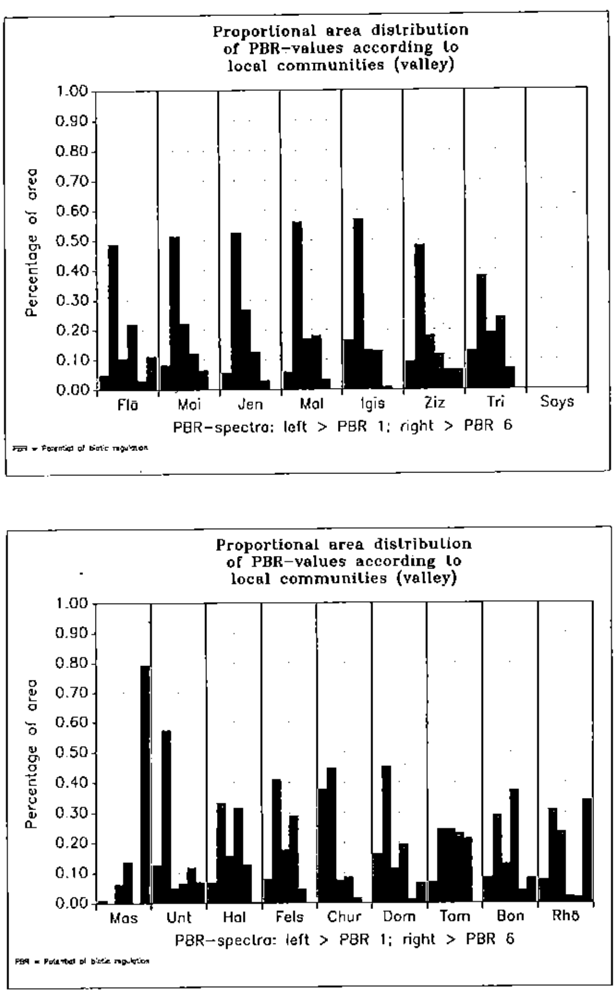

Fig. 4: Proportional area distribution of PBR-values according to the valley-sections of the 17 local commųnities of the planning region "Rhine valley ofthe Grisons"

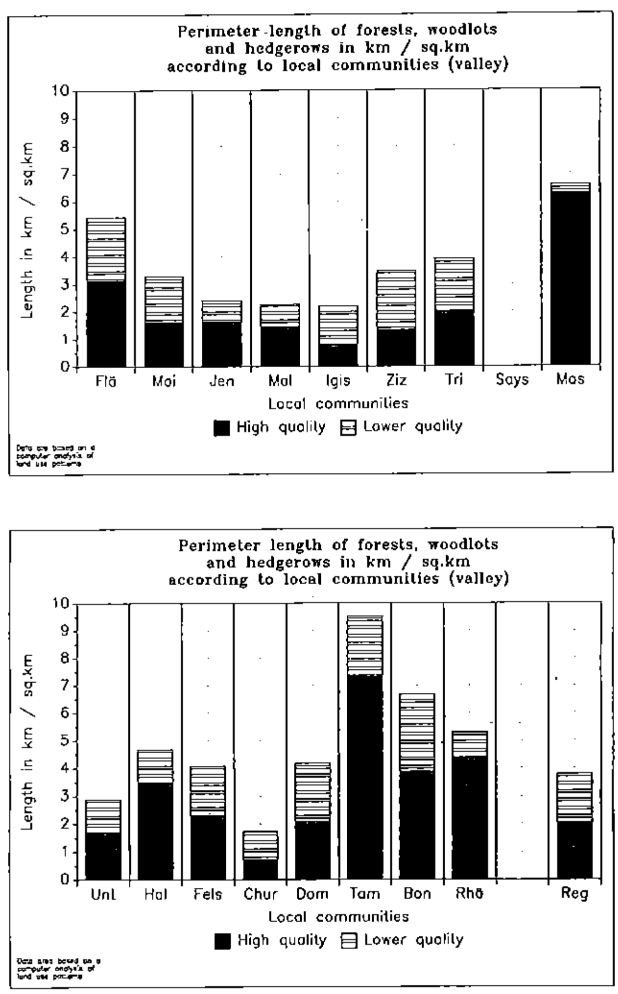

Fig. 6: Perimeter length of forests, woodlots and hedgerows in km /kmū according to the valley-sections of the 17 local communities of the planning region "Rhine valley of the Grisons"

3. Impairment of biotic resources

Following a few examples of data analysis concerning the risk of impairment of biotic resources by other land uses will be shown. The first is the loss of biotic resources due to future building activities. To analyze this problem the map of "potential of biotic regulation" has been overlaid with the zoning plan. The result is shown in fig. 7. This makes it possible to balance the loss of biotic resources in the individual quality categories for each local community.

A second analysis concerns the possible impairment of biotic resources in the neighbourhood of roads. Therefore the roads of the region have been classified according to their traffic frequency and buffer–zones have been constructed around them. An overlay of these buffers on the map of "potential of biotic regulation" gives an overview of the quality of biotic resources within the influence zone of roads (fig. 8).

A third analysis gives an overview of biotic resources within noise corridors. Concretely this is a refinement of the analysis previously described concerning one specific aspect. It is based on a noise dispersion model specifically developed for application on a regional scale. It produces noise information for the whole area of investigation on the basis of a selectable grid system, in this case a grid of 50 by 50 m. To simulate the noise dispersion a digital terrain model is used as well as land use data for the individual grid cells.

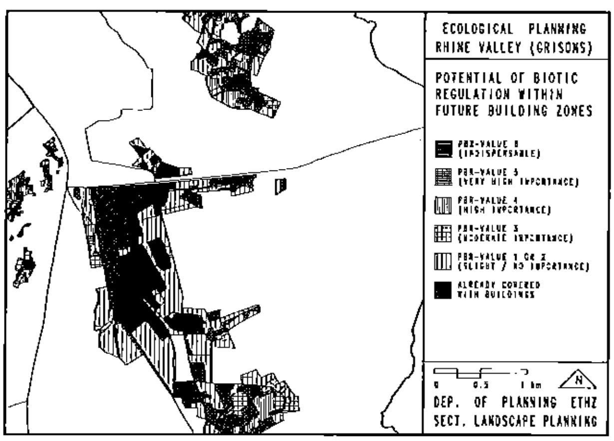

Fig. 7: Loss of biotic resources due to future building activities

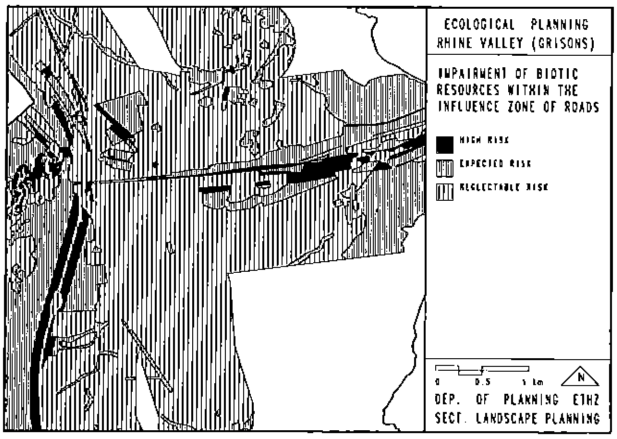

Fig. 8: Impairment of biotic resources within the influence zone of roads

For the overlay of the noise map and the map of "potential of biotic regulation", only those areas of the latter were taken into consideration that are classified as "high importance" or better. The result of the analysis is shown in fig. 9. Some further analyses have been carried out that cannot be discussed within this paper due to lack of space. But nevertheless I hope I have been succesful in showing how modern computer technology can be applied to the preparation of biotope–relevant data for use in spatial planning. As already mentioned at the outset, the goal is intensified consideration of this information within the spatial planning process.

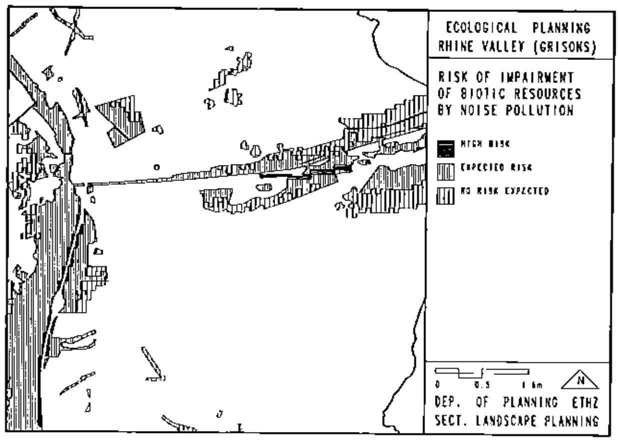

Fig. 9: Risk of impairment of biotic resources by noise pollution

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Münstersche Geographische Arbeiten 29, 1988, Münster

LANDSCAPE ECOLOGY IN THE FIELD OF CONFLICT BETWEEN NATURE CONSERVATION AND FUTURE INDUSTRIAL SETTLEMENTS

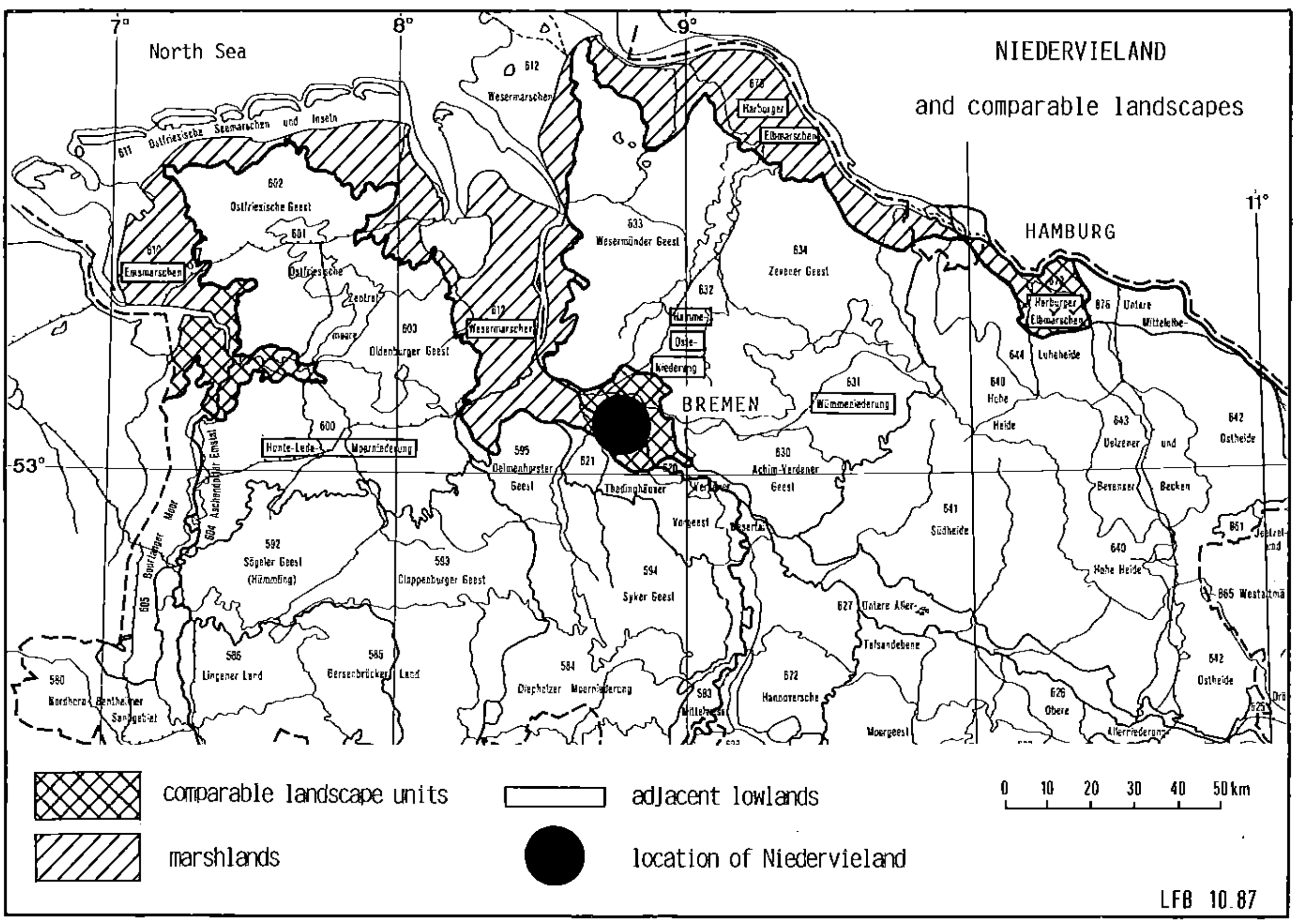
T. Lecke, K. Handke, W. Kundel, K.-F. Schreiber

Ecological Research and Consulting Activities within the Scope of Large– scale Building Projects. – Example: Niedervieland/Bremen, FRG –
Poster at the Annual IALE Meeting in Münster 1987

The Niedervieland region is a lowland of approx. 2000 ha located in the direct proximityof the seaport of Bremen (550,000 inhabitants). The greenland area has been reserved for harbour extensions and industrial settlements for some time: therefore, there has been no intensive farming there. Also, certain methods of clearing the ditches have been maintained. Thus, a unique riverine marshland flora and fauna have been preserved or been able to develop. The combination and variety of species as well as the density of the individuals differ significantly from those of the remaining riverine marshlands of Northwest Germany (cf. Fig. 1). Special attention is to be paid to the importance of the vertebrates (meadow birds, ducks, amphibians) invertebrates (e.g. dragonflies and beetles) and plants (cf. Fig. 2, Table 1). In particular, the meadow birds and the flora and fauna of the ditches are of supraregional if not national importance.

Although the planned construction projects have been considerably reduced, it can be expected, that more than half of the especially valuable areas will undergo a great change as a result of building (cf. Fig. 3). Even now only two of the once widespread breeding territories of the lapwing (*Limosa limosa*) remain (cf. Fig. 2).

According to the legal situation in the Federal Republic of Germany compensation measures are required in the case of such impacts (see Bundesnaturschutzgesetz § 8: Eingriffs– / Ausgleichsregelung (Federal Nature Conservation Act § 8: Impact / compensation regulations) cf. Table 2). The realization of such compensation measures is a rapidly expanding field of work for landscape ecologists. Here, one is unanimous on the fact that compensation in a strictly scientific sense is not possible. However, a certain compensation is seen in the increment of adjacent sites or their reconstruction as habitats for the species driven out of the impact area. In the present case these compensation measures mean e.g. that certain wet grasslands are to be limited to extensive land use i.e.:



Quelle: Niedersächsisches Landesverwaltungsamt – Fachbehörde für Naturschutz – Hannover

Fig. 1: Niedervieland and Comparable Landscapes in Lower Saxonia, FRG

species	status red data book FRG/NS		habitats: Weser-river	creeks	ditches	grassland	reeds	border of ditch	bushes, trees	border/mud areas	sanddeposits	black-headed gull-colony
Aves												
1. Botaurus stellaris	1	1									x	x
2. Ciconia ciconia	1	1		(x)	(x)	(x)						
3. Anas querquedula	3	2		x	x	x	x					x
4. Anas clypeata	4	2		x	x	x	x					x
5. Anas strepera	4	2										x
6. Perdix perdix	2	3				x		x			x	
7. Coturnix coturnix	2	2				x						
8. Crex crex	2	2				x	x					
9. Porzana porzana	2	2									x	x
10. Philomachus pugnax	1	1				x						
11. Limosa limosa	3	2				x						x
12. Tringa totanus	2	2				x						x
13. Numenius arquata	2	2				x						
14. Gallinago gallinago	2	2				x	x					x
15. Asio flammeus	2	2				x	x					x
16. Acrocephalus arundinaceus	2	1					x					
17. Acrocephalus schoenobaenus	3	2					x					x
18. Locustella luscinoides	4	2					x					x
19. Oenanthe oenanthe	3	2				x					x	
20. Saxicola rubetra	2	2				x		x				x
21. Luscinia suecica	1	1					x				x	x
Pisces												
22. Petromyzon marinus	2	1	x									
23. Lampetra fluviatilis	2	1	x	x								
24. Lampetra planeri	3	1	x	x								
25. Osmerus eperlanus	2	3	x									
26. Salmo salar	1	1	x									
27. Salmo trutta	1	2	x									
28. Leuciscus idus	2	-	x	x	x							
29. Misgurnus fossilis	2	2	x	x	x							
30. Cobitis taenia	2	2	x	x								
Odonata												
31. Aeschna viridis	1	1	x	x								
32. Anaciaeschna isosceles	3	1	x	x								
33. Leucorhinia pectoralis	2	2										x
34. Sympetrum depressiusculum	2	2				(x)						
35. Lestes virens	3	2			(x)							
Orthoptera												
36. Labidura riparia	1	/									x	
37. Oedipoda caerulescens	-	1									x	
38. Tetrix subulata	-	2					x			x	x	
39. Tetrix nutans	-	2									x	
40. Mecostethus grossus	3	2					x					
41. Chorthippus apricarius	-	2						x			x	
Coleoptera												
42. Hygrobia tarda	1	/			x							
43. Hydrous piceus	2	/		x	x							
Hymenoptera												
44. Colletes cunicularius	2	/									x	
Lepidoptera												
45. Plusia festuca	/	2				x						
Araneae												
46. Sitticus helveticus	2	/									x	
Mollusca												
47. Valvata pulchella	2	/			x							
Total			9	11	11	14	13	3	-	1	12	14

Table 1: Table of animal taxa "threatened with extinction" or "highly threatened" in the Niedervieland area, the loslands of the Ochtum River and Ochtumsand (1983-1987) according to "Rote Liste bestandsgefährdeter Tier- und Pflanzenarten der Bundesrepublik Deutschland" (BLAB et al. 1984) and several lists of regional importance

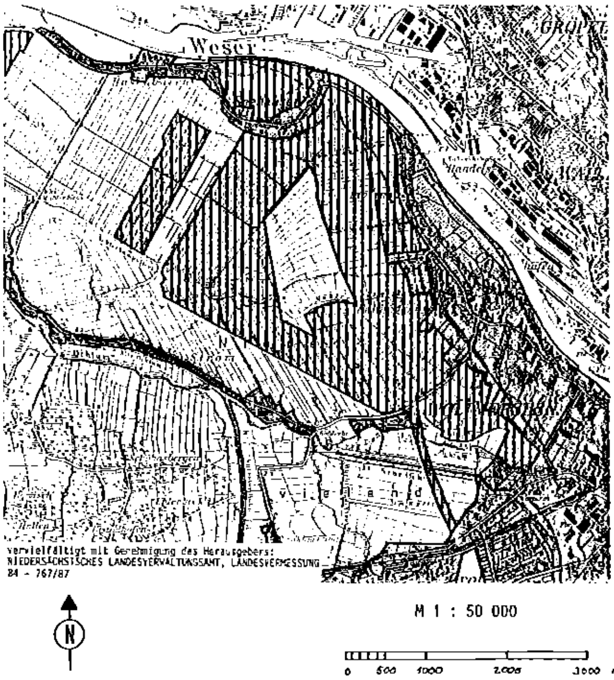


Fig. 2 : Dynamics of Land-use Change

settlement, harbour and industrial zone 1960

settlement, harbour and industrial zone 1985
or projects in planning stage or nearly finished

(Quellen: Topographische Karten Bremen L 2918 1961, 1981
Flächennutzungsplan 1983)

Table 2: Ecological Research and Consulting Activities within the Scope of Large-scale Projects (according to Bundesnaturschutzgesetz (1976) § 8: "Impact-Compensation-Regulations"

1. Evaluation of the Impact Importance
   - impact analysis to work out the main problems which should be covered in the planning process
   - estimation of the changes within the natural balance
   - mapping of the relevant floristic and faunistic elements (s. documentation)
   - estimation of the external effects on populations
   - evaluation of the habitats and life communities concerned with regard to their importance for nature conservation (replacement, scarcity)
2. Proposals for avoidance and reduction of negative influences
   - site location and extension
   - protective measures
   - ecological design principles (e.g. concept for a differentiated run-off management)
3. Proposals for the compensation of negative impact effects
   - search for suitable compensation areas
   - conceptions of the compensation areas
   - proposals e.g. for the "resettlement of organisms"
   - proposals for a habitat management in the compensation areas
4. Oberservation of the construction, documentation of the compensating activities
   - conusltation e.g. on resettlement measures
   - observation of the process of succession within the compensation areas
   - occasional proposals for a long-term maintenance concept or for a modified biotope management

- quantitative limitation of fertilizer
- designation of certain plots for mowing which would be negatively effected by pasture
- determination of late mowing dates
- prohibition of certain land use measures in early spring
- prescription for the management of waterlevels in ditches as well as for methods of ditch maintenance, etc.

In addition the resettlement of vegetation and sediments (cf. Table 3) is to be carried out in order to accelerate the succession in newly constructed "compensatory" ditches or sections of lesser value. Table 2 comprises a list of the steps to be taken in a concrete

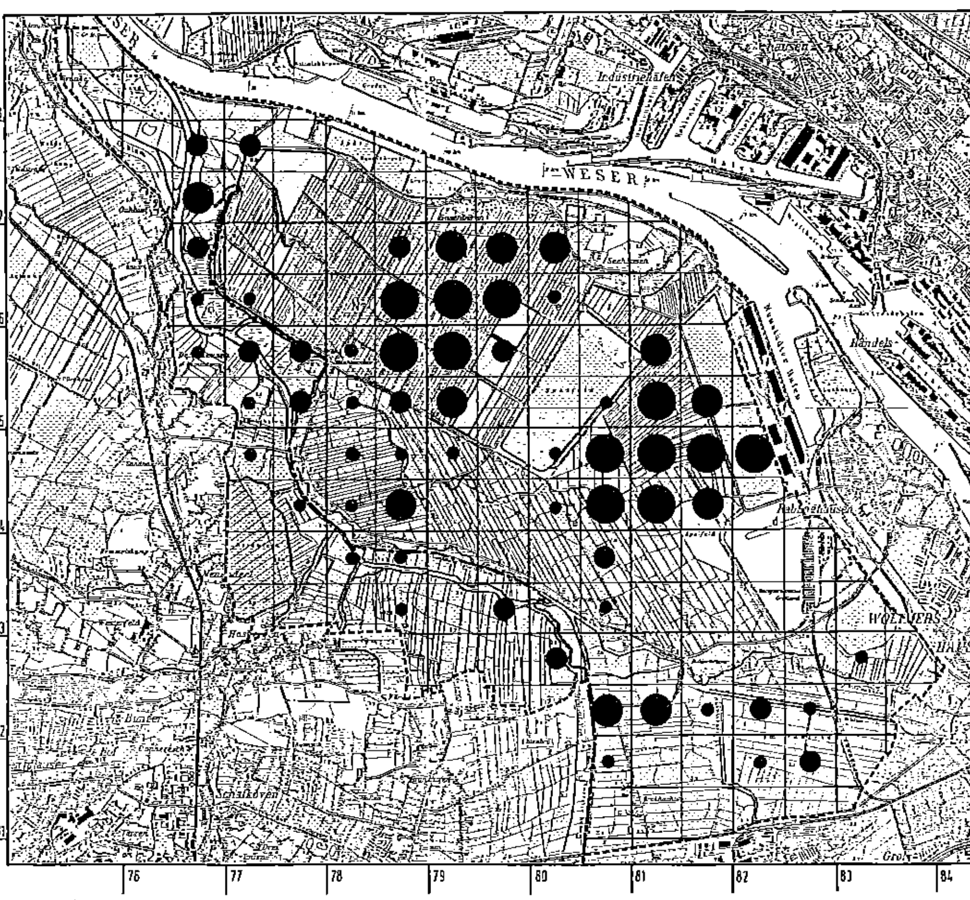


Fig. 3 : Number of territories of Limosa limosa in the area of the "Niedervieland" and the marsh of the Ochtum River

Results of grid mapping 1986/87 (500x500 m)

● 1 territory
● 2 territories
● 3-5 territories
● > 5 territories

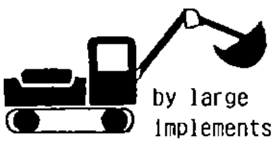
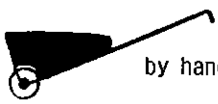
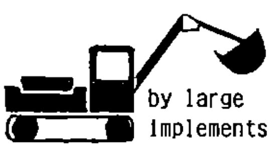
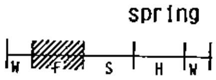
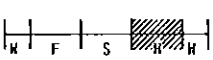
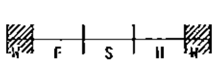
border of the investigation area
border of country

Kartengrundlage: TK 1:25000 - reduced
Blatt 2817 Vegesack 1974 2818 Bremen Nord 1976
2917 Delmenhorst 1981 2918 Bremen 1981

vervielfältigt mit Erlaubnis des Herausgebers:
Niedersächsisches Landesverwaltungsamt
Landvermessung 84 - 767/87

N 0 500 1000 1500 2000 m

Table 3: INVESTIGATIONS OF OPTIMAL TECHNIQUES OF REPLACING STANDS OF PLANTS IN DITCHES AND ON THEIR BORDERS - preliminary experience (two years' experiments) -

Method	Advantages	Risks/Disadvantages
 TAKING OUT THE PLANTS by hand	very specific taking of certain species	not all species are equally covered only few individuals high cost
 by large implements	taking out with site specific material, by that also catching diaspores and larvae	mechanical damage to plant material
TRANSPORT  by hand	simple coordination little damage	small quantity time intensive, high cost
by large vehicles 	quick transport large quantities	damage on transport dependent on weather (e.g. is the ground passable?)
 PLANTING by hand	specific treatment of the different species	quantities of plants too small to have good inoculation effect
 by large implements	catching animals as well large quantities of plants	high losses strong impairment of the biotope
SEASON spring 	plants grow on well when left in their substratum	disturbance of fauna (birds) specific determination of the plants is difficult
summer 	plants are easily determinable little damage by transport driving on dry ground	damage to animals and to existing plant stands
autumn 	in general little disturbance of animals, suitable for a number of plants	not suitable for all plant species some animal species are damaged
winter 	little damage by transport	not suitable for all plant species damage of some animal species difficult determination of the plant material

case of impact compensation. On the one hand, this list of measures clearly shows the importance of questions of landscape ecology. On the other, the lack of knowledge that still exists in this field becomes obvious.

At present, the estimation of the consequences of impacts is only possible as regards short–term and direct effects (e.g. loss of organisms and areas). The present background of knowledge does not allow a reliable answer as to the long–term effects on species numbers and diversity in reduced habitats.

The complex of questions concerning the connectivity of biotopes plays an important part with regard to the determination of the necessary size and the location of the compensation areas. In the present case, it is presumed that moist grasslands serving as breeding areas for Limikolae should comprise more than 100 ha. This may appear small: the size can only be justified when one takes into account that additional, larger greeding territories exist in the planning area which have to be connected with the management areas (cf. Fig. 4). Furthermore, questions of connectivity play

- description of the soil condition, water levels and methods of cultivation
- repeated plant inventories and mapping of floral and vegetation patterns in permanent plots to which mapping of the surrounding plant societies will be added at larger intervals
- repeated mapping of breeding birds, amphibians, dragonflies, grasshoppers, butterflies and, at specific sites, beetles (Carabidae), water bugs (Heteroptera), diving beetles(Dytiscidae) and other groups of beetles (cf. Fig. 5).

This work is necessary in order to obtain scientific evidence. It is also the only way to develop appropriate methods of biotope management. Furthermore, one can check whether the resettlement of sections of ditches (vegetation and sediments) does in fact accelerate the process of succession (cf. Fig. 5, Table 3). In addition, a studygroup lead by Prof. Weidemann from the University of Bremen is examining the soil fauna which serves as nutrition for the meadow birds.

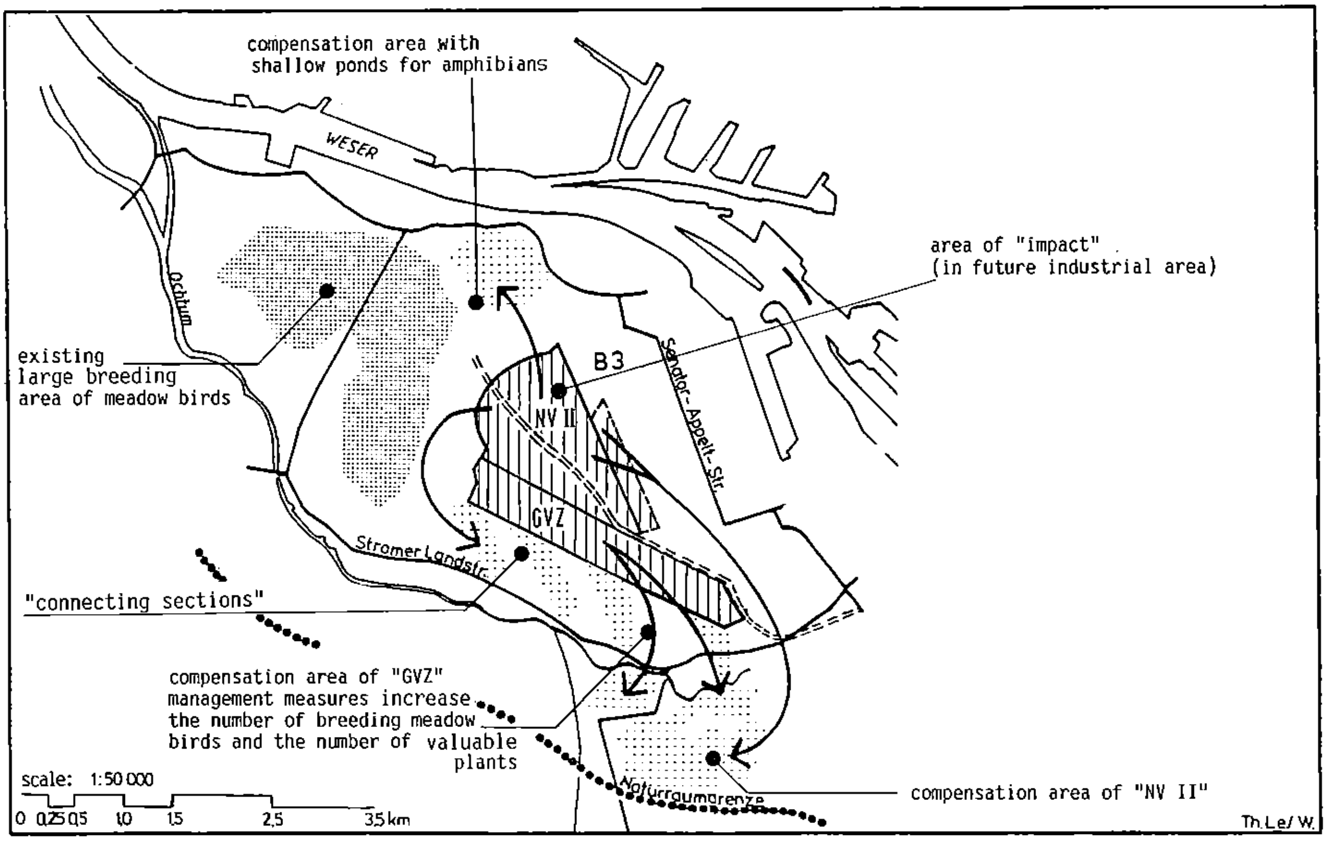


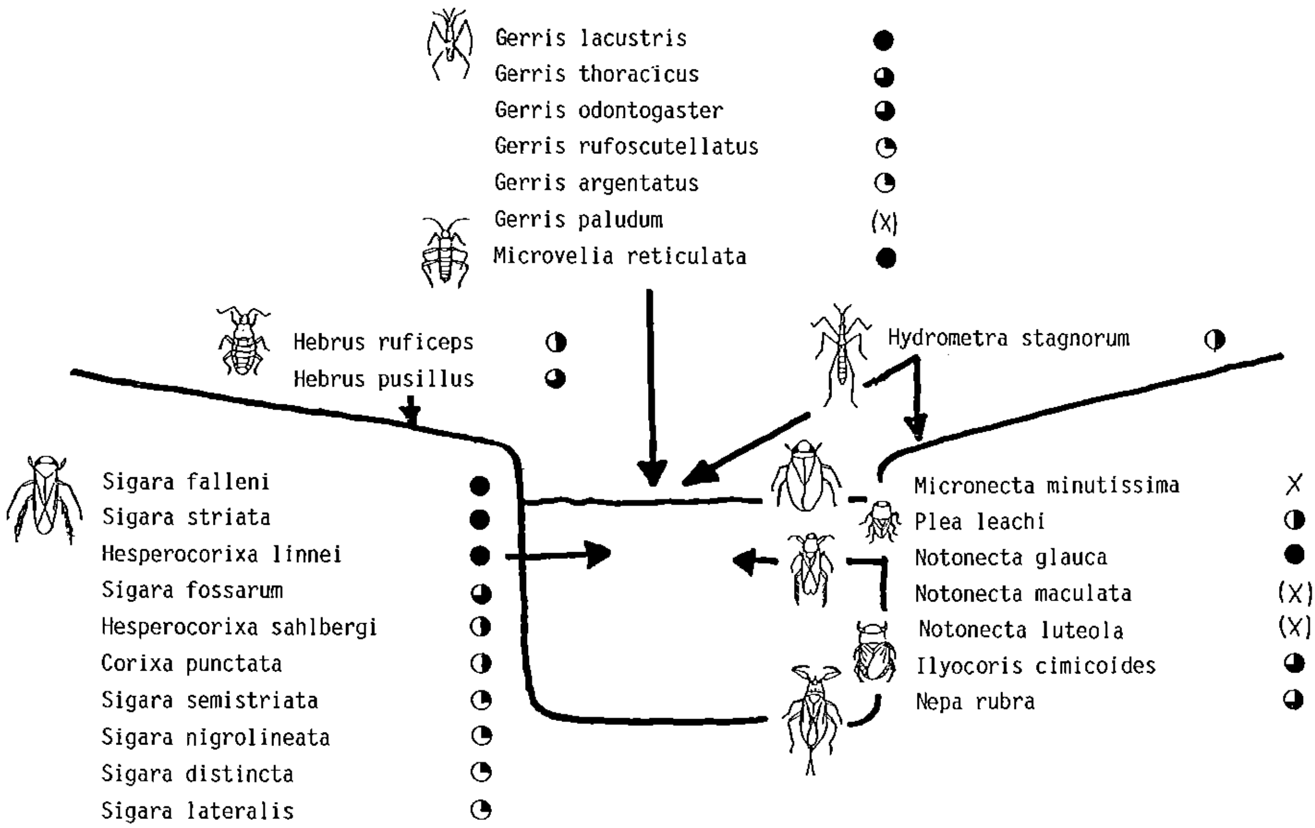
Fig. 4.: Location of Compensation Areas

a role when the distance between the impact and compensation areas and the undisturbed areas is to be determined in order to enable an immigration of less mobile species.

The investigation of the process of succession in the compensation areas is of central importance in this project. At present, we have the impression that the above–mentioned compensation measures might quite possibly be successful for certain species and biotopes. However, considering the short period of investigation it is yet too early to come to a definite conclusion. In particular, the success of the measures and the biotope management in the area will be examined by means of the following methodes:

Finally, we should like to make some critical remarks concerning the problems of landscape ecologists involved in such projects.

In Principle, it is to be appreciated that the compensation regulation in connection with large–scale building projects leads to increasing importance being placed on questions of landscape ecology. However, a great danger lies in the belief that, due to the success of particular compensation measures, one only has to spend enough money on compensation measures in order to be free to go through with all kinds of building projects without restrictions. One tends to forget that in most cases irreversible damage is done to the landscape. Rarely can such favourable predictions be made for the



Within each waters an average of 12 species for 6-8 samples had been found (6- max. 20 species).

● present at > 75 % of the sampling points
◕ present at 50 - 75 % of the sampling points
◑ present at 25 - 50 % of the sampling points
◔ present at < 25 % of the sampling points
X single place of discovery

Fig. 5: Occurence of water bugs (Hydrocorisae) within the ditch system of Niedervieland and the lowlands of Ochtum-River - Result of the investigation at 48 sampling sites (more than 2000 ind.) 1985/86

success of compensation measures as those made regarding the example described above.

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RECONSTRUCTION OF FORMER STREAMLET COURSES

Use of Aerial Photographs within the Frame of Habitat Network Planning

H.-C. TIELBAAR

1. Introduction

Recultivation of roads and channels, reconstitution of former landscapes – those ideas have an increasing meaning for planning authorities. A retracing of former streamlet courses is hardly possible by field work, because the present land use pattern does not reveal the old structures. Interpretation of aerial photographs has found application for archeological purposes since many years. The method is as well applicable for this special ecological investigation.

The study area is a left-side tributary of the Lower Rhine. In order to improve the drainage system, it was straightened in the thirties and fifties. The construction of a channellike river bed caused the loss of valuable habitats as well as frequent flooding of the neighbouringagricultural land.

The reconstitution of the streamlet courses is supposed to recreate the former ecological conditions by using the original river bed wherever possible. Even though this measure cannot guarantee suitable habitats for all typical and adapted species that have vanished due to the changed situation, it will help to improve and enrich the present landscape.

2. Situation of Connectivity Planning in the North West of Germany

In the last decades experts like ecologists, biologists and geographers note an increasing number of species being endangered in their population or eterminated.They are listed in the so-called "red data books" of endangered species (IUCN 1970). In the Federal Republic of Germany

53 % of the mammals
75 % of the reptiles
58 % of the batrachians
71 % of the fish and
35 % of the plants

are listed in the federal "red data book" (BLAB et al. 1984). The reason for the reduction of plant species has been studied by SUKOPP and others. As to aquatic ecosystems, 173 fern- and blossom-plants are endangered by drainage, 155 by filling in and development, 69 by regulation of streamlets and rivers, 56 by eutrophication of waters and 31 by water-contamination (SUKOPP et al. 1978). This concerns about 15 % of the German Pteridophyta and Spermatophyta. 70 % of the endangered birds breeding in Germany are belonging to species prefering wet and moisty areas or open water.

The above shown examples demonstrate the extent of losses caused by "melioration" of agricultural areas and by regulation of runningwaters. In order to stop this disastrous development new biotopes are planned and constructed They mostly have been settled on remnant areas that, after a field clearing, could no longer be cultivated economically. A preceding check of their ecological suitability has often been missing. Present German landscape often is characterized by dissimilar and isolated habitats.

One possible step to prevent complete isolation of biotope islands is habitat network planning. Optimizing existing ecotones like hedges, road sides, banks and shores is a first step to improve the system of connections. Its advantage is low operating and technical expenditure and the existance of corresponding areas. But from the ecological point of view those measures are less promising.

A more comprehensive exemplary plan to create a close meshed network of aquatic habitats is demonstrated by this example taken from the Lower Rhine area: the reconstitution of former streamlet courses and their connection with existing biotopes.

3. Historical Review

The study area is situated in the left-hand Lower Rhine region. The receiving streamlet has a length of about 130 km in a rather flat landscape. In consequence, the streamlet used to flow in many often changing meanders within a riverside that was up to 1500 m wide and some meters deep. Except for a few farms and water--mills no human settlement and agricultural use was possible. Only one bridge every ten kilometers crossed the swamplike area. Fenwood with willow-, alder-, poplar-, ash-, elm- and oak--trees (ELLENBERG 1982) covered most parts of it.

At the end of the 19th century people began to straighten 3 kms of the streamlet and other parts were smoothed by cutting off the largest meanders. Probably this measure must be seen in relation with the elimination of a nearby channel. In the thirties of this century another section was straightened.

4. Present Situation

Nowadays we cannot speak of a streamlet or river any more. The run of it has been changed completely. Today, no single dead channel is left. In the study area the bed does not follow any historical course of the main streamlet. It has been placed at the south-western edge of the former riverside.

Some farm-yards have been built beside the new dikes and agriculture use is dominant. Fenwood can only be seen in rudiments. In spite of the high level of ground-water farming dominates in more than 50 % of the area while meadows dominate in the smaller northern part. Both meadows and fields are drained by crop drainage systems and numerous ditches.Nevertheless, reduction of yield caused by inreased soil moisture can be stated.

5. Planned Reconstitution of the Former Streamlet Courses

5.1 Inventory Design

The above shown ecological and scenic consequences made the responsible planning authority look for a measure to improve the present situation. The idea of the reconstitution of the former streamlet courses was born.

In order to get an idea of the position of former streamlet courses, aerial colour-infrared (CIR) photographs were taken of a part of the riverside with an extension of 17 sqkm. For an adequate impression of the soil-moisture and of the other soil structures, the month of may 1986 was chosen as the optimum period for the photo flight. Some days later a field check was carried out followed by an interpretation of the photographs with the WILD AVIOPRET APT 1 -stereoscope.

The early date of the flight in spring offers the advantages of a more refined reproduction of soil structures and of a smaller size of the fieldcrop. The advantages of CIR–photographs are described by SCHMIDT–OSTLENDER (1987) in these proceedings and, among others, by COLWELL (1983) and SCHERZ/STEVENS (1970).

An inventory of landscape of the district is the first step of the planning phase. 17 types of landuse can be distinguished. Additional information is taken from a soil map 1 : 5000. Its detailed information is generalized into 14 soil units to receive precise hints where soil is suitable for the planned reconstitution. The inventory of hydrological peculiarities is the last step of the data collection, but it is a very important one. Five degrees of moisture content are analyzed as well as the important draining ditches, subsidences or mire, wetlands, dead channels and supposed former channels.

The results are all gaines from aerial photo interpretation except for the types of soil.

5.2 Results

Agricultural landuse is dominating and each former streamlet and ditch has been straightened. Close to nature parts of landscapes as dead channels or riverside forests do not exist any more. Nevertheless, relicts of ancient structures can be found although they do not have an ecological value any more. Several moisty and swamplike plots in meadows and fields are obvious as well as soil peculiarities that allow the reconstruction of the former run of streamlets, ditches, hedges and infrastructure. Assisted by the soil maps a classification is possible. It must be emphasized that especially former streamlet runs cannot be found in the field, except for areas with a different vegetation cover like juncaceae and cyperaceae.

By means of interpretation of CIR aerial photographs two former streamlet runs and some swampy areas are found. Problems of recognition only turn out in human settlement such as Grenzdorf, a village built about 1933 along the new channel bank.

6. Comparison of the Interpretation Result with Historical Maps and Aerial Photographs

Fortunately, there are many historical topographic maps, aerial photographs and aerial maps of this region:
– the first official topographic map at scale 1:25.000 of 1844, – two ordnance survey maps of 1910 and 1926, – an aerial map at scale 1:25.000 of 1934, – b./w.aerial photographs of 1951 and 1968 at a scale of 1:10.000, – the latest topographical maps at 1:25.000 and 1:5.000 scale and – the above cited CIR aerial photographs at 1:5.000 scale of May 1986. By means of those documents it is possible to obtain information of the former landscape: the change of landuse, the number of settlements, the time of the convertion of the bodies of water.

The comparison of the interpretation with the historical documents show great correspondance. The reconstitution of former streamlet runs is correct, former roads, paths and hedges can be found.

7. Summary

It has been proved that ecological analysis of CIR aerial photographs enables planning authorities to get reliable information of former land use structures. Thereupon it is possible to propose sites for the reconstition of former habitats like streamlets. Potential areas of conflicts with agriculture, watersupply, recreation etc. can be shown as well.

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METHODICAL APPROACH TO REGISTRATION AND DEVELOPMENT OF URBAN HABITAT NETWORKS BY MEANS OF REMOTE SENSING

K.SCHMIDT–OSTLENDER

1. General Aspects of Urban Ecology and Mapping of Urban Habitats

The steady increase of urbanization is closely correlated to the vanishing of species that are unable to adapt to the changed ecological conditions.

The urban ecological situation varies a lot from that of the surrounding countryside. Climatological changes, pollution and surface sealing are well–known aspects. The species existing in urban areas are adapted to these conditions and the species composition and diversity is specifically urban. They are determined by the intensity of human activities as well as by the way of land use.

The importance of urban habitats is evident (cf. SUKOPP 1980, SEIBERT 1986, GÄLZER 1980 and others):

- They contribute a lot to the city scape.
- They allow to experience nature near to the populatiońs living quarters.
- They are a frequented area of recreation and function as childreńs playground.
- Last not least parks and green areas improve the bioclimate of the surrounding quarter by increasing air moisture and decreasing temperature.

Near to cities there is not only a remarkable decrease of indigenous species, also the specific urban flora is partly vanishing (cf. SUKOPP et al. 1979). As a basis for preserving typical urban habitats, a lot of cities carry out a mapping of their biotopes (MÜLLER and WALDERT 1981, KIENAST 1978 and others).

According to the urban land use pattern, the data collection has to include

- open built–up living quarters with gardens
- living quarters with densely built–up blocks
- industrial estates
- rural areas
- public green areas
- parks
- cemetries
- roads and railway lines
- rivers
- sites of refuge and sewage

(cf. SUKOPP et al. 1979, SUKOPP 1981, SEIBERT 1986).

Parks and graveyards, public green areas, groups and rows of old trees, and ruderal places are the predominant types of valuable biotopes.

Additionally, in the surrounding countryside

- agricultural land
- pastures
- grassland
- fallows
- forests and forest relicts
- hedges, groups and rows of trees
- aquatic habitats

have to be distinguished. But the mapping itself is not enough to guarantee the surviving of urban flora and fauna.

2. The Urgent Necessity of Developing Urban Habitat Networks

Any species community can only be a stable ecosystem if a certain diversity is guaranteed. Thus, species exchange is a necessary requirement. This can only take place if similar habitats are near to each other or, if not, are connected. A phytosociological registration of urban habitats may be used as a basic information on site conditions. The development of an urban habitat network, however, is aimed at connecting different biotopes like ruderal places or forest relicts where the various associations only play a minor role. The registration of communities is more urgent when a declaration of urban nature reserves or valuable biotopes is asked.

On one hand, the specific types of urban biotopes have to be connected by stepping stones and connecting links (cf. AUHAGEN and SUKOPP 1983). Stepping stones may be groups of trees, ruderal places or gardens, connecting links can be created along existing linear elements (roads, railway lines, channels). Often, a connection does not have to be a new element; improving existing elements, such as planting adequate trees or bushes in public green areas or avoiding herbicides along traffic lines, can already help a lot.

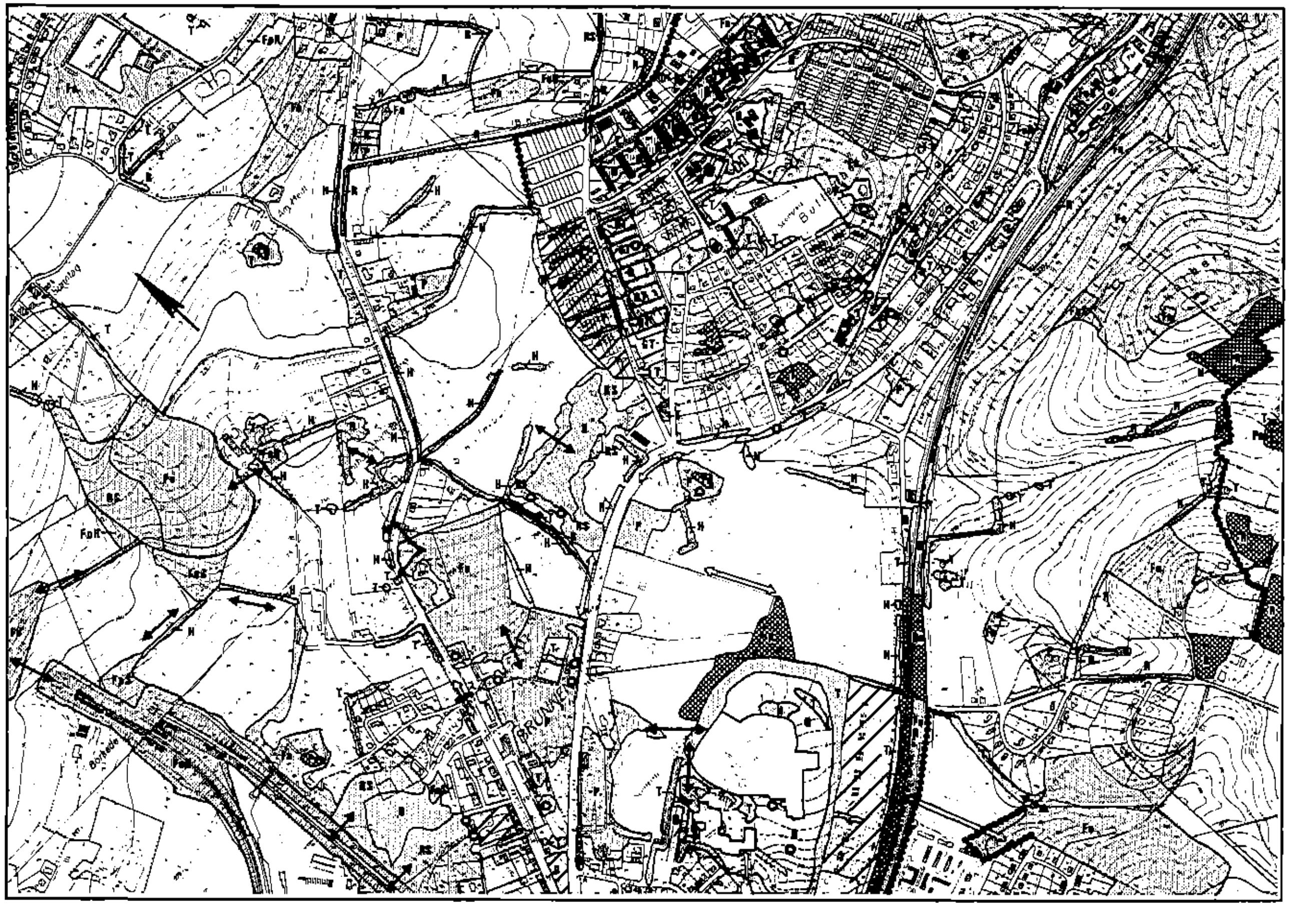
On the other hand, cities or city belts often form an abrupt barrier for species of the surrounding countryside. The transition zone between urban and rural areas are characterized by structural elememts of both sides. It should therefore enable indigenous species to penetrate into the cities and settle on suitable habitats or pass via stepping stones. This penetration will enlarge the urban species richness, even if only temporarily. Examples are the appearance of birds or insects "from outside" within city parks, gardens or ruderal places.

These "guests" can also increase the attractivity of cities for their inhabitants. An ecology–based regional planning in urban areas should therefore guarantee a minimum equipment with green areas and their connection to natural or seminatural systems (cf. KAULE 1978). The urban fringe as transition zone is thus an area where intensified geoecological research has to be carried out (cf. RICHTER 1984).

3. Colour Infrared Aerial Photograph – Basis of Registration of Habitat Types and Structures

Registration of habitat types and mapping of biotopes that need to be protected or developped takes a long time and manpower if done in the traditional way of field work. Remote sensing, for large–scale data collection preferably the use of colour infrared (CIR) aerial photographs, is a suitable means to carry out this basic work within a reasonable time. For example, an area of 1 sqkm can be mapped in an average time of 2 hours with a working scale of 1:10.000 and the field work can be reduced to phytosociological data collection and and checking of possibly valuable sites. Ground mapping would take about four times as long. For example, it took five years time to register the ruderal vegetation of Düsseldorf (GÖDDE 1987); over this period the first collected data might have changed when the whole work is finished. Due to a lack of time, the mapping often is limited to a selection of valuable sites (cf. SUKOPP and WEILER 1986). Applying this method, valuable

ISOLATION AND CONNECTIVITY



Biotopes

Fa/FaS	Fallow/Fallow with Natural Succession
Fo/FoR	Forest/Forest Relict
G/GT	Public Green Area/Public Green Area with Trees
H	Hedge, Bushes
P	Park and Park-like Garden
Po	Pond
R/RS	Ruderal Place/Ruderal Place with Natural Succession
Ro	Rock/Wall
T	Tree(s)

Network Structure

- Network Element of High Quality
- Network Element to be Improved
- Isolated Habitat
- Transition Zone
- Existing Connection
- Necessary Connection
- Barrier
- Trees of Low Vitality

Scale
0 50 100 200 300
meters

Hansa Luftbild
Consulting

connecting links between biotopes might be neglected, but those are essential for developing a habitat network. A complete, most recent and simultanous information on an area under investigation is provided by aerial photographs. In order to reveal existing structures as detailed as possible a scale of 1:5,000 up to 1:10,000 is recommendable.

For mapping of vegetation colour infrared aerial photographs are superior to real colour photographs due to the following qualities (cf. COLWELL 1983):

- The number of red shades – representing green parts of the vegetation – is much higher than the number of green shades possibly obtained by real colour photographs.
- This provides the possibility of distinguishing different types of vegetation and – depending on the scale – vegetation communities much more clearly.
- Soil moisture condition are made evident. Moisty pasture and less humid or dry fallow lands e.g. will show apparently very different shades on the infrared film, whereas they are hard to distinguish on real colour or even black and white film.
- The vitality condition of vegetation can be seen on infrared aerial photographs. This is due to the fact that physiological disturbances in the leaves cannot be detected while they are still green. But the reflexion of the leaves is changed (compared to that of healthy leaves) and thus creates different shades of red on the CIR film.

This last aspect is a valuable hint that should be included in the development of urban habitat networks. Certain trees are much more often in a bad condition than others, which means that they are not strong enough to exist in more or less polluted cities. In order to develop a long-term network those sensitive species should be avoided and very damaged trees should be replaced by more resistant ones.

4. Isolation and Connectivity of Urban Habitats

The study area is the north eastern urban fringe of the city of Schwelm near Wuppertal in the northern Federal Republic of Germany. It is situated on paleocoic slate and limestone formations at an altitude of 230 to 290 m a.SL.

The CIR photographs prove that a lot of relicts of natural habitats (small forests, hedges, rows of trees, fallow land with different states of natural succession) surround the built-up area. An exchange of species between the rural and the urban sectors can e.g. take place along the clefts of the railway lines bearing a dense vegetation. Several hedges extend to the border of the settled area, partly continuing in private or public hedges and tree rows, partly ending abruptly. In this case connecting links to innerurban parks have to be created by planting hedges and tree rows. Also within the city, CIR photographs reveal a lot of valuable biotopes. In many towns there are similar structures as in the study area. Private gardens and lawn, hardly accessible by ground mapping, appear to be possible stepping stones.

Parks and park-like gardens, public green areas with and without trees as well as ruderal places are the predominant valuable specifically urban habitats in the study area. They are partly connected, but especially the ruderal places need more connecting links. It is clearly visible on the CIR photos that public lawn are cut and "clean" and that there is no spontaneous vegetation along many roads. With low financial means and a changed public conciousness this situation could be improved and thus contribute to create green lungs throughout the city.

Aquatic habitats are not specifically urban, but several ponds are located within the study area. All of them are surrounded by trees and / or falllow lands that are valuable stepping stones. But the ponds themselves are isolated. As there are no moisty grasslands or small channels within the city, there is no practicable solution for integrating the ponds into a habitat network. Despite their evident pollution they should, however, be protected as island biotopes and, if possible, be improved.

The study proves that the interpretation of CIR aerial photographs is an adequate and essential method for the registration of urban habitats, their quality and connectivity and thus forms a sound basis for the development of network structures.

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HABITAT NETWORK PLANNING INTEGRATED IN INFRASTRUCTURAL PLANNING SCHEMES

K.–U. KOMP, K.SCHMIDT–OSTLENDER, H.–CHR. TIELBAAR

1. Recent Development in Infrastructural Planning

An ever increasing population mobility demands an adequate infrastructural system. This is the main argument for a steady extension of the existing traffic network. In the Federal Republic of Germany, e.g. traffic infrastructure consumes an area of 28 hectares per day. About 4,9 % of the total area of the Federal Republic is covered by traffic area (UMWELTBUNDESAMT 1986). Apart from surface sealing with is known consequences, the visual disturbance of the landscape aspect as well as the ecologically important separation of formerly connected habitats are the main impacts of this development.

Recently, the ecological understanding has led to a changed strategy. Checking of the belongings of nature as well as comprehensive environmental impact analyses before starting detailed plannings are inalienable. Besides abiotic factors, these investigations register above all valuable habitats, sites of endangered species, habitat connections and the landscape aspect.

According to legislation in the Federal Republic, a construction or retracement of a road or railway line causes various intrusions on nature and landscape. According to the "polluter pays principle" any intrusion that cannot be avoided has to be compensated.

In order to minimize negative effects, the traffic authorities nowadays often trace new lines very close to existing ones, e.g. railway lines are planned parallel to existing motorways. Thus, a cutting of existing connections can be avoided to a great extent. The modernizing of frequented railway lines and their adaption to an increasing traffic volume is another way of combining economical needs with ecological belongings. In this latter case, only very winding parts of the track are smoothened.

2. Consideration of the Ecological Aspect

Roads and railway lines separate without doubt habitats that formerly were larger (e.g. forests, grasslands) or connected. Thus,species exchange is reduced. The construction of any further road or railway track divides an existing system into several smaller ones, that now are isolated. The latest planning schemes in the Federal Republic strengthen the idea of transport concentration along existing corridors and thus avoid being reproached for cutting connections.

On the other hand, linear biotopes along the infrastructural elements are created. Those might be of quite a different quality. Particularly on road sides the pollution by exhaust fumes, heavy metals, salt and oil supports the development of an adapted and resistant vegetation. But anyway, those habitats can be important links between island biotopes and, depending on their conception, prove to have quite a species diversity (cf. ELLENBERG et al 1981).

Railway dams and clefts often bear a thermophile vegetation with a rich species diversity. Left to natural sucession, they are important links between habitats. Giving–up of old tracks should therefore not mean destroying those habitats but preserving them with their important ecological and aesthetic function.

3. Consideration of the Landscape Aspect

Each landscape is perceived as a distinctive unity with quite a different quality than that of its elements into which it might be separated (RICCABONA 1981). This theory of landscape aesthetics has to be a basis for all jugdements of impacts on the landscape. An infrastructural planning carried out with regard to existing ecological connections (avoiding new separations) will therefore, in many cases, not cause additional visual barriers and thus preserve the present landscape.

In areas with an intensive agricultural land use, road sides with tree rows or dams with a dense vegetation might, however, be the only structural elements.

Some examples, taken from recent railway planning in southern-Germany shall demonstrate the integration of habitat network planning into the general conception of railway network planning.

4. Railway Planning in Southern Germany

According to the "Bundesverkehrswegeplan 1985" the construction of a new railway connection between the cities of Nuremberg and Munich is necessary. An environmental impact study was carried out in order to judge possible tracements, showing ways to avoid intrusions on landscape and nature and suggest compensations for inevitable intrusions (HANSA LUFTBILD CONSULTING 1986). The general ideas are either the construction of a line parallel to an existing motorway from Nuremberg to Ingolstadt and then modernize the existing railway line to Munich or to retrace the existing connection Nuremberg–Munich via Augsburg. This latter solution includes the construction of a 45 km track through forest area as well as adding two rails to the existing line at a length of approx. 37 kms. Both plans follow the above mentioned strategy and try to avoid cutting existing networks. Certainly, projects of this size cause intrusions that have to be compensated.

In the area of the calcareous Franconian mountains the bends of the existing railway line have to be smoothened. This has to be compensated, because the new line disturbes the present ecological and aesthetic situation. The dams are covered with a mesoxerophytic meadow (Mesobromion), a vegetation form that is typical for an extensive land use. Due to the usually intensive land use those sites are valuable habitats. The species composition of these dams contains: *Bromus erectus, Brachypodium pinnatum, Anthyllis vulneraria, Euphorbia cyparissias, Onobrychis viciifolia, Salvia pratensis, Centaurea scabiosa, Dianthus carthusianorum, Thymus pulegioides, Lotus corniculatus. Typical trees on railway dams and clefts are: Robinia pseudoacacia, Quercus robur, Cornus sanguinea, Frangula alnus, Acer campestre, Acer pseudoplatanus, Fraxinus excelsior* and *Rubus spec.* A lot of these "railway habitats" are registered within the bavarian cadastre of valuable habitats because of their important function as connecting elements. The adequate compensation for the necessary intrusion by smoothing bends would be to leave the old dams to natural succession (see fig. 1) and develop the grassland by extensive care (cutting twice a year). The area between the old and new dam as well as the new dam itself have to be included in the habitat. In this way larger areas of refuge are created which are connected by the vegetation along the railway line.

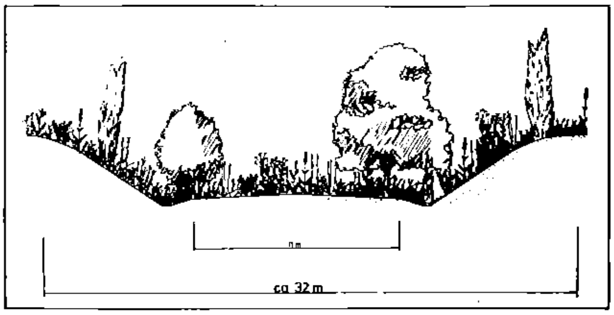

Fig. 1: Natural Succession on a former Railway Cleft

Evitable intrusions on landscape and nature are not permitted according to the legislation of the Federal Republic. The construction of any traffic line right through natural forest areas is certainly an intrusion with lots of consequences for this habitat structure. Another example taken from the possible retracement of the railwayline Augsburg–Munich demonstrates this problematic. The most economical solution for the southern by–pass of Augsburg is the crossing of a forest on the banks of the river Lech. Apart from the general protection of forests, this area is a very valuable habitat with lots of different types of vegetation (mesoxerophytic meadow, light and hard wood riverside vegetation, rough meadow, spring zones, cut–off meanders). A tracement through this forest means an unbearable loss of a rather intact riverside ecosystem (fig. 2). The area is declared as a nature reserve and is furthermore an important water protection area. In order to avoid a destruction of the system, a less economical solution for this part is suggested.

The sensitive area will be passed on a detour of about 1.5 km. South of the city, the railway line can take over a part of another track, then cross through agricultural land and end up parallel to a street. A suburb of Augsburg has tobe tunneled.

These two examples show how the aspects of habitat structures can be integrated in infrastructural planning schemes in order to avoid a further decrease of natural and valuable sites within a densely settled and greatly influenced country.

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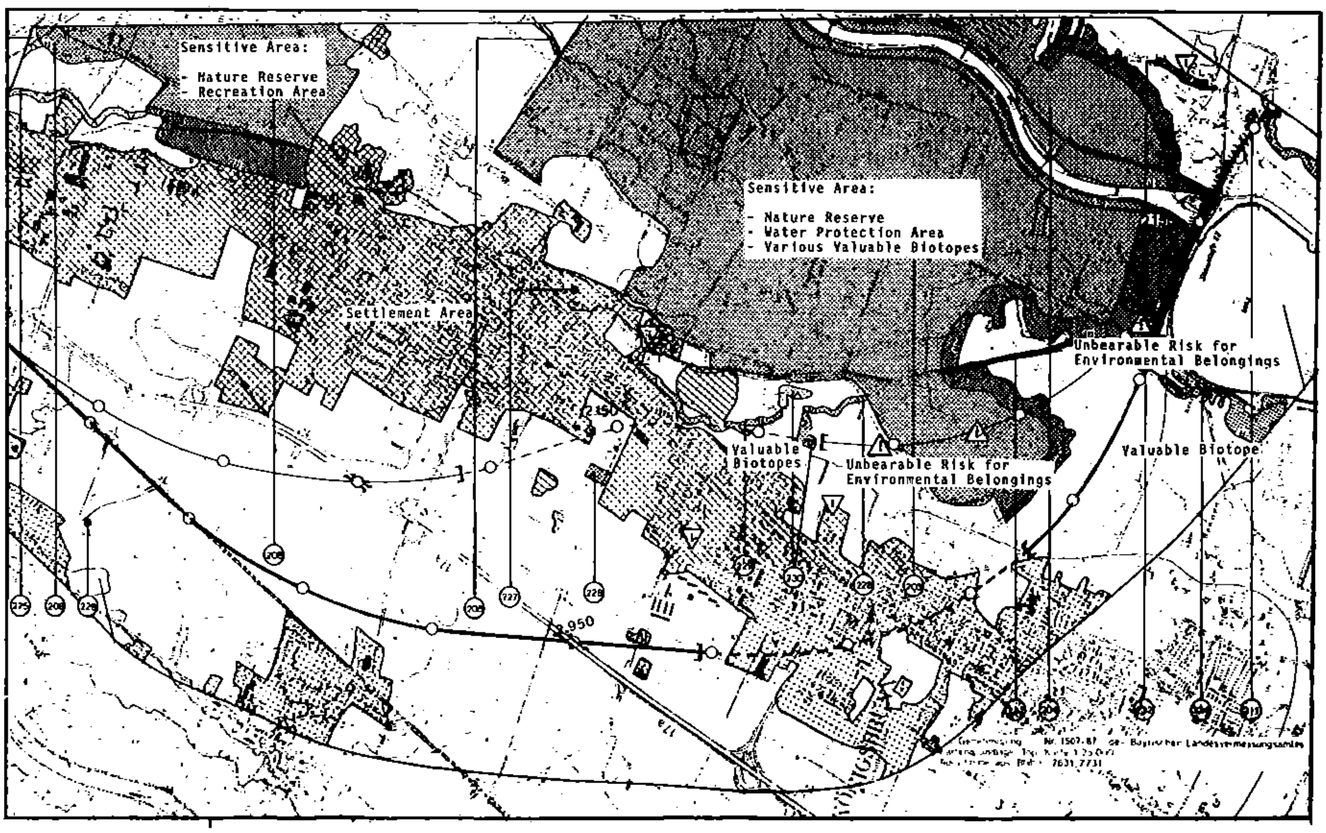

Fig. 2: Choosing the ecologically compatible Railway Alternative

THE IMPORTANCE OF A RESTAURATION OF FORMER HABITAT NETWORK–STRUCTURES AND THE CONSTRUCTION OF NEW ONES IN THE MANAGEMENT OF BIRDS OF PREY; ESPECIALLY THE PEREGRINE FALCON, THE WHITE–TAILED EAGLE AND THE HOBBY.*

D. Vogt

1. Introduction

Thanks to a recovery trend and the resulting need of appropiate habitat the connection between the biotopes of former habitats (cf.: Habitat Key, VOGT 1978, 1983 and 1987) with actual and potential habitats (also such that have never been occupied), with the habitats of the prey animals (i.e.: by the protection of the vegetation of the edges of the fields, hedges and walls ...), with general protected areas corresponding to the principle of "economy", becomes necessary!

A program for the establishment of connections between the biotopes in Rhineland–Palatinate, on regional level in co–operation with the Regional Administration has been translated into action (in co–operation with the Senior Government Official Friedrich, Koblenz), since June 1987. First negotiations concerning its realization in the whole country are going on with the Department for Environmental Protection of the Land in Oppenheim (Dr. Grünwald). Other institutions and countries like Tchecoslovakia (Dr. Trpk) and the GDR (Dr. Dornbusch), who both attended the symposium of the German Haliaaetus Association, have shown interest in this project.

2. Structure of the poster exposition

1.1. Monotope of the Peregrine Falcon (VOGT in preparation)

1.1.1. Studies on the day rhythm and behaviour(VOGT 1979, 1984, 1986) among other things: preferred places and duration of stay relationship between the pair – tenacity towards the clutch – the young – the nest.

1.1.2. Parameter of the habitat structure
- spectrum of possible parameters
- importance of the different parameters(VOGT 1978, 1986)
- evaluation of the different parameters(VOGT 1987 in the offing)

1.1.3. Parameter of habitat structures of the different prey animals (VOGT in prep)

1.1.4. Conclusions to be drawn for the protection or rather the management of the habitat (comp. also habitat key)

2. The establishment of connections between the biotopes

2.1. Former – present peregrine falcon habitats – potential, but not so far used habitats (comp. also habitat key)

2.2. Peregrine falcon habitats – prey animal habitats

2.3. Peregrine falcon habitats – general areas of protection

3. Application of the results acquired from studies of the peregrine falcons to the white–tailed eagle, the hobby and the goshawk.

Parameters (comp. Habitat Key (VOGT 1987) (1.1.2.))
Cliff (quarry, buildings): Height, Width, distance from cliff – next stretch of water; width of water; shape of facing slope, vegetation of the nesting cliff, ground vegetation of the opposite slope, ground vegetation of the habitat in area percentage: Forest, open country, built – up area.

Additional parameters relief – climate, incline of slope, exposition of slope, humidity content, degree of evaporation, winds on slope – winds in the valley, currents of air, daily cycles; direction of the valley, concave (warm in the night), convex (cold in the night), contour of the country, lakes of cold air, effects of narrowing of valleys a.s.o.
Risk of disturbance (fig. 1), perching – trees a.s.o.

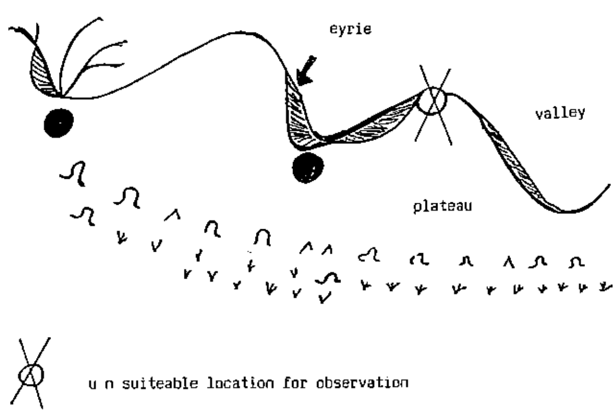

Fig. 1: Disturbance due to protection. Influence of direct nest control : possible stress on breeding pair (comp.: JUNGIUS and HIRSCH 1979)

A Habitat Key for the Regristation and Classification of Peregrine Falcon Habitats.

The habitat key presented here (comp. BLANA 1975) is the result of several years of investigations (1970–1978) (VOGT 1978 a,b, in print) at 20 peregrine falcon nesting sites, 4 of which are still active today; 144 cliffs or quarries in their vicinity (within the radius of 5–6 km) in Rhineland–Palatinate, Hessen and the adjoining areas have been studied as well.

Special thanks for financial support and the furnishing of map–material to the Ministry of Agriculture, Vineculture and Environmental Protection as well as to the Governmental Station for the Protection of Birds of Hessen, Rhineland – Palatinate and the Saarland and to Dr. Hemmer(Johannes–Gutenberg University, Mainz) for the many years of intense care for the investigations and – on behalf of the many sources and people who helped with the search of eyrie sites and data – to Dr. von ESCHWEGE, GIESSLER, ROCKENBAUER, SCHARBERT, SCHULER, SINGER and VOLKENING.

The habitat key ("habitat" is used here according to the definition of BERNDT & WINKEL 1976) has been developed by comparing structural charasteristics of optimal and inferior peregrine falcon habitats (described in detail in VOGT 1978a, in print). Its purpose is to enable nature conservation authorities and people engaged in landscape management to find out from a multitude of possible peregrine habitats the optimal and best and worth protecting and thus put those people into the position to initiate landscape management and habitat protection measures (VOGT 1987b, in print).

Such landscape protecting measures become all the more important (comp. RATCLIFF in CHANCELLOR 1977, p. 415) the more successful the present efforts for the protection and reproduction of peregrine falcons have been. A growing population engenders growing pressure of population. This leads the peregrine falcon to accept habitats which are under–optimal, and consequently offer bad surviving conditions (comp. BERNDT & WINKEL 1976, GEILER 1968). Insofar wildlife conservation measures might at first be assumed as successful but will remain without success if there is not enough quality biotope at their disposition. The most urgent tasks for a successful protection of peregrin falcons for the years to come will therefore be:the registration, conservation and improvement of the habitat offered. The allotment of the different scores and resulting weighting of the individual characteristics of the individual structures among each other is effected on the basis of the evaluation pattern which has been worked out already (VOGT 1987a, in print) and constitutes one of many conceivable and possible score systems. Hence it follows that the habitat key – for enlarged habitat key comp. VOGT 1984 –introduced here in this outline can only be considered as an aid for the field worker and should be repeatedly revised to take in account new knowledge and insights.

The following should be added to Addition No. 1 of the habitat key:

1. Structural characteristics given in the form "habitat key" are to be compared with the structural charasteristic of the habitat in question. Note thoroughly the score of each applicable charasteristic in the little square on the left margin of the form.
2. Work down all points in the established order for the following reason: if in section 2 a score above 20 is aready attained (an optimal habitat only scores 8), it appears only sensible not to continue working at the following, very labour–intensive passage No. 3 the habitat being in any case one of the least valuable ones and therefore not worthwhile protecting.
3. Add up all scores.
4. Judge the habitat in question on the basis of the following facts:
   Optimal habitat : 11 scores
   Inferior habitat: 36 scores

The score attainable ranges between 11 and 36 points (polar variation). The closer the attained score draws to 11 the "better" is the habitat in question it is therefore more sensible and economical to protect such an habitat. The closer the score gets to 36 points the less sensible such a habitat protection does appear. All habitats scoring above 25 should be ruled out from all protection considerations anyway.

According to the draft for the establishment of connections between the biotopes area A has priority to area B : (direct contact of the peregrine falcon habitats with protected area, in which potential-prey animals are to be found just as in the peregrine falcon habitats). Within area A nesting sites 1 and 3 have the priority. The draft appears – comp.: KNUTZEN and FIUCZYNSKI (1986). Applicable also to the white–tailed eagle and the hobby as well as to the goshawk (VOGT 1987).

Thanks to their varied requirements to the size of their living space the white–tailed eagle, hobby and peregrine falcon serve as good "models" for the clearing up of possibilities and limits to the

Addition No. 1

Habitat key

Registration of Landscape

```
1.        Preliminary works
1.1.      Procurement of a topographical map 1:25 000
          Number of map ................................
1.2.      Marking of the nesting eyrie on the map
1.3.      Drawing a circle (radius 5,5 km) around the eyrie
1.4.      Source
          Name .........................................
          Address ......................................
          ..............................................
          Last activity at the eyrie : 19...............
          ..............................................
          ..............................................
1.5.      Literary references
          Place of quotation ...........................
          ..............................................
          Last activity at the eyrie : 19...............
          ..............................................
          ..............................................
1.6.      Assignment of the eyrie to a group of eyries :
          A = still active after 1970
          B = given up between 1965 and 1970
          C = given up before 1965

2.        Structure of the Habitat
2.1.      Cliff – quarry – buildings
                 1 = free-standing
                 3 = not free-standing
2.1.1.    Height
                 1 = > 100m
                 3 = < 100m
2.1.2.    Width
                 1 = > 300m
                 3 = < 300m
2.2.      Distance from cliff – next stretch of water
                 1 =    0 –  125m
                 2 =  125 –  250m
                 3 =  500 – 1200m
                 4 =       > 1200m
2.3.      Width of water
                 1 = > 20  – < 100m (river)
                 2 = >  5  – <  15m (large stream/small river)
                 3 = >  0  – <   5m (rivulet/small stream)
                 4 =            100m (very large river)
2.4.      Shape of facing slope
                 1 = slope opposite less steep than the nesting slope
                 2 = slope opposite same steepness as nesting slope
                 3 = slope opposite steeper than nesting slope
2.5.      Nesting cliff
                 1 = hardly any vegetation, occasional trees and bushes
                 2 = covered with vegetation
2.6.      Ground vegetation of opposite slope
                 1 = pastureland, farmland, vineyards or built-up
                     area opposite nesting slope
                 2 = oppsite slope overgrown, exclusively forests,
                     no pastureland, no farmland, vineyards nor built-up
                     areas

3.        Ground Vegetation of the Habitat in Area Percentage
3.0.      Preliminary works
3.0.1.    Drawing of a raster screen of 2 cm per edge into a circle
          around the eyrie on the topographical map.
3.0.2.    Assignment of 16 area units to every raster square
3.0.3.    Counting and noting down the area portions (%)
          Forest .......................................
          open country (pastureland, farmland, vineyards ) .
          ..............................................
          built-up area ................................
3.1.      Portion of forest (%) in the habitat
                 1 =   65 – 80%
                 2 =   45 – 65%
                 3 =   25 – 45%
                 4 =      < 25%
3.2.      Open country (%) in the habitat
                 1 =   20 – 35%
                 2 =   35 – 45%
                 3 =   45 – 60%
                 4 =   >60% ,< 20%
3.3.      Built-up area (%) in the habitat
                 1 =    0 –  5%
                 2 =    5 – 10%
                 3 =   10 – 15%
                 4 =       >15%
```

Addition No. 2

Improving the structure of the habitat

If at points 2.5.–3.3. the scores differed from 1, landscape management measures for the improvement of the habitat should be started. These measures become increasingly difficult and expensive from points 2.5. to 3.3. on.

```
2.5.  Freeing the eyrie site of too much vegetation
      (comp. KLEIN–STAUBER 1936).
2.6.  Freeing of the slope opposite eyrie site of too much vegetation.
      Open landscape has to be created by the promotion of meadows
      and pastural agriculture and scattered orchards.
3.1.  Fostering of a recultivation in the whole habitat by keeping
      about 20% of open landscape, however.
```

If the score is above 2 at the points 3.1. and 3.3. a new habitat should be looked for because landscape management measures for an improvement would be too expensive and costly.

```
Landscape management measures:...........................
.........................................................
.........................................................
executed, date:
Revised calculation of the score, executed, date:........
.........................................................
old score..........................new score.............
Name of person in charge of this work....................
.........................................................
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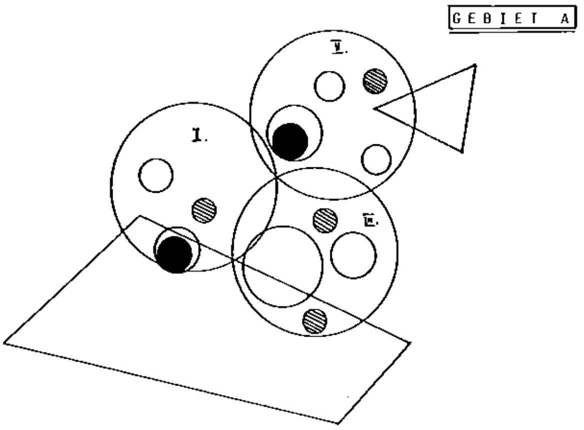

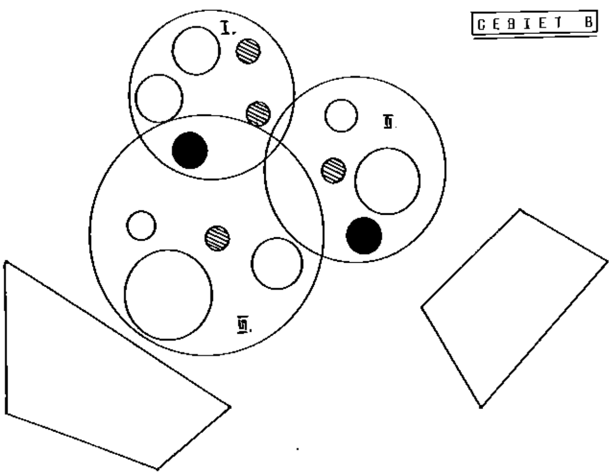

establishment of connections between the biotopes for raptors in general.

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THE INFLUENCE OF EEC–AGRICULTURAL POLICY ON THE CONDITIONS FOR DEVELOPMENT OF BIOTOPE STRUCTURES IN RURAL LANDSCAPES – SOME DANISH EXPERIENCES.

J. Brandt and P. Agger

The agricultural policy within the Common Market has until now been based on prize– and purchase–garanties for the existing but steady increased production. The agricultural fonds amounted last year to 65% of the whole EEC budget and 96% of these agricultural fonds were used for the prize– and market arrangements. Only 4% has until now been used for structural purposes. This has not only created the wellknown problems of overproduction and huge and expensive stocks of agricultural products. It also means, that the necessary change of production amount and composition has been postponed through many years. The forthcoming surely rather drastical changes in the agricultural sectoris therefore not only a challenge to the traditional agricultural policy, it is also a challenge for our future work as landscape ecologists and landscape planners. How will this development affect the agricultural landscape? In Denmark, the conflict between the agricultural sector and the increased environmental pressure has become extremly critical, for various reasons, which has to be added to the problem of overproduction:

1. The general trends of concentration and specialization within the agriculture has accelerated since the 60ties. The average farm size has doubled from 15 to 30 ha. Today the former dominant mixed farming makes up only a quarter of the holdings. The changes in the biotope structure is continuing, too, as seen on Fig. 1 (for further details, see AGGER & BRANDT 1987):

Fig. 1: Rates of changes (% per year) of small biotopes (linear biotopes and patch biotopes greater than 10 square meters and lesser than 2 ha) in Eastern part of Denmark (average for 5 field study areas of total 20 square kilometer):

	1954–68	1968–81	1981–86
Line biotopes	–0.6	–2.3	–0.5
Patch biotopes	–0.5	–0.8	–0.2
below here:			
– wet patch biotopes	–1.0	–2.5	–2.0
– barrows	–0.4	–1.0	–0.0
– thickets *	+0.7	+0.3	+0.3
– other patch-biotopes	.	.	+6.7
*including solitary trees			

Allthough the general rate of removal of both line–formed and patch biotopes has slown down in the 80ties, this hides some very different trends for the different biotope types. Especially small lakes and ponds are still very threatend. As a new tendence, the group "Other patch–biotopes", comprizing first of all small given–up areas, is growing rapidly.

2. The agricultural intensification has let to serious pollution problems, too. First of all through an alarming situation for the freshwater resources and the sea around Denmark, resulting in a wide–spread fish–death during the last autumns. This almost led to a cabinet crises for our government this spring, where a bill was passed for lowering the pollution of the Danish seas, the most expensive antipollution program ever made in Denmark (to an equivalent of 400 US Dollars per inhabitant over the next 5 years). The agriculture was definetely seen as the big bad wolf in this case.

3. In the same period a growing pressure for planning of the open land for water supply, forestry, recreational use, nature conservation etc. has developed. Facing tendencies of declining agricultural prices and agricultural reconstruction within the Common Market, these interests has been coordinated within the Ministry of Environment as a general attack on the agricultural sector, traditionally the strongest, most well–organized and efficient economic lobby within the Danish society. In fact, up till now the socalled 'agricultural planning' in Denmark has almost exclusively been a question of keeping the open land free from any non–agricultural interference. The normal procedures for areal planning, f.ex. setting up binding land use plans for local areas, are in danish agricultural areas simply forbidden. But facing the agricultural and environmental problems; what is the tendencies, and what to do? In an official preliminary report from 1985 the futural marginalization of agricultural land has been estimated up to 15% of the total national territory. A comprehensive research programme involving more than 40 research groups from different institutions has been carried out last year as basis for formation of a policy on the socalled 'marginal soils' which has been discussed in the parliament in spring 1987. Our study–group has been responsible for the investigation of the tendencies of land use in the Weichel moraine landscape, forming 2/3 of the Danish territory, and responsible of giving proposal for a management for the marginal soils in these areas. This could partly be based on our investigations on the development of small biotopes carried out since 1978, see AGGER & BRANDT (1984), AGGER & JENSEN (1984), BRANDT (1986), BIOTOP-GRUPPEN (1986). Comparing our surveys in 1981 with 1986 we could in fact record clear tendencies of abandoning agricultural land in areas, where it was not seen 5 years earlier, as seen on fig. 1. Dispite these tendencies the decline of especially wet biotopes are still going on. But in fact two different directions of changes can be seen: Areas with poorer agricultural conditions might be more stabiliezed, concerning biotope structure, due to the general low pressure on the land use and due to growing environmental protection and recreational use. Areas with better agricultural conditions seems however to show a continued – and maybe strengthend – intensification of land use with the result of continued reduction of the number and areas of small biotopes. This has been studied especially in the surroundings of greater Copenhagen:

In the rather sandy and hilly landscape north of Copenhagen – traditionally the social upper class residential areas – we can see clear tendencies of more extensive land use. Small plantations are made, and former areas within the rotation are used for grazing sheep and horses. And within the rotational areas the character of the rural landscape is stabilized: Almost no reduction in the amount and composition of the biotope structure is to be seen during the last years. A growing part of the farmers has to be characterised as spare–time–farmers, with other priorities and economic possibilities than full–time farmers. In the hinterland of Kge Bugt south of Copenhagen on the flat and loamy ground morains, some of the best soils in Denmark – where a row of new working class residential areas has been situated – the tendencies quiet opposite: Here no signs of spontaneous marginalization can be seen. On the contrary. The intensification goes further on. The majority of the agricultural land is cultivated by full–time–farmers. The amalgamation of production units goes on as well as the reduction of the biotopes. This happens in a region with a growing need for recreational areas. This diversion of developmental tendencies calls obviously for different recommendations concerning management strategies: In the areas with spontaneous marginalization the biotope structure can mostly be preserved through voluntary arrangements:

The main problem is the accessibility for the public due to private ownership. Allthough only a very minor part of the biotopes in the agricultural landscape from a biological point of view need to be protected against the public, it has nevertheless been used as a general argument to prevent increased rights on public accessibility to the open land. In the areas with good agricultural conditions more strict regulations seems to be needed:

Expropriative conservation can be used, but are extremely expensive, and are practically only used in areas of special natural or cultural interests, and such areas are seldom concentrated on the good agricultural land. The most important single mean of regulation is here the so called paragraph 43 in the nature conservation act, which states that changes in the beds of open watercourses, of lakes, bogs, moors, heaths, salt meadows and salt marshes of certain size shall be subject to the permission of the nature conservation authorities. Since 1972 the range of biotope types covered by this paragraph has been widened several times and the minimum size has been lowered, see KOESTER (1984). Today the paragraph comprizes the following types and minimum sizes, as shown in the first coloum of Fig. 2:

Fig. 2. Existing, recommended and governmental sugested minimum sizes in square meters for paragraph 43-areas in Denmark.
(): The percentage (of number (or lengh) of biotopes within the given group) that estimated would be covered by the recommended regulation.

	Existing	Recommended	Proposed
Lakes and ponds	500	100 (65%)	250
Bogs	5000	500 (80%)	4000
Meadows and commons	0	10000 (80%)	0
Woodlots	0	500 (65%)	0
Headgerows and dikes from before year 1900	0	All (50%)	0
Bufferzones around certain watercourses (meters)	0	10 (7)	6

Our recommondations, shown in the middle coloum was generally to lower the limits to secure the regulation of at least half of the existing biotopes. As a result of the debate in the parliament the government has suggested once again to reduce the minimum size of small lakes and ponds as shown in the right coloumn, and a majority in the Parliament (outside the Government) has suggested an even more radical reduction. Also the problem concerning connectivity has been taken up and supported by the majority in the parliament. A bufferzone of 2 times the bottom width on each side of the smaller watercourses is suggested, along with 6 m. broad bufferzones around all other biotopes protected by paragraph 43. Pesticide–free zones along hedges are discussed, too. In order to maintain a minimal connectivity in the landscape our study group recommends a set of structural models, see AGGER & BRANDT (1986), AGGER et al. (1987):

A. The corridor model, that guides the planning of connections between all the more important wetlands, forests or pasture areas – primary guided by bio–ecological principles.

B. The road structure model, that gives guidance to where marginalization of fields might be given opportunity to satisfy recreational needs(guided by recreational principles).

C. The boundary model, which states, that all farm–boundaries shall carry some sort of small biotopes –guided mainly by a historical–geographical principle, but in practise, the other principles are here in some way incorporated. Now, to elucidate these models, we have to go a little into the different experiances and philosophies concerning landscape development: From the very beginning of the formation of IALE, the linkage between landscape ecology and landscape planning has been stressed. The development of landscape ecology as an interdisciplineary scientific field of work is our main purpose, but it can only be developed in interrelation with practise.But practise is not only the physical planning, say the construction of an optimal biotope structure within an agricultural landscape. This is so to say the technical side of practise. But there are also economical, juridical, political and ideological preconditions, which has to be taken into consideration, if we want to take the linkage between theory and practise serious.A general – or probably the general – practical question concerning the theme 'connectivity in landscape ecology' within the high industrialized countries, has to do with the consequences of agricultural development – especially the intensification through industrialization, chemification, amalgamation and specialization of farm holdings. The very engaged "hedgerow movement" within IALE has also to be seen in this context.But different experiences within the study of agricultural development migth give rize to different ideologies concerning the status of the biotope structure and the landscape management: If we look at the development of the areal structure of agricultural areas of the mid–west of the USA during the period of European settlement, the patch biotope structure can obviously be seen as remnants of the former dominant forest (see WHITNEY & SOMERLOT 1985 and SHARPE et al. 1987). The development of the Danish agricultural landscape during the same period gives quite another picture. Around year 1800 the forest area of Denmark was on its absolute minimum of 4%. The non–reclaimed areas was mostly wetlands used as pastures and peatbogs. Almost none of the existing biotopes can be seen as primary biotopes, i.e. remnants from an original natural biotope structure. This is in fact the case for most european agricultural landscapes.In Denmark, the principal structure of the cultural induced biotopes in the agricultural landscape is indeed very old. It goes back to the beginning of the last century, where a very comprehensive land reclamation (in german: Flurbereinigung) was forced through all over Denmark within very few years. It was a real landscape revolution, which basically formed– designed – our present agricultural landscape for almost 200 years ago.The removal of small biotopes since the 50ties has been most comprehensive within the farms. So, in Eastern Denmark, some 80% of the remaining small biotopes are related to farm boundaries, of which a significant part goes back to the time of the big land reclamation. In the present context two points concerning practice should be stressed upon:

1. Aiming at maintenance and improvement of the living conditions for wild plants and animals – and human beings – in the

agricultural landscape cannot be separated from the general trends within the agricultural development. It has to be seen not as a supplementary, but as an integrated part of the planned and unplanned agricultural development.

2. Since the biotope structure has to be seen as an antropogenious structure, its management cannot and should not only be based on landscape ecological principles. Historical functional non-agricultural (e.g. recreational) and esthetical viewpoints might be of much more importance in the political proces, see BRANDT (1987). The philosophy behind the three models can be formulated in this way: Sience is normally a well reputated argument. But we might produce confusion if we to much stress upon the narrow bio-ecological arguments, wich probably will come out of our focusing on the problems of connectivity. In fact, a lot of other tendencies and interests concerning connectivity goes in the same direction. And these should not be underestimated. Finally we have to underline the first point mensioned above: We have to admit, that this way of conservation strategy is a very defensive and dangerous way of acting. Maybe it will not work at all. Probably the hole philosophy is wrong, unless it succeeds in taking the agricultural changes, which are taking place in the intensively used parts of the agricultural landscape into consideration.With the environmental political winds blowing for the time being we might secure a formal biotope structure and a certain connectedness. But it would not fit functionally - ecologically as well as economically - into the intensive agriculture. Despite of a lot of discussions an reports on the structural problems within the agricultural sector it is most probable, that general prize- and marked regulations will continue to dominate within the Commen Marked. With falling prizes the discribed diversion will be speeded up with the result of marginalization of great areas, and further intensification of the good agricultural areas.There is a strong connexion between the general landscape ideology within the population, and the understanding and acceptance of the functions of the landscape elements. So if the trend continues, we wonder if the political popularity of the very succesfull eureopean "hedgerow movement" would not suddenly disappear, and we would be blamed for keeping a system of quite artificial and academic landscape design principles, which nobody would understand and accept.

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STUDY OF SOME CONNECTING LANDSCAPE STRUCTURES AND THEIR RECENT EVOLUTION IN THE BASIN OF MONTMEYAN (PROVENCE, FRANCE).

G. LARNOE

1. INTRODUCTION

Starting from the late nineteenth century, the country-side of the Provence was, and still is, the scene of many important agrarian transformations and related socio-economical changes as never before. This process exerts pressure on several landscape elements that build up the structural identity of the area, and also affects the social livability of the village communities.

In this context, a study has been carried out in the Basin of Montmyan (department of the Var). Especially the former item (landscape structure) is focused in this article. For a detailed analysis of the socio-economical aspects, the reader is referred to LARNOE (1987).

2. AIMS OF THE STUDY

It is possible to distinguish three specific aims:

- the detection and construction of the "traditional landscape structure" (different habital networks).
- the study of the evolution of the agrarian structures during the last forty years (1944-1983).
- the analysis of the impact of this recent evolution upon the landscape patrimony.

3. LOCATION OF THE STUDY AREA

The Basin of Montmyan (department of the Var) is situated in the north of the "Basse-Provence calcaire", which is characterized by a succession of ridges and plateaus of Secondary rocks (limestone), separated by Tertiary basins (clay, marl, sandstone). Nearest regional centres are Aix (50 km), Manosque (30 km), Castellane (35 km), Draguignan (40 km) and St-Maximin (25 km) (fig.1). Due to this isolated location, the socio-economical situation in the study area depends almost completely on agriculture.

Fig. 2 shows the different agrarian regions of the Provence. The Basin of Montmyan lies peripheral to the "core region" of two agrarian zones: the "Montagne de Haute Provence" and the "Coteaux de Provence". The former is characterized by large exploitations (› 50 ha), sheep-rearing and the production of fodder-plants; the latter is an area with small exploitations (‹ 5 ha) and a monoculture of vineyards.

4. METHODOLOGY

The applied methodology - tripartite - is a combination of a number of techniques in regional geography and landscape science. As a first step a chorological land classification (synthetic-parametric approach) was made, based upon lithology and average slope.

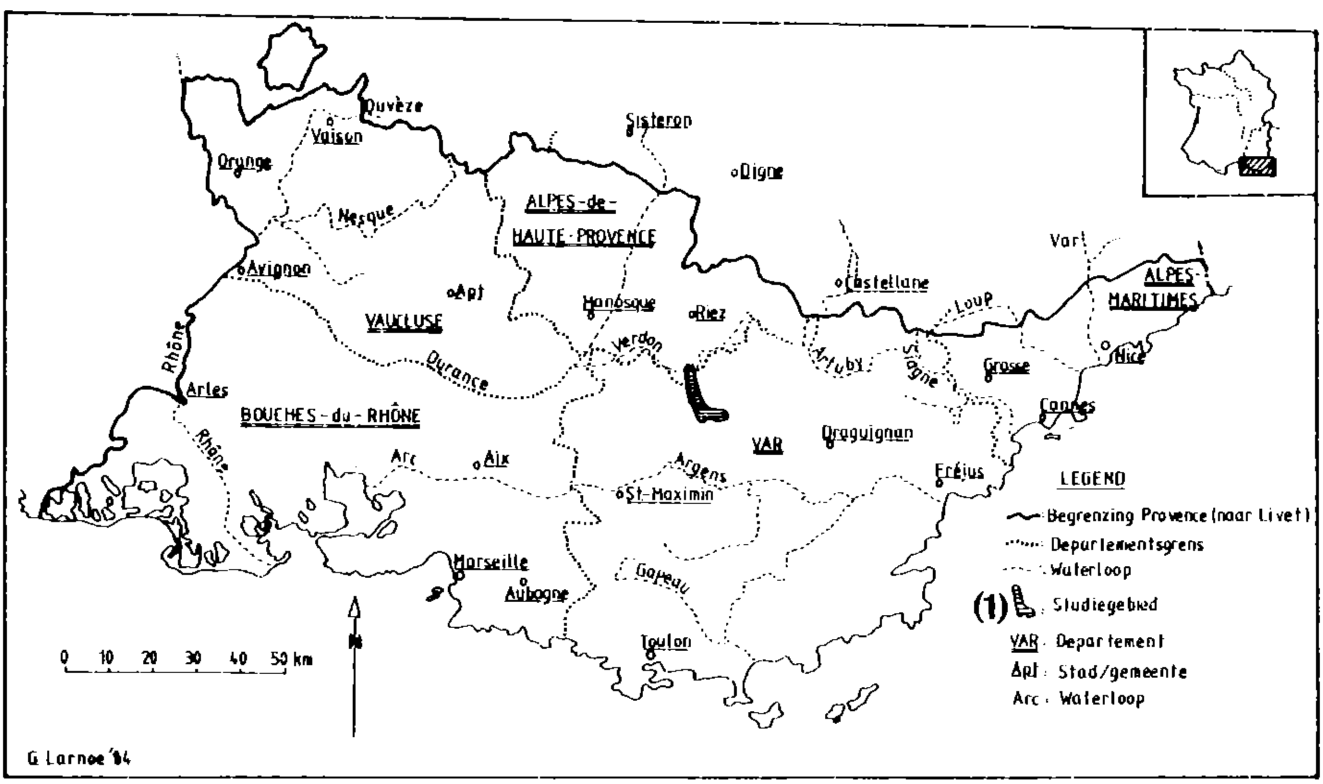

Fig. 1: Location of the Basin of Montméyan in the Provence (1) : Study area

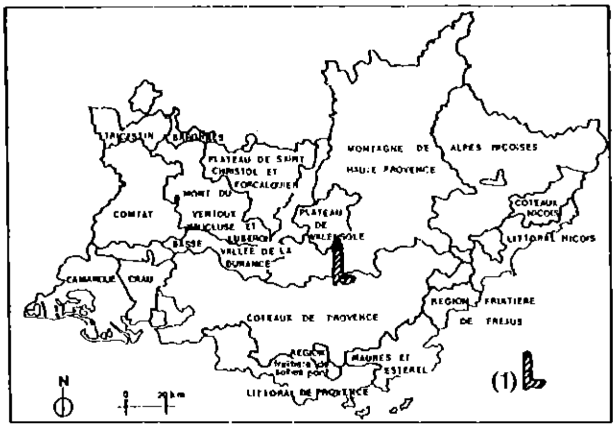

Fig. 2: Agrarian regions of the Provence
(1) : Study area
Source: M.C. AMOURETTI et al. 1977, p.71 fig.34)

This provided a proper basis for a multitemporal analysis of the different landscape elements and components, by means of a supervised aerial photo interpretation (1944 – 1958 – 1979) and complementary field–work (1983). Attention was fixed on settlement patterns, land use and agrarian structures (arrangement of parcels, field system, size of agricultural exploitations, land tenure,...). Finally, it was possible to draw a chorological landscape classification map (synthetic –parametric approach), based on settlement patterns, land use and agrarian structures.

More information about the technique of land(scape) classification can be found, among others, in the articles of DAELS & ANTROP (1977) and HOWARD & MITCHELL (1980).

5. RESULTS

Fig.3 gives an overview of the typical arrangement of patches, lines and dots within the landscape as it originated from an intimate relationship between man and nature through centuries. The following traditional "landscape units" are distinguished:

I. Terrace area

- bundle of long and narrow strips within a pattern of fragmented holdings.
- no farmstead access.
- oliveyards (& vineyards).
- typical terraces: bench terraces & irrigation terraces.
- absence of farms.

II. Village–area with traditional polyculture

- bundle of regular small blocks within a pattern of fragmented holdings.
- no farmstead access.
- small scale traditional polyculture.
- typical isolated farms: "mas".
- "cabanons" (little sheds) spread all over the fields.

III. Area with large exploitations

- bundle of regular large blocks within a pattern of compact holdings.
- farmstead access.
- specialization in cereals or vineyards.
- large exploitations (› 50 ha).
- typical isolated farms: "bastides" and "domaines".
- absence of "cabanons".

IV. Village–area with exploitations of intermediate size

- bundle of regular blocks (intermediate size) within a pattern of fragmented holdings.
- rarely farmstead access.
- combination cereals/vineyards.
- exploitations of intermediate size (10–50 ha).
- typical isolated farms: "mas" and "bastides".
- "cabanons" spread all over the fields.

The impact of economic policy concerning agriculture on the agrarian structures during the last forty years is illustrated by fig.4. Notice the decline of the small scale traditional polyculture ("mediterranean trilogy" – cereals, vines and olives): on the one side there is a transformation to wasted lands and residential zones near the villages of Montmeyan and Quinson; on the other hand big landowners switch–over, mostly to cereals sometimes to vineyards.

Finally, the consequences of this evolution for the "structural identity" of the different landscape units is also indicated on fig.3 : areas in black already lost their identity; shaded zones are under severe "stress".

6. FINAL CONCLUSIONS

The traditional polyculture, and with this certain social classes (small landowners and tenant–farmers) are suffering from the effects of the economic policy concerning agriculture (mechanization, scaling up, switch–over to cash crops,...).

Consequently some zones, especially the areas surrounding the villages and also the terraced agricultural zones on the slopes, are loosing their identity and function within the related habitat network. Those typical landscape units threaten to disappear by changing into wasted lands, residential zones (second homes) or uniformized agricultural areas.

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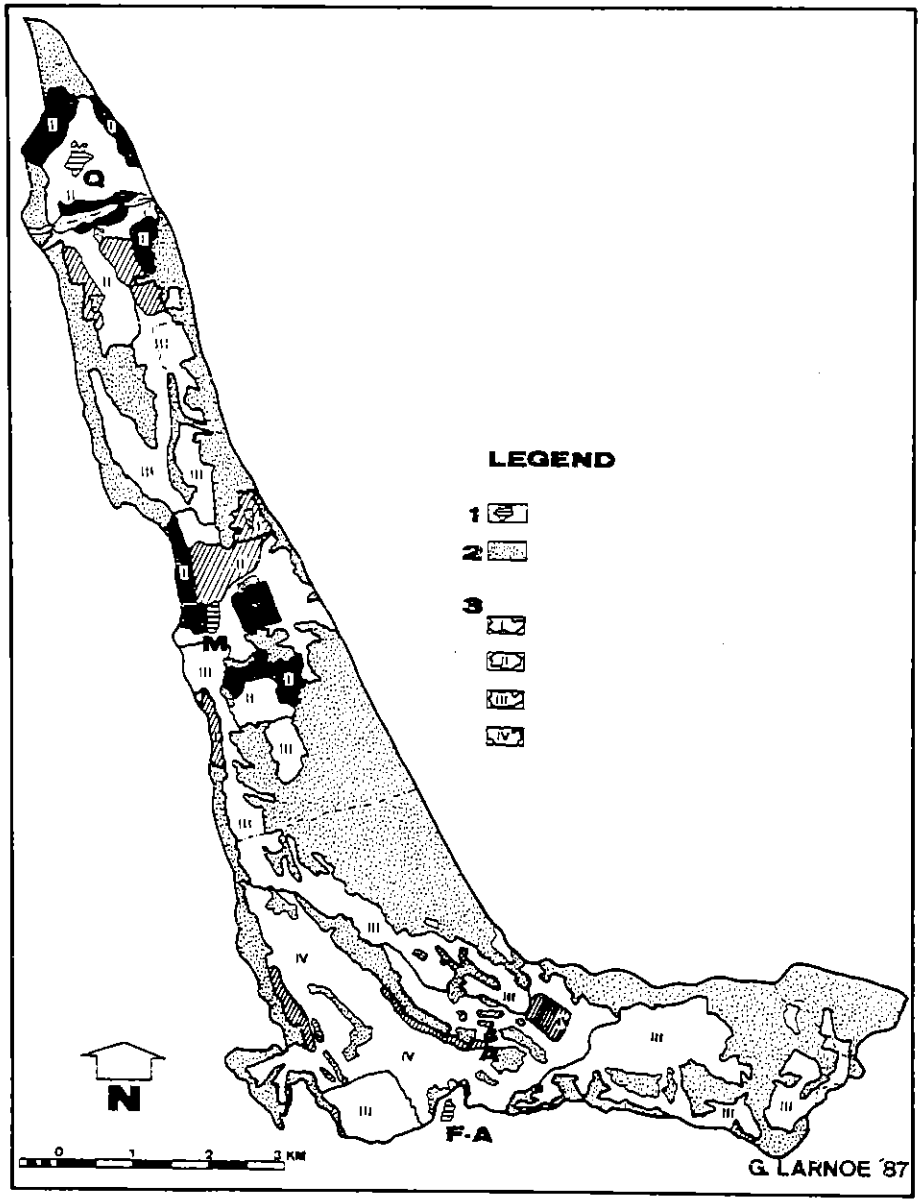

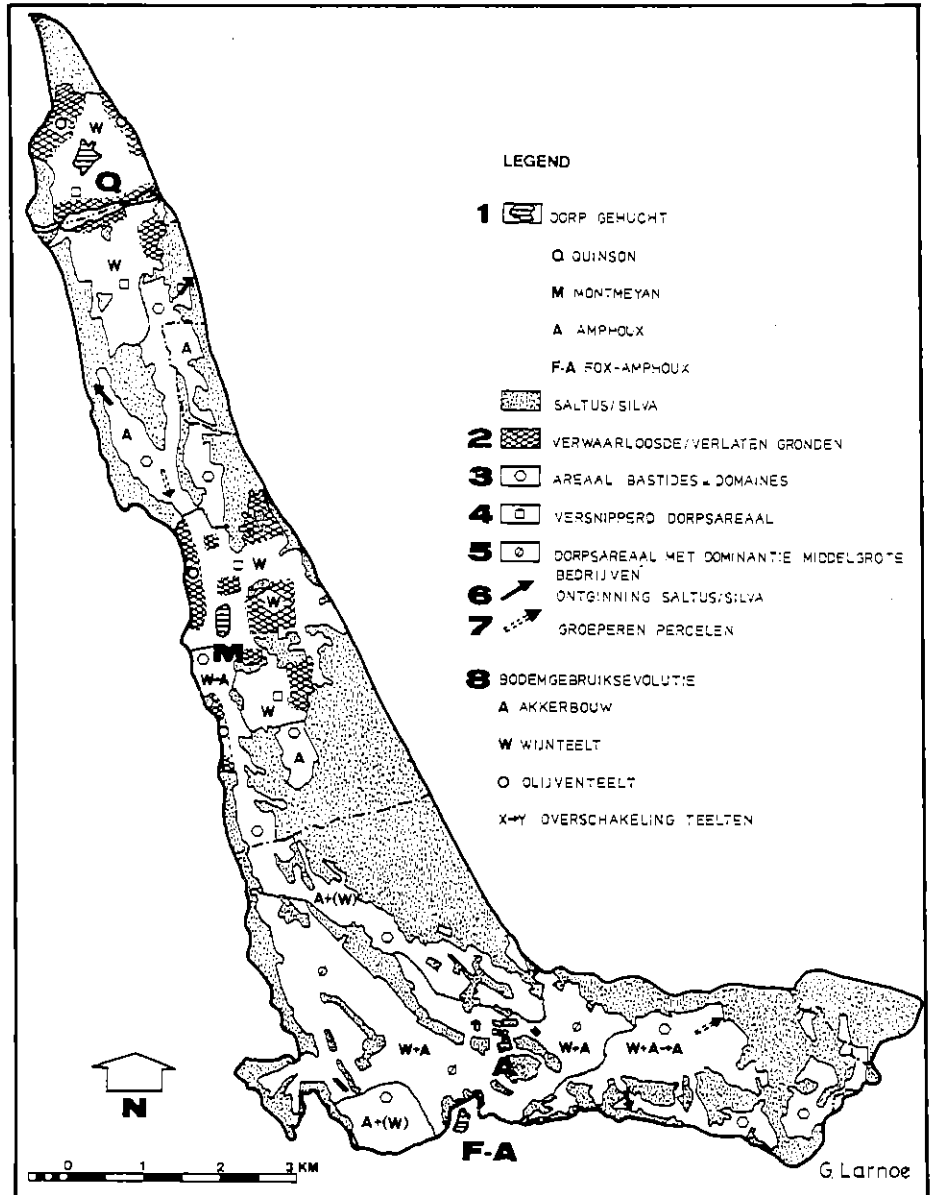

Fig. 3: Basin of Montméyan – Chorological landscape classification 1) Village/hamlet Q:Qiunson M:Montméyan A:Amphoux F–A:Fox–Amphoux 2) Saltus/silva 3) Landscape units (explanation: see text)

Fig. 4: Basin of Montméyan – Evolution of the agrarian structures(1944–1983) 1) Village/hamlet 2) Neglected/wasted lands 3) Agricultural area with large exploitations (>50ha): "bastides" and "domaines" 4) Agricultural "village–area" characterized by small exploitations (<10ha): "mas" 5) Agricultural "village–area" characterized by exploitations of intermediate size (10–50 ha) 6)Reclamation of saltus/silva 7) Compact grouping of parcels by one farmer 8) Evolution land use A:arable land (cereals) W:vineyards O:oliveyards X→Y: switch–over of cultures

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ORDER AND DISORDER IN LANDSCAPE: THE ANALYSIS OF THE TRANSFORMATION OF A SUBMEDITERRANEAN–MONTANE LANDSCAPE (1935–2035)

A. VAN DEN BERG, A.H.F. STORTELDER, W. VOS

1. Introduction

There are many definitions of landscape (e.g. ZONNEVELD 1979, TJALLINGII & DE VEER eds. 1982, NAVEH & LIEBERMAN 1984, FORMAN & GODRON 1986). Landscape is interpreted here as a region with a characteristic spatial arrangement of ecotopes. Therefore, its analysis may be understood as the assessment of order and disorder in the patterns of ecotopes at any map scale and in any stage of development.

The present study deals with the Solano Basin (ca. 10.000 ha; eastern Tuscany, Italy) (Figure 1). The order of its landscape was

Fig. 1. Location of the Solano Basin (Tuscany, Italy).

analysed by: (a) identifying the different constituent landscape units, each of them formed by recurrent patterns of ecotope types, with the divisive cluster program TWINSPAN (HILL 1979), (b) determining the most characteristic combinations of ecotopes within each landscape unit by the application of spatial mutual information analysis.

In the past 50 years, land use changed radically in the Solano Basin and the surrounding Tuscan Apennines. The population number fell by more than 50%, and the number of people working in agriculture and forestry decreased considerably more. Abandonment of land and relaxation of land use are widespread: arable fields and pastures became eroded sites, shrublands, secondary canopy forest, etc. Only locally did land use intensification occur. Erosive sites were forested, favourable sites were occupied by modern vineyards, etc. As a result, the traditional landscape gradually transformed, and may be expected to change still more in future.

These landscape transformations were studied by quantifying not only the present–day patterns of ecotopes (1985), but also those that could be reconstructed for 1935, and the situation that may be expected in 2035. The latter simulation resulted from on a simple land use scenario, based on current trends.

2. Information and landscape

Order and disorder in landscape as perceived by people serves as a source of information. In this sense, different landscapes, representing different arrangements of ecotopes, differ from each other as sources of information. In the literature, the concepts of order and disorder are associated with some degree of predictability in the occurrence of elements or events in space and/or time (e.g. PHIPPS 1984). The higher the predictability of an ecotope type as a neighbour of an other ecotope type, the larger the order in the landscape concerned: in an ordered landscape, ecotope types occur in predictable, recurrent, patterns.

In ecology, information is considered to be at its minimum when a system characteristic is completely random (e.g. KWAKERNAAK 1982, 1984); disorder or entropy is then at its maximum. This is the case if the phenomenon (here ecotope type) is everywhere or randomly distributed. Finding it at a randomly chosen place does not add to what is known, and therefore provides little information on the spatial organisation of landscape. This is also true when it is absent or occurs fortuitously. Much spatial information is provided, however, by an ecotope type that occurs in a recurrent pattern with other ecotope types. Finding it reduces the uncertainty in the occurrence of neighbouring ecotopetypes considerably.

3. Ecotope clustering procedure

According to our definition, the ecotopes within a landscape constitute 'characteristic' arrangements. This brings forward the problem how to determine the latter. We approached this problem by applying a TWINSPAN cluster analysis to the pattern of ecotopes, given by an ecotope map at scale 1:50,000 with 80 ecotope types(see VOS & STORTELDER in prep.), that was transformed into a grid data base. The grids correspond with field–dimensions of approximately 80 × 80 metres and map–dimensions at scale 1:50,000 of 1.6 × 1.6 mm.

Recurrent patterns of ecotope types, that may be found in this way, constitute larger spatial units at different levels of agglomeration. In our case, we identified landscape units and landscape systems respectively, both with a characteristic arrangement of ecotopes. The subsequent steps in the conversion of ecotopes to landscape units and landscape systems are schematically depicted in Figure 2.

With a search program applied to the grid data base, we determined which ecotope types are neighbours and how frequently this occurs. For more detail, see VOS & STORTELDER (in prep.).This procedure resulted in a relative frequency table of ecotope types (centralgrids) x ecotope types (neighbouring grids). These frequencies were subsequently corrected for the population dimensions in the other dimension of the frequency matrix too, with a method given by GUILLERM (1971). The ecotope types were clustered,

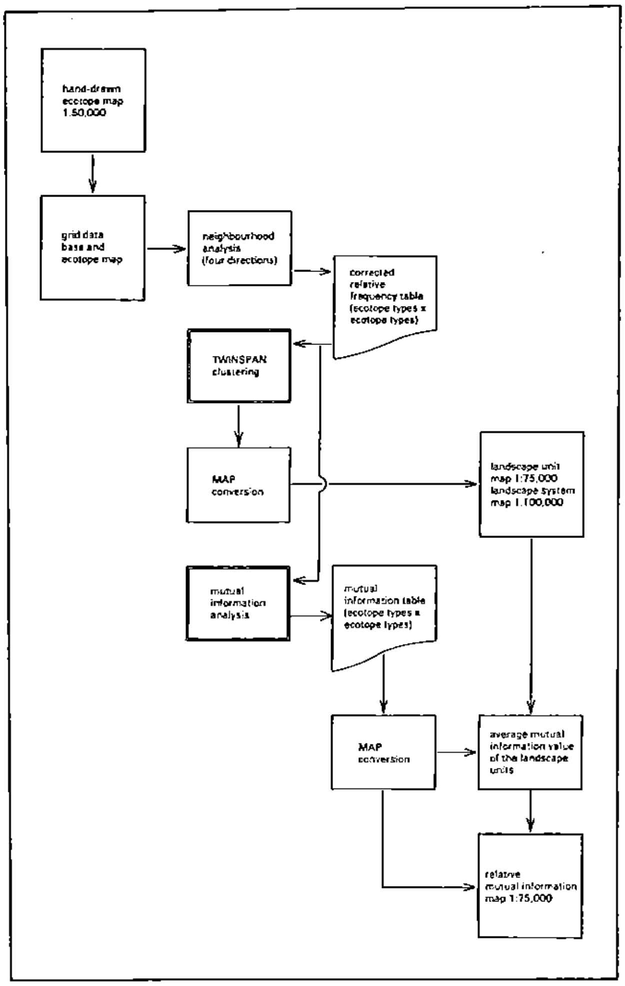
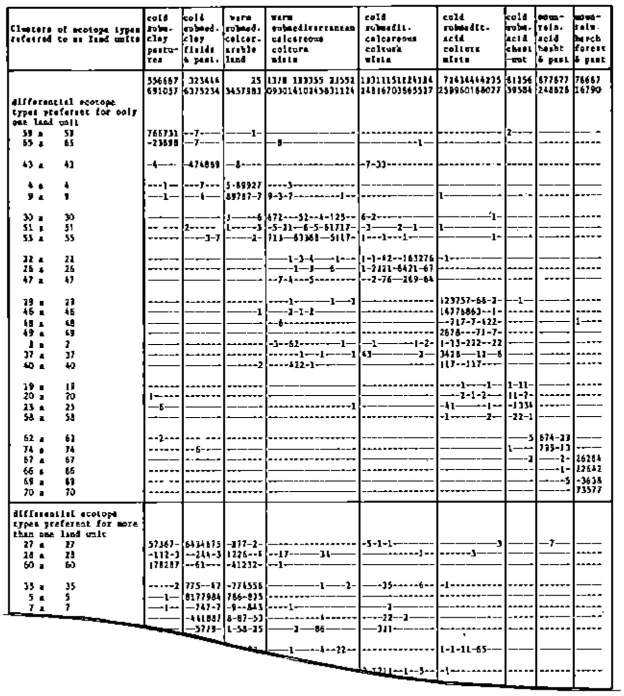


Fig. 2. Simplified procedure of the present study.



Clusters of ecotope types referred to as land units	cold submed. clay pastures	cold submed. clay fields & past.	warm submed. calcar. arable land	warm submediterranean calcareous coltura mista	cold submedit. calcareous coltura mista	cold submedit. acid coltura mista	cold subm. acid chestnut	mountain. acid heath & past	mountain. beech forest & past
	556667 691057	323444 6375234	25 3457883	[illegible]	[illegible]	[illegible]	61356 39584	677677 248878	76667 16790
differential ecotope types preferent for only one land unit									
53 a 53	766731	--7----	-----1-				2---		
65 a 65	-23698	--7----		---8---	---------1-				
43 a 43	-4----	-474859	--8----		-7-33----				
4 a 4	---1---	---7---	5-89927	----3----					
9 a 9	---1---	---4---	89787-7	9-3-7--------1--		1------			

Fig. 3. Part of the ordered two-way table of ecotope types (central ecotope types (neighbouring grids), made with TWINSPAN.

using the neighbouring ecotope types as attributes and their corrected relative frequencies as 'weights'. The TWINSPAN-output is a two-way table of central ecotope types against neighbouring ecotope types (Figure 3), that proved to be very important for the identification of the combination of ecotope types forming landscape units. Upon closer observation of the rows of the table, it appears that some ecotope types, (so-called exclusively differentiating ecotope types)occur more or less exclusively within one landscape unit (with more than 50% of the ecotope types of that land unit as neighbour and with less than 25% of the ecotope types of another given land unit as neighbour). Other ecotope types occur nearly exclusively in two or three landscape units. A combination of just these two categories provides a rather 'complete' pattern of land units. Some land units appear to be defined very well by these relatively exclusive ecotope types while others are less so, displaying more disorder. Land systems were identifiedand mapped in the same way as land units, although at higher levels of aggregation.

4. Mutual information assessment

Information as defined in information theory by SHANNON & WEAVER (1949), refers to the amount of uncertainty in an event that is reduced by an observation. The information obtained, is assumed to equal the negative logarithm of the probability of the occurrence of that event or phenomenon, here an ecotope type. Mutual information, negentropy or redundancy, may be defined as the overlap of the information contents of phenomena with respect to each other. Spatial mutual information refers here to the mutual information of spatial units (ecotopes) within an area. In that case the uncertainty of the occurrence of a given ecotope type will be reduced by finding a 'message' from it, in this case a neighbouring ecotope type with redundant information. Mutual information analysis has been applied to the relationships between plant species and their site factors by GODRON (1968), GUILLERM (1971), LEPART & DEBUSSCHE (1980), KWAKERNAAK (1982, 1984). Mutual information theory has been discussed fundamentally by ABRAMSON (1963).

The level of order of the landscape units and the contribution of separate ecotopes to it, were assessed by applying the mutual information concept to the spatial arrangement of the ecotopes.

The data were generated by applying search programs from MAP to the grid data base: our samples are grids with a particular ecotope type, that have neighbouring grids with the same or other ecotope types. Mutual information values of the ecotope types were computed as indicated by GUILLERM (1971) (compare KWAKERNAAK 1982, 1984, VOS & STORTELDER in prep.).

The possibility that ecotope types with high mutual information values are part of any characteristic arrangement of ecotopes, is large compared to ecotope types with low mutual information values. In this sense, land units and ecotope arrangements within them, may display different levels of order. This was traced in the following way.

All separate couples of one particular ecotope type E with its neighbouring ecotope type S contribute to the mutual information value of that ecotope type E. In fact, the mutual information value is a summation of a number of so-called 'partial' information values. In a particular landscape, where only some of these couples occur together in a limited space, one part of the area contributes especially to some of the 'partial'information values, whereas other parts contribute to other ones. Where ecotope types with high 'partial' information values occur in recurrent combinations, the arrangement of ecotopes has a high level of order, and will surely be relatively characteristic. For each of the more than 16,000 grids we determined with a search procedure the neighbouring ecotope types in eight directions. The 'partial' information values belonging to these eight combinations were added and the average 'partial' mutual information value of the grid concerned was computed. This resulted in a relative figure, to be used only in comparisons with other grids. By averaging the obtained grid values for entire land units, the average 'partial' mutual information values of these larger units was also determined. In our opinion, the figures give a good indication of the relative levels and order of the different land units within the Solano Basin.

Finally, the contributions of the separate ecotopes to these average 'partial' mutual information values of the land units were determined by computing their ratios. These ratios were subdivided into five classes and visualized with MAP (Figure 4). The resulting map gives some insight in those parts of the land units that have more characteristic arrangements of ecotopes, or higher levels of order, than others.

5. Changing landscapes

Changes in land use have schematically been depicted in Figure 5. For the reconstruction of the land units at a time about 50 years ago, information was gathered by panchromatic aerial photographs, old

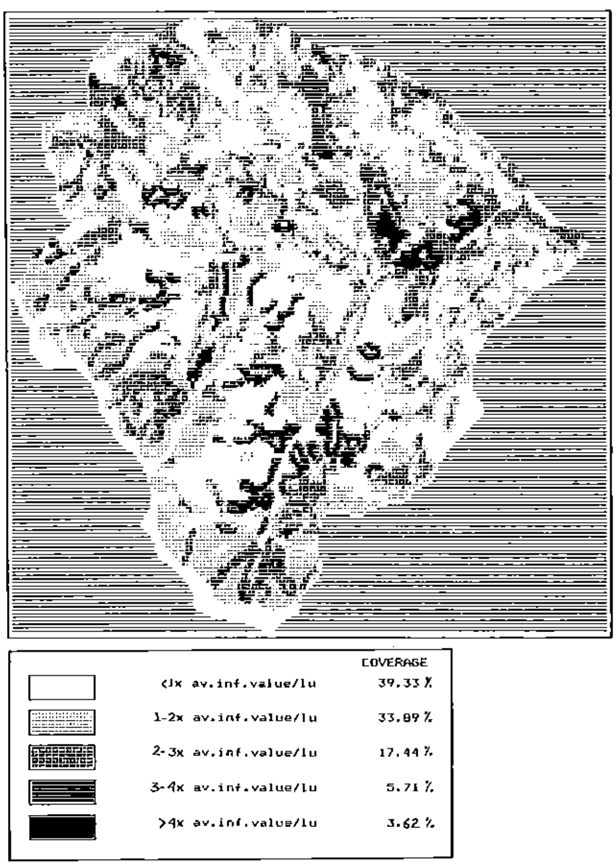


Fig. 4. Ecotope information values (relative 'partial' mutual information values of the ecotopes, displaying levels of order and charactericity within the land units).

topograhical maps, present–day field indications of former land use, and inquiries among farmers and forest managers. In addition historical documents have been studied. For the simulation of land units 50 years in the future, a scenario was formulated which was roughly based on current trends in land use transformation (Figure 6). The ecological consequences of the scenario at ecotope level, have been assessed by the use of sequential series of ecotope development (see VOS & STORTELDER in prep.). Knowing the ecotope types from 1935, and simulating those from 2035, the same procedures were followed as for the recent situation. Land units of the Solano Basin in 1935, 1985 and 2035 are shown in Figure 7.

6. Results

Main results are (a) maps of land units in 1935, 1985, 2035, and (b) a map of 'ecotope information values'. The former enable conclusions on trends in landscape transformation, the latter on the places where the most characteristic combinations of ecotopes within the different landscape units are situated. A main trend in landscape transformation, is the replacement of the fine–grained pattern of the traditional landscape by a coarse pattern. The former has a rather high diversity of ecotope types, expressing a broad spectrum mutually dependent land utilization types. The latter is dominated by production– and erosion–control forests on one hand and intensive agriculture on the other. Pastures, coppice forest for charcoal burning, sweet chestnut forest, and coltura mista on man–made terracettes, determined to a large extent the character of the Tuscan Apennine landscape. They will not continue in the traditional way and, as a consequence, some traditional Tuscan landscapes will vanish. Highly informative places are spread over the whole area. They occur especially where recurrent patterns of North– and South–facing slopes, separated by dry grassy interfluves and wet stream beds, are prominent. Other highly informative places are those where man–made terracettes with coltura mista combine in a characteristic way with both sweet chestnut fruit forests and oak coppice forests. Of all traditional landscapes, that of the high pastures is the least informative; at this moment a great part of it is in fact already replacedby shrublands that spatially hardly differentiate.

These developments appear to be highly autonomous. There are as yet no efficient plans at, variously, local, regional, national or international levels, that deal with these developments by allocating new functions and management regimes to fit in with the character of these landscapes.

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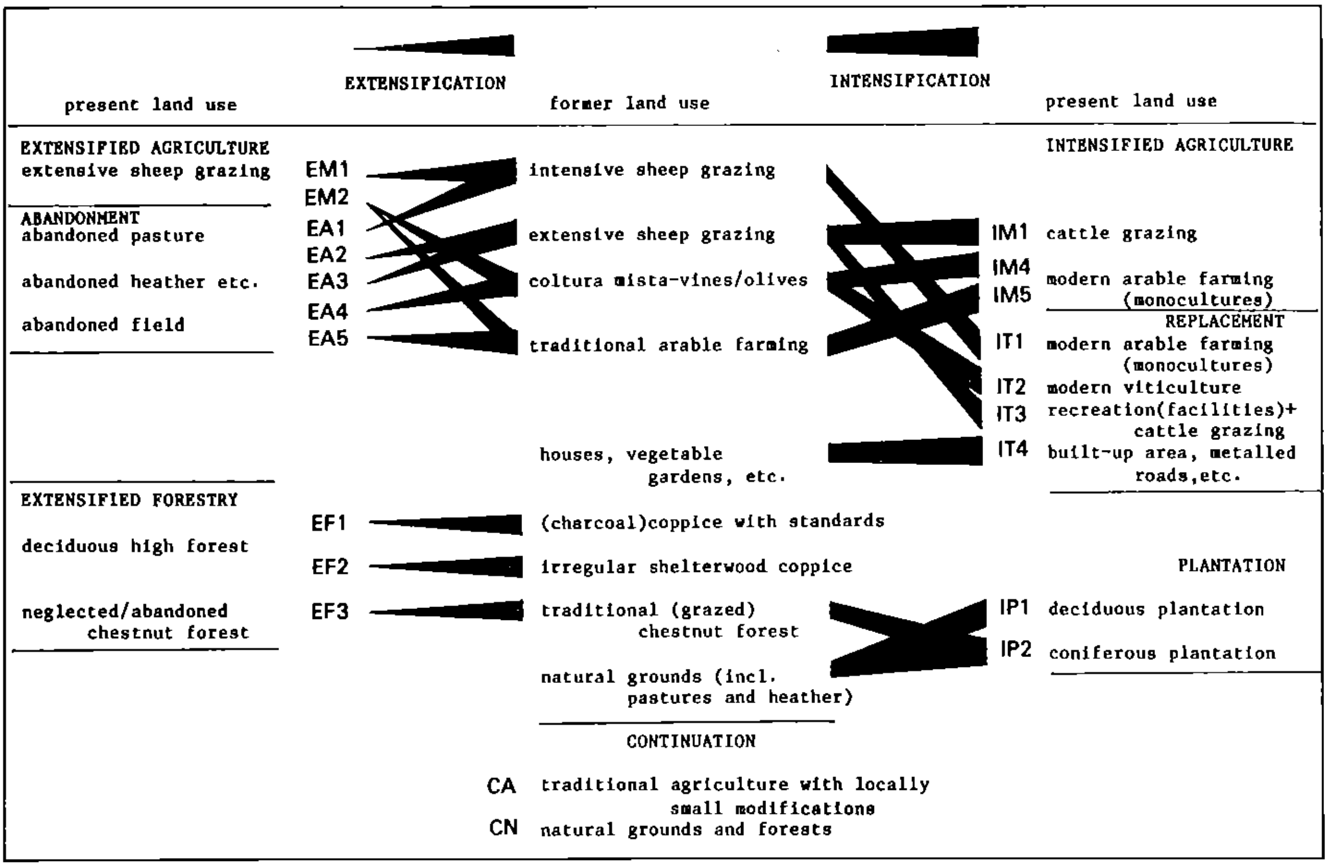

Fig. 5. Transformation of landuse 1935 – 1985 – 2035.

PRESENT LAND USE		LAND USE 2035
extensive sheep grazing cattle grazing	abandonment → secondary succession	secondary shrubland and open beech forest
abandoned heathland abandoned pastures/fields	abandonment → secondary succession	open oak forest
charcoal coppice with standards	transformation by selective felling	canopy beech forest
traditional and abandoned chestnut forests	abandonment → secondary succession	mixed deciduous forest
natural grounds (open forests)	succession	canopy oak forest
pastures and heathlands	plantation	coniferous stands
coltura mista farming on terracettes	abandonment → secondary succession	mixed deciduous forest
coltura mista farming	intensification	modern arable farming
traditional arable farming on terracettes	abandonment → secondary succession	mixed deciduous forest
traditional arable farming	intensification	} modern arable farming
modern arable farming	continuation	

BACKGROUND LAND USE TRANSFORMATION 1985 - 2035

Fig. 6. Background of land use scenario 2035.

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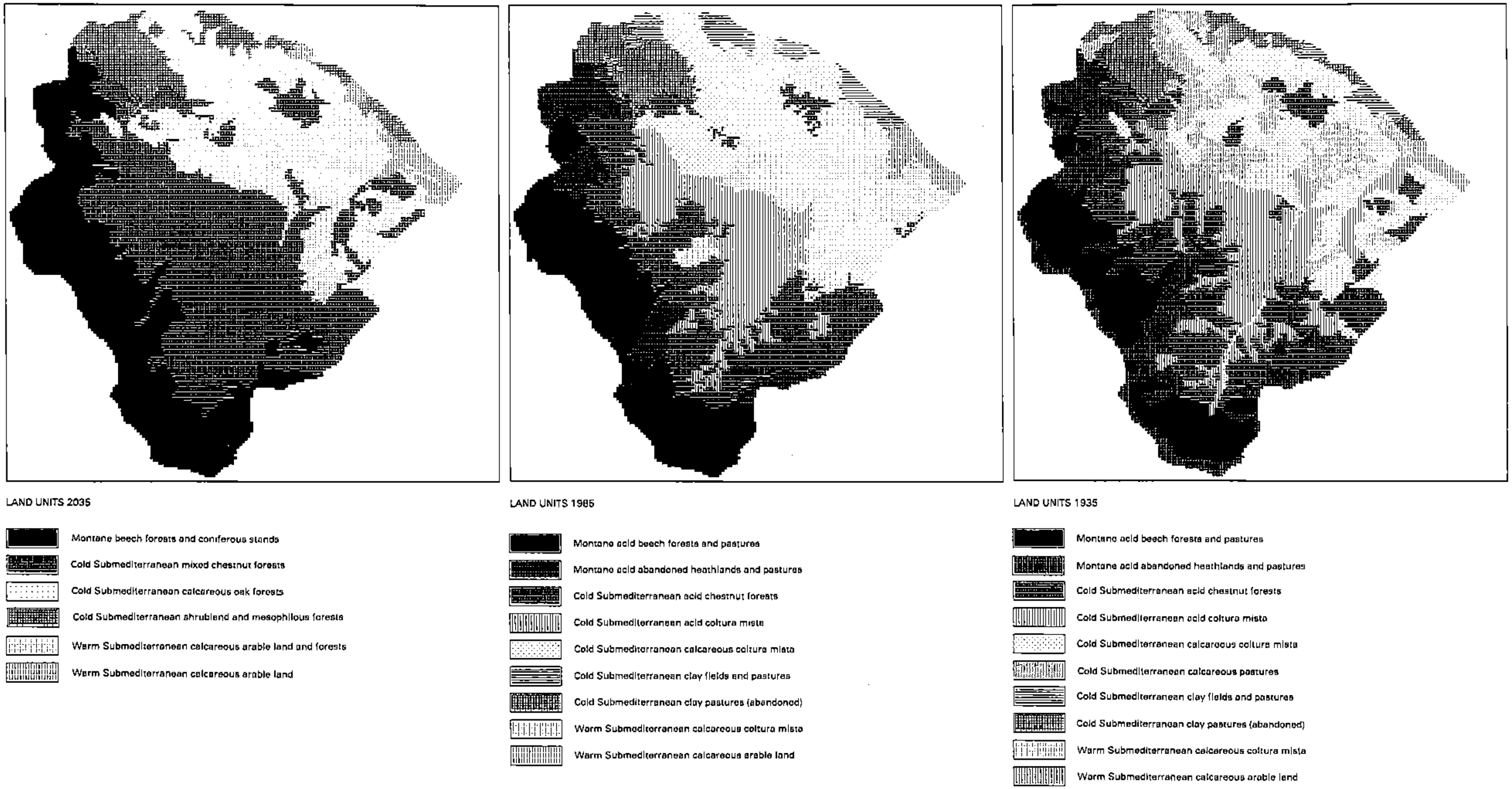

Fig. 7. Land units 1935 – 1985 – 2035.

SAHEL TRANSHUMANCE

EXAMPLE OF CONNECTIVITY OF HABITATS WITH SEASONAL CONSTRAINTS: TWO COMPLEX CONNECTED SYSTEMS IN BURKINA FASO/MALI

Description – Analysis – Consequences for land use planning

S.M.E. Groten

Transhumance is an extensive livestock production system, in which more or less regular seasonal movements are made between summer– and winterpastures. It will be described as a system, in which herdsmen live close together with the animals,

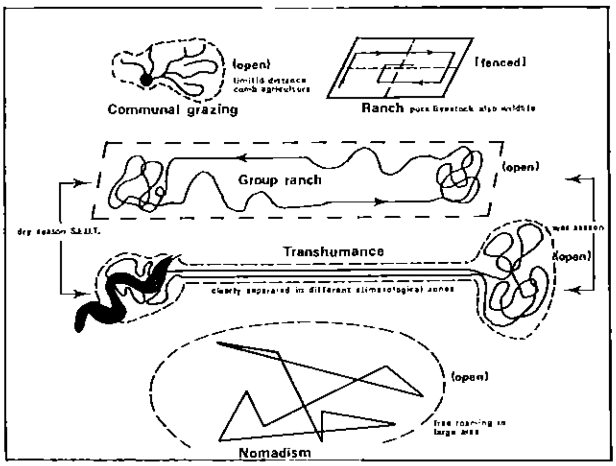

Fig. 1: Extensive grazing systems (from H.V. GILS, I.S. ZONNEVELD, W.V. WIJNGAARDEN, 1982).

and where human and animal requirements are integrated. The difference with Nomadism lies in the

- existance of a permanent settlement in one of the grazing areas
- different climatological zones: Nomadism in N–Sahel and Sahara, Transhumance in S–Sahel to S–Sudan Zone.
- Higher regularity of N – S movements due to lesser variability of rainfall. (see fig. 2)
- More integration into agricultural systems: settling of herds on farmers fields after harvest and exchange of products: millet and water against milk, manure and handicraft products.
- less vulnerability to drought spells because of better integration/ communication with high rainfall areas.

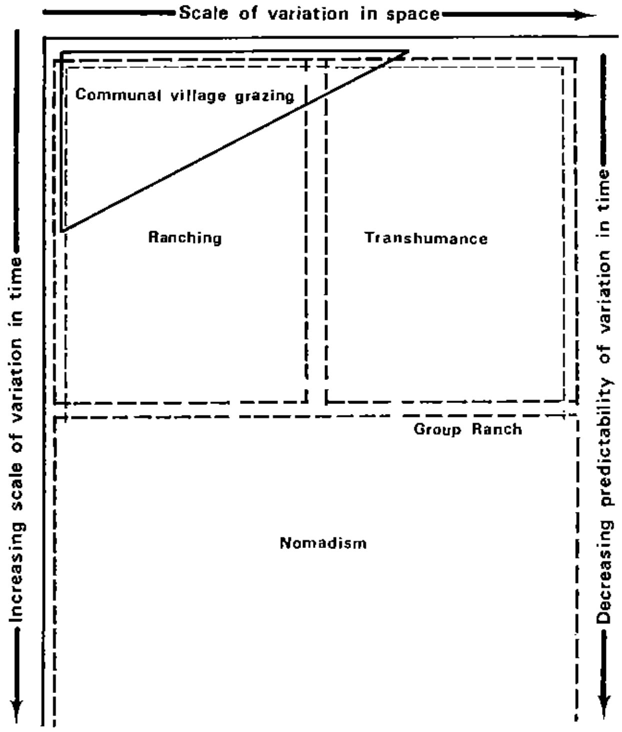

Fig. 2: Territoriality in pastoralism as dependant on variation of the environment in space and time, from I.S. ZONNEVELD (1984).

Study area + methods

The study area are the three sahelian provinces of Burkina faso with traditional wet season– and some dry season pastures, which are connected by transhumance and through nomadism to grazing areas in Mali, Southern Burkina faso, and to a lesser extent, to Niger (see fig. 3). These transhumance cycles are described in the poster.

Table 1 shows some characteristics of the transhumance, nomadic– and sedentary systems.

This presentation is mainly based on group– and individual interviews and discussions during the wet season 1986 with (agro) pastoralists on 16 sites of the study area, by a multidisciplinary

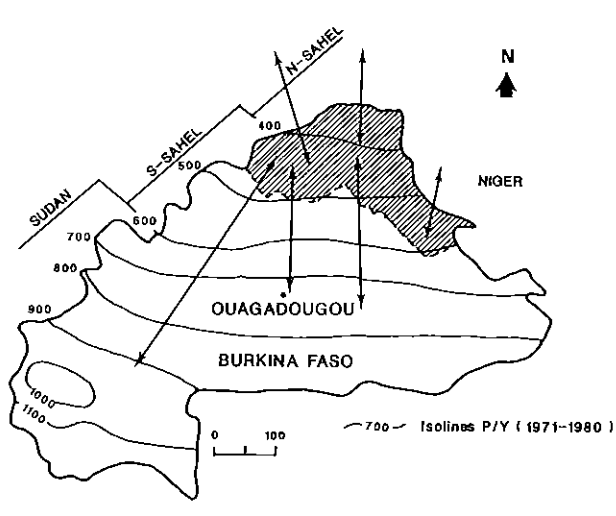

Fig. 3: The study area in northern Burkina faso, where different grazing systems are originating.

Tab. 1: Some characteristics of 2 transhumance – and related grazing systems originating form the sahelian provinces of Burkina Faso (situation in 1986).

GRAZING SYSTEM	N-SAHEL NOMADISM		NORTHERN TRANSHUMANCE (N/S Sahel)		SOUTHERN TRANSHUMANCE (S-Sahel/Sudan)		SEDENTARY SYSTEM S-Sahel	
GRAZING ZONE								
wet season	arid		arid		semi arid		semi arid	
dry season	semi arid		semi arid		sub-humid		semi arid	
RAINFALL (mm/y)	200-400		200-400		300-1200		400-600	
MAIN ETHNIC GROUPS								
Peulh (Fulani)	x		x		x		x	
Tuareg	x		x		–		–	
Bellah	?		?		?		x	
Mossi	–		–		–		x	
SPECIES COMPOSITION LIVESTOCK								
Cattle	xx		xx		xx		xx	
Sheep	x		x		x		xx	
Goats	xx		x		x		xx	
Camels	x		x		–		–	
DISTANCES COVERED	xx		xx		xx (x)		x	
CATTLE HERD SIZE	x		xx (x)		xx		x	
IMPORTANCE OF:								
Agriculture (recent)	x		x (x)		xx		xxx	
Collect. wild areals	xxx		xx		x		–	
Exchange products	(x)		xxx		xx		x	
MAIN FODDER RESOURCES	WS	DS	WS	DS	WS	DS	WS	DS
Annual Dune Pastures	xxx	–	xxx	–	xx	–	xx	–
Herb. veg. depressions	x	xxx	x	xxx	xx	x	xx	xxx
Browsing	–	xx	–	xx	–	xx	–	xx
Crop residues	–	–	–	x	–	xx	–	xx
Fodder crops	–	–	–	–	–	–	–	x
Regrowth savanna grasses	–	–	–	–	–	xx	–	–

team. The interviews were conducted systematically with the help of a checklist prepared on the basis of a set of preliminary interviews and identification of key issues.

The sites (including nomadic camps, and an illegal goldcamp), were chosen according to the criteria: agroecological stratification (on LANDSAT – MSS imagery + maps), ethnical composition of the population, degree of degradation of the area, distance from provincial capitals (far + close by), proposals of local authorities.

Exploitation of complementary land resources by transhumance:

Under the mono–modal and semi–arid rainfall regime, land resources of the Sahel show typical seasonal constraints to livestock production and human living, which can be avoided by movements to areas with better resources at that time (table 2).

Tab. 2: Factors influencing decisions on transhumance movements (Burkina Faso – Mali)

	Movement to wet season area		Movement to dry season area	
	Northern Transhumance	Southern Transhumance	Northern Transhumance	Southern Transhumance
Nat. forage availability	x	x	x	xxx
Forage quality	xxx	xx	–	–
Water	–	–	xxx	x
Avail. Crop residues	–	–	x	xx
Salt licks	x	(x)	–	–
Avoidance diseases	x	xx	x	x
Avoidance agric.area	xx	x	–	–
Cultivation	(x)	xx	(x)	–
Collection wild cereals	x	–	–	–
Collection handicraft material	–	–	seperate	x
Reunion family	–	x	x	–
Trade	–	–	xx	x

x – xxx = low to high importance

Each timely movement by herdsmen to a complementary non––degraded habitat means increase of the overall productivity of the system. These movements can be avoided in a sedentary system in a semiarid zone only by partly using external inputs (lick stones, agro–industrial byproducts) or by risking over–grazing around the settlements.

Productivity of a transhumant system compared to a sedentary system

Under the conditions of high variability of resources in space and time, and in absence of available supplementary resources, a mobile grazing system performs better than a sedentary system.

Table 3 shows that according to calculations of H. BREMAN (1986)the carrying capacity of similar grazing systems in Mali can differ at least by a factor two between a mobile and a sedentary system. The dry season transhumance in Mali to the delta of the Niger can be considerd comparable to the northern transhumance described by this article.

Tab. 3: The necessary area (ha) per UBT for 6 stock–farming systems in Mali during a year with normal rainfalland during a year with very low rainfall. (H. BREMAN 1986)

grazing systems	Rainfall normal	10% probability dry
nomadism	14	42
transhumance		
d.s. Delta	3	7
d.s. savane	4	10
sedentaire		
sud Sahel	10	20
Delta	4	10
savane	6	15

Bottleneck of the overall productivity is then not the seasonally occuring constraints of individual small land units, but the stocking rate in relation to the carrying capacity of large bioclimatic zones. However one constraint can be so important, that it cannot be overcome even by movements.

These constraints limiting the overall productivity of the whole agropastoralist system are:

1. climatic disasters
2. widespread overgrazing contributing to desertification
3. widespread reduction of (dry–season) pastures due to increase of agricultural (valleys + depressions)
4. occurance of diseases (tsetse etc...) in the savanna area

Drinking water is no major limiting factor. In 1984 the animals died from starvation, not from thirst!

Some considerations on management aspects of transhumance and on land use planning:

Considering the 4 major constraints, we see that 2 (widespread overgrazing and reduction of dry season pastures due to agriculture) are subject to land use planning, while no 1 (climate) cannot directly be influenced.

Since feasable concepts and positive experiences with rangement management and land use planning were lacking, the development of the livestock sector has mainly concentrated on constraint no 4 (diseases) and on increase of water availability, and thus increasing the importance of constraint no 2 and 3 (overgrazing and increase of agriculture).

Meanwhile, the conditions for policy making have changed partly and justify new attempts: Mainly the introduction of the land reform by the government of Burkina faso by its law of 4–8.1984, the fruit of some years of silent work of some development projects and the increasing awareness of a part of the agropastoralist population of land degradation and the necessity of changes.

Transhumance or sedentarisation? – theoretical versus practical considerations

From an ecological and livestock production point of view we know that the carrying capacity of the land is higher under transhumance than under a sedentary system (under the condition: low available inputs, high variability resources): but is it higher on a sustained basis?

Sustained basis means that it will not lead to land degradation. Land degradation can be avoided by regulation of the stocking rate and avoidance of destructive practices. But this is difficult, if herdsmen, like in shifting cultivation, don't care about degradation since they think, they can move somewhere else. Only a part starts to see that their environment has its limits, and that they have to take responsibility for rangeland management.

From a rangeland management point of view, a transhumance system is far more difficult to manage than a (semi)sedentary system:

- Necessity to construct transhumance cattle tracks through densely populated agricultural areas
- Adressing of herdsmen only possible during a part of the year
- Generally no fixed individual land richts but communal grazing, which decreases feeling of responsibility for proper rangeland management.
- Movements across national boundaries.
- Little inclination of traditional–feeling pastoralists to land preparation methods necessary to regenerate certain rangelands.
- little control of destructive practises possible.
- little social–professional organisation.

It would be unrealistic to do the second step (improvement transhumance) before the first step (village and inter–village pasture reserves), which can be realised due to the laws imposed by the land reform of Burkina Faso, under the condition of real participation of the population.

Infact this would be possible for the transhumants also around their permanent dwelling, but in a conflict over grazing rights in other areas a sedentary agropastoralist will nearly always be the winner, since he can keep all year round control over the area and can use agriculture + artificial watersources as weapon to defend his rights against (other) livestock holders. So the other will have to become (semi)sedentary as well.

At the same time large grazing reserves in the S–Sahel and N–Sudan savanna zone have to be created as buffer for climatic disasters such as the "brousse tigr" which might be controlled by closing water points.

Recent trends of land use

After the 1972/73 drought another year affected the area with some 200mm under "normal" (taken the average of only the last decade, fig. 3.), followed by a "good year" in 1985, and a "moderate year" in 1986. The climatic unstability together with increased land degradation has perturbated strongly the landuse systems, so that the traditional "transhumant", "nomadic" and "agricultural" systems cannot be distinguished as sharply as before.

Recent trends in land use systems in the sahel of Burkina faso and adjacent areas can be resumed as follows:

- Turn to agriculture by nearly all traditional pastoralists due to heavy losses of livestock in 1984, and increasing livestock production by farmers: both become semi–sedentary agropastoralists.
- Increase of desertification, by human, climatic and soil factors, causing sheetwash and sealing of soils of fine texture and destruction of woody vegetation: decrease of productivity of agriculture and livestock production.
- reduction and fragmentarisation of pastoral areas.
- increased land use conflicts between farmers and pastoralists and within these groups esp. due to competitive use of lowlands ("we are just like two men married to the same wife").
- evacuation of livestock by exeptionally strong southern transhumance from the Sahel during the drought year 1984/85 caused heavy losses due to diseases and different diet of non–adapted livestock = no solution for drought years
- temporarily small herd sizes, low stocking rate, high livestock prices regeneration of sandy dune pastures and high productivity are encouraging investments into livestock (little alternatives) + intensification of production. But this will quickly return to less farorable conditions if marketing is not improved.
- strong increase goat stocking rate – destruction woody vegetation
- the "gold boom" the widespread exploitation of marginal gold resources, saved the Sahel in 1984/85 from starvation, but its consequences are difficult to assess:
- increased disintegration of rural societies
- less time for agriculture + pastoralism (reduced movements transhumance) at least for some years
- quicker acceptance of innovations
- investments into livestock production

Evaluation of land use trends

The previous analysis of recent trends show that transhumance (with permanent dwellings) is likely to further increase on the expense of nomadism which is pushed into remote areas of high risk of rainfall.

Transhumance itself becomes integrated into a semi–sedentary system, in which a part of the family conducts agriculture, and does some intensive livestock production at home (sheep, calves, milk cows), another part of the family moves with the herd, and some members will go for off–farm activities (gold digging).

Consequences on the 4 major constraints and policy consequences mentioned earlier are:

1. on climatic disaster:

- High vulnerability of nomadic pastorralists pushed into remote areas of high risk of rainfall: communication and infrastructure must be improved (northern markets, extension work, road improvements (river crossings), improved regular marketing)
- in drought years, massive movements to the south are no solution! Solutions have to be found in the Sahel itself by preventive regulation of the stocking rate and by the recreation of pasture reserves, and destocking actions.

2. wide spread overgrazing and desertification.

- Sedentarisation in the Sahel leads to local land degradation and decreases the carrying capacity at short term and especially threatens woody vegetation.

- Grazing reserves of large dimensions on a rotational basis have to be created. First trials show that pasture reserves at village level seem to have highest chance of succes (without fencing off), under the condition of a bottom–up planning approach.
  - Intensification fo livestock production is not possible on crop resdues alone (little soil cover in the fields leads to increase ofwind erosion), nor on local pastures, but requires external inputs which could be financed by gains from gold digging. This intensification will be only economic, if regular marketing takes place. marketing organisations of pastoralists have to be created or improved.
- Regulation of the stocking rate needs clear government policies, avoidance of actions leads to increase of the stocking rate (veterinary service; financing of inputs...) if improvement of marketing is not achieved.

3. widespread reduction of dry season pastures:

The decrease of dry season pastures esp. in depressional areas can limit the overall productivity of the system, so that productive wet season pastures in the north can become underexploited. Reason is that upland agriculture of millet is turning into a kind of run–on agriculture of sorghum in depressions in vast areas due to degradation of the uplands (sealing, sheetwash). Increased use of soil land water conservation methods is necessary in the uplands.

A third competitor for the lowland areas are the foresters, since the valleys and depressions have become refugee zones of vegetation disappeared from the water divides. Management plans have to be made urgently for the main valley systems!

4. occurence of diseases.

Elimination of the diseases (tsetse...) in the south and further improvement of the veterinary service will increase even more the stocking rates. More emphasis should be put on rangeland management, marketing and the regulation of the stocking rate.

The carrying capacity of the land during sedentarisation can only be maintained sufficiently high under the actual conditions (small herd sizes, sufficient rainfall, but less goats and no increase agriculture) Technically the first option for rangeland management has to be: avoidance of losses from the ecosystem by erosion, destructive cutting and burning, trampling and overgrazing of vegetation, exposition of valuable fodder to atmospheric conditions, and the use of external inputs.

Socially – the sensibilisation and organisation of pastoralists : sedentary, transhumant and nomadic, for marketing and rangeland management, and the diversification of tasks of the extension services from veterinary tasks to rangeland management have to be first priority.

Final conclusions on transhumance

The preceding conclusions show that (partial) sedentarisation of pastoralists ia an unavoidable process, caused by mainly internal factors.

Since the carrying capacity of the land will be reduced by sedentarisation, intensification of livestock production by using external inputs, and financed by better marketing and income from gold, has to be stimulated.

Since intensification will take time, transhumance possibilities have to be maintained at short term and infrastructure (tracks, grazing reserves, feedlots) has to be created.

The need for modeling of the Sahel agropastoral landuse system

The analysis of transhumance in the Sahel of Burkina faso and Mali shows that it is strongly connected with other agropastoral landuse systems and that is is interacting with ecological and socioeconomic conditions.

To help scientists and decision makers to owersee the consequences of land use trends, sectoral policies, climatic conditions, prices for agropastoral products and other factors involved, a general qualitative model including socio–economic factors, and quantified submodels should be developed. Socio–economic factors have to be included since they are strongly influencing land use systems and therefore the ecology and carrying capacity of the region. The Sahel has never been a completely closed human ecosystem, but has always symbiotically depended on trade with higher rainfall areas for exchange of pastoral products and salt against agricultural products, gold, textiles and, nowadays, industrial products. (KI–ZERBO 1978)

That is why with increasing degree of dependace, the economic terms of trade are increasingly influencing landuse, although the traditional pastoral systems have more been a way of life then a market–oriented production system. Up to present times, unbalanced development of certain sectors like water resources, health and food care, and agriculture have led to vicious circles of increase of human and livestock population and deterioration of pastures, follwed by more and more severe drought – starvation cycles leading to desertification (NAVEH 1987, see fig. 4)

One tragic example is the starvation of tenthousands of cattle close to the teep well "forage Christine" in the Sahel of Burkina faso in the 70's, due to unbalanced development of water– and grazing resources.

Quantitative submodels are existing nowadays mainly for the physical parts of the system, showing the effects of rainfall, soil structure and soil fertility on primary production, forage quantity and quality, carrying capacity and crop yields. (PPS, 1982, WOFOS) Remote sensing models for satellite data serve to determine drought and rainfall areas, biomass index, locust breeding areas, cultivated areas and in future possibly amounts of rainfall, crop and pasture production etc. (GROTEN 1986).

In the tentative general model presented in fig. 4 most relationships can be quantified, either from ground surveys, available statistical data, remote sensing, or combinations of the three.

On some unsure (– –) relationships, on possible positive feedback loops and possibilities for their interruption, more intensive research is needed, as well as on the regulatory functions.

However in this variable environment with few available or reliable historical data, uncertainties remain, and have to be dealt with in a transparent way (without camouflage by mathematical models).

Some examples of uncertainties and unforseeable effects:

- explosion of pests and diseases (eg. locusts, rats, mildew, weaverbirds) and the effect of counter measures. Population
- dynamics models are needed which link its development to measurable meteorological and environmental conditions.
- Cultural behaviour: adaptation of landuse systems of various ethnical groups to change in ecological and economic conditions. However, as stated before, there is a general tendancy to diversification and uniformisation of formely specialised land use systems.
- the goldboom of 1985/86 and its effects
- the political conditions

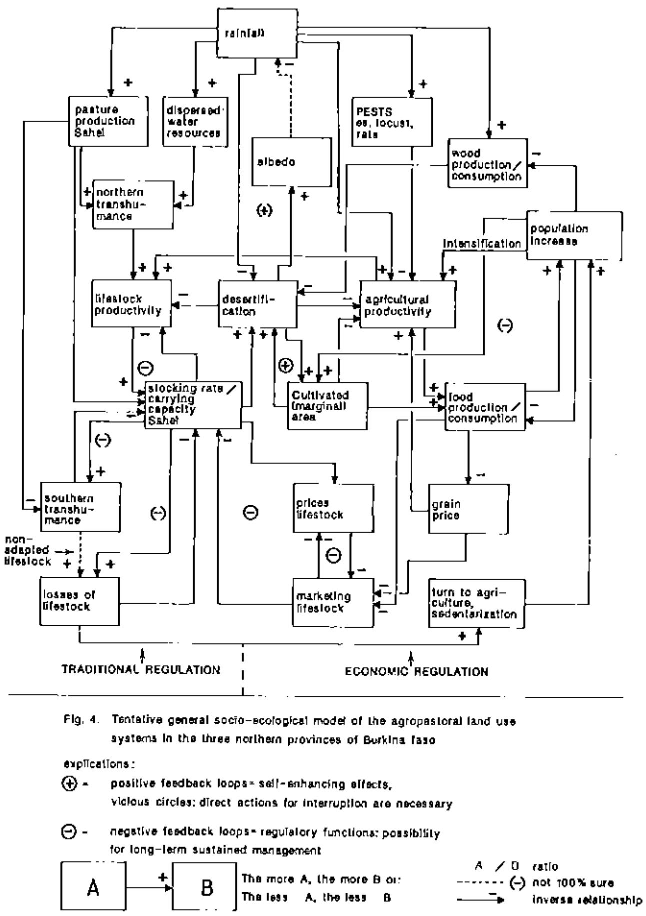

Fig. 4: Tentative general socio-ecological model of the agropastoral land use systems In the three northern provinces ofBurkina Faso

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ASPECTS OF CONNECTIVITY IN THE LANDSCAPE OF UJUNG KULON (WEST JAVA, INDONESIA)

P.W.F.M. HOMMEL

Introduction

Ujung Kulon is a peninsula on the westernmost tip of the island Java, Indonesia (fig. 1).The area covers some 30 000 ha, and has been a conservation area since 1921. Fame and importance of

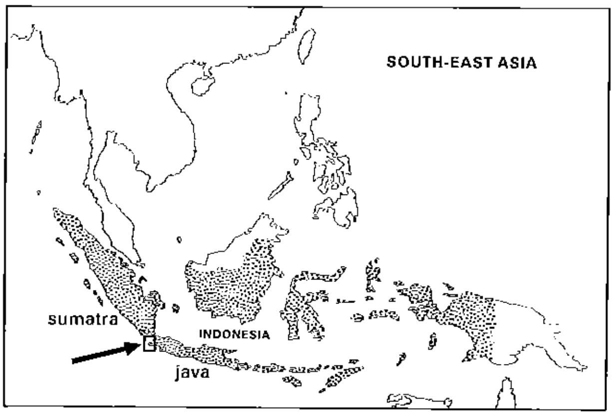

Fig. 1. Location map of Ujung Kulon.

Ujung Kulon are mainly due to its population of Javan rhinoceros (*Rhinoceros sondaicus*), which is probably the last remaining one in the world. The area is, however, also known for the occurrence of other valuable, rare species such as Wild ox or Banteng (*Bos javanicus javanicus*), Javanor Grey gibbon (*Hylobates lar moloch*) and until recently Javan tiger (*Panthera tigris sondaica*), as well as for its scenic beauty. As early as 1854, the famous naturalist Junghuhn drew attention to the superb nature of this out-of-the--way corner of Java. In the thirties of this century Ujung Kulon became the favourite reserve of A. HOOGERWERF, the godfather of conservation in the Indonesian archipelago, who was later to write a fascinating monograph on the area (1970).

During the past two decades, the World Wildlife Fund has been involvedin both management and research in Ujung Kulon. The first grant was made in 1965 for the purchase of equipment, and in 1967 Prof.Dr. R. Schenkel started his research on the ecology and behaviour of the Javan rhino (SCHENKEL and SCHENKEL-HULLIGER 1969; SCHENKEL et al., 1978). An almost continuous series of WWF sponsored researchers have worked in Ujung Kulon ever since, mainly focussing on the most important animal species of the area.

In 1980 the area changed status from strict nature reserve to national park a the the number of visitors, scientists as well as tourists, increased strongly.

Objectives of the survey

In spite of all interest in the area, Ujung Kulon is not a scientifically very well known area. A systematic study of the area's vegetation cover was never made. Other ecologically important aspects of the landscape (e.g. soils)were also still very poorly understood. This holds even for something as basic as topography, which may be explained by the very inaccessible and unsurveyable character of some of the area's vast thorny shrub-vegetations, the lack of trails into the interior and the fact that aerial photographs of a reasonable quality were lacking until very recently. This, of course, implied a most serious handicap to all management and conservation orientated research (HOMMEL, 1982).

Therefore, the World Wildlife Fund initiated a mapping project, especially focussing on the major vegetation types of the area and their distribution. A second objective was to give a broad estimate of the suitability as a rhino-habitat for the various sub-regions of the area. Thus, the survey was aimed primarily at vegetation mapping and land-evaluation. However, since many data were collected on the distribution and ecology of separate plant and animal species, the results of the study may also be interpreted in a different way, i.e. to describe the significance of both connectivity (and its counterpart isolation) for the floristic and faunistic composition of the area.

Methods and materials

As for methods, we have opted for a broad landscape-ecological approach (ZONNEVELD, 1979). Thus, our study was aimed primarily at the landscape as a fully integrated entity, in which vegetation is but one of the ingredients, though (within the scope of this study) the most important one.

Zonneveld's approach emphasizes the use of aerial photographs before the actual fieldwork, resulting in a preliminary delineation of landscape-units and providing a basis for an efficient sample strategy. For our survey we used ordinary, panchromatic, black--and-white aerial photographs, dating from 1981/1982 (scale 1 : 75 000).

After the stage of preliminary photo-interpretation, fieldwork was done, which implied the description of vegetation, soil, landform and lithology (as far as possible) on 336 sampling sites, located along carefully planned transects. We generally used a stratified sampling strategy, i.e. in every photo-interpretation unit a more or less equal number of sample points were planned. Units of high internal complexity did, however, require a higher density of sample points ('preferential sampling').

The vegetation was described by its structure and complete floristic composition. A classification of vegetation types was consequently compiled by tabular comparison of the floristical plot-data, using the Braun-Blanquet approach (MUELLER-DOMBOIS and ELLENBERG 1974). The arguments against the use of this approach in the humid tropics, as forwarded by VAN STEENIS (1958), were found to be invalid.

The soils were described by augering, using mainly morphological, diagnostic characteristics. In only a few, representative sites, pits were described, allowing the gathering of more detailed analytical data. All plot data were used to compile a local classification system, which was only afterwards translated into the FAO/ UNESCO terminology (1974). In addition, simple classification systems were compiled for landform and lithology, based on an earlier, tentative classification by VERSTAPPEN (1956).

Integration of these classification systems and re-interpretation of the aerial photographs resulted in the description of landscape-units, which were shown on a landscape-ecology map at a scale of 1 : 75 000. Land–evaluation on behalf of the Javan rhino was done using the FAO–approach (FAO 1976). However, the results of this evaluation are beyond the scope of this paper. For more details, we can refer to HOMMEL (1987).

The landscape of Ujung Kulon

The main geomorphological units of Ujung Kulon are shown in fig. 2. These units served as a basis for the landscape–ecology map

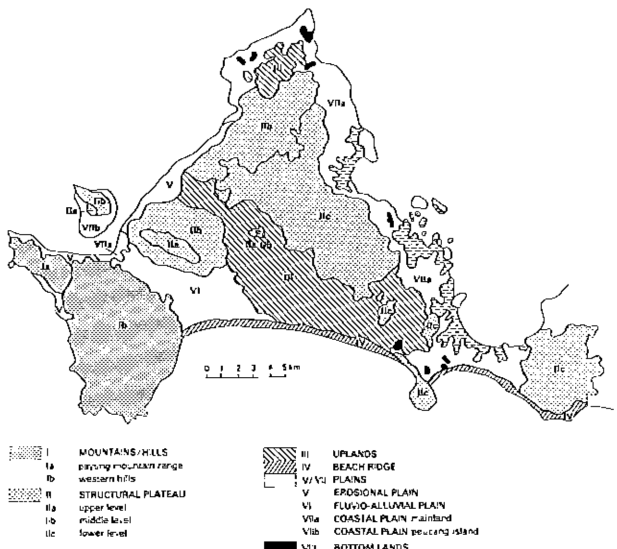

Fig. 2. The main geomorphological units of Ujung Kulon.

(scale 1 : 75 000), published by HOMMEL (1987). A concise legend to fig. 2, summarizing the main (vertical) landscape–ecological relations, is given in table 1. The here presented map and legend only show the most important units, soil–types and vegetation–types. Moreover, the original vegetation–types, described as plant–communities, are here clustered into more broad structural types. A short description of this sketch–map and its legend will be given below, focussing on those aspects, which are of significance for the phenomena of connectivity which will be discussed later.

Evergreen rainforest in Ujung Kulon is restricted to altitudes above 150 m, i.e. to the mountaineous area in the southwest (Mt. Payung). This evergreen forest is predominantly of primary nature. Below the altitude of 150 m, virtually all forests are (semi–)deciduous. The reason for this phenomenon is a climatological one. The rainfall data for Java's First Point (the westernmost tip of the peninsula), representative for the area's lowlands, show a yearly average of 3249 mm (HOOGERWERF 1970) and some 30–40 rainy days during the four consecutive driest months of the year (VAN BEMMELEN 1916). As for the possible growth of evergreen rainforest such an average is a borderline case (VAN STEENIS 1965). It is assumed that in Ujung Kulon's lowlands the growth of rainforest is prohibited by the incidental occurrence of a very pronounced dryseason, which does not show from the yearly averages, since extremely wet years do occur, too. The strikingly trifling height of the clouds in the Payung area (150 to 200 m on average) causes a higher atmospheric humidity and a more equal distribution of rainfall throughout the year, thus allowing the growth of rainforest above such altitudes.

Tab. 1. Main landscape–ecological relations in Ujung Kulon (concise version of the legend of the map published by HOMMEL 1987)

Table 1. Main landscape-ecological relations in Ujung Kulon
(concise version of the legend of the map published by Hommel, 1987)

No.*	Landform	Subdivision	Parent material	Main soil type	Main vegetation type
I	Hills and mountains				
Ia	Hills	western part	tuff	eutric cambisol	palm-forest
		eastern part	andesite	eutric cambisol	palm-forest
Ib	Mountains	150-500 m	tuff	dystric nitosol	evergreen rainforest
		0-150 m (cliffs)	tuff	dystric cambisol	deciduous open forest
		0-150 m (less steep)	tuff	dystric cambisol	palm-forest
II	Structural plateau				
IIa	Upper level	mainland	limestone	dystric cambisol	semi-dec. forest
		Peucang Island	limestone	eutric cambisol	semi-dec. forest
IIb	Middle level	mainland	limestone	dystric cambisol	palm-forest
		Peucang Island	limestone	dystric cambisol	semi-dec. forest
IIc	Lower level	central part	limestone	gleyic luvisol	rattan-shrubland
		periphery	limestone	gleyic luvisol	palm-forest
III	Uplands	main area	unknown	gleyic luvisol	bamboo-forest
		western parts	unknown	gleyic luvisol	rattan-shrubland
IV	Beach ridge	main area	sandstone	dystric cambisol	mixed shrubland
		lee-side zone	sandstone	dystric cambisol	palm-forest
V/VII	Plains				
V	Erosional plain		variable **	eutric cambisol	palm-forest
VI	Fluvio-alluvial plain	western part	alluvial sed.	gleyic cambisol	palm-forest
		eastern part	alluvial sed.	gleyic cambisol	rattan-shrubland
VII	Coastal plain				
VIIa	Mainland	coastal zone	coral	calcaric regosol	semi-dec. stubforest
		main area	alluvial sed.	dystric gleysol	semi-dec. forest
		interior zone	alluvial sed.	dystric gleysol	rattan-shrubland
VIIb	Peucang Island	-	coral sand	eutric cambisol	semi-dec. forest
VIII	Bottom lands (depressions)	dry season	alluvial sed.	calcaric fluvisol	herbac. swamp veg.
		wet season	water	-	hydrophytic veg.
IX	Tidal swamps (mangroves)	inner part	alluvial sed.	dystric fluvisol	semi-dec. open forest
		outer part	alluvial sed.	thionic fluvisol	evergreen forest

(*) the numbers refer to the main physiographic regions (see fig. 2)
(**) parent material corresponding to the adjacent landscape units.

As for the (semi–)deciduous forest below 150 m, there are only a few stands of primary forest left, mainly on Peucang Island and the upper parts of the limestone plateau of the mainland (see fig. 2). This is explained by the fact that Ujung Kulon was formerly inhabited and used for shifting cultivation. At present, a considerable part of the secondary forests of Ujung Kulon are strongly dominated by one species, viz. the 'langkap'–palm (*Arenga obtusifolia*). Using the complete floristic composition, it is possible too discern several types of *Arenga forest*. These types show a remarkable good correlation with differences in soil type and parent material. However, the *Arenga* forests are almost completely confined to moderately well and well drained soils. On both the more excessively and the more poorly drained soils, they are replaced by other types of forest. Examples are respectively the stub–forests (dominated by *Ardisia humilis*) of the coastal plain and the bamboo–forests (dominated by *Bambusa blumeana*) of the calcareous uplands.

However, vast parts of Ujung Kulon's lowlands are not covered by forest, but by extensive shrublands. On the basis of their physiognomy and the abrupt character of their boundaries (unrelated to abiotic factors), such shrublands can be interpreted as an early succession stage following deforestation by man (VAN STEENIS 1961). The presence of the shrublands, situated on the sandstone beachridge along the southcoast and characterized by the abundance of the nettle–tree (*Dendrocnide stimulans*), is easily explained by former vegetation management on behalf of the banteng population (and poachers!). Probably, uncontrolled forest fires are of importance, too. However, the presence of vast, thorny and almost impenetrable rattan–shrublands in the interior is less easily explained. It is known that there has been no human interference in these parts for about one century. We assume these rattan–vegetations to be former shifting cultivation sites, which became covered with a thick layer of volcanic ash (at least 30 cm) at the time of the eruption of the nearby volcano Krakatau in 1883. The very poor structural qualities of these open, exposed sites hampered the settling of invading seedlings, thus allowing rattans and other lianas to penetrate the glades from the surrounding forest edges. The resulting rattan–blankets are known to be able to persist over long periods (VAN STEENIS 1939).

Connectivity

The location of Ujung Kulon is a very special one. The area is remote and rather isolated. On the other hand, its location between the more vast land-masses of Sumatra and Java gives the area the character of a biological stepping-stone. Thus, phenomena of both connectivity and its counterpart isolation may be discerned, which are further complicated by the turbulent history and the specific climatological position of the area.

As for connectivity on a supra-regional scale, the peninsula and adjacent regions have been of considerable importance as a corridor for species, migrating from Sumatra to Java. Plant species bound to seasonally dry climates took advantage of low sea levels, coinciding with a dry climate, during the Pleistocene. At present, Ujung Kulon's lowland is a drought-island in predominantly ever-wet West Java. At least 11 species, known to occur in predominantly dry Central and East Java, have their single occurrence in West Java in Ujung Kulon. Nine of them are restricted to altitudes below 150 m. As for rainforest flora, Java is less rich than Sumatra. In fact, one might consider the Javan rainforest flora as an impoverished version of the Sumatran flora. This is explained by habitat destruction by volcanism and by the incohesive character of the Javan rainforest areas (VAN STEENIS 1965). However, the flora of the utmost western part of the island, which is nearest to Sumatra, shows some interesting similarities with the Sumatran flora. For instance, at least 4 Sumatran genera have their only representatives on Java growing in Ujung Kulon (viz. *Botryophora, Endocomia, Leuconotis and Vatica*). Finally, as for the distribution of species by means of stepping-stones, attention should be drawn to what might be called 'island-species'. These are species which are more or less restricted to small islets, but do not grow on the mainland of larger islands. Two clear examples are *Smythea lanceolata* and *Knema globularia*, occurring on Peucang island, but not on the mainland of Ujung Kulon, neither elsewhere on Java. For both species a similar habitat preference is reported from other parts of their distribution area. Less clear examples are provided by e.g. *Pandanus bidur* and *Heritiera percoriacea*, which are present on the peninsular part of Ujung Kulon, but also absent on the mainland of Java. These 'island-species' are a most interesting, but not yet fully explained ecological phenomenon.

On a more regional scale, it is of interest to compare the Ujung Kulon rainforest with the originally more extensive rainforest areas in the adjacent part of Java's mainland, i.e. on Mt. Honje (see fig. 3).

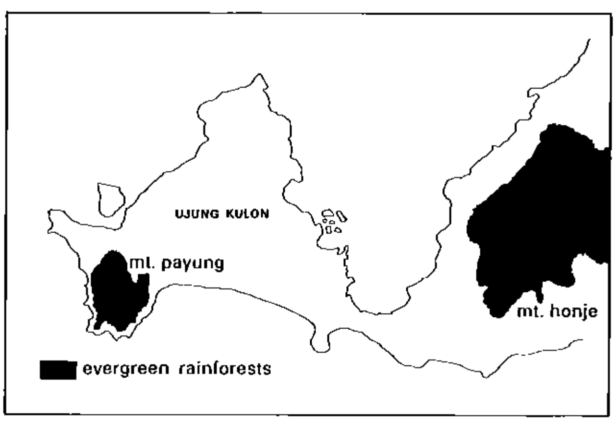

Fig. 3. Original area of evergreen rainforests in Ujung Kulon and the adjacent part of Java's mainland. (The map does not show the present situation. Recently, large parts of the Mt. Honje rainforests have been destroyed).

It proves that both areas are quite similar as far as their floristical composition is concerned. However, the Ujung Kulon rainforest is characterized by a relatively low species-diversity and by the occurrence of a certain degree of species-dominance in all strata, including the upper tree-layer (a very rare phenomenon in a primary rainforest). There are indications that similar conclusions may drawn from a comparison of the fauna of both areas. Again the rainforest of Mt. Payung is relatively poor. For instance, the Pangolin (*Manis javanica*) is said to be present on Mt. Honje, but definitely missing in Ujung Kulon. The same holds for the Javan gibbon (see below). These phenomena are explained by the small size and isolated location of the stand (climatologically 'an island within an island') and the higher vulnerability of such small-sized stands to disturbances, e.g. the destructive impact of the 1883 ash rains.

Finally, connectivity on a local scale can be illustrated by the distribution of two animal species in the isthmus-area. The Javan rhinoceros is most attracted to open, secondary vegetations. However, virtually all types of terrain are accessible to the animal. At present, the rhinos extend their distribution area across the swampy isthmus towards the mainland (fig. 4). On the contrary, the

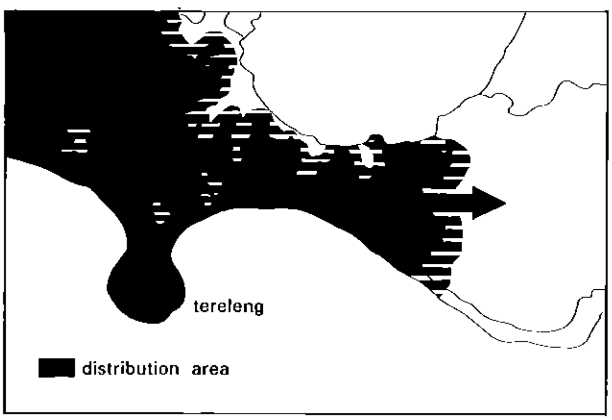

Fig. 4. The distribution area and migration-pattern of the Javan rhinoceros (Rhinoceros sondaicus) in the isthmus area of Ujung Kulon.

Javan gibbon is bound to coherent stands of forest and the animals are known to avoid the forest floor and even its proximity (KAPPELER 1981). Although throughout Ujung Kulon there are large areas of potential gibbon habitat available, the species is completely lacking in the western and central part of the peninsula. Probably, it died out in 1883, due to the complete defoliation of the forest caused by the ashrains. In the adjacent forests of the mainland many gibbons are still present. Over the last decades, gibbons were also observed several times in the isthmus-area, but never further westward than the Tereleng peninsula. Coherent shrub-vegetation and the rivulet Cibandawoh put strict limitations totheir distribution area, preventing further migration westward (fig. 5). Since the gibbon habitat east of the isthmus area is highly endangered, reintroduction by man into the central part of Ujung Kulon should be seriously considered. Moreover, attention should be paid to the availability of a network of forest-corridors throughout the area.

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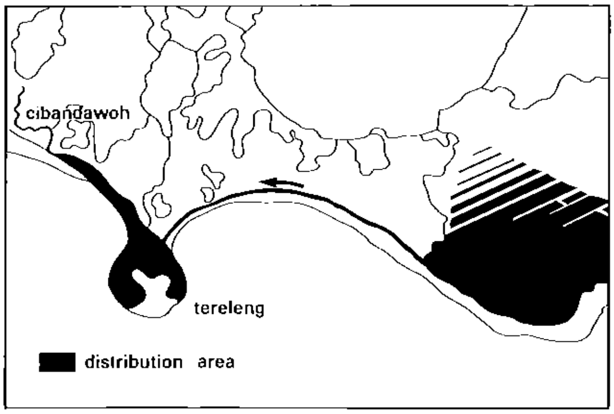

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Summary

This paper deals with Ujung Kulon, a conservation area on the westtip of the island Java (Indonesia). The results of a landscape-ecological survey are interpreted in terms of connectivity and isolation. It is emphasized that such phenomena act on various spatial (and temporal) scales. Several examples are given, focussing on those aspects, which are of importance from a view-point of nature conservation.

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AGRICULTURAL LANDSCAPE IN THAILAND TOWARD 2000

P. KUNEEPONG

ABSTRACT

Agricultural in the tropical area of south–east Asia is largely subsistence in nature und geared to the domestic market and cannot therefore develop unless there is a concomitant development in other sector of the economy. The degradation of agricultural lands are of inherently poor marginal soils, erratic rainfall or water resources, and stagnating production in the more densely populated areas of inherently good soils, reliable rainfall and water resources.

Tab. 1 : Problem soils of Thailand

PROBLEM SOIL TYPE		EXTENT AREA (KM)²	%
SALINE AND ALKALINE SOIL	.....NORTHEAST,COASTAL AREA,	2068.11	1.9
ACID SULFATE SOIL	.....CENTRAL PLAIN	8381.29	7.7
SANDY TEXTURE	......NORTHEAST,EASTCOAST SOUTH	9360.90	8.6
HARD PAN SOIL	......SOUTH	870.78	0.8
HIGH CONSISTENCY SOIL	......CENTRAL PLAIN	3374.28	3.1
PEAT AND MUCK SOIL	......SOUTH	805.47	0.7
SKELETAL SOIL	......SCATTERING	83987.17	77.1
TOTAL		108848.00	

SOURCE : PANICHAPONG (1981)

The problems in Thailand are from both an ecological and from an economic point of view there is a preference for concentrating – agricultural land use on those lands which are best suited for these purposes. In order to meet the human requirements on these rather often limited areas a sufficiently high and substained production types need to be developed. Extension of food production into less suitable or marginal lands only provides a short–term solution with long term deleterious effects. Those soils which are less suitable for intesive production, which are in general also the lands most vulnerable to – land degradation, should be put to the other alternative use such as, – extensive grazing, forestry, nature conservation or catchment protection.

The increasing of food in the problem areas would be possible – in 2 ways: by increasing the stock of arable lands through land development and by increasing the land yield through the application of modern agricultural input.

The agricultural sector (crops, livestock, forestry, fisheries) is the largest and most important sector of the Thai economy, although its contribution to the Gross Domenic Product has declined (39.4 percent in 1961 to 24.3 percent in 1982). In 1985 agriculture provided nearly 60 percent of total exports value, while agricultural imports remained verylow. Major export items showing high growth rate in 1985 included rubber (18.5%), tapioca (12.9%), maize (52%), shrimp (20.8 %), canned sea food (35.6%), although rice and sugar export earnings dropped by 14.6 percent and 17 percent respectively (FAO, 1986).

Nearly 40 percent of the country's land area is used for farming and at least another 30 percent is forest land. Farm activities occupy around 71 percent of the labour force, with another 19 percent engaged in agribusiness.

Over the past 10–15 years the growth of the agricultural sector in Thailand has been high by international standards, at an average annual rate of 4 percent, with most of the growth being attributable to increase in area of crops planted and without any consistant increase in yield. At the same time there has been considerable diversification of land use and production. Thailand's agriculture has therefor been characterized by a considerable increase in production and diversification, based on increased utilization of land area, labour and machinery, with low levels of fertilizer application, stagnant yields and high inter–annual variations in production caused mainly by weather conditions.

The reasons of diversification are not hard to find. The global economic expansion created a buoyant demand for exportable cash crops and many areas of Thailand, particularly the uplands, were found to be suitable for their cultivation. Through an efficient marketing and distribution system, to which the building of a modern road system has contributed, the commercial advantages of alternative crop cultivation were quickly transmitted to farmers who have shown a remarkable capacity to move into production of new crops in response to price signals. The comparative commercial attractiveness of alternative crops was also enhanced by the imposition of a tax on rice farmers, called the rice Apremium, although this has recently been largely removed.

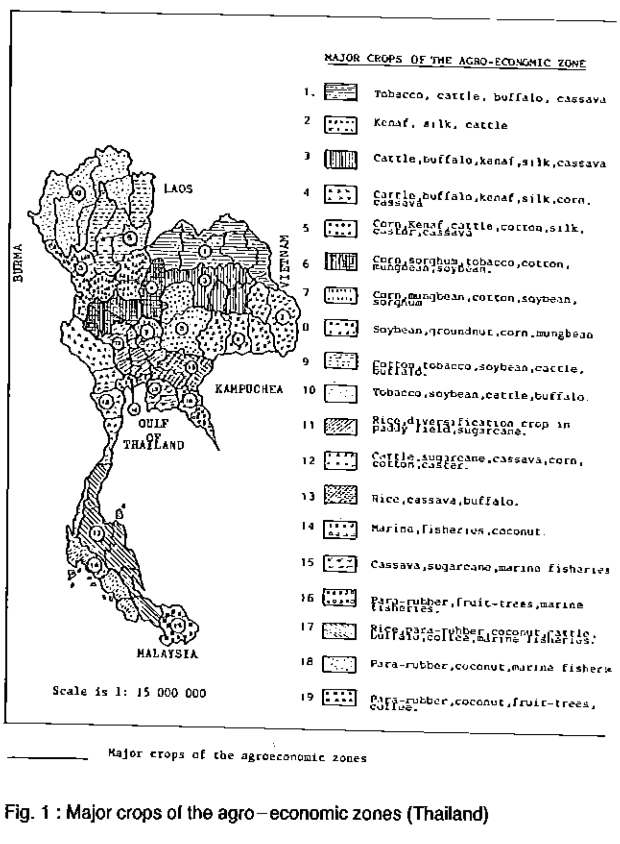

Fig. 1 : Major crops of the agro–economic zones (Thailand)

Tab. 2 : Crop diversification 1950–1980 (Thailand)

	1950		1960		1970[a/]		1980[b/]	
	Area ('000 ha)	Production ('000 tons)	Area ('000 ha)	Production ('000 tons)	Area ('000 ha)	Production ('000 tons)	Area ('000 ha)	Production ('000 tons)
Paddy	5 540	6 782	5 921	7 834	8 218	12 442	9 297	15 086
Maize	36	27	286	544	766	1 656	1 466	2 884
Tapioca	14	269	72	1 200	198	3 040	1 070	14 666
Sugarcane	54	839	156	5 300	148	5 856	478	17 747
Coconuts[c/]	80	579	165	1 010	303	730	419	761
Groundnuts	70	63	118	152	110	136	104	122
Soya beans	20	12	22	26	54	48	134	120
Kenaf	5	5	140	181	355	357	242	257
Cotton	37	20	56	46	87	63	115	137
Rubber	337	114	481	172	862	276	1 553	489

a/ Average of 1968/69, 1969/70 and 1970/71 crop years. b/ Average of 1978/79, 1979/80 and 1980/81 crop years.
c/ Production converted at the average rate of 1.25 kg per nut.

Source: EIU (1984)

The expansion into alternative crops has required significant further extensions of the land frontier, and the cultivated area sown with crops other than rice has risen more than fourfold in the post–war period. Many of these alternative crops are grown on relatively poor soils, or in dry areas not suited to paddy. Further extensions of arable land have been facilitated by the very rapid process of deforestation which has reduced forest cover from over one half to barely one quarter of the total surface area of the country since the early 1960s.

The main alternative crops have consisted of those that are essentially new to the country, such as hard maize, tapioca and kenaf, as well as those whose production levels have been revived, such as cotton, coconuts, sugarcane, fruit and vegetables. Rubber production on an important scale dates from the 1920s; the other major primary commodity is teak which has been important since the last century but whose production is now being curbed in the interests of forest conservation. A summary of the growing significance of crop diversification is to be found in Table.

The fortunes of Thailand's agricultural sector are closely tied to world markets and the rise and fall in relative importance of individual crops is geared to changes in those market conditions. The production profile of agriculture is thus a restless one. From the 1970s, kenaf's importance has declined and the the land has been used increasingly for tapioca. Other newer crops have recently gained importance, however, including coffee, mung beans and palm oil, and there remains considerable potential for the cultivation of yet others.

PRODUCTIVITY CONSTRAINTS

1. Physical constraints
   - climate (rainfall, temperature, etc.)
   - relief (highland)
   - poor drainage
   - poor soils
   - erosion and run off
2. Technological constraints
   - irrigation
   - drainage and flood control
   - stabilizied of highland agriculture and forest
   - managment
   - improvement of seeds and varieties

Tab. 3 : Production of major crops 1983–1986 (Thailand)

PRODUCTION OF MAJOR CROPS 1983–86
('000 tons)

Crop	Crop year 1982/83	1983/84	1984/85	1985/86
Major rice	14 774	16 943	17 275	17 930
Second rice	2 104	2 606	2 630	2 334
Cassava	18 989	19 985	19 263	15 255
Rubber	576	594	617	773
Maize	3 002	3 552	4 226	4 934
Tobacco	402	337	330	324
Sugarcane	24 407	23 869	25 055	24 093
Kenaf	200	235	162	247
Coconut	1 076	1 102	1 128	1 226
Cotton	122	119	79	102
Mung bean	281	288	352	323
Sorghum	236	327	374	404
Soya bean	113	179	246	309
Groundnuts	145	147	172	171
Oil palm	254	303	394	610
Kapok	34	40	41	44

Source: MAC, 1986

3. Institutional constraints
   Credit of farmers is provided by:
   - Bank of Agriculture and Agricultural Cooperatives
   - Cooperatives and Farmers' Welfare Found
   - Comercial Bank
   - Private money lenders
4. Socio-Economic constraints
   - Social constraints (rapid population growth)
   - Economic constraints (population pressure)

CONCLUSION AND RECOMMENDATION

Conclusion

1. Agricultural productivity rose rapidly in 1950-1970 because of increasing in cultivated land, crop yields and crop intensity.
2. Yield have generally remained stagnant since 1970. Only rubber has been steady increased.
3. In 1983-1986 there has been upturn in the yields of several crops (especially major rice), only cassava are declining.
4. Problem soils and step land limited productivity.
5. Water limited are still available on a large scale and there is scope for a good deal more growth in irrigation.
6. Productivity is mainly due to physical constraints.
7. Increase productivity needs increasing implementation of technological measures.
8. Institutional and infrastructural constraints in Thailand are not significant compared to most developing countries.
9. The most important constraints on long term agricultural - productivity are created by socio-economic factors.

Recommendation

1. Methodology
   The project would offer a less ambitions and perhaps more realistic alternative to the all-embracing and highly expensive. The project objective would be:
   1. Increasing crop yield
   2. Increasing cropping intensity
   3. Crop diversification
   4. Land conservation
   5. Increasing cultivated area without land degradation
2. Policies
   There are now several government policies of more positive assistance to farmers. Government agencies have been very beneficial to farmers and have been imposed minimum farm-gate prices for some crops to help safe guard rural incomes. The 6th National Plan (1987-1991) emphasis the importance of proper utilization of renewable natural resources and recognized the needs for a effective land use planning.

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LANDSCAPE ECOLOGY IN THE GREENBELT AREA IN KOREA

N. NAKAGOSHI and Y.-D. RIM

1. Introduction

Like many other developed countries, the Republic of Korea (ROK) is suffering from environmental degradation caused by rapid urbanization and industrialization. The development began in the 1930s and has accelerated since that time. The urban population of ROK in 1930 was only 5.6%, in 1949 12%, and in 1984 it reached 64.5% (MINISTRY OF HOME AFFAIRS 1985). Almost one quarter of the total population of ROK, i.e. 9.5 out of 40.4 million, is concentrated in Seoul, the country's capital, where the population has increased about 6 times during the last 36 years.

One of the most important environmental problems, especially in big cities, is air pollution. In the case of Seoul, the incidence of respiratory diseases is much higher for city dwellers than for rural inhabitants, although pollution levels have tended to be significantly lower in residential areas.

The ROK government has taken a variety of measures to improve the environmental situation in general and in particular in the urban environment. They include the creation of a new administrative capital, as well as the preliminary assessment of the environmental impacts caused by urban development, and by large-scale construction of industrial complexes, harbours, dams, highways, etc. The inner cities are being rehabilitated or renovated, and industrial facilities are relocated to new satellite cities, thus at the sametime reducing transport needs and traffic impacts.

Among the major measures to fight environmental and ecological degredation in urban areas, the creation of greenbelts around large cities deserves special attention. Greenbelt areas, where construction of new buildings, roads and other technical facilities is strictly prohibited by law, are aimed at controlling both unorganized urban sprawl and population migration from rural areas to cities, and at conserving natural landscape.

The ROK is firmly determinated to implement the greenbelt policy, as it does with other major environmental issues. For one thing, the Korean people are too proud for the beautyful landscape to allow it to be destroyed. For another, the political philosophy that prevails in ROK today transcends mere modernization and economic welfare, searching for harmonious satisfaction of the spiritual and material needs of the nation as a whole. Of course, this will inevitably lead to socio-economic systems different from those of today. In order to survive we should develop what might be called a steady state instead of the philosophy of unlimited quantitativ economic growth. The greenbelt system is one of the necessities imposed by the steady state philosophy.

2. Natural conditions of the Republic of Korea

The establishment of greenbelts depends on the natural conditions of ROK. Summers are short, hot, and humid, while winters are long and cold. From June toAugust, the air masses dominating Korean weather come from the subtropical waters of the East China Sea. In the winter months, northwestern winds prevail, and cold dry air from Siberia moves southward across the Korean Peninsula (BARTS 1972). The annual precipitation in ROK is between 1,000 and 1,500 mm (KIM 1973).

The mean temperature in January at Seoul is −4.9 C. The mean temperature of the hottest month is above 25C in most of ROK, for example 25.4C at Seoul, an annual range of 30.3C. The range of temperature is much greater in the north and the interiour than in the south and in the coastal region.

Geographically, ROK is characterized by many hills and mountains which occupy nearly 70 %. Low hills, which are mostly located in the south and west, give way gradually to increasingly higher mountains toward the east and the north. ROK has a relatively wide distribution of pre-Cambrian metamorphic rocks and Paleozoic sedimentary rocks, granite and gneiss. The intrusion of the Cretaceous granite which composes the major mountain ranges was the last major addition to the geology of Korea. Brown soils are common in the granite and gneiss areas.

The natural vegetation of ROK about 1,400 B.P. was mainly a temperate deciduous broad-leaved forest mixed with pines (KIM 1980). The tree species included *Quercus mongolica, Q. serrata, Q. acutissima, Q. variabilis, Acer mono, Betula platyphylla var. japonica* and *Carpinus laxiflora*. In the southern coastal region and on its offshore islands, where the mean annual temperature exceeds 13C, the original vegetation was a warm-temperate evergreen broad-leaved (laurisilva) forest. Following YIM & KIRA (1975), the distribution of this forest type is delimited by the coldness index of −10C month. Subalpine coniferous forests still occur in several mountains of ROK at high altitudes (SONG & NAKANISHI 1985; YIM & BAIK 1985).

Over the centuries, the combined effects of ever-spreading agriculture and of extensive use of forests for timber and firewood have changed the character of its natural vegetation. The Korean "Ondol" heating system consists in directing hot air from a furnance on one side of the house through stone-lined flues beneath the room floors. The fuel used was, and in the rural districts still is,wood (RIM & NAKAGOSHI 1986). Around villages, the natural forests was entirely removed and replaced by grassland or by small pine savanna (KAMADA et al. 1987).

After the Korean war, ROK underlook many afforestations using imported *Pinus rigida* and its hybrid *P. rigitaeda* as well as the native *P. densiflora, P. thunbergii*, and *P. koraiensis. Populus nigra*, the hybrid *P. tomentiglandulosa, Castanea crenata*, and *Larix leptolepis* were planted in lowland areas and along streams and rivers (FOREST ADMINISTRATION 1984-1986).

3. The greenbelt areas in the Republic of Korea

Greenbelt establishment was started by the ROK government on 30 July 1971, with the following aims (MINISTRY OF CONSTRUCTION 1985):

1. Control of the drift of human population toward cities by creation of a green boundary which at the same time will improve the environment around the cities.
2. Mitigation of noise by tree planting.
3. Restriction of building activities (houses, factories) and conservationof the traditional semi-natural or rural landscape.

Of the 53 cities of ROK as of 1984 , four are administrated by city government, i.e. Seoul, Pusan, Taegu and Inchon. Not all cities are in need of a greenbelt. Cities selected for greenbelts are as follows:

1. Large cities requiring control of population inflow from rural areas such as Seoul, Pusan, Taegu, Inchon, and Kwangju.
2. Cities where a disorderly development is expected and having the provincial Do office: Taejon, Kwangju, Chonju, Chongju, Chunchon, Changwon, and Cheju.

3. Cities where accelerated urbanization according to the ROK government decisions will take place: Ulsan, Masan, and Yochon.
4. Cities in need of conservation of sight–seeing resources and of natural environments: Chunchon, Chinju, Chungmu, and Cheju.

Following the aims, greenbelts were established in 13 areas between 1971 and 1973, in Yochon not before 1977 (Table 1).

Tab. 1. Greenbelt areas in the Republic of Korea

Area number	Cities	Number of districts: cities and counties	Area (km²)	Mean Annual temperature (C°)	Annual precipitation (mm)	Date of set up
1	[Capital] Seoul, Inchon, Suwon, Songnam, Uijongbu, Anyang, Puchon and Kwangmyong	8; 9	1,566.8	11.1	1,259	30 July 1971*
2	Chunchon	1; 2	294.4	10.5	1,225	27 June 1973
3	Chongju	1; 1	180.1	11.4	1,171	27 June 1973
4	Taejon	1; 5	441.1	12.0	1,161	27 June 1973
5	Chonju	1; 2	225.4	12.6	1,240	27 June 1973
6	Kwangju	1; 5	554.7	12.8	1,223	17 January 1973
7	Yochon	1; 1	87.6	13.7	1,314	18 April 1977
8	Taegu	1; 4	536.5	12.6	979	25 August 1972
9	Chinju	1; 2	203.0	13.4	1,343	27 June 1973
10	Masan, Chinhae and Changwon	3; 3#	314.2	14.0	1,410	27 June 1973
11	Pusan and Kimhae	2; 2#	597.1	13.8	1,381	20 December 1971
12	Ulsan	1; 1	283.6	12.8	1,200	27 June 1973
13	Chungmu	1; 1	30.0	14.7	1,357	27 June 1973
14	Cheju	1; 1	82.6	14.7	1,439	5 March 1973
	Total	24; 38	5,397.1			

Kimhae county includes two greenbelt areas. * last adjustment in 4 December 1976.

Some climatic data (KIM 1973) are included in Table 1. Seoul, Chunchon, Chongju, Taegu, Chonju, Kwangju, Taejon, and Ulsan are located in the temperature deciduous broad–leaved forest region, the six remaining areas in the warm–temperate laurisilva region. Area size varies between 1,566.8 km² in the capital (Seoul) and 30 km² in Chungmu, depending on population, city size, and degree of urbanization.

In the decade 1974–1984, there was a remarkable population increase in ROK's cities (MINISTRY OF HOME AFFAIRS 1975, 1985), especially in those with greenbelts (Table 2). Population density in cities with greenbelts was 38 times greater than that of rural areas in 1984, where it decreased from 193 per km² to155 between 1974 and 1984. A deluge increase of 455 % was recorded in Puchon City which is a dormitory suburb of Seoul. Rapid development of modern industry caused a more than 100 % increase in Anyang City and in Ulsan. Even in slower growing cities such as Masan, Chinhae, and Chungmu, the population increase was 17.9 % above the nation's average.

Tab. 2. Population trends in the Republic of Korea from 1974 to 1984. Figures in parentheses are relative percentages

	Cities		Rural: counties	Total
	With greenbelt	Without greenbelt		
Population in 1974	14,348,848 (41.9)	1,606,725 (4.7)	18,321,986 (53.4)	34,277,559
Population in 1984	22,749,777 (56.3)	3,325,756 (8.2)	14,354,604 (35.5)	40,430,137
Population increase 1974 – 1984: %	58.5	107.0	–21.7	17.9
Area in 1974: km²	3,024 (3.1)	1,071 (1.1)	94,819 (95.8)	98,914
Area in 1984	3,872 (3.9)	2,734 (2.8)	92,485 (93.3)	99,091
Population densities in 1974: persons/km²	4,745	1,500	193	347
Population densities in 1984	5,875	1,216	155	408

For effective management of greenbelts, the ROK government took the following measures:

1. For a clear demarcation of the boundaries, white polls were set up every 100m .
2. Guard points, occupied by two persons, were established every 10km.
3. The managment leader has the right to prevent illicit building within the greenbelt area.
4. Air photographs are taken more than once a year to detect illegal developments or changes in the greenbelt areas.
5. Special district supervisors inspect the greenbelt every month or, if necessary, at shorter intervalls.
6. Greenbelt supervision is placed under the responsibility of the Ministry of Construction.
7. Areas damaged by disasters are to be restored to the state of the original landscape.
8. Illegal building or managment is placed under penalty of one year of prison or of a fine of 1 million won (ca. us$ 1,200).

These political measures have a proven very effective. The greenbelt areas have been fully protected, excluding natural disturbances or accidental forest fires.

4. The greenbelt in Seoul area

From 1974 to 1984 the population of Seoul increased by 45 %, its density per km² from 10,432 to 15,695, and this increase continous steadily. It is accompanied by environmental deterioration such as air and water pollution.

Table 3 shows areal composition of the city planning area in Seoul, which exceeds the administrative area by 10,300 ha, in 1986. Using maps (4 maps of 1 : 50,000 scale) and field observations, greenbelt and non–greenbelt areas were identified and counted by the authors from 1984 to 1987. The total greenbelt area consists of forest (64.9 %), cultivated land (16.3 %), residential areas and land covered by other artifacts (18.8 %). In non–greenbelt areas, these percentages are 19.9, 16 and 63.7 %. In general, the recent urban sprawl was limited to non–greenbelt areas.

Tab. 3. Areal composition of the city planning area in Seoul in 1986. The relative areas (%) are shown in parenthesis

	Greenbelt area (ha)	Non-greenbelt area (ha)
Forest		
Deciduous broad-leaved forest	2,304 (13.8)	2,189 (4.0)
Coniferous forest	2,034 (12.2)	1,385 (2.6)
Mixed forest	5,916 (35.5)	4,670 (8.6)
Miscellaneous forest stand	560 (3.4)	2,570 (4.7)
Non-stocked forest stand	0	166 (0.3)
Cultivated land	2,727 (16.3)	8,664 (16.0)
Residental area and other artifacts	3,141 (18.8)	34,499 (63.7)
Prepared site	0	13 (0.1>)
Total*	16,682	54,156

*sum total in the city planning area: 70,838 ha.

Following the procedure of the Forest Administration, a coniferous forest is identified when the percentage of coniferous cover reaches 75 % or more, and the same hols for deciduous forests (Forest Research Institute 1981). Thus 13.8% of greenbelt area are deciduous broadleaved forests, 12.2 % coniferous forests and 35.5 % mixed forests. The areas of coniferous forests and mixed forests are larger in greenbelt forests than in non-greenbelt forests, because the area of micellanious forests is significantly large. In the micellanious forests, the growing stocks are small compared with the other stocked forests. Representative tree species of deciduous broad-leaved forests are *Robinia pseudo-acacia* (introduced species for erosion control), *Quercus serrata, Q. mongolica, Q. acutissima, Q. dentata*, etc. The coniferous forests are characterized by *Pinus nigra* (introduced species for afforestation), and *P. densiflora*. Mountain tops in Seoul are covered with low-growing *P. densiflora*. These tree species also play an important role in the other greenbelt areas in ROK.

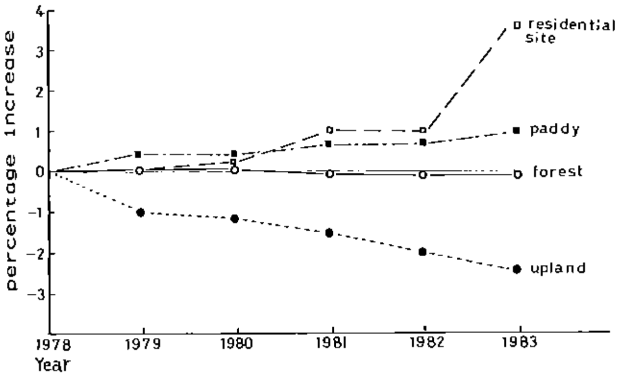

Fig. 2. Changes of land utilization of the Republic of Korea from 1978 to 1983. Each category is shown in percentage increase based on the area in 1978 as 100%. Revised from MINISTRY OF HOME AFFAIRS 1984.

5. Greenbelts as natural landscapes in the Republic of Korea

On account of urbanization, technological development, and population drift, the ratio of land utilization types has changed in the course of the years. As shown in Fig. 1, two thirds of ROK are still covered with forests (66.6 %) which dominate the mountains. Cultivated land, roads, and residential areas are mostlyrestricted to lowlands and plaines. Cultivated land, mostly rice paddy and upland cropland, has a share of only 12.9 %. Increase of residential, industrialand transport areas takes place at the expense of cultivated land mostly in plains.

The change of land utilization from 1978 to 1983 is shown in Fig. 2. Paddy areas and in particular residential areas have increased, while upland cropland areas have decreased. In fact this decrease is due to the growth of residential areas caused by shortage of housing and by environment and landscape deterioration. Forests area showed only little fluctuation due to afforestation and strict forest protection by the government.

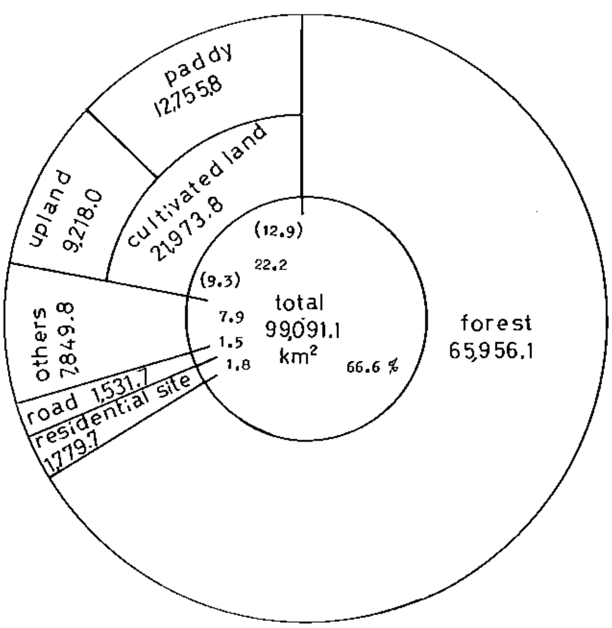

Fig. 1. Land utilization of the Republic of Korea in 1983. Each category is given by sq. km and relative percentage. Revised from MINISTRY OF HOME AFFAIRS 1984.

One of the aims of greenbelt establishment was creation and maintenance of good forests. This requires efficient forest protection and skilful management. Tree cutting, change of land use, and erection of new buildings in greenbelt areas have to be strictly controlled, because landscape or forest restoration usually is difficult to achieve following degradation or destruction. In particular, agricultural activities within greenbelt areas are regulated in every detail.

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THE URBAN LANDSCAPE–ECOLOGICAL STUDY IN CHINA

DONG YAWEN

Abstract

In China the problems associated with urban landscape–ecology are those that man has rather intensely changed the Nature, especially in the more developed areas where the impacts on the landscape elements resulted from the urbanisation process have involved the exploitation, utilization and protection of waters, soils and plants stc. and various measures of regulation of them. Urbanisation process can inevitably cause the changes in natural landscape, but it is important to certain degree to limit the unfavourable influences and results caused by man–made changes.

Introduction

A city within a certain territorial scope is locally a center in politics, economy and culture of that region. With the urban population mainly devoted to such activities as industries, transportation and trade, the city has become a complex ècological system of nature–society–economy in which man is the subject, nature the object. In this system the elements of physical environment like geology, landform, climate, hydrology and plants etc. having closest relations with mankind are not only the conditions for urban sites, but also the support for the urban development of society and economy. Today in China, the problems associated with urban landscape–ecology are ones that man has rather intensely changed the physicàl environment, especially in the more developed areas where the impacts on the landscape elements resulted from the urbanisation process have involved the exploitation, utilization and protection of waters, soils and plants etc. and various measures of regulation of them. In the present article, through the landscape–ecological study on several cities in Taihu lake region, while some relative questions are put forward, certain effective ways by which to build the ecological cities are discussed.

Ecological Problems of Urban Waters

Taihu lake region is covered with dense networks of rivers and in most cases there are several streams flowing through an urban poper, so a river in one city, according to its character of flowing into or flowing out the city proper, can be divided into three districts, i.e. the district of flowing into the city from outside region, the urban river district and the district of flowing out of the city. The three districts have different funcitons respectively in respect to urban development of society and economy. In general, the flowing–in river districts are suitable for the urban water supply sources and also can provide the urban rivers with adequate flows for diluting or washing out the polluted waters in these rivers.As an important part of urban landscape, urban rivers mainly flow through densely populated residential areas, because of the municipal public facilities and drainage system not keeping steps with the needs of urban development, presently some parts of the urban rivers are used as sewage–discharging channels. Flowing–out rivers are primarily treated as ones of draining off waters. In addition, the urban rivers together with the rivers their surrounding areas, play important roles in flood control and flood draining, agricultural irrigation and water transportation etc.. Since the urban rivers are substances with multifunctions and benefits, man's activities should be directed to seek comprehensive benefits for multipurposes. In the past from the lack of experiences, for a long time there existed blindness in exploitation, utilization of urban waters and consequently not only landscape structure and function were changed, but at the same time the regulation ability of water body by nature was reduced.The following text will take Suzhou city, a famous water city in China as a case study so as to summarize the characteristics of urban water changes and the benefits obtained by human regulation of and control on the water bodys.

(1) changes of water system pattern

It is true that the water conservancy projects build along the Yangtze river–Taihu Lake control line have had roles in promoting benefits and abolishing harms, however these facilities have to a certain extent destroyed the region's reasonable water system formed historically in the process of the city's development. In the past, there were three east–west streams and three north–south streams which constituted the Suzhou city's water system, however, mainly as a result of human's interference, the last two or three centuries have witnessed considerable changes of the system, for example, the six rivers' total length had been shortened from more than 80 km to less than 50 km by the liberation of the country in 1949 and here after it continued to drop to only about 25 km in a response to the two river–filling up campaigns launched respectively in 1950s and 1960s. The reduction of river length and the disappearence of some river parts from the city's map have made more complicated the stream flows and the current directions.

In the history, the streams running through Suzhou city proper were basically replenished by the east Taihu Lake, the Xuhe river and the Grand Canal. Ordinally with waters coming into the urban rivers from the western and northern parts of the city, while draining waters out through the eastern and southern parts of the city, this practice is well coordinated with the city's water system pattern described above. Unfortunately, the Xitanghe river connecting the urban area with the east Taihu Lake and the Weitanghe river connecting the outer urban rivers with the Yangchenhu Lake have been transformed from the original single inflowing rivers to the undefinite ones with both inflows and outflows. According to the instantaneous measurement data obtained in 1983, the six cross––sections controlling the discharges into the city have become ones with uncertain current direction, some of them even with stagnant ocurrents. The destruction of watersystem pattern results in varied current directions which in turn cause pollutants sayed to and from in rivers and in some severe conditions the drinking water supply sources of the city are endangered.

(2) benefits of municipal engineering regulation

Generally, it is difficult for urban waters to restore their original better conditions only relying on their own regulation ability when it has been changed by human beings. Therefore some regulation and control measures applied by man like engineering techniques and compulsory urban management etc. are necessary. But if such measures are not fully proved feasible before they start, the consequent results would be half with twice the effort and the objectives would not be reached as surposed previously. In the early 1970s, the urban construction sector of the municipality in order to change the situations of the stagnant urban rivers successively build three pumping stations and two drainage stations at five city gates, with each station having a rated flow of $2m^3/s$ and running three hours respectively in every morning and afternoon. Sometimes flowing automatically, sometimes being drained by pumps, the inner urban streams' water can be replaced once every 1.32 days. Owing to high power consumption and therefore expensive electricity charges, it is too lang a time for the pump stations to be remained to operate for six hours a day at present. The inner urban rivers are depending on the outer urban rivers for their water supply for pumping, the latter, however, receive about 74,600 T pollutants form 60 important pollution sources of the city every day. Followed is a list of comparison of waterquality between pre– and after–water replacement of inner urban rivers. DO: 0.5mg/L versus 2.68mg/L; COD:6.0mg/L versus 4.28mg/L; Total N: 1.45mg/L versus 0.59mg/L; Total plankton: 1.0×10^9 cell/ml versus 9.71×10^7 cell/ml, of which the algae and planktonic bacteria totaly keeps similar both before and after the water–replacement practice, total zooplankto accounts for 9.1 and 2.7% respectively, aerophile bacteria account for 32.2 and 58% of total bacteria respectively and anaerobic bacteria 67.74 and 41%. The obvious result by mechanical water replacement practice is improvement of some sensory indexes such as water colour, water transparency etc., the effect on elimination of organic pollutants is not satisfactory however. So we think that the ideal scheme is to take a complete set of comprehensive management measures, i.e. to intergrate the realignment of inner urban rivers with that of outer urban rivers, to gradually reduce the discharging volumes of pollutants from important pollution sources and to intensively build domestic sewage treatment plants (in eastern, wester and southern parts of the city respectively) and if necessary to divert waters from both Taihu Lake and Yangchenhu Lake to drain out or to dilute pollutants etc.

Landscape–Ecological Effects of Urban Soils and Trees

(1) soils

Based on the determination and analysis of some 20 elements from 50 samples collected in Wuxi city, Changzhou city and Suzhou city respectively and at the same time by comparison them with their surrounding areas' soil background values of farmlands (table1)

Tab.1: comparisons of some elements (in ppm) between the urban soils in Suzhou, Wuxi, Changzou and the yellow mud soil or cyanosis earth

soils / elements	yellow mud soil	cyanosis earth	soils in Suzhou	soils in Wuxi	soils in Changzhou	urban garbage
Zn	67.50	73.12	321.35	153.50	154.29	166.3
Pb	28.99	27.31	350.00	240.71	241.43	67.4
Co	10.24	11.72	18.33	32.50	31.29	
Ni	27.10	29.72	29.05	65.43	44.71	
Cd	0.13	0.16	2.13	2.33	2.11	1.12
As	10.19	7.98	400.89	555.00	690.00	19.2
Cu	23.69	24.20	119.03	40.79	53.14	42.3
Cr	61.79	57.52	60.58	82.21	89.14	

(yellow mud soil and cyanosis earth), it can be found from the comparison that some elements content in the urban soils is generally higher than in the contrasting soils, among them Pb is about 19 times mores, Cd one time more, As 40–70times and Zn 2–5 times more than that in the contrast soils respectively; As for the remainer, for instance, Cr is similar to that in the contrasting soils, Co, Ni and Cu appear no any accumulation. The accumulation of pollution elements such as Pb, Cd, As etc. is most closely related to the sampling places which are mainly distributed over either the urban industrial areas or highly populated residential areas. However in Warsaw, the capitol of Poland,some people have engaged in certain determination works of the city's soils and compared such heavy metal elements as Pb and Cd etc. in the soils of the forest park with those in the soils industrial areas, the result showed that under natural–ecological conditions, the soils of the forest parks suffered no heavy metal pollution.

(2) trees

In terms of different ecological conditions, the column samples from eleven trees in Suzhou, Wuxi and Changzhou cities' factories, residential areas and roads were collected. By determination of contents of macroelements and heavy metal elements in the xylem of annual rings of the collected samples by using plasma emission spectrum method, the dynamic variations of element content in the annual rings of trees can be found out, especially the accumulation of elements related to human activities demonstrates the variation characteristics of tree habitats. The growth and decline of elements in the tree annual rings, except attributable to the urban soils and urban climate, are also affected synthetically by tree age, tree species and management techniques.

Putting the determined data into a dynamic variation program and dealing with the program by PC–1500 computer, the variation trend can be described as follows:

(a) The Ca content in the tree annual zones varies with the tree habitat conditions and tree species. There only exists a weak difference between years in Ca content in the annual rings of *Zelkova schneideriana* with a 60 years growth history growed in gardens (Fig.1); the same trees of the same age growed in factory areas began to show a sharp increase in Ca content and certain Ca accumultion trend (Fig.2) after the tree had been growing for 7–8 years; to years later, this growth trend begins to become gentle gradually. If the tree habitat keeps unchanging, the Ca content varies with the tree species, for instance, the Ca content in the annual rings of *Pinus thunbergii* in the garden exhibits a descending trend year by year.

(b) Pb, Cr, Cd, As have been detected in the growth rings of most tree species, of which Cd content in the growth rings of *Platanus orientalis* planted in the Wuxi clay – figure – making factory shows certain accumulation trend with the increase of age of the tree (Fig.3), this may be a response to that the question areas are more developed in industrial areas; Cd content in the annual rings of *Platanus orientalis* of 15–20 years old is increased to above 0.18 ppm which is one –thirteenth of 2.33 ppm on average content in the polluted soils of the city, only 0.02–0.05 ppm higher than that in the contrast soils. Elements Pb, Cr, As content demonstrates no greater variation. The maximum Pb content is 0.44 ppm (Fig. 4). It is only a rate of one to several thousands of mean content apearing in the urban soils; the maximum Cr content is 2.08 ppm (Fig.5) which is one–thirtieth to one–fortieth of that in urban soils. The maximum As content is about 1.6 ppm (Fig.6), one–eighth to one–tenth of that in the contrast soils, one–three hundredth in the urban soils respectively.

(c) S content in the annual rings varies with tree habitats. Since 1950s the *Zelkova schneideriana* (about 30 years old) growed in the Wuxi television factory showed a continuous increase in S content (Fig.7) that reached 640 ppm by the end of 70s and is several–decade times higher than the mean S content (8.5 ppm) in the soils, while the S content in the young *Salix babylonia* planted in Huanhe road of the city is highly 1690 ppm (Fig.8). The absorption of S exhibited by the green tree species under different habitat conditions is favourable in the purification of urban air pollution environment.

What has described above is the temporal–spatial distributional situation of different urban ecological–functional districts in terms of individual element detected in tree annual rings, i.e. a simpler analysis about element content levels under different tree age states and tree habitats. The adsoption to heavy metal elements exhibited by the tree xylem through soils is an effective measure of bio–purification in protection and control of soil heavy metal pollution. Therefore such a characteristic held by tree xylem can be considered in the urban green land planning and environmental protection planning to deliberatedly develop some quick–growed tree species which can absorb and accumulate a great volume of pollution elements and toxic heavy metals.

Conclusion

It can be seen from the above examples that in the more developed Taihu Lake area, the urban dense population and speed–up of industrial development have resulted in profound changes of natural landscape, especially the last two decades have experienced the greatest of these changes which are mainly the consequences of untimely restoration and management of the landscape. However the restoration and management of the natural landscape is by no means to reverse the nature or restore it to its original state, but is to mould it from the new start point and to build the balance relationship between the man and the nature. Economical developments can inevitably cause the changes in natural landscape, but what is important is to adroitly guide action according to circumstances, i.e. to certain degree to limit or restrain the unfavourable influences and resutls caused by man–made changes. Correctively dealing with the relationsship between man and nature and combination of conforming to nature and directional control of nature are the fundamental starting points of optimizing theurban landscape–ecological designing plan.

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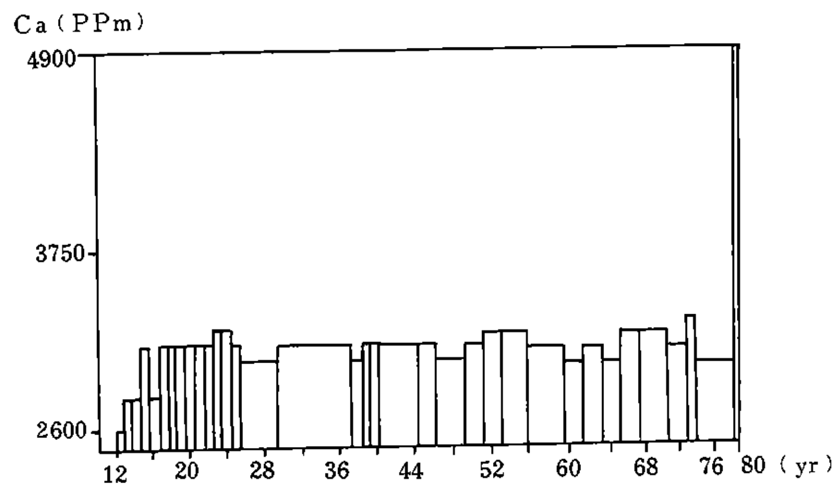

Figure 1. Ca content variation in the annual rings of *Zelkova Schneideriana* in Changzhou Park

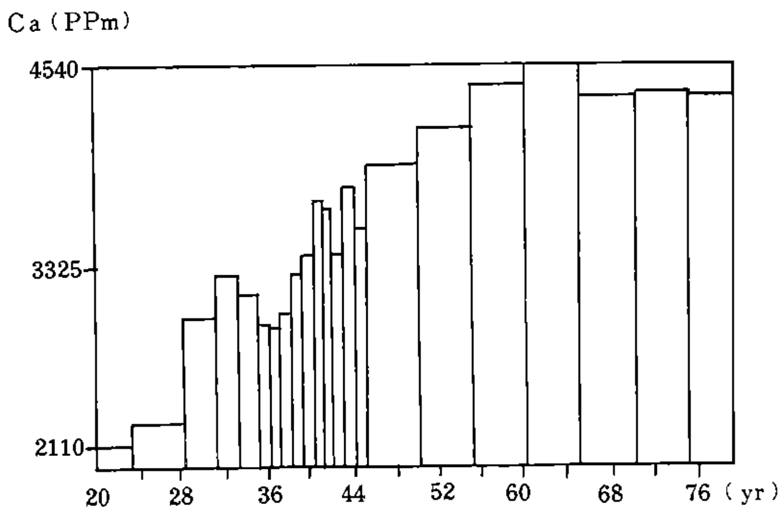

Figure 2. Ca content variation in the annual rings of *Zelkova Schneideriana* in Wuxi Television Factory

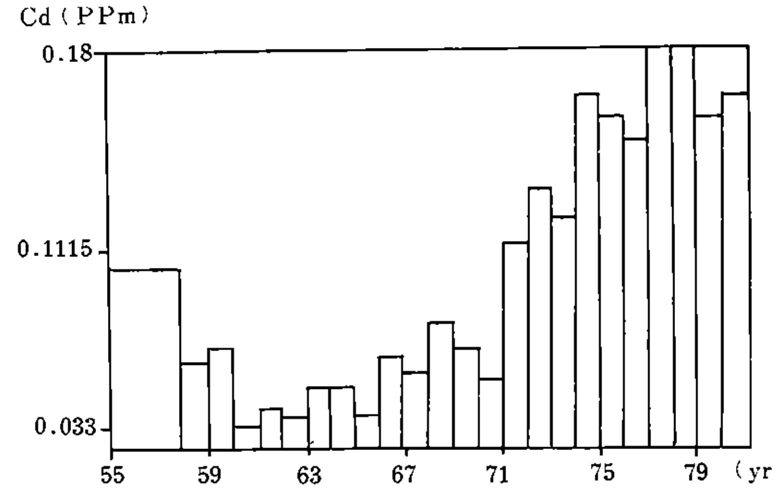

Figure 3. Cd content variation in the annual rings of *Platanus Orientalis* in Wuxi Clay-figure Making Factory

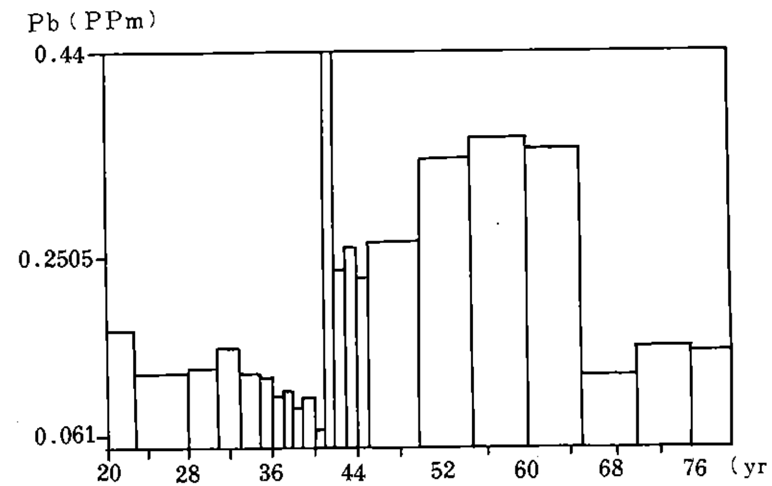

Figure 4. Pb content variation in the annual rings of *Zelkova Schneideriana* in Wuxi Television Factory

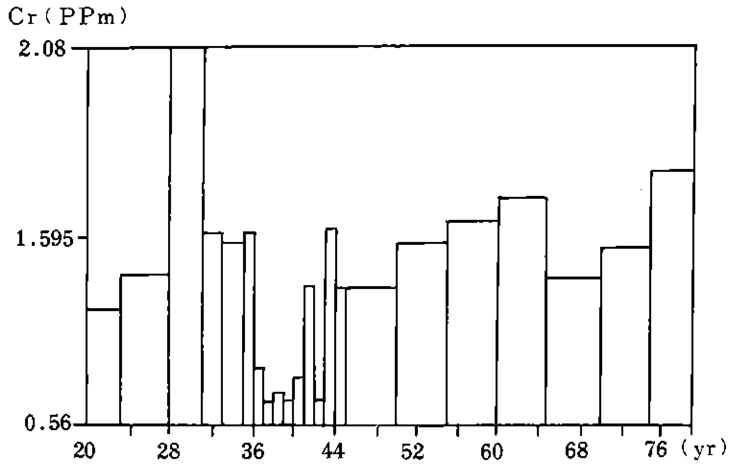

Figure 5. Cr content variation in the annual rings of *Osmanthus Fragrans* growed in one alley of Suzhou City

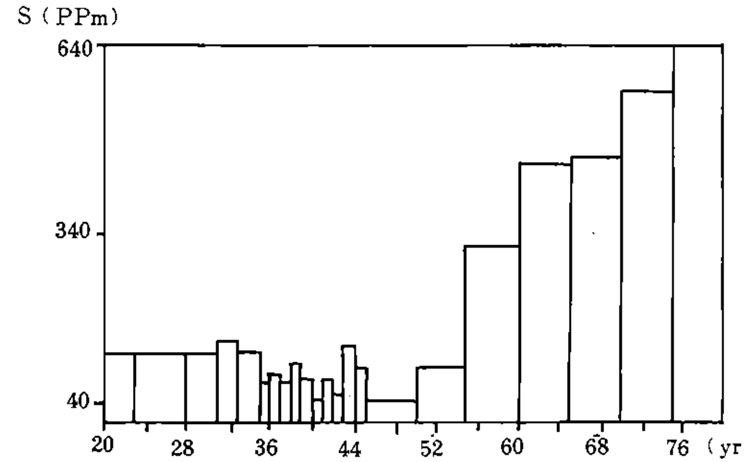

Figure 7. S content variation in the annual rings of *Zelkova Schneideriana* in Wuxi Television Factory

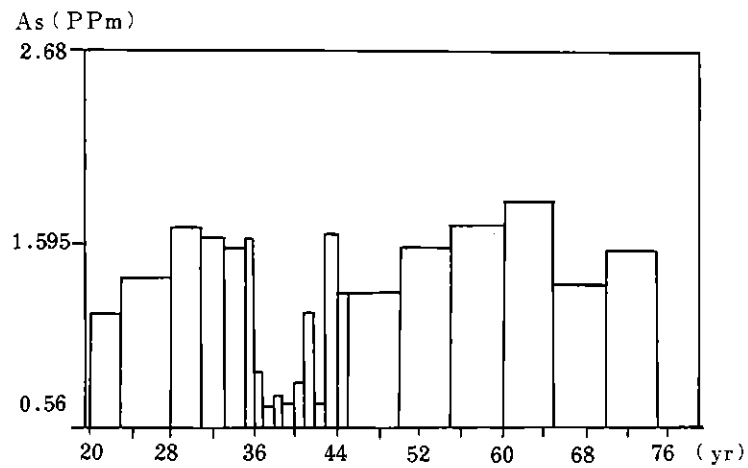

Figure 6. As content variation in the annual rings of *Zelkova Schneideriana* in Wuxi Television Factory

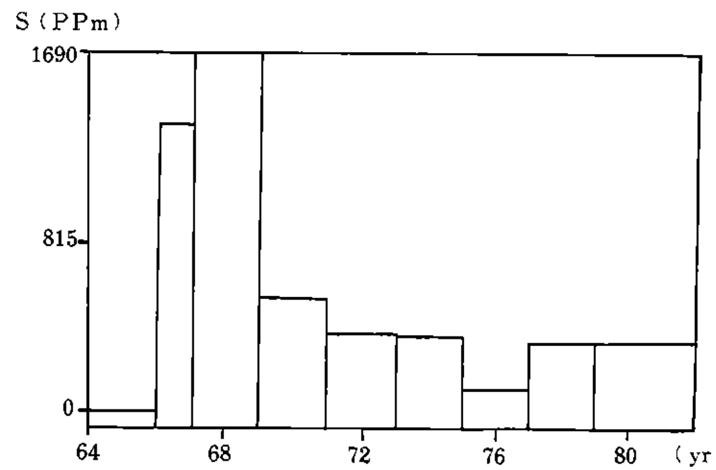

Figure 8. S content variation in the annual rihgs of *Salix Babyloniea Planted* in Huanhe Road in Wuxi City