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PRESS

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CONTENTS

ABSTRACT

Palang, H. 1998. Landscape Changes in Estonia: the Past and the Future. Dissertationes Geographicae Universitatis Tartuensis No 6, 144 p. Tartu University Press. Tartu.

The current thesis concentrates on investigation of land use and landscape diversity changes in Estonia, their impact on the ecological networks and outlining the future landscape development in Estonia.

The main land use changes in Estonia during the 20th century have been the decrease in the share of agricultural land from 60% in 1918 to 30% in 1994 and increase in the share of forests from 14% to 42% during the same time. Despite these changes, the average landscape diversity has remained stable. While some test areas have undergone significant simplification, the others have changed towards more complex structure, thus compensating the change.

The latter refers to the ability of Estonian landscapes to compensate human impact. This is largely due to the ecological network, a system of interconnected natural and seminatural areas. However, this existing network does not yet have a legislative support. Thanks to this the existence of the network is under threat during the on-going societal restructuring. Another threat to the ecological network is the probable fragmentation that may be caused by some projected infrastructure developments, such as the planned Tallinn—Tartu highway.

The simple statistical models based on the land use data of the Soviet period show that the area of fields will remain more or less stable in Estonia. Some models predict an increase in forests, while others show that the peak in forest area has been reached. All models predict that natural grasslands should disappear altogether. In order to steer these changes, more attention should be paid to landscape planning. Landscape values could serve as criteria here. Sustainable land use planning should guarantee the use of landscape values without compromising the values of future landscapes. Therefore the main tasks of landscape management should include creating an environmental GIS, inclusion of landscape aspects in the EIA procedures and inclusion of the ecological network into Estonian legislation.

ORIGINAL PUBLICATIONS

This thesis is based partly on unpublished data and partly on the following papers, which are referred to in the text by their Roman numerals and included as appendices at the end of the thesis:

I Mander, Ü., **H. Palang** 1994: *Changes of Landscape Structure in Estonia during the Soviet Period*, GeoJournal, 33.1, 45–54.

II Mander, Ü., **H. Palang** 1998: Landscape Changes in Estonia: Reasons, Processes, Consequences. *Land Use Changes and Their Environmental Impact in Rural Areas in Europe*. Parthenon *(in press)*

III **Palang, H.,** Ü. Mander, A. Luud 1998: Landscape Diversity Dynamics in Estonia. *Landscape and Urban Planning*, 33. *(in press)*

IV Mander, Ü., **H. Palang,** J. Jagomägi 1995: Landscape change and its impact on ecological network: case of Estonia. *Landschap,* 2–3, 27–38.

V **Palang, H.,** M. Mikk, Ü. Mander 1997: Ecological network and road network: The case of Estonia. Canters, K. (ed.) *Habitat Fragmentation and Infrastructure. Proceedings of the international conference on habitat fragmentation, infrastructure and the role of ecological engineering, 17–21 September 1995, Maastricht and The Hague, the Netherlands.* Ministry of Transport, Public Works and Water Management, 104–108.

VI **Palang, H.,** E. Kaur 1997: Possibilities for sustainable land use planning. Munzar, J., A. Vaishar (eds.) *Rural Geography and Environment. Proceedings of the 2nd Moravian Geographical Conference CONGEO'97.* Geokonfin, 97–100.

VII **Palang, H.,** K. Sepp, T. Mauring, Ü. Mander 1998: Landscape Conservation and its Perspectives in Estonia. *Estonia Maritima,* 3. *(in press)*

VIII **Palang, H.,** Ü. Mander 1999: Predicting the Future of Estonian Rural Landscapes: Analysis of Alternative Scenarios. *Landscape Ecology (submitted).*

Author's contribution

Publication I: The author is responsible for the analysis of land use changes, driving forces of these changes, but also for making the figures and writing the manuscript.

Publication II: The author is fully responsible for the parts concerning land use changes and their driving forces and participated in writing the parts concerning ecological network.

Publication III: The author is responsible for designing the research, data collection, analysis and writing the manuscript.

Publication IV: The author equally participated in carrying out the research and writing the manuscript.

Publication V: The author is fully responsible for designing and carrying out the research and preparing the manuscript.

Publication VI: The author is responsible for designing the research and preparing the manuscript.

Publication VII: The author is responsible for designing the research and preparing the manuscript.

Publication VIII: The author is responsible for designing the research, creating the scenarios and preparing the manuscript.

1. INTRODUCTION

Landscape is a kind of backcloth to the whole stage of human activity, writes Jay Appleton (1996). Moreover, this backcloth itself is largely a result of human activities. Landscape is not a stable entity, but rather an ever changing process. This change might be natural, but might also be accelerated, induced or slowed down by human activities.

Landscape changes have been a rather popular subject among scientists from different fields. It has attracted landscape ecologists, physical geographers, cultural geographers, but also planners, architects, and political scientists. Therefore the amount of literature available is relatively numerous (see, e.g., Forman 1996, Jongman 1996). The landscape changes of Estonia are not so well documented. Kasepalu (1991) has outlined the development of Estonian village and rural life. Several authors (Varep 1964; Arold 1991) have summarised the knowledge physical geographers have acquired about Estonian landscape changes. In recent years, remote sensing has been used to detect recent changes (see Peterson and Aunap 1998).

This thesis concentrates on four main objectives. These are

- to describe the land use changes having occurred in Estonia during the 20th century
- to describe the landscape diversity changes caused by the land use changes;
- to investigate the impact of landscape change to the ecological network;
- to create a basis for modelling future landscape changes in Estonia;
- to outline the main tasks for landscape conservation.

The thesis consists of four main parts. After this introduction, the second part creates the theoretical background to the following study. Different definitions of the term landscape are explained, as are possible ways of distinguishing between natural and cultural landscapes. Particular attention has been paid to the development of these ideas in the Estonian geography.

The third chapter describes the land use changes in Estonia during the 20th century, the driving forces of these changes and also landscape diversity changes caused by these. The main results of this study is presented in Publications I, II, and III.

The fourth chapter of the thesis concentrates on the impact of land use changes on the ecological network and fragmentation of habitats. The chapter summarises the results of investigation included as Publications IV and V.

Finally, the fifth chapter outlines the tasks and principles of sustainable land use and presents scenarios for possible future landscape changes. The main outcome of this part of the study is presented in Publications VI, VII, and VIII.

2. THEORETICAL BACKGROUND

2.1 Landscape

Every study focusing on landscape change should first explain how the term landscape is understood in that very context.

As landscape is the basic concept of geography (Sauer 1925), it has obtained several different meanings and understandings. It can be understood as something mental, perceivable, or, *vice versa*, something very realistic, visible. Landscape can be at the same time a general term or a term indicating a certain delimited piece of land with its specific character. Usually the division line between understanding landscape lies somewhere in between physical and cultural geography.

In Estonian geography, landscape has mostly indicated something natural, not human. The common approach, so largely used in 1980's, says landscape is a regional unit with similar natural conditions, which has, mainly due to geomorphological features, certain preconditions for its appearance and management (Arold 1991).

The term *landscape* (in Estonian, *maastik*) was brought into Estonian geography by the Finn Johannes Gabriel Granö, who was in 1919 invited to become the first professor of Geography to the newly established University of Tartu. For him, landscape did not have the same meaning as it has today. He defined *surrounding* (in Estonian, *ümbrus*) as the object of geography. This object lies in the field of natural science, even if the surrounding perceived by human senses is dealt with. "*Because nature is not only uninhabited forests and deserts, mountain ranges and oceans, but as well the settlements, villages and towns*" (see Kant 1933: 42). According to the extent of the scenery, the surrounding was divided into two main parts: the *milieu* (close surrounding) that can be perceived by all human senses, and the *landscape* (far surrounding) that can only be seen. Moving or standing human is the centre of these, but "*in geographical research one has to get rid of the person of the observer, and to explain the qualities of the* milieu *and the* landscape *of the studied area, independently of the point of observation and the limited possibilities of the observation*" (Granö 1924). Finally, Granö describes landscape as a territorial unit that has defined, visible, constant, far surroundings' characteristics (Granö 1924).

Granö himself (1922) and later also his disciple, August Tammekann (1933), have used this approach to give the regionalisation of Estonian landscapes. The authors pay equal attention to both natural (geomorphology, waters, vegetation) and artificial, human-made (mainly the distribution and shape of rural settlements) features. Differently from Granö, Tammekann took also the genesis of the landscape into account (Roosaare, 1994). At the same time, for several other researchers, the term *maastik* meant something close to its grammatical meaning — a collection of lands.

In 1940, a new chapter in the history began — the country became occupied by the Soviet Union. This also marked a turn in the spread of scientific ideas. The generation of scientists that had shaped the Estonian geography fled to the West, and a new start was made with new people. While for Granö and his disciples landscape included both natural and human features[1], the emerging generation concentrated mainly on the nature in the landscape. This approach, typical for the Russian school of physical geography, was not something essentially new, as Eduard Markus, one of the leading natural scientists of the pre-war period, had introduced some of the ideas in his studies. Nevertheless, the change resulted not in exchanging the concepts used by Granö's disciples, but in diversification of the concept itself. In 1966, K. Kildema and V. Masing, reviewing the development of landscape science in Estonia, stated that the word *landscape* had still three different meanings. First, according to the oldest understanding, it indicated the appearance of the area, the colours and the forms in a scenery, paysage. The authors added that in geography an approach like this was hopelessly out of fashion. Second, landscape was a general term to mention territorial units. Third, landscape was described as a territory of certain size that has a number of characteristic features (Kildema, Masing 1966: 259–260).

In 70's and 80's, a somewhat funny tendency can be observed. In these decades two editions of the *Soviet Estonian Encyclopaedia* were published that summarised the 'official' understandings of those times. In the first edition (ENE 1973), landscape had two meanings, one being the basic unit of defining landscape regions and the other indicating a territorial unit with interrelated landforms, soils, vegetation, and human features. Differently from Granö, the landscape did not move together with the observer, and it was defined by the causal relationships between the parts of the landscape, rather than delimited by the sense of vision. This approach refers to the bigger concreteness, desired by Kildema and Masing. However, in the second edition (EE 1992), two new meanings had been added. One of these was the understanding spread in the GDR and Czechoslovakia about a natural-territorial system with interrelated purely natural parts and several results of human activities. The other new meaning was of course the 'old-fashioned' understanding of landscape as a scenery.

To conclude, one has to state that there is no single understanding of the term landscape in Estonian geography, although several attempts to gain it have been made. The comparison of these different ideas can be found in Table 1.

[1] The influence of the views of Granö on the modern geography is still often discussed, see, e.g., Roosaare 1994, Paasi 1984, etc.

Table 1. Hierarchy of the term *landscape* (after Palang *et al.* 1998, Jagomägi *et al.* 1988, Kant 1933 etc.)

ECOSYSTEM	LANDSCAPE Geocomplexes	EXTENT	LANDSCAPE Perceived space	HUMAN SPACE
		3000–5000 km		
	Province	1000–1500 km		
Coenoregion	Subprovince	300–500 km		Country, state, regional settlement system
	Group of landscape regions	100–150 km		Group of counties
Coenocomplex	Landscape region	30–50 km		County
	Group of localities	10–15 km	District	City, local settlement system
			Neighbourhood	
	Locality	3–4 km		Town
Coenosis		1–2 km	Landscape	Settlement, borough
		300–500 m		Block, large park
Merocoenosis		100–200 m	Milieu	
Parcel		30–50 m	Space of moving person	
			Space of standing person	

Elsewhere, landscape has been understood more widely. In Russian (Soviet) geography, some 8 different definitions appear (Reimers 1990). However, all these handle landscape as natural geographical complex defined mainly through its natural features. Isachenko (1991) handles landscape as the main category in the hierarchical system of territorial units. He also admits that there also exist larger units that result from territorial integration of landscapes. Milkov (1973) argues for the term anthropogenic landscape, which encompasses landscapes created by man as well as geocomplexes at least one component of which is radically changed by man.

In Israel, Naveh (1995) defines landscape as a concrete tangible entity of the total human ecosystem. The *ecosphere*, composed of *biosphere* and *technosphere* landscapes, is its largest global landscape unit, and ecotopes are the smallest mappable units of these natural, semi-natural and cultural landscapes.

Landscapes are also becoming more important as a policy target. However, as the term itself is unsettled, it has proved difficult to define it in policy papers. In the draft of the European Landscape Convention, landscape appears as a cultural feature. The draft Convention aims at preserving the cultural heritage and historical appearance of the landscape. The same does the Dobris Assessment (EEA 1995), which, based on Meeus' works (1995), considers cultural landscape as 'characterising distinctive interrelationship between nature and people and encompass a group of mostly rural landscapes'. So cultural landscapes here are handled as recognisable parts of the surface of the Earth, which have a characteristic composition, structure and scenery. Based on these ideas, an attempt has been made by a working group lead by the European Centre for Nature Conservation to classify European landscapes and identify their trends and threats (EEA, forthcoming).

In this work, landscape is understood as Emmelin (1996) defines it: *the visual sum of objects and processes in a given locality at a given time.* An important idea in this definition is that landscape is understood not as a static phase of a locality, but as a process continuing through time.

2.2 Natural and cultural landscapes

Also, a question arises how to divide landscapes. Usually people distinguish between natural landscape and cultural landscape. Again, especially the term *cultural landscape* is extremely difficult to define. According to Jones (1991), there are at least 3 ways to distinguish between these two. The first is the traditional division based on the intensity of human impact. *Landscapes are the product of interactions between human management and nature. We speak of cultural landscapes when management is manifest and the interaction of such factors as soil conditions, elevation, use, management, and history are visible in the landscape and are expressed in its form and layout* (Meeus et al. 1990). *By definition, landscape is the physical surface of the Earth. Natural landscape is formed by the forces of nature (tectonics, weathering, erosion, sedimentation and occupation under different conditions of climate and parent material), cultural landscapes can be defined as recognisable parts of the surface of the Earth, which have a characteristic composition, structure and scenery. They are distinguished by the degree of anthropogenic influence and are defined by a particular configurations of land form, soil topography, climate, vegetation, land use, history and scenery* (Meeus 1995).

According to Naveh (1995), the first cultural landscape patches and ecotopes were created apparently in the front of the inhabited karst limestone caves, around the open forest gaps and campground fireplaces, already several hundred thousand years ago. The so-called natural landscapes of Europe are, in reality, relics of earlier types of land use.

The critics of approach like this (Jones 1991; Isachenko 1991) say that division of landscape according to the intensity of human impact is meaningless, as there is no intact landscape left on Earth, or the limit between these two is extremely difficult to define. Instead, several other terms to indicate landscapes with different degree of human interference have been proposed by Milanova and Kushlin (1993), Isachenko (1991), and others. Isachenko (1991) himself defines cultural landscape as a landscape the structure of which is rationally changed and optimised on a scientific basis in order to better meet the interests of the society. The two criteria to decide whether a landscape is cultural include high productivity and economic efficiency on one hand and optimal conditions supporting the needs for human life, on the other.

Second approach to cultural landscape lies in defining cultural landscape as human material input in the landscape. In this case, natural and cultural landscape are no more opposites, but rather different layers of the total landscape (Jones 1991). In this understanding, natural landscape is not removed by the cultural one, but the latter is superimposed on the former during time. The best illustration for this approach is a study by Keisteri (1990), where she creates a multilayer model for the term landscape that contains both natural and human-made objects as well as underlying factors.

The third way to distinguish between natural and cultural landscape is to define the latter as subjective, perceivable part of the landscape, consisting of symbols, meanings and understandings. From here, a direct way leads to landscape aesthetics (Appleton 1996; Porteous 1996; Bourassa 1991; Jackson 1989) and further into the field of psychology.

In policy, the most important definition of cultural landscape has been provided in the Convention for the Protection of the World Cultural and Natural Heritage, also know as the World Heritage Convention. There three categories of cultural landscape have been mentioned. These comprise *garden and parkland landscapes*, which are designated and created by man for aesthetic reasons; *organically evolved landscapes* which result from an initial social, economic, administrative and/or religious imperative and develop their present form by association with and in response to the natural environment; and finally *associative cultural landscapes*, which are essentially natural landscapes that harbour powerful religious, artistic or cultural associations (Bennett 1996).

It is difficult to say when Estonian geography started to distinguish between natural and cultural landscapes. For Granö it was not a problem. His contemporary, untimely departed J. Rumma (1922) delimited 5 types of land use, cultural landscape[2] being one of them. He defined cultural landscape as land where humans try not only to take from the nature, but also to give, for example by introducing new plants, fertilising the land, etc. As examples of cultural landscapes Rumma counted fields, orchards, cultivated grasslands, etc. Some decade later, the most famous Estonian geographer, Edgar Kant, gave a more clear picture. He insisted that *research, delimitation, description, and explanation of cultural landscapes must follow the same rules applicable to geographical study of every other landscape, that is underlining their artificial character*

[2] Again problems with translating the terms occur. Rumma never used the term *kultuurmaastik*, the usual translation for cultural landscape. Instead, he used *kultuurmaistu*, that can literally be translated as the collection of cultural (cultivated) lands.

shaped by human activities (Kant 1933: 59). *In research of cultural landscape the geographer needs more than elsewhere the help of social and economical sciences to solve his tasks... It is clear that the geographical surrounding, especially cultural landscape is in causal relation with human society and social milieu, and the latter in turn may in a great extent be dependent on geographical surroundings* (Kant 1933: 61). Kant did not oppose cultural and natural landscapes, for him natural landscape, garden landscape, and industrial landscape were different stages of formation of the cultural landscape.

To sum up, in the pre-war period natural and cultural landscapes indicated the different phases in the succession of landscape. But more and more the terms start to mean the landscape that is either changed or unchanged by humans.

During the Soviet times, the latter tendency became ruling. Cultural landscape was defined as landscape reshaped by human activities (ENE 1973), later the word 'purposefully' was added to the definition (EE 1992). Of course, opposing the two landscapes was a problem not only in Estonian geography. The reason should be sought in the different concerns behind the researchers, some of whom departing from natural, the others from social sciences, caused in turn by the *rapid spread of cultural landscapes and growth of urban agglomerations, accompanied by total increase in human population,* as Kant (1933: 60) posed it. However, the main attention of landscape scientists tended to concentrate on the areas with less artificial elements, but stopped before urban areas.

2.3 Landscape change

Setting aside the natural succession of landscape, there are several other ways to define and determine landscape change. One of these is tracing the appearance of human elements in the natural background, or, in other words, formation of cultural landscape, as some authors pose it (Naveh 1995 etc.). According to this, humans turn natural landscape into cultural one, constantly increasing the human impact till the former natural landscape is totally replaced by something anthropogeneous, townscape or urbanscape being the ultimate form of it.

However, as there is almost no purely natural landscape left (Jones 1991; Isachenko 1991), one has to abandon the strict division of landscape into either natural or cultural and adopt the kind of definition where cultural and natural landscapes are understood as layers of one total landscape. In that case the study of landscape changes focuses on the change in land use, which has its specific driving forces, but also has its ecological and social consequences.

Keisteri (1994) asks for studies in cultural landscape and cultural ecology to be based on the ideas of circulation landscapes. This idea, similar to that of

Emmelin (1996) handles landscape as a result of former activities and basis for future alternatives. The landscape we have today may have had several past alternatives that can be restored using old maps, photographs, descriptions. At the same time the landscape has several future alternatives that depend on the decision made today. The choice between these alternatives depends on the values and valuations associated with the landscape.

Bastian (1994: 148) demarcates the objectives of the investigation of landscape change as

> *1. Early recognition and assessment of development tendencies give the possibility of intervening in a regulating manner and countering efficiently possible undesired processes in due time and thus with relatively small economic expense.*
>
> *2. Knowledge and documentation of the ecological situation of epoch passed are absolutely part of the preservation of our historical and cultural heritage*

From here, several ways for further studies depart. One leads to predicting the possible future change. This will be discussed later. Another focuses on the consequences of the change, in order to evaluate the possible effects and thereby steer the changes. On one hand these studies concentrate on the effects on nature, while another group of studies focuses on cultural/social/aesthetical side of landscape change.

2.4 Landscape values

Landscape values are of main importance in the study of landscape change. Humans reshaping landscapes try to make them suitable for some specific purpose, to better meet some specific need. The landscape is able to meet several such needs.

Usually people tend to idealise the old landscape, the one they remember from their youth. However, very often that old ideal does not correspond to the needs of modern technology. Therefore the landscape should be reshaped. How to reshape, depend on the values people associate with landscape and the assessment or ranking of these values.

Mitchell (1989) finds three general approaches to landscape evaluation. The first is an informal process through which experts strive for a consensus about the landscape attributes of an area. The second approach attempts to describe the landscape in terms of its different components or in its totality. Emphasis is given to identifying and measuring critical landscape variables, determining their interrelationship, and assessing their relative importance. The third approach, termed landscape preferences, seeks to discover which aspects of the environment are seen as attractive and unattractive.

In different works, the lists of values one can find in a landscape vary considerably. Usually people talk about ecological, economical, and cultural/aesthetical/social values. Boyce (1995) indicates 6 classes of benefits a consumer can get from a forested landscape. These are aesthetics, habitats, fuelwood, timber, cash flow, and biological diversity. Jones (1993) goes further and provides a more thorough classification of landscape values, which will be used in the purposes of the current work.

Jones distinguishes between three groups of values associated with the landscape as a resource. Economic values represent the different material benefits one can get from landscape. Landscape has also a value for non-economic or amenity activities, such as seeking for some kind of experience. Finally, Jones points out the security value of a landscape, providing defense or demarcating territoriality.

A terminological confusion occurs when the abilities of the landscape to satisfy human needs are listed. Bastian (1994), departing from the German school, defines landscape potential as the ability of landscape to satisfy needs and demands of human society. As synonym to potential, he uses function, that more reflects the effects which are concretely and immediately realised by landscape for human society in a broad sense. He also lists a number of landscape functions (such as *productive*, *ecological*, and *social* functions) and of landscape potentials (biotic regulation and regeneration potential; water potential; yield and decontamination potential; air hygienic and microclimate balancing potential; and recreation potential including landscape aesthetical and ethical value).

Another school uses the term landscape value instead of function or potential. As Jones (1993) puts it, landscape value is a value associated with the landscape. The values are not intrinsic to the landscape, they rather lie within people or groups of people and depend on perceptions of the way in which landscape can serve or satisfy the needs and desires of these. Or in other words, landscape is seen as a resource.

An interesting theory concerning landscape values has been put forward by geographers dealing with landscape aesthetics. Appleton (1996) has formulated two theories explaining human preferences of landscape. First, the *habitat theory* argues that aesthetic satisfaction, experienced in the contemplation of landscape, stems from the spontaneous perception of landscape features which, in their shapes, colours, spatial arrangements and other visible attributes, act as sign-stimuli indicative of environmental conditions favourable to survival, whether they really are favourable or not. Second, the *prospect-refuge theory* says that the ability to see without being seen is conductive to the exploitation of environmental conditions favourable to biological survival and is therefore a source of pleasure. Bourassa (1991) has gone further and explains that the landscape taste of any individual stems from *biological laws*. These are cross-cultural, genetically transmitted elements of survival behaviour. Out of these biological laws, each cultural group begins to develop its own particular ways of seeing; its *cultural rules* impose its own system of values, its own criteria of excellence, determined in accordance with its own fashions, customs and conventions. Cultural groups in turn are made up of the individuals who comprise them, and each individual forges his own personal strategy, his own unique mix of meanings, preferences and typical behavioural responses, out of his inherited behaviour patterns and within the context of the cultural rules imposed by the group at whatever scale — the family, the peer group, the nation state, etc.

3. LANDSCAPE CHANGES IN ESTONIA

3.1 Driving forces of land use change

Land use can be considered as reflection of different social, but also natural processes. In Estonia, agriculture and forestry have been the main sectors influencing land use. Consequently, the appearance of Estonian landscapes largely depends on the development of these two sectors. On the other hand, three groups of features determine the changes in land use. These are *physical*, *political*, and *economic*.

Of physical features, *natural conditions* are the most influential. Different bedrock — limestone in the north, sandstone in the south — cause differences in soils and vegetation. The division of the country into Lower Estonia that has been flooded either by the sea or glacial lakes and into Upper Estonia that has not been flooded also influences the soil cover, but as well determines the scale of the landscape. Lower Estonia is plain, often swampy, while Upper Estonia is more mosaic and hillocky. Finally, a climatic border enables to distinguish between the more maritime western part of the country and more continental eastern half.

The political features include *land reforms*, *deportations*, and *urbanisation*. There have been 4 land reforms carried out during the 20th century. The first in 1919 aimed at transferring the land ownership from Baltic-German landlords to Estonian peasants, thus increasing dramatically the number of farms. The second in 1940 targeted land nationalisation. It reversed the previous reform, however, the number of farms still increased. The third reform in late 1940's aimed at collectivisation of agriculture, small private farms were gradually replaced by ever larger collective ones. Finally, since 1989, private farming is again introduced and the state tries to reprivatise the land. Two mass deportations occurred in 1941 and 1949, during which more than 30,000 people were removed. As a great share of these had been involved in agriculture, it resulted in a decline in the sector. The last deportation together with collectivisation of agriculture triggered also urbanisation, which in turn lead people away from countryside, thus deepening the decline.

Of economic issues, *land amelioration* and *concentration of agriculture* are of major importance. Amelioration activities in Estonia started in the middle of the 19th century and reached the number of 731,000 ha of improved land by 1991. Basically these were undertaken to improve natural grasslands, but curiously a simultaneous decrease of agricultural land took place. The more energy was spent to occupy new agricultural land, the less remain to maintain old lands. This induced a process were main land use shifted from old lands that got occupied by settlements, mines and infrastructure, to newly reclaimed lands. Concentration of agriculture, especially during the Soviet time, had the greatest influence on landscape pattern. It removed the former mosaic of small patches, creating instead large-scale monotonous polarised landscape.

3.2 Changes in land use

Changes in land use and landscape in Estonia have been an interesting research subject for many scientists. These include Aaviksoo (1993), Kasepalu (1991), Peterson and Aunap (1998), Ratas *et al.* (1996), to name just some of them.

Several methods can be used for backtracing the past land use changes. Using statistical data is perhaps the most common way. Another is to use old maps. Third possibility lies in using remotely sensed data. However, none of them may be exact enough. Statistical data depends on the methods of how the data have been collected. In Estonia, additionally, some of these data may be distorted because of political reasons. Also, statistical data may not be precise enough. Similarly, old maps may have distortions. Habits of map makers and surveyors, classifications and generalisation used may influence the outcome. Finally, remotely sensed data is available only for the last decades. In this analysis, official statistical data has been used.

The main milestones of land use change of the 20th century are the following.

The main trends in Estonian land-use dynamics have been a decrease in agricultural land from 65% in 1918 to 30% in 1994 and an increase in forested areas from 21% to 43%, respectively. The share of agricultural land was largest prior to the first land reform, as agriculture was the main branch of economy then. In different counties this number varied largely. It was the highest in Saaremaa, reaching an unbelievable 88% and even in Virumaa, the least agricultural county, it exceeded 60%. A sharp decline in the share of agricultural land can be observed after the World War II, when in coastal areas the share of agricultural lands hardly exceed 20% and even in the most fertile inland counties it had dropped significantly. Partly this change can be explained by the different administrative division better enabling to display regional differences, partly by some mysterious tricks of Soviet statistics. However, the war touched coastal areas seriously, many people fled to the West in 1944 while other were removed when coastal zone was declared military in late forties. By 1980's the share of agricultural land stabilised. The share of forests has increased constantly during the whole century, Partly this is caused by natural succession, partly by abandonment of former agricultural land, partly also by afforestation campaign during which less fertile lands were planted with trees.

After political collapses the main agricultural activities have been shifted from the western part of Estonia to the eastern part. This pendulum-like movement is caused by the geopolitical location of Estonia.

Land-use changes, the concentration of agricultural production, land amelioration, and the oil-shale based industry in north-eastern Estonia have caused the main ecological disturbances and a great polarisation of rural landscapes. Polarisation is best expressed in the changing pattern of landscapes. The patchy mosaic of small fields, grasslands and woodlots has been replaced by extensive fields and extensive forests, while the area of grasslands has diminished drastically. In North-East Estonia, vast areas have been taken under oil-shale mines, ash heaps and terricones.

Concentration of agricultural activities has been a main reason for eutrophication of water bodies and groundwater pollution. Nevertheless, the decreasing agricultural activities during the first half of the 1990's have caused a slight improvement of water quality in inland waters and aquifers.

Land amelioration has shifted the agricultural activities from the former arable lands to marginal areas (natural grasslands, wetlands). It caused an essential disturbance of the stabilised nutrient cycling in landscapes.

The increase in mineral fertiliser use and intensive land amelioration in 1950's–1980's have been essential factors in eutrophication and groundwater contamination by nitrates. However, the end of collectivised farming system in recent years has seen a significant reduction of mineral fertiliser use and land amelioration.

A well-developed network of ecologically compensating areas consisting of nature protection areas, forests, mires, meadows and coastal waters, has been formed during a turbulent development. This network, a relatively low population density and a high polarisation rate of the territory have maintained a major part of biodiversity. Nevertheless, extinction of wooded meadows and alvar meadows could be guided with a significant loss of species. It is very important to maintain and enhance the ecological network during privatisation.

3.3 Landscape diversity changes

In theory, land use changes as described in previous chapter should bring along also changes in landscape diversity. To follow these probable changes, a study was undertaken on 56 randomly selected test sites all over Estonia. Four maps from different times were used. On these maps, 8 categories of land use were determined: 1) settlements; 2) waters; 3) fields; 4) grasslands; 5) bushes and brushwood; 6) forests; 7) mires; and 8) quarries and wastelands. Roads, watercourses, ditches, hedgerows, and various ecotones served as borders between different patches. Based on the area and the perimeter of the delimited patches, several diversity indices were computed.

Summarising the results of this analysis, the most unexpected outcome is that despite all kinds of land use changes landscape diversity has remained stable. Thanks to the low population density, Estonian landscapes have had the space to buffer change. Land use dynamics do point towards some overall shift in landscape diversity. This shift has occurred, but only in certain places, while at other places an opposite shift has happened, thus keeping the average diversity stable. The reason for this is that the population of Estonia is so sparse that often, when land is reclaimed, it is quickly abandoned due to the lack of suitable management. This observation is one more suggestion supporting the argument that the so-called network of ecologically compensating areas (see Mander *et al.* 1995) is still functioning.

The analysis has shown that despite the large changes in land use pattern, landscape diversity changes have been minor. Also that regional differences appear only for certain indices. The indices used measured different kinds of diversity, altogether describing 80% of the variability. In this, the 'classical' indicators like the edge index, Shannon-Wiener's heterogeneity and Pielou's evenness cluster in one group.

Although the parameters used in this analysis do not allow a determination of significant landscape diversity changes to be made, one may presume that on a higher hierarchical level these changes may be more easily traceable (using, e.g., satellite imagery), especially on uplands and islands, where land use changes are greatest. Therefore there is a need to improve the analysis of landscape diversity by using different parameters and technologies.

4. LANDSCAPE CHANGE AND ECOLOGICAL NETWORKS

4.1 Ecological network

Ecological networks are becoming an increasingly important issue in European nature conservation. Estonia, together with Lithuania and the former Czechoslovakia, was among the first countries in Europe to work out the concept (Jongman 1995a, 1995b; Baldock *et al.* 1994). In early 1990s, similar ideas became widespread in Europe that have resulted in several policy documents (The EECONET Declaration 1993; PEBLDS 1996). After that, several applications of the idea of ecological networks have been demonstrated (IUCN 1995; 1996). Despite the fact that the ecological network of Estonia has come up already in early 1980's (Jagomägi 1983) and was accepted among the first analogous systems in Europe, the Estonian nature conservation legislation has not fully supported it yet. Nevertheless, new laws on nature conservation and environment protection in Estonia leave enough place to handle buffer zones of protected areas and all natural/seminatural ecosystems outside protected areas as elements of the ecological network (see Peterson 1994).

The network of ecologically compensating areas (later also the ecological network) can be observed as a subsystem of the anthropogenic landscape — an ecological infrastructure — which counterbalances the impact of anthropogenic infrastructure in the landscape. Also, the ecological infrastructure guarantees the realisation of the main ecological functions in landscapes. The term "compensating" is given a broad meaning by the authors and ecologically compensating areas are related with following functions: (1) to accumulate material and energy, mainly the energy in the dispersion of which people are involved, (2) to receive and make harmless all that is unsuitable for populated areas: polluted water, air and solid wastes, (3) to recycle and regenerate resources, (4) to provide refuges for wildlife populations, and to conserve genetic resources, (5) to serve as a migration-tract for biota, (6) to be a barrier, filter and/or buffer for fluxes of material, energy and organisms in landscapes, (7) to be a support-framework for the system of settlements in the region, and, consequently, (8) to provide recreation areas for people; (9) to compensate and balance all inevitable outputs of human society. Of course, all these functions are time-dependent and can collapse in conditions of continuing anthropogenic load. Therefore, the concept of ecological network is rational only in combination with other measures of environment protection and nature conservation. Ecologically compensating areas combined with areas of intensive human activities form a strongly polarised (nonbalanced) system that has the ability to reduce entropy and increase order of self-regulation of the region. However, to level differences between these two poles, buffering areas are of great importance.

Considering the data provided in this collection of papers and the ecological network map (Külvik, Sepp 1998), one could say that Estonia has enough compensating areas at the national level. From the point of view of fragmentation, Estonia looks nowadays more like forest land than a land with old agricultural traditions. The land-use pattern seems to consist of small open fields in the forest rather than woodlots in the matrix of agricultural land. Therefore, the classical MacArthur-Wilson theory of island biogeography does not fit for Estonian agricultural landscapes (Mikk, Mander 1995). However, on local level, there are big differences between different regions. For instance, in the vicinity of cities (Tallinn, Tartu, North-East Estonian industrial area) and in Pandivere Hydrological Reserve, the expansion and enhancement of the ecological network is necessary. At the same time, in South-Estonian hilly areas or on alvars and wooded meadows of West Estonia, the expansion of forest — owing to decreasing agricultural activities — has damaged the ecological and recreational potential of these areas. Thus, it is important to optimise the ecological network.

The most relevant general objectives for the optimisation on each hierarchical level are: (1) compensation, (2) polarisation, and (3) connectivity.

The principle of compensation means that all changes of the ecological network caused by human activities must be compensated through the creation of qualitatively equal amount of biotopes to support the biodiversity and the local material cycling equilibrium (e.g., forestation of clear-cutting areas, recultivation of open-pit mines, restoration of wetlands, rivers, and lakes etc.). At present economical situation, the compensating principle is not very actual. Nevertheless, considering the increasing wood and peat export, as well as increasing importance of local bioenergy resources, the compensating activities should be undertaken by the state and local authorities.

The landscape polarisation concept provides to functional contrasts between land-use units. Typically, there is a spatial distance between the most contrast units like centres of human activities (towns, industrial complexes and intensively managed agricultural fields) as one pole, and large natural areas (i.e., protected areas) as another. To smooth the contrasts, especially, if the spatial gap is small, various transitional (buffer) ecosystems (e.g., buffer zones for rivers, lakes, wetlands, and protected areas, green belts for towns) must be maintained and (re)established. In general, landscape polarisation is an objective process that supports the normal functioning of human-influenced landscapes. However, it must be regulated using the buffers.

Importance of connectivity between ecosystems increases significantly when human-made infrastructure (roads, energy transmission lines) accelerates. At present time, there is a sufficient connectivity between ecosystems in Estonia at all hierarchical levels. However, due to planned re-establishment of traffic system that Estonia badly needs for balanced regional development, the rate of biotope isolation will increase. Therefore, mitigating and compensating measures like bridges and tunnels for migration of animals will become as normal in practice of infrastructure construction.

There are not many examples for the optimisation of the ecological network in literature. Proceeding from the broad sense of ecological compensation, Kavaliauskas (1989) proposed a complex of indices measuring the optimality of landscape structure (i.e., ecological network). It contains partial indices for its "bio-, psycho-, techno-, economo- and humanitaro-ecological conditions". Unfortunately, it was only a theoretical approach and was not supported by practical application. The EECONET concept mainly applies to the optimality of the network from the point of view of species migration (The EECONET Declaration 1993; Baldock *et al.* 1994). We consider that both ecological and social criteria should be counted for the optimisation. According to the hierarchy of the network, the optimisation criteria are combined differently for various hierarchical levels:

— for the macro-scale compensating areas the criteria for optimal size and connectedness are mostly determined by material, energy and organisms flows on regional and continental level (transport, deposition and ecosystem buffering capacity of SO_2, NO_x, heavy metals and other pollutants; ecosystem capacity to stabilise $CO_2 - O_2$ balance, migration of birds, fishes and mammals; regeneration capability of renewable resources);

— at meso-scale, the criteria are both ecological (see macro-scale criteria, plus self-purification of water in rivers, lakes and coastal seas, groundwater protection aspects) and social (e.g. recreational potential of the area);

— the most of works have been done considering the optimisation of landscape structure at micro-scale on which the biggest variety of criteria could be used; for instance, buffer zones parameters for rivers and lakes (Knauer and Mander 1989; Mander 1995; Mander *et al.* 1997a), buffer zones for groundwater (Wohlrab 1976) and forest islands in agricultural landscape (Ivens *et al.* 1988); also, most of works on physical and socio-economic planning of regions apply for this hierarchical level.

4.2 Ecological network and road network

Until present, the problem of interaction between infrastructure and ecological network has not had a high priority in the Estonian research and policy. Research has been carried out into the effects of roads on the neighbouring areas (spread of pollutants — Mander 1985; counting killed animals — Mardiste 1992, etc.), but mostly this has been casual and not systematic. Consequently, no special measures have been foreseen to mitigate the possible problems. Usually the main issue is that the big animals (elks, roe deer, wild bores, once or twice even a bear) appearing on the road provide danger for the drivers.

However, in 1960–1970's, a huge lobby was made under the general heading of landscape care to guarantee the right placing of the roads in the landscape. Certain rules of good practice were worked out and often these were followed by the road builders. These rules included issues like the road should not cut the wetlands, but pipes should be built in the road to let the water pass; hedges were planted along the road to keep the snow, but also pollutants and noise, etc. Often these unwritten rules are valid also today.

Currently, the ecological network somewhat compensates the influence of road network. For the next several years, such a compensation could continue. The current tendencies in the state policy let us presume that the expansion of (semi)natural areas will go on for some more years, and at the same time main attention in the field of infrastructure will be paid to upgrading the existing roads system rather than to building new connections. Considering this, one should state that landscape and habitat fragmentation due to development of infrastructure on country level is not a significant problem yet. However, the problem may gain new dimensions. These may include the need for building by-passes for animals, fences to isolate the most dangerous places, etc. Where, what and how to build are the questions that will be asked in the next decade.

Recently, a series of investigations have been carried out in order to give a preliminary environmental impact assessment for proposed route options for the Tallinn—Tartu highway (Mander *et al.* 1997b, Oja *et al.* 1998). In these, fragmentation has been considered as one of the main probable impacts of the highway and places where conflict might occur between the highway and the ecological network, are indicated.

5. PREDICTING THE FUTURE

5.1 Values in landscape planning

In previous chapters we have demonstrated that the landscape changes in Estonia are relatively big. It is also obvious that the changes have not stopped. According to Emmelin (1996), landscape is a visual sum of objects and processes in a given location at a given time. This landscape has had its past, it also has several alternatives for the future. Which of these alternatives will become true, depends largely upon our today's decisions and policies concerning landscapes.

Sustainable development has been declared as the aim or a basic principle that should guide our decisions. How to apply the principles of sustainability to landscapes? One way is to base landscape planning on sustaining landscape values. Derived from the definition of sustainability (WCED 1987), the current land use should provide preconditions for future landscapes in a way that the values of those future landscapes are not compromised. In other words, the task of sustainable land use planning is the optimisation of the use of different landscape values.

In Estonia, the economic values have often been considered the only values the landscape has. Most of the landscape changes have been lead by the idea of increase these values. This has been done at the expense of amenity values. However, areas with the highest amenity values are sometimes protected. As landscape can be understood as process, sustaining the landscape values mean at the same time sustaining the process behind these values, as both intensification and abandonment of land use may hinder the values.

5.2 Perspectives for Landscape conservation

The land use changes having happened in Estonia and the influence of these on the ecological network, the backbone for nature conservation create a need to review the principles and tasks for landscape management and conservation.

Although the ideas of landscape protection appeared in Estonian nature conservation policy already in the first half of the 20th century, recent political changes force to rethink the basics. The main problem landscape conservation faces is how to reorganise itself in conditions of private land ownership (Sepp *et al.* 1996).

The main tasks can be gathered under four headings. First of these is handling the landscape as a resource. The landscape is able to satisfy several needs of humans. So attention should be paid to identifying and mapping this ability.

While the economical values of the landscape are well mapped and well used, one cannot say the same about amenity values. Areas with the highest nature protection value are conserved under the Act on Nature Conservation Objects. Outside protected areas almost no rules apply. This leads to the second major task, introduction of landscape planning into the planning system.

Landscape planning should guarantee the future use of landscape values without compromising theme. It also has to make choices between the future alternatives of the landscape. As one can expect serious changes in values and valuations, connected with the application of EU legislation and policies in Estonia, landscape planning must be carried out with extreme care and perspectives in mind.

To give good grounds to planning decisions, an environmental information system is necessary. It should not be a target in itself, but rather a tool to base decisions upon.

Last, but not least, the concept of ecological network should serve as the backbone for nature conservation policy and decisions.

5.3 Scenarios for future landscape

There are two possible techniques to create scenarios for future land use, backcasting and forecasting (Harms 1995). Forecasting scenarios project present-day trends or expectations onto the domain of the probable future. Backcasting scenarios, on the contrary, design possible alternatives and confront them with the present situation in order to determine the most desirable alternative.
Several attempts have been made to predict the future of landscapes and both these techniques are often used. As examples one could mention works by Harms (1995), Jones and Emmelin (1995), Willis and Garrod (1992) etc.

For Estonia, two types of scenarios to predict land use changes are created. First, forecasting technique has been used to extend the tendencies prevailing during the Soviet time, into future. This gives us the idea what would have happened to the Estonian landscapes if the Soviet style of agriculture would have continued. Second, backcasting techniques have been used to describe the probable landscape impact of the four scenarios for the development of Estonia, created by the Institute of Future Studies (Raagmaa, Terk 1997).

According to the forecasting scenarios, the area of fields remains stable regardless of political fluctuations. The area of natural grasslands has been constantly diminishing and not surprisingly, forecasting scenarios predict that natural grasslands would have ceased to exist altogether. Concerning forests, linear trends show constant increase in the forest area, while polynomial trend predicts the increase has reached its peak and a decline is to start soon. In reality, the situation seems to follow the polynomial trend, caused by the boom in forest industry.

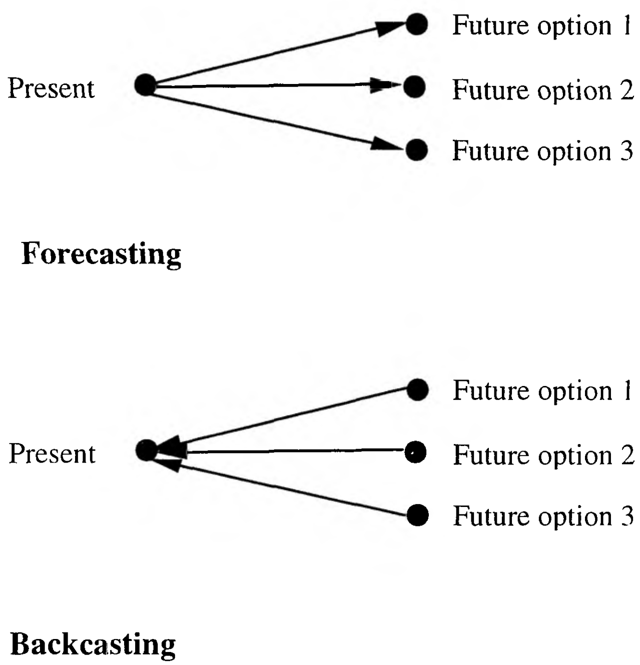

Figure 1. Forecasting and backcasting scenarios (after Harms 1995)

For backcasting scenarios, the four *Eesti 2010* (see Raagmaa, Terk 1997) scenarios have been used. Of these, the Great Game Scenario has been declared the official guideline for policy. This scenario predicts decrease in the areas of fields, forests and natural areas to create more space for industry and settlement, but at the same time causes polarisation, increase in landscape diversity, and more pollution.

At the same time, in reality the trend is towards the Southern Finland scenario. This scenario brings along a decline in agricultural land use, with large field remaining in North and Central parts of the country and increasing share of natural areas in the rest.

However, these scenarios do not take into account the probable changes in valuations and thereby in policies. Building scenarios that include also those changes is one of the possible extension of this study.

6. CONCLUSIONS

The thesis enables to draw following conclusions.

1. The main land use changes in Estonia during the 20[th] century have been the decrease in agricultural land from 65% in 1918 to 30% in 1994 and the increase in forests from 21% to 43%, respectively.
2. After political collapses, the main land use concentrates in the Eastern part of the country.
3. The main driving forces of land use change in this century, apart from natural features, have been land reforms, deportations, urbanisation, and concentration of agriculture during the Soviet period. Also, oil-shale mining and amelioration have induced land use changes.
4. Surprisingly, the landscape diversity changes have nit followed the land use changes. In certain places diversity changes have been significant, while on other places an opposite change has occurred. Altogether these changes compensate each other keeping the average diversity stable.
5. Based on the previous, one can conclude that the ecological network of Estonia is still able to compensate human impact to a certain extent. However, to maintain this ability, ecological network should get included into Estonian legislative system.
6. Fragmentation of habitats has not become a problem yet, although some new infrastructure projects demand a full attention, as they may cause fragmentation.
7. Different scenarios for future landscape development predict that the area of fields will remain stable or decrease a little while the share of forests will grow. However, these scenarios do not take into account the current booming forestry industry.
8. Sustainable land use planning should guarantee that the current landscape values are used without compromising them. Therefore, these values should be more considered in planning activities.
9. Finally, the tasks for landscape management in Estonia should include also creating an environmental GIS to support planning, implementing ecological networks and including landscape aspects into the EIA procedures.

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MAASTIKU MUUTUSED EESTIS: MINEVIK JA TULEVIK

Kokkuvõte

Maastiku muutuste uurimine on olnud geograafide, maastikuökoloogide ning teiste teaduste esindajate üheks meelisuurimisobjektiks. Maastiku muutused on seotud tihedalt inimtegevusega, sest inimesest on saanud suurim maastikku muutev jõud.

Käesolevas töös vaadeldakse maastiku muutusi Eestis 20. sajandil. Töö eesmärgiks on kirjeldada sel sajandil toimunud maastiku muutusi, uurida nendest muutustest tulenevaid maastiku mitmekesisuse muutusi, teha selgeks, milline on olnud maastiku muutuste mõju ökoloogilisele võrgustikule, näidata võimalusi maakasutuse muutuste ennustamiseks lihtsate statistiliste mudelitega ning esitada maastikukaitse ja -korralduse ülesanded lähiaegadeks.

Töö põhitulemused on esitatud lisas toodud publikatsioonides. Töö koosneb sissejuhatusest ja neljast peatükist. Pärast sissejuhatust, teises peatükis antakse ülevaade maastiku mõiste erinevatest kasutusviisidest. Rohkem tähelepanu on seejuures pööratud Eesti geograafias toimunud arengule.

Kolmas peatükk kirjeldab Eestis aset leidnud maakasutuse ja maastiku mitmekesisuse muutusi. Suurimaks muutuseks on olnud põllumajandusliku maa osatähtsuse vähenemine 65%lt 1918. aastal 30%ni 1994. aastaks ja metsamaa osatähtsuse kasv 21%lt 43%ni samas ajavahemikus. Samas on peamine maakasutus pärast suuremaid poliitilisi muutusi nihkunud Lääne-Eestist Ida-Eestisse. Põhilisteks maakasutust mõjutavateks jõududeks on peale looduslike protsesside olnud maareformid, küüditamised, linnastumine ja põllumajanduse kontsentratsioon nõukogude perioodil. Maakasutuse muutusi on põhjustanud ka põlevkivi kaevandamine Kirde-Eestis ja maaparandustööd. Üllatuslikult avalduvad maakasutuse muutused maastiku mitmekesisuse näitajates. Üksikutel testaladel on olnud suured mitmekesisusnäitajate muutused, samas on teistel testaladel toimunud vastassuunalised muutused, mis kokkuvõttes kompenseerivad üksteist ja hoiavad keskmise mitmekesisuse stabiilse. Maastikumustri mitmekesisus on nihkunud ühest kohast teise.

Eelnevast lähtudes jõutakse neljandas peatükis järeldusele, et Eesti kompenseerivate alade võrgustik on veel võimeline kompenseerima inimmõju. Et aga ökovõrgustikul puudub seadusandlik alus, võib see seni veel funktsioneeriv võrgustik praeguste ümberkorralduste käigus kaduda. Samamoodi võib eksisteerivat ökovõrgustikku ohustada infrastruktuurist põhjustatud fragmentatsioon. Seni saab käsitleda Eestit veel ühtse elupaigana, kuid mõned kavandatavad rajatised, nagu uus Tallinna—Tartu maantee, võivad situatsiooni tunduvalt muuta.

Töö viiendas peatükis on keskendutud maastikumuutuste tulevikule. Nõukogude aja maakasutuse muutuste põhjal tehtud lihtsad statistilised mudelid

näitavad, et põllumaa pindala ei tohiks samade tingimuste püsides Eestis oluliselt muutuda. Metsamaa osatähtsus kasvab, samas kui teised mudelid näitavad, et metsamaa osatähtsus on oma maksimumi juba saavutanud. Kõik mudelid ennustavad rohumaade pindala edasist vähenemist. Nende muutuste ennetamiseks ja/või sobivamaks suunamiseks tuleb pöörata rohkem tähelepanu maastikuplaneerimisele. Kriteeriumiks peaks olema maastikuväärtused. Säästev planeerimine peab tagama maastikuväärtuste kasutamise nii, et see ei välistaks ühegi väärtuse edasist kasutamist, st et ükski väärtus ei muutuks nulliks. Sellest tulenevalt olgu maastikukorralduse eesmärkideks keskkonnaalase infosüsteemi loomine, mis aitaks kaasa planeerimisotsuste tegemisele, maastikuliste mõjude arvestamine keskkonnamõjude hindamisel ning seadusandliku baasi tagamine kompenseerivate alade võrgustikule ja nende võrkude arvestamine planeeringutes.

PUBLICATIONS

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Changes of Landscape Structure in Estonia during the Soviet Period,
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Changes of Landscape Structure in Estonia during the Soviet Period

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ABSTRACT: The development of land-use structure during the Soviet period (1940–1991) has been analyzed. The main trends in land-use dynamics have been a decrease in the percentage of agricultural land and an increase in the share of forests. The most important driving factors of such a shift have been the land reforms of 1940, 1949 (collectivization followed by deportations), and 1989; and urbanization and concentration of agricultural production. Changes in land-use structure on the county level reflect well the socio-economic and political changes in Estonian society. An especially significant decrease in agricultural lands took place during the first ten years of collectivization. In coastal areas it has been combined with state political activities. Natural conditions also play an important role, particularly in local changes of land-use structure. The concentration of agricultural production, which is greater in the eastern part of Estonia (Upper Estonia), has caused many environmental problems. Likewise, land amelioration is one of the reasons for environmental disturbances. It has shifted agricultural activities from former arable lands to marginal areas (natural grasslands, wetlands). That is one of the reasons for nutrient cycling disturbances in agricultural landscapes. Despite many disturbances, Estonia has a well-developed network of ecologically compensating areas consisting of nature protection areas, forests, wetlands, and coastal waters. It is important to maintain this ecological network during privatization.

Introduction

There is much interest in land-use change issues in different European countries. Due to the collapse of the former Soviet Union and the communist regimes in Eastern Europe, the significance of the problem is especially high. On one hand, it is now possible to use all official, formerly secret data; on the other hand, no ready solutions are available for further development. Therefore, analysis of long-term land-use dynamics could give a theoretical background for developmental conceptions.

In this study the land-use dynamics in Estonia following World War II have been analyzed. The main driving forces, both socio-economic and natural, form the issue of an analysis. Among them, land reforms, political campaigns, land amelioration (draining and contour obliteration), urbanization, and concentration of agricultural production have been considered. An analysis of land-use development in Estonia has been carried out by A. Kasepalu (1991) and some other authors, but these works have been published only in Estonian or Russian. The dynamics of changes in local land-use structure have never before been demonstrated in the form of a series of cartodiagrams, which allow a better characterization of those changes. Some ideas developed previously by Estonian geographers could be easily used for the sustainable reconstruction of rural landscapes (eg Jagomägi 1983; Roosaare 1975; Mander 1978).

Data Sources and Analysis

The data used are taken mainly from the official Land Cadastre of the Estonian SSR for different years (Data of Estonian Land Cadastre 1990; Land Balance... 1967; Land Cadastre... 1986; Yearbook... 1993). All the data concerning land-use comes from those sources. Other data also have been drawn from official statistics. Demographic

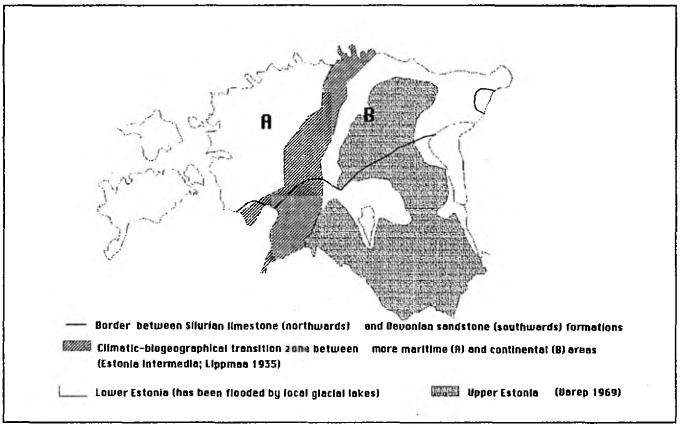


Fig 1
Main landscape features of Estonia

data, as well as data on animal populations on farms, come from the small encyclopedia "Estonia: A & O"(1993). Data analysis has been carried out with the help of MapGrafix™ software on an Apple Macintosh Centris 650 computer.

Main Factors and Tendencies

Driving Factors of Land-Use Changes: Natural Conditions

Apart from socio-economical and political factors of land-use changes, natural factors are of great importance. In dealing with the natural conditions in Estonia, it should be noted that there are two main boundaries which influence the land-use pattern (Fig 1). First, according to E. Varep (1964), the upper limit of local glacial lakes divides Estonia into Lower and Upper Estonia. Lower Estonia, which has been influenced by glacial lakes and the sea, is a low plain with large bogs and forests. Upper Estonia, on the contrary, has never been flooded by local lakes and, therefore, the landscape pattern is much more mosaic in character with different kinds of glacial, fluvioglacial, and limnoglacial landforms . ;vailing – kame fields, drumlins, eskers, and so on. Landscape diversity is especially pronounced in the uplands of SE Estonia. This division is important in dealing with the age of landscapes. Ice cover retreated from Upper Estonia approximately 12,000 years ago, while the landscape development of Lower Estonia began only some 7,000–9,000 years ago.

Second, the border between Silurian and Devonian bedrock formations influences both the soils and vegetation. North of the border, Silurian limestones make the soils more alkaline, while Southern Estonia, where Devonian sandstones occur, has mainly more acidic soils.

Another border divides Estonia. It is a climatic-biogeographical border, first described by T. Lippmaa (1935), which separates the more maritime Western Estonia from more continental Eastern Estonia. The transition zone between these two regions, a large belt of forests and bogs stretching from the N to the extreme SW, has been called by T. Lippmaa, *Estonia intermedia.* Likewise, vegetation characteristics (eg, dominant species of raised bogs) vary between W and E Estonia.

The approach presented is a very simplified view of Estonian landscapes, but it synthesizes basic information about the variety of both abiotic and biotic factors in Estonian landscapes.

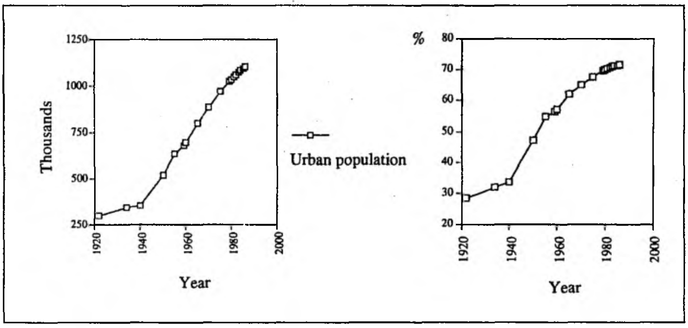
Land Reforms: 1940

The first Soviet land reform in Estonia was announced on July 23, 1940, when land was nationalized. In reality it meant that all the land exceeding 30 ha per farm was reallocated to the State Land Reserve to support the creation of new farms. Everybody possessing less than 10 ha of land was supported to get more, so that the medium size of farms would grow to at least 12 ha. In fact, the added land created new farms with an average area of only 10.4 ha (Kasepalu 1991). Altogether, some 50,000 new farms were established during the first two Soviet years (including farms which received additional land).

World War II and subsequent years

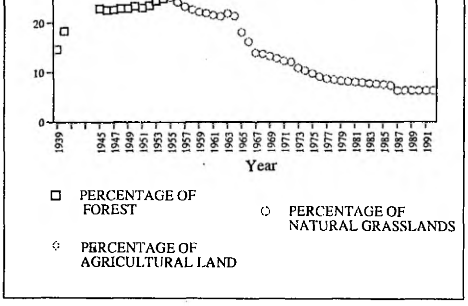
During the German occupation (1941–1944) reallocated land was generally returned to its former owner. After the

Fig 2
Growth of urban population in Estonia



war the Soviets reestablished their initial land distribution of 1940–41. Initially, farmers were made to believe that the land they possessed was theirs to use without restrictions, both at that time and in the future; but starting about 1947, farmers were pressured increasingly to unite into collective farms (*kolkhoz* in Russian tradition). The first kolkhozes in Estonia were formed already in 1947. The collectivization of agriculture was finished after the Great Deportation on March 23, 1949, when the majority of farmers, who managed to escape deportation, joined collective farms.

Fig 3 Dynamics of land-use structure in Estonia in 1939–1992



During the summer of 1950 the kolkhozes used 87.2% of arable land and they employed 81.8% of the farmers (Kasepalu 1991).

1989–1991

In 1989 a new farm law came into effect that again legalized private farming. Although a few dozen people hurried to use the situation, in general, the new start was quite slow. From 1991, the land, once collectivized, began to be returned to its former owners or their heirs. It was supposed to be a rapid process, in order to give a major boost to agriculture, but the usually amateur farmers faced severe difficulties – lack of knowledge, technical equipment, animals, etc. – so that in the beginning of 1993 only some 250 private farms were (re)established. Today another problem is the lenghtly reform process itself, with a bureaucracy unwilling or unable to carry out government policy; or to develop an agricultural policy where none exists.

Deportations

Two great mass deportations occurred at the beginning of the Soviet regime. On June 14, 1941, and March 23, 1949, respectively, 10,157 (by another source 10,205) and 20,702 persons were dispersed throughout the endless expanse of the Soviet Union, leaving the Estonian countryside without its best people. The people deported were mainly owners, having either some land or a kind of business. The latter deportation, together with collectivization, created a kind of chain reaction – the most skilful farmers were deported, those who remained were joined to kolkhozes, with the work being done by women and unskilled men. This resulted in a worsening situation, almost famine, with wretched wages paid in kind. This in turn forced those who were able to leave the countryside to move to towns,

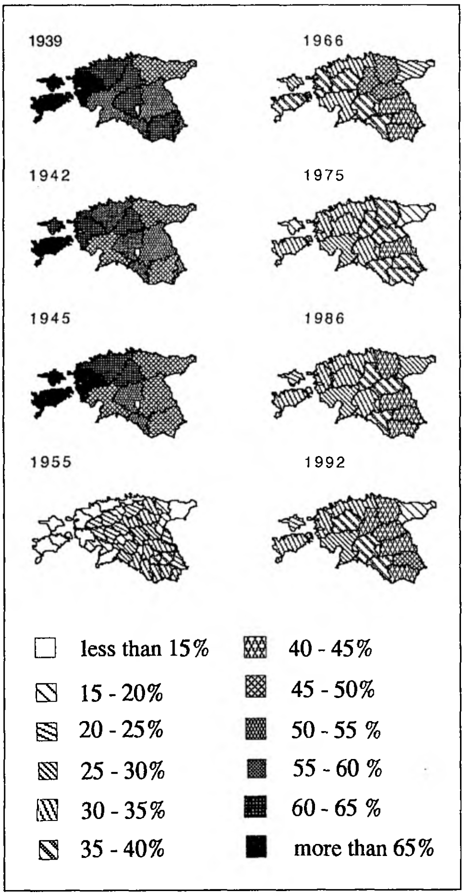


Fig 4 Dynamics of the share of agricultural land in the counties of Estonia in 1939-1992

decreasing the number of workers and so on. The carrousel stopped only when new technical equipment arrived in the countyside, which aided the most difficult jobs.

Urbanization

Urbanization is one of the factors tightly connected with and influencing the land-use pattern. From a totalitarian regime's viewpoint, it is essential to concentrate people where they can be better scrutinized. Thus, the 1950's were a time of rapid growth of the population of smaller towns and townships (Fig 2). In the context of land-use patterns, one must consider the fact that, while the bigger towns got new inhabitants via immigration, smaller towns gathered mainly "refugees" from the countryside, escaping the awful living conditions in the early kolkhozes. Population concentrations in rural centres and rural borderlands should be considered also. The concentration of agricultural production also resulted in building central settlements (some for every kolkhoz), which attracted mostly younger people and specialists, while the population outside those central settlements grew older and sparser.

Land Amelioration

Land amelioration was one of the driving factors in land-use pattern changes. Before the Soviet period, in 1940, the total area of ameliorated land (unlike Soviet practice, mainly high water tables were lowered, while contours were left alone) was 350,074 ha, of which 44,488 ha was used for drainage (Juske et al. 1991).

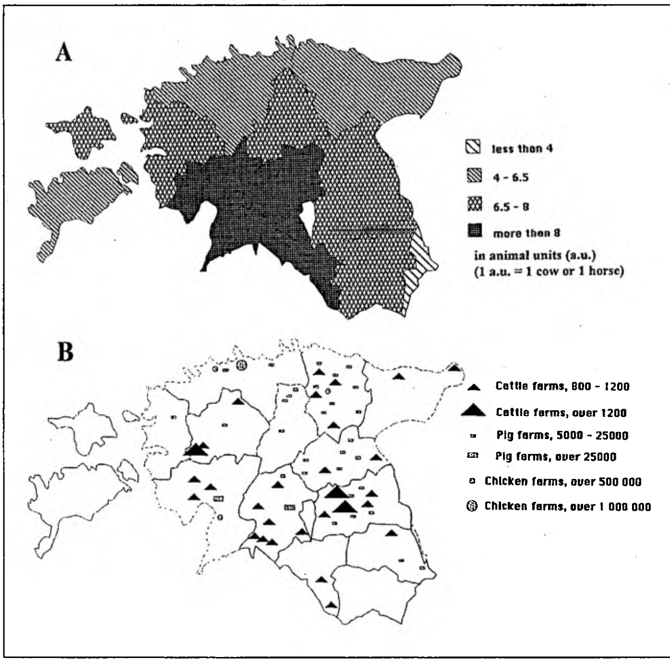
Under the Soviets this figure nearly doubled, being 731,000 ha in 1991. Such growth was achieved primarily by two campaigns, the first of which occurred in the mid-fifties and brought about mainly open-ditching; while the second began in the mid-sixties with extensive draining activities. These activities basically reduced the share of natural grasslands. Curiously, the share of agricultural land diminished simultaneously. The more energy that was spent on maintaining new agricultural land, the less there remained to maintain old lands, resulting in an increase of forest area. This, in turn, lead to great disturbances in material and nutrient cycling.

Concentration of Agricultural Production

By the end of the first independence period (1940), the average area of a private farm was as small as 22.4 ha. As previously demonstrated, the first CPSU campaign to influence agriculture was collectivization. The first kolkhozes were formed in 1947; in 1949 the average size of a kolkhoz was 567 ha (Kasepalu 1991). Later this number increased quite quickly. In 1950 the average area was about 900 ha; in 1960, 2700 ha; 1970, 4900 ha; 1980, 8321 ha (Kasepalu 1991). The 1980's marked the peak of concentration. Subsequently the average area began to decrease. By 1985 the average size had fallen to 8162 ha, by 1990, to 7081 ha. One likely reason for this decrease was that such megaenterprises became unmanageable, eg, the costs for transportation within the kolkhoz grew unmanageably large.

Another feature characterizing concentration is the number of enterprises. The number of farms in 1939 has

Fig 5
Concentration of agricultural production in Estonia
a) average number of animals in farms in 1939
b) location of large animal farms in 1990



been estimated by different sources to have been 139,984 to 146,205. It is too difficult to even guess the number of active farms during and subsequent to the war. Beginning in 1949, kolkhozes and *sovkhozes* (state farms) became the most important agricultural production units and the changes in their numbers can be easily traced. The most intensive year of kolkhoz formation was 1949. By the end of that year the number of kolkhozes reached 2898; together with fishery kolkhozes and state farms the total number of agricultural enterprises was 3122 (Kasepalu 1991). In 1950, according to the CPSU CC directive, the process of uniting smaller kolkhozes began. This resulted in a decrease in the number of kolkhozes to 1051 by the end of 1951. During the 1950's and 60's the number of agricultural enterprises fluctuated slightly, the general tendency being the connection of weaker kolkhozes with state farms. The beginning of the seventies brought a new wave of concentration in Estonian agriculture. The characteristic feature of this wave was the uniting of smaller adjacent kolkhozes. According to A. Kasepalu (1991), the aim of such unification was to obtain better wages from the state for the leaders of the kolkhoz, but also to subsidize the building of large cattle and pig farms. The last great unification of kolkhozes took place in 1976. From then until 1985, the number of agricultural enterprises remained stable at 302. Starting in 1985 an accelerating deconcentration began. Between 1985 and 1989, 22 enterprises were divided into smaller units. In 1989 private farming started again, and 1990 was the first year since the early fifties that the share of land in private use exceeded 2% of the total.

To conclude, one can distinguish several stages in the concentration of agriculture in Estonia during the Soviet period: first, the uniting of private farms into kolkhozes in 1947–1951; second, the uniting of small kolkhozes into larger ones in 1950–51; third, the connecting of weaker kolkhozes with state farms in the late fifties; fourth, the joining of neighbouring kolkhozes in the early seventies (until 1976); lastly, the beginning of accelerating deconcentration in the late eighties, which is still on-going.

Changes in Land-Use Patterns

Main Tendencies in Land-Use Structure

Several general tendencies can be distinguished in land use dynamics during the Soviet period, the most important being the following.

First, the shift in principal land-use should be noted. Before World War II the share of agricultural land was greater in western counties than in eastern ones. Later, linked with intensification in agricultural production, the dominant land-use began to migrate towards more fertile lands. This process already had entered its final stage prior to 1966, when a clear belt with a larger share of agricultural land could be distinguished in Upper Estonia. The share of agricultural land in this belt exceeded 35%. At the same time, the western counties (Lower Estonia) had lost their high percentage of agricultural land. As agricultural production became increasingly intensive, the lack of genuinely fertile fields began to restrict the expanse of farming, while extensively used pastures were very often simply abandoned.

Tab 1 Land-use structure development in Estonia during the Soviet period 1940-1991 (in thousands of hectares)

Year	Fields	Agricultural land	Forest	Natural grassland	Arable
1939	1047.4	2753.5	696		
1940	1043.8	2652.4	872.7		1112.1
1941					
1942	1013.3	2516.4		1478.3	1038.1
1943					
1944					
1945	970.3	2454.6	1036.8		978.6
1946	978.7	2494.3	1022.8		
1947	984	2500.8	1026.1		
1948	990.1	2542.5	1036.7		
1949	891.9	2504.5	1015.6		
1950	897.8	2496.5	1021	1481	949.4
1951	924.5	2499.5	1014	1506.2	950.8
1952	943.3	2530.7	1035.2	1513.5	982.2
1953	939.2	2490.7	1076.3	1443.9	997.8
1954	919.9	2437.4	1121.5	1385.4	985.8
1955	894.3	2175.1	1347.3	1135.2	968.3
1956	865.3	2083.1	1383.3	1094.5	954.6
1957	856.8	2076.4	1410.2	1053.7	940.9
1958	861.8	2067.5	1418.5	1026.5	965
1959	866.9	2051	1439	1003.7	979
1960	873.5	2037.6	1461.6	993.7	985.2
1961	869.6	2024.6	1471.7	974.7	990.3
1962	868.5	2017	1481.5	964.3	996.1
1963	866.8	1999.5	1462.6	990.3	1009.2
1964	864.3	1990.7	1522.3	967.2	1022.7
1965	860.9	1851	1582	819.4	1030.4
1966	802.6	1786	1650.3	732	1033
1967	807.6	1669.8	1710.8	631.7	1035.9
1968	814.8	1656.5	1721.1	617.1	1038.5
1969	824.3	1648.7	1719.5	599.4	1048.9
1970	843.1	1643.2	1722	580.3	1062.4
1971	878.7	1632.6	1728.1	555.8	1076.5
1972	905.6	1629.7	1763.3	543	1086.5
1973	927.3	1589.2	1766.2	491.8	1097.3
1974	962.7	1572.1	1774.9	465.1	1106.9
1975	969.8	1559.6	1793	443.3	1116.3
1976	976.7	1535.5	1833.2	412.3	1123.1
1977	980.7	1521.4	1854	394	1127.4
1978	981.2	1511.9	1870.3	384.1	1127.8
1979	986.1	1506.9	1885.9	373	1133.9
1980	983.6	1500.1	1901.9	366.2	1133.9
1981	980.9	1494.6	1918.5	360.2	1134.4
1982	977	1490.9	1936.3	356.2	1134.7
1983	975.6	1484.2	1946.4	347.6	1136.6
1984	976.2	1481.5	1933.2	343.7	1137.8
1985	976.8	1478.8	1914.7	338.9	1139.9
1986	935.1	1417.1	1917.2	328.8	1088.4
1987	977	1476.6	1920.2	283.2	1142.9
1988	976.4	1474.8	1922.1	284.2	1144.9
1989	975.9	1471	1924.4	282.5	1144.7
1990	1129.5	1431.3	2012.2	284.2	1147.1
1991	1129.5	1431.1	2014.3	284.1	1147
1992	1130.3	1430.4	2019	282.6	1147.8

Second, the land-use pattern demonstrates a tendency towards distinct polarization. As a rule, the portion of agricultural land has been continuously diminishing, while the portion of forests has been increasing (Fig 3). Increase in forest area has been generally at the expense of natural grasslands, while the areas of arable land and meadows have remained almost constant since 1939. The increase in forest area means greater naturalism in the landscape. However, areas used intensively by agriculture are becoming increasingly artificial. The average area of a field is increasing, gained by amelioration activities which often remove natural elements of the landscape - woods, grasslands, even wetlands - and unite smaller fields into great blocks. In this manner areas used by agriculture loose their naturalism. In short, the greater portion of land evolves towards a more natural state, while cultivated land becomes increasingly artificial.

Relevant Changes in Different Periods (Fig 4)

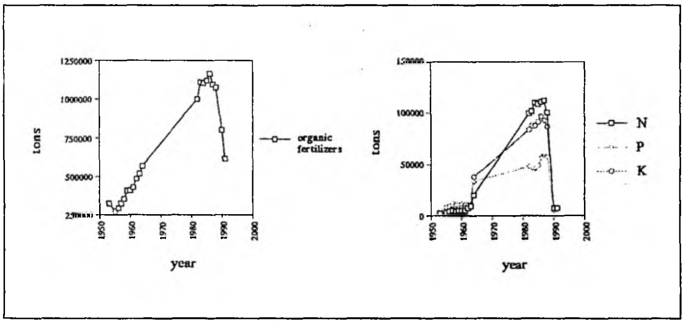
As noted before, in 1939 the share of agricultural land was greater in the western counties. In Saaremaa and Läänemaa it was as high as 69%, while in Virumaa it hardly exceeded 46%. In the West, agricultural land consisted mainly of pastures and coastal grasslands; tilled fields did not play a great role here.

By 1942, the first Soviet years and half a year of German occupation had passed. It is clear that generally the share of agricultural land had diminished, especially in Pärnumaa and Võrumaa. This was due to the consequences of the first deportation and of the war, in particular. We can only speculate what would have happened, had the first Soviet occupation lasted longer...

By 1945, after three years of German occupation, the land-use pattern was again similar to that of 1939. The share of agricultural land had increased in the W counties and decreased slightly in the E counties, demonstrating that German occupation did not ruin Estonian agriculture.

The most dramatic changes in land-use patterns occurred between 1945 and 1955, a time of radical changes in social and economical life. It is clear that the share of agricultural land diminished drastically. The coastal areas in the West, which consisted of more than 60% agricultural land ten years before, contained almost none. The share of agricultural land was greatest in the most fertile areas in Upper Estonia. These dramatic changes can be explained, on the one hand, by statistical distortions and differences in data collection, and on the other, with differences in socio- economical changes. First, quite a large number of people, particularly from coastal areas, fled to the West in the fall of 1944 (this factor is not reflected in statistics from

Fig 6
Use of fertilizers in Estonia



1945); second, in 1949 a mass of people was deported to Siberia by the Soviets; third, the remaining inhabitants of coastal areas were pressured to move inland, while collectivization frightened others into towns; and last, the loss of life during the war was substantial. These factors caused a decrease in the share of agricultural land to 20–30% during the ten years.

A kind of recovery period ended in 1966. Due to amelioration, the share of agricultural land had stabilized. At this time, formerly weak kolkhozes had managed to improve their situation, while the rate of urbanization had slowed. The "golden era" of Estonian agriculture began. This continued until recent years, when deconcentration processes began. The main land-use tendency during these years had been a slow but constant decrease in the extent of agricultural land, and a rapid decrease in the natural grasslands, which together constituted a basis for increase in the forest area.

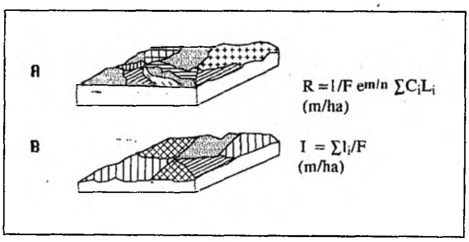
One can observe a kind of contradiction between different data, explained by Soviet-style statistics, the main aim of which was to make data incomparable. There are some differences in what had been considered agricultural land (eg, during some years natural grasslands were included, others not), and there are some quite curious fluctuations in county areas, which also influence the results. These probable errors have been taken into account as much as possible, but still may distort the given results.

Land-Use Pattern as a Mirror of Socio-Political Changes

As the preceding discussion demonstrates, the proportion of agricultural land in specific counties and in Estonia, in general, mirrors socio-economical changes. The five-number system used by the official Land Cadastre to characterize the land-use situation (areas of agricultural land, arable land, fields, natural grasslands, and forest) indicates that the extent of agricultural land was evidently most sensitive to various changes. Of course, while a part of the sensitivity could easily be caused by statistical distortions, it still helps to understand social changes. While the areas in arable lands and meadows had remained almost unchanged, even during the most difficult of times, fluctuations in agricultural land are good indicators of important social events (the War, results of deportations and collectivization, urbanization, amelioration campaigns, etc.). Each major change in the proportion of agricultural lands could and should be explained with certain new trends in society (Tab 1).

Fig 7 Corresponding diversity of potential and actual (cultural) landscape pattern

A) Natural (potential) landscape diversity determined on the basis of the landscape or soil maps:
R the natural landscape diversity index
F area
m number of types
n number of individuals.
C_i contrast between two adjacent units (contrast of i-the border)
L_i length of i-the border (from Roosaare 1975, modified by Mander 1978)
B) Cultural (ie actual or present) landscape diversity determined on the basis of land-use map (Mander 1978)
a) I cultural landscape diversity index
l_i length of i-the ecotone between intensively managed and natural/seminatural biotope
F area



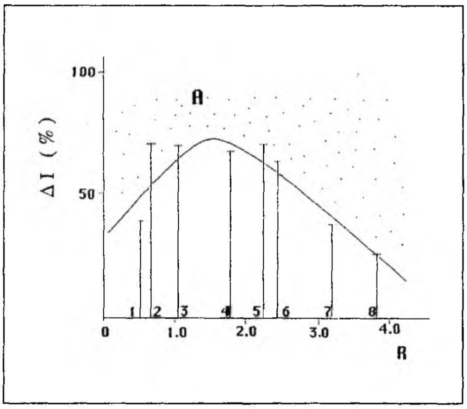


Fig 8 Recommended levels for simplification of landscape structure via land reclamation. Main landscape types of Estonia critical for agricultural use:

1 marine-sandy plains
2 palustrine plains
3 lacustrine-glacial (limnoglacial) plains
4 till-covered kame fields
5 limestone plateaus
6 moraine-hilly landscapes composed of large hills
7 undulated marine-sandy plains
8 moraine-hilly landscape composed of small and medium-size hills
A area of simplification values at which negative anthropogenic processes (ie erosion deflatation etc.) occur.

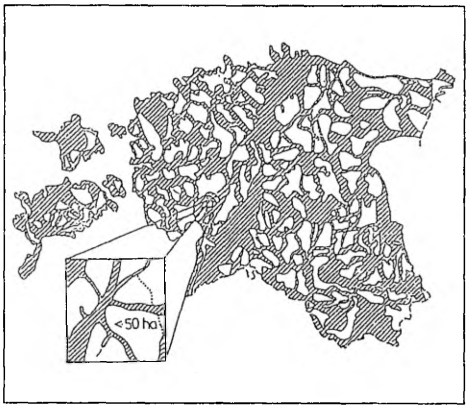


Fig 9 Network of ecologically compensating areas of Estonia (Jagomägi 1983)

Environmental Impacts of Land-Use Changes

The aforementioned changes in land-use structure have caused several environmental impacts. Most of them are connected with the concentration of agriculture. The biggest problems are soil, groundwater, and surface water pollution in the vicinity of large farms (Fig 5) and intensively fertilized fields. In South Estonia about 60% of draw-wells and shallow bore-wells are contaminated with nitrates (NO_3 concentration more than 45 mg/l – Mander et al. 1993). During the last three years fertilization intensity has significantly dimished (Fig 6). However, it is not (yet) reflected in shallow groundwater quality, which is still worsening.

One of the important, diffuse sources of water pollution is extensive land amelioration, which disturbs the nutrient cycling stability of low-lying areas. During and after land amelioration activities, losses of nutrients into groundwater and surface water bodies increases significantly. Therefore, a shift of land-use activities from formerly arable lands in more high-lying areas (many former fields are now covered with forest on Haanja, Otepää, and Karula Heights in South Estonia) to marginal areas (former semi-natural grasslands, depressions, wooded meadows, riparian and coastal meadows) can be treated as a major anthropogenic disturbance factor in the landscape. The problems of soil degradation are also linked to the pressure of over-heavy agricultural machinery (eg, the Soviet tractor K-700, originally meant for missile transportation, weighs 13 tons; some new harvesters weigh even more), land amelioration, and overly intensive crop rotation without any leguminous plants (the so-called barley monoculture, ie, ten years of only barley on the same field).

Fortunately, during the last ten years land amelioration activities have been partially focused on ecological purposes, such as design and construction of buffer strips ecological engineering for wastewater treatment, landscape architecture, and so forth.

Ecological Criteria to Limit Landscape Changes

Ordinarily certain parameters are used to characterize the ecological conditions of landscapes, such as productivity, stability, and diversity, the last one being the most informative and characterizing (with reference to the spatial structure) mosaic alteration of natural and cultivated ecosystems. Ecological diversity of landscapes may be estimated using various techniques. To recommend ecological criteria for limiting landscape changes during land reclamation activities, one should distinguish natural (primeval) and cultivated (final) landscapes (Fig 7). The criteria of ecological diversity for these two landscape types are different. For natural landscapes, the distribution of individual units and their types, as well as the length and

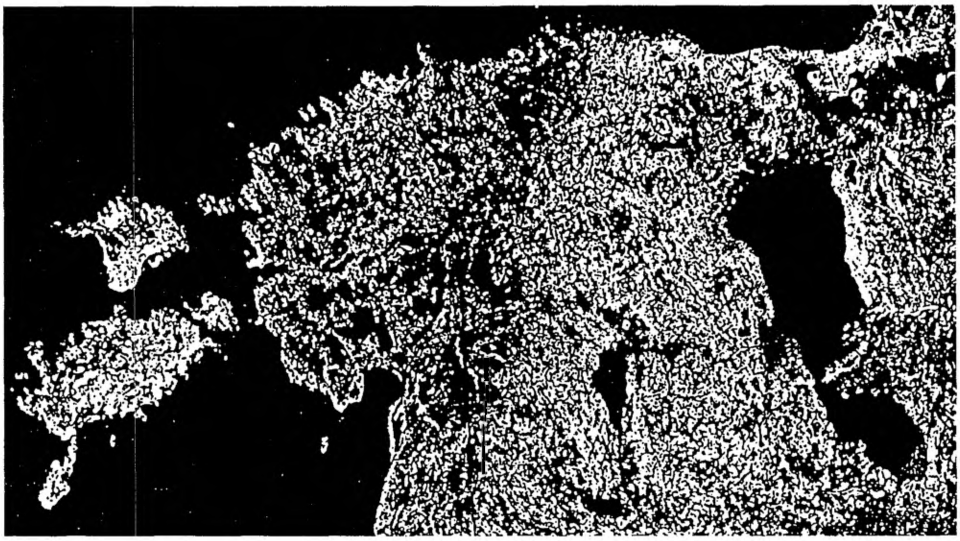


Fig 10 Satellite image of Estonia

strength of borders, have been taken into account (Roosaare 1975) and analyzed on the basis of soils as the most informative landscape factor. Ecological diversity of the cultivated landscape may be estimated on the basis of ecotones, defined as transition belts between agricultural lands and natural biocenoses (Fig 7). Ecotones, as kinds of "stress belts", through which is realized compensatory action of natural biotopes upon simplified agricultural ecosystems, are the most informative and sensitive elements of cultivated landscapes. In the course of land amelioration, many ecotones are usually eliminated, while no new ones are designed. This frequently induces undesirable processes, particularly within landscapes with low land reclamation potential. It is desirable to analyze ecological diversity of the landscape expressed in terms of ecotone size in order to develop recommendations for field reconstruction (Mander 1978). Within marginal landscapes, the overly expansive simplification of reclamation may induce undesirable natural and anthropogenic processes (erosion, deflation, humus mineralization, loss of scenic, and recreation value, etc.). Fig 8 indicates the rough simplification levels for some landscape types in Estonia, particularly those in agriculture. Studies of about 600 land amelioration objects in different landscape types have given a standard value for landscape pattern simplification (ΔI; $\Delta I = I_1 - i_2 / I_1 * 100\,\%$, where indexes 1 and 2 indicate the situation before and after land reclamation, respectively). As can be seen in Fig 9, simplification (ΔI) could be least (<40-50%) in landscapes with both very simple and very complicated potential structure. A simplification rate of more than 75% could produce undesirable effects. Thus, the diversity of cultivated landscape structure should be determined by natural (potential) landscape structure. Further land reclamation activities should be proceeded according to these considerations.

Network of Ecologically Compensating Areas in Estonia

In spite of the many disturbances in Estonian landscapes caused by political collapses, a network of less intensively used areas (nature reserves, wetlands, forest areas) and strips connecting them, has been developed in Estonia, attaining its present pattern during the last decades. Compensating areas form a hierarchical system (Fig 9). This might be called an ecological infrastructure, which serves to compensate intensive economic activities, causing shifts in energy flows and material cycling. These are also areas of renewable natural resources and refuges for wildlife. Comparing the satellite image of Estonia (Fig 10) with the network of ecologically compensating areas (Fig 9), a good correlation can be seen between these two

II

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LANDSCAPE CHANGES IN ESTONIA: REASONS, PROCESSES, CONSEQUENCES

Ü. Mander and H. Palang

1. INTRODUCTION

The socio-economic situation has changed five times during the last hundred years on the territory of nowadays Estonia. Moreover, the last change, the reprivatisation of lands that begun in early 1990s, is still continuing. These shifting policies and ownership relations have influenced the landscape, through changing land use and landscape diversity. In this chapter of the book these changes in landscape will be analysed.

The analysis will deal with the dynamics of land use and landscape diversity in both country and county levels. This approach gives a more or less general overview of the processes behind the landscape change, but as well enables to follow the results of these processes as they are reflected in the landscape. Furthermore, the changes in land use have an effect on the environmental conditions. The analysis of the environmental consequences of landscape change is also presented in the chapter. Finally, as a result of the nature conservation policy and the environmental protection concept, the ecological network in Estonia will be characterised. This has a dense connection with the idea of the European ecological network — EECONET (see Bischoff and Jongman 1994; Bennett 1994).

2. MATERIAL AND METHODS

Data sources and analysis

The data concerning land-use before the World War II come from official statistics (CADASTRE BOOK... 1918; ESTONIAN LAND USE CADASTRE 1939). Data about the period after the World War II are taken from the official Land Cadastre of the Estonian SSR and the Republic of Estonia for different years (DATA... 1990; LAND BALANCE... 1967; LAND CADASTRE... 1986; YEARBOOK... 1993). Fertilization level is presented based on the official data of the Ministry of Agriculture.

The impact of land-use changes on nutrient runoff from agricultural catchments is demonstrated on the base of the Porijõgi River basin (see MANDER *et al.* 1995a). Land-use changes in this area were characterized using land-use maps in 1:10000 scale from 1987–1990. Actual land-use pattern has been estimated during the field work.

Meteorological data (precipitation, air temperature, wind velocity, and humidity measured 6 times a day, as well as daily, monthly and annual mean values) originate from the Tartu—Ülenurme Meteorology Station of the Estonian Meteorology and Hydrology Institute (EMHI). It is located in the northern part of the Porijõgi catchment. At the Reola hydrological measuring point (EMHI) daily mean stream discharge ($m^3 s^{-1}$) in Porijõgi was determined.

The Porijõgi River drainage basin, was divided into 8 subcatchments each with different land use structure (MANDER *et al.* 1995a). Since 1987 from the closing weirs of each subwatershed once a month water discharge was measured and water samples were taken. In the South Estonian Laboratory of Environment Protection (during the period 1987–1991) and in the laboratory of the Institute of Environment Protection, Estonian Agricultural University (1991–1995), BOD_5 value, NH_4-N, NO_2-N, NO_3-N, PO_4-P, total-P, and SO_4 content was analyzed. The total inorganic nitrogen (TIN) was calculated as the sum of NH_4-N, NO_2-N, and NO_3-N. All water analyses were made following COMECON- countries standard methods compatible with the international methods for examination of water and wastewater quality (APHA 1981). This paper presents some data on nutrient dynamics in the whole catchment of the Porijõgi River.

Map analysis

In the purposes of investigating landscape diversity changes in Estonia during the last hundred years, 30 test areas (20 km^2 of each) were chosen in the territory of nowadays Estonia (PALANG 1994). Their even spatial distribution in four territorial parts (North, West, Middle and South Estonia) and availability of maps were considered. The latter also determined the scale of the research. Landscape changes were followed on four maps from different times: 1) Russian topographic map 1:42000 that was compiled in 1895–1917, later referred as 1900; 2) Estonian topographic map sheets 1:50000 from 1935–1939, later referred as 1935; 3) land-use map in scale 1:50000 from 1960; 4) Soviet topographic map sheets 1:50000 from 1977–1990, later referred as 1989. Land use served as the basis for differentiating landscape units. Linear elements — borders of land-use types, bigger roads, rivers, lakes, streams, main ditches — were considered as borders between landscape contours. Areas and perimeters of these units were measured and, based on these, several diversity indices — heterogeneity (Shannon-Weaver index H; see BASTIAN 1994), evenness (e; after Pielou, 1966), complexity of patches (T), "curvedness" (irregularity, formerly called also as "cavityness"; MANDER *et al.* 1995b) of patch borders (P), edge index (I) — were computed using the following formulae:

(1) $H = -\Sigma\{(n_i/N)*\log(n_i/N)\}$ (2) $e = H / \log S$

(3) $T = 4\pi A / p^2$ (4) $P = p / \{2\,(\pi A)^{1/2}\}$

(5) $I = \Sigma\,(p_i) / A$

where n_i — number of units of i-th land-use type, N — total number of land-use units, S — number of land-use types, A — area of land-use unit (ha), p — perimeter of land-use unit (m).

The chosen indices express different types of landscape diversity. While patch complexity as well as edge index characterizes the topological diversity of landscape, heterogeneity and evenness describe the distribution of different types of landscape units. The results of such an investigation could be used while planning ecological networks.

3. DRIVING FORCES OF LAND USE CHANGES

3.1 Physico-geographical conditions

Two main boundaries could be found in Estonia that influence the land use pattern. First, according to VAREP (1964), the upper limit of local glacial lakes divides Estonia into two parts, Lower and Upper Estonia (see Fig. 1). Lower Estonia, which has once been the bottom of the sea or some local glacial lakes, is a low plain with large bogs and forests. Upper Estonia, in the contrary, has never been flooded by the local lakes and, therefore, the landscape pattern is much more mosaic, with different kinds of glacial, glaciofluvial, and glaciolimnic landforms as drumlins, eskers, kames, *etc.*, prevailing. Landscape diversity is especially greater in South-Eastern Estonia. This division is important while speaking about the age of landscapes. Ice cover left Upper Estonia approximately 12,000 years ago while the landscape development in Lower Estonia could begin only some 7,000–9,000 years ago.

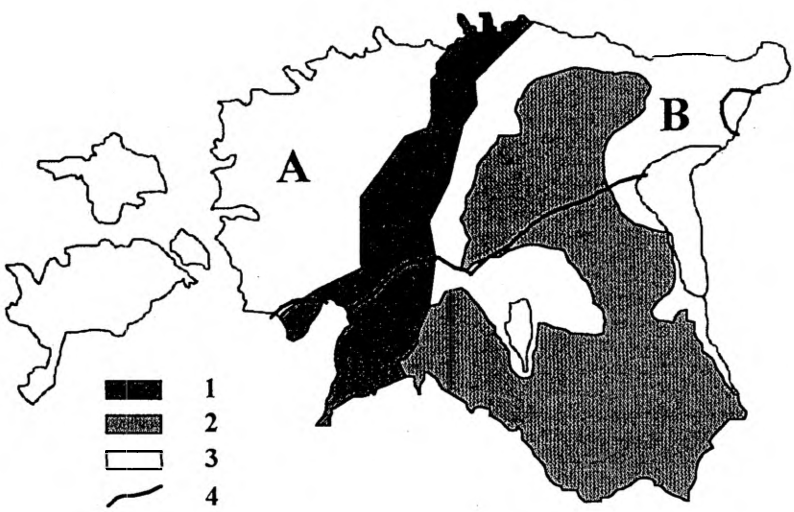

Figure 1. Main landscape features of Estonia. 1 — climatic-biogegraphical transition zone between more maritime (A) and continental (B) areas (*Estonia intermedia* (LIPPMAA 1935)); 2 — Upper Estonia; 3 — Lower Estonia (has been flooded by local glacial lakes; VAREP 1964); 4 — border between Silurian limestone (northwards) and Devonian sandstone (southwards) formations.

Second, the border between Ordovician/Silurian and Devonian bedrock formations influences both the soils and vegetation. North of the border Ordovician and Silurian limestones make the soils more alkaline while Southern Estonia, where Devonian sandstones occur, has mainly more acidic soils.

The third border that divides Estonia is a climatic-biogeographical one, first described by LIPPMAA (1935). This border separates more maritime Western Estonia from more continental Eastern Estonia. Between these two regions there lies a transition zone, a large belt of forests and bogs stretching from the north to very south-west (Fig.

1). Likewise, the vegetation characteristics (*e.g.*, dominant species of raised bogs) vary between Western and Eastern Estonia.

3.2 Political issues

3.2.1 Land reforms in the first half of the century

The first land reform of the newborn Republic of Estonia was proclaimed on October 10, 1919, and carried out in the subsequent years. This reform greatly influenced the land ownership. In the very beginning of the century most of the land belonged to Baltic-German landlords. According to the reform, these lands were nationalised and later distributed to Estonian peasants. The former large estates were divided into small particles, that also resulted in greater mosaic of landscape pattern as well as maintaining many formerly unused lands.

After the first Soviet occupation, one of the first actions was to redistribute the land. The Soviet land reform was announced on July 23, 1940, only a month after the annexation. According to this, land was again nationalised. In reality it meant that all the land exceeding 30 ha per farm was reallocated to the State Land Reserve to support the creation of new farms. Everybody possessing less than 10 ha of land, was supposed to get some more so that the average size of farms should grow to at least 12 ha. In fact, the added land allowed to create landholds with an average size only 10.4 ha (KASEPALU 1991). Altogether, some 50,000 new farms were established during the first Soviet year (1940–1941).

During the World War II, the Germans mostly returned the reallocated lands to their former owners.

3.2.2 The Soviet times: collectivisation, deportations, urbanisation, concentration of agricultural production

In autumn 1944, the Soviet troops again entered Estonia, and a new era in land use began. First, the land use situation of 1940–1941 was reestablished as much as possible. Initially, the farmers were made to believe that the land they possessed was theirs to use it without restrictions, both at that time and in the future, but starting around 1947, the farmers were increasingly pressured to unite into collective farms — kolkhozes. The first kolkhozes in Estonia were already formed in 1947, but majority of the farmers joined the kolkhozes after the great deportation on March 23, 1949. Next summer, in 1950, the kolkhozes used 87.2% of arable land and employed 81.8% of farmers.

Two great deportations occurred in the beginning of the Soviet regime in Estonia. On June 14, 1941, and March 23, 1949, respectively 10,157 (by another source 10,205) and 20,702 persons were sent out, leaving the countryside without its best. The deported people were mainly owners, having either some land of a kind of business. The latter deportation together with collectivisation created a kind of chain reaction that ruined rural life for a decade. The most skillful farmers were deported and those who remained were joined into kolkhozes; the work being done by women and unskilled men. This resulted in a worsening situation, almost famine, with wretched wages being paid in kind.

Urbanization is one of the factors tightly connected with and influencing the land-use pattern. The 1950's were a time of rapid growth of smaller towns and townships (see Fig. 2). While the bigger towns got their new inhabitants through immigration, the smaller towns mainly gathered "refugees" from the countryside, escaping the miserable living conditions of the early kolkhozes. Starting from 1960's, the situation in countryside improved, and the concentration of rural population began. This resulted in building central settlements (some for every kolkhoz), which attracted mostly younger people and specialists. Also, new technical equipment arrived in the countryside which eased the most difficult jobs.

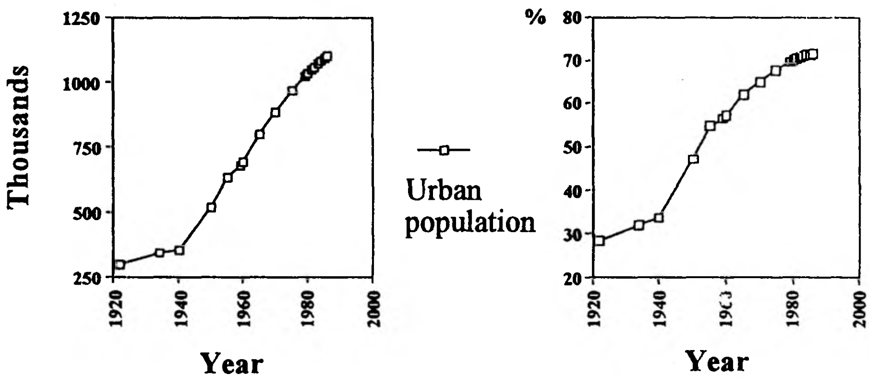

Figure 2. Growth of urban population in Estonia.

Concentration of agricultural production in Estonia can be characterized using the distribution of animal farms (Fig. 3). In 1939, before the World War II the number of animals in farms was quite equal over all the territory varying from 3 to 9 animals per farm. In 1990, just before the collapse of collectivized agriculture, there were significantly less farms with much higher concentration of animals. For instance in largest cattle farms and pig farms the number of animals was up to 2,500 and 80,000, accordingly. In the same time, one can see the concentration of large farm complexes in the eastern part of Estonia which is influenced by both fertile soils in Upper Estonia (see Fig. 1) and political reasons (see the part of landscape diversity).

3.2.3 Current regional policy and re-privatisation

In late 1980's, already during the collapse of the Soviet power the process of reprivatisation of lands began. To regulate this, many legislative documents have been adopted. For instance, the Land Reform Act determines procedures for the return, replacement, and compensation for land. It gives the former owners or their descendants first priority concerning land claims, with the exception of cases where land had already been allocated under the 1989 Act on Private Farming. It applies to physical persons whose land was nationalised on June 16, 1940, and to a limited extent to legal bodies (including non-profit organisations and the church). Part of the land will remain in state ownership which is possible by some specific cases. Land lots which are not subject to return or substitution, nor in state or municipal ownership, may be privatised. Because the circle of relatives of former land owners is defined to be too large, there are difficult problems in the whole privatization process. Also, it influenced the agricultural production which has been reduced more than 30% when to compare with the level in 1991 (see MANDER and PALANG 1994). Another factor of reducing agricultural production is the marketing situation that is inconvenient for Estonian farmers (*e.g.*, low prize products from Scandinavian countries, Germany and the Netherlands; lack of knowledge and experiences to provide initiatives in marketing, *etc.*)

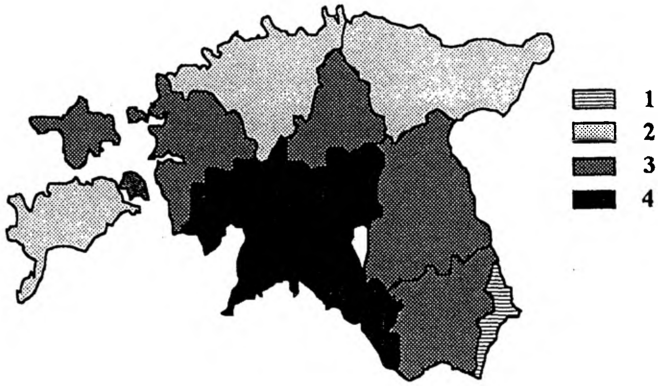

Figure 3. Concentration of agricultural production in Estonia. A — average number of animals in farms in 1939: 1 — <4; 2 — 4–6.5; 3 — 6.5–8; >8 (all in animal units (a.u.), 1 a.u. = 1 cow or horse). B — location of large animal farms in 1990: 1 — cattle farms, 800–1200 a.u.; 2 — cattle farms, >1200 a.u.; 3 — pig farms, 5000–25000 pigs; 4 — >25000 pigs; 5 — chicken farms, 500000–1000000; 6 — chicken farms, >1000000.

By the data of the Yearly Cadastre, the area of agricultural land in Estonia was 1,499,555 hectares (32% of total area) and the area of arable land was 1,127,824 ha (78% of agricultural land) on 1 January 1995 (AGRICULTURE 1995). According to the Estonian Enterprises Register, there were 983 active agricultural enterprises, and by the data of the National Land Board, there were 13,513 private farms on 1 January 1995. The average size of a private farm was 23.1 ha (AGRICULTURE 1995). Agricultural enterprises (cooperatives, state farms, and agricultural auxiliary enterprises) have been reorganized from former kolkhozes and sovkhozes. Although the cadastrial data show relatively low decrease in agricultural land, a significant part of formerly used arable lands and cultivated grasslands is set aside. Likewise, the number of livestock was significantly reduced. For instance, the number of cattle and pigs dropped from 770,000 and 960,000 in 1991 to 420,000 and 470,000 in 1994, respectively (AGRICULTURE 1995).

4. MAIN TENDENCIES

4.1 Changes in land use pattern

4.1.1 Situation by the beginning of the century

The land use situation in the beginning of the XX century was determined by the abolishing of serfdom in Russia in 1861. After this, every peasant was allowed to buy land. A massive renting and buying land for perpetuity began as the landlords smelled the possibility to make money. Mainly marginal areas were distributed. As the established system of ancient fields still survived, the new farms consisted of either many pieces often situated in different places separated by some other farms or of narrow and long strips. The marginal situation of new farms also supported the wide distribution of pastures or meadows.

During the first decades of the 20th century land amelioration activities intensified. While in 1850's open ditching was rather common in the estates, in the beginning of the new century drainage was used on about 70% of ameliorated land. In 1897–1918 the Estonian and Livonian Bureau for Land Culture designed draining for 366,000 ha. By 1917, 108,000 ha (20,000 ha on meadows, 15,000 ha on drained arable lands, the left in forests) of the plan was fulfilled (KARMA 1959). The year 1918 also marked the time when the greatest percentage of agricultural land occurred. Even in Virumaa, the less agricultural county in Estonia, the share of agricultural land exceeded 50%, while in Saaremaa the number was as unbelievably high as 88.5%. All these numbers are caused by increase of grazing that step by step became the most important branch of agriculture instead of crop growing.

4.1.2 The first independence period 1919–1940

On October 10, 1919 the Parliament of Estonia nationalised the land formerly belonging to Baltic-German landlords. Immediately the distribution of nationalised land to peasants began. The 23,023 tenants possessing their land before the reform, maintained their possessions (KASEPALU 1991). However, the number of persons applying for land increased constantly and in 1924 all the nationalised land was distributed.

To solve the problem, a special Homestead Board was created in 1929. The main task of this was to occupy unused mineral soil areas as well as wetlands. As due to market situation the Government of Estonia supported grain growing in 1920's, it resulted in increase in amelioration activities. In 1921–1929 16.7% of arable lands and 7.3% of grasslands were ditched (RINNE 1939). It sounds paradoxical, but during the economical crisis in 1929–1933, more than 400 new farms were established, in addition 2,000 more by 1939, which altogether resulted in 35,000 ha of engaged less fertile mineral lands. During the 20 years of independence about 350,000 ha were ameliorated (JUSKE *et al.* 1991).

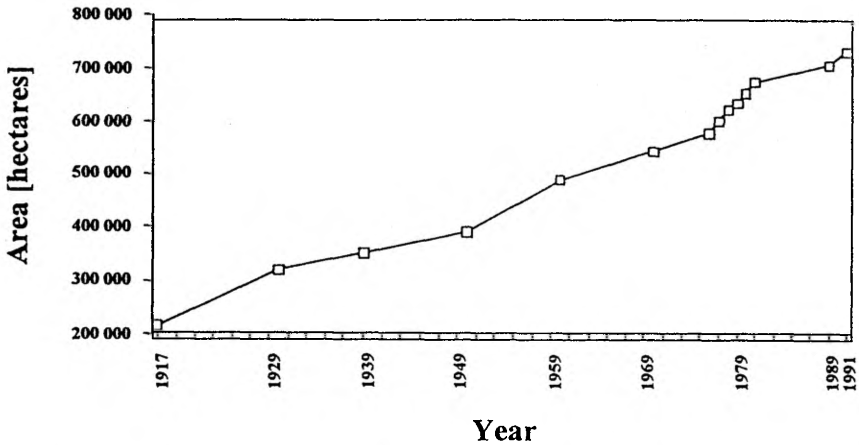

Figure 4. Land amelioration in Estonia.

Summing up the trends in land use pattern one should mention that altogether 33,180 new homesteads were established during the first independence period, the total number of farmholds being 139,984 by 1939 (KASEPALU 1991). During this period, the area of fields increased 1.36 times and that of arable land 1.44 times, reaching 1072.7 and 1141.8 thousand hectares, respectively (EESTI 1992). At the same time, the share of agricultural land diminished slightly, being higher in the western and lower in the eastern counties.

4.1.3 Concentration during the Soviet times

In 1942, after the first Soviet year and half a year of German occupation, the share of agricultural land has generally diminished, especially in Pärnumaa and Võrumaa. This is due to the consequences of the first deportation and the war. By 1945, after three years of German occupation, the land use pattern was more similar to that of 1939. The share of agricultural land had increased in western counties and slightly decreased in eastern counties.

he most dramatic changes in land use took place in the period between 1945 and 1955, the time of most drastic changes in social and economical life. This time, most of agricultural areas along the whole border line of the USSR were classified as state reserve lands which practically meant ending of all agricultural activities. The whole coastal zone of Estonia (coastal line reaches about 3700 km) and many islands lost their agricultural importance (Fig. 5; see also MANDER and PALANG 1994).

One can distinguish several stages in the concentration of agriculture in Estonia during the Soviet period. First, uniting of private farms into kolkhozes in 1947–1951; second, the uniting of small kolkhozes into larger ones in 1950–1951; third, the connecting of weaker kolkhozes with state farms (sovkhozes) in the late fifties; fourth, the joining of neighboring kolkhozes in the early seventies (until 1976); lastly, the privatization process (*i.e.*, accelerating deconcentration) that began in late eighties and has been stabilized. All these stages were connected with changes in land-use patterns.

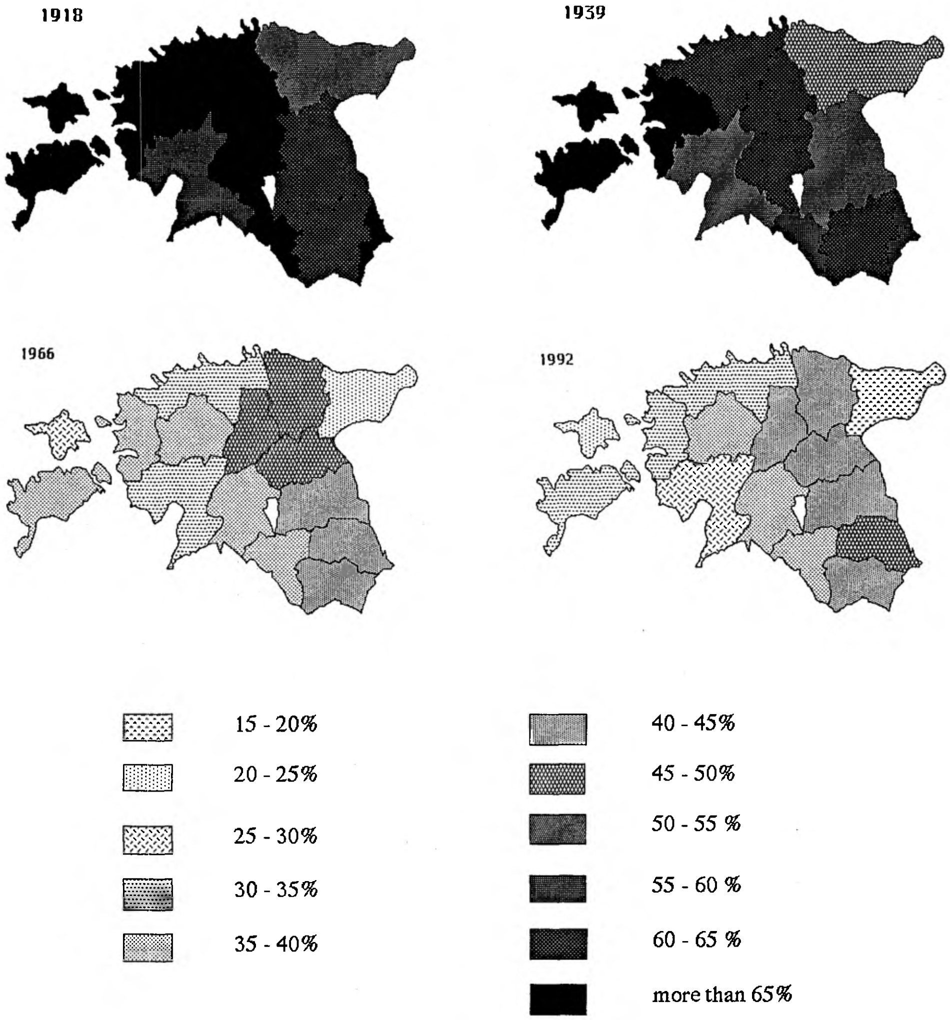

Figure 5. Dynamics of the share of agricultural land in the counties of Estonia in 1918–1992.

Summarizing the dynamics of land-use pattern one can observe a wave-like (pendulum-like) shift in the land-use change: after political collapses and during the Soviet period (1944–1991) the share of agricultural land decreases in western part of Estonia and increases in the eastern part, and in opposite, during the period of independence (1919–1940 and 1991–1994), the main development could be followed in the western part (see MANDER *et al.* 1994b). It looks like the consequence of a huge "gravitational" influence from the East.

4.2 Dynamics of landscape diversity

The results presented in this part have a preliminary character because the total area of test sites represent only 1,5% of Estonian territory. However, these 30 test areas have been chosen from various landscape types (about 70% of landscape types after VAREP (1964) have been presented). In addition, using different maps from different times may cause problems while comparing data. It may occur that the changes in landscape pattern reflect only differences in working habits and understandings of the map compilers. Nevertheless, often maps are the only source that enables us to trace the past landscapes.

Although the changes having occurred on some test areas are rather big, landscape diversity in Estonia in general has remained at the same level for the whole time period investigated (Fig. 6). One still can find differences both in spatial distribution and dynamics of landscape diversity pattern. The tendencies of change could be described as following.

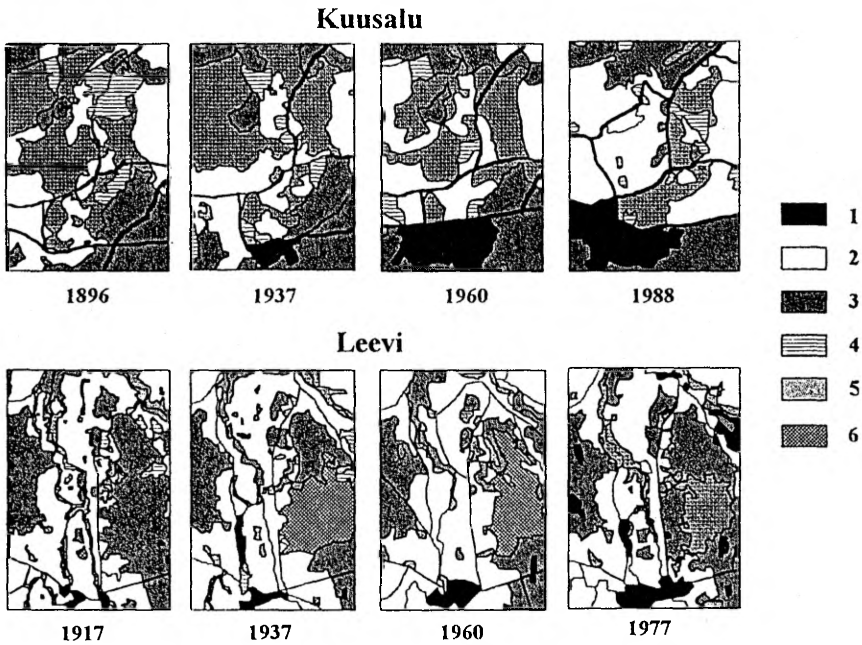

Figure 6. Landscape dynamics in Kuusalu, Harju County, North Estonia in 1896–1988 and in Leevi, Võru County, South Estonia in 1917–1977. 1 — settlement, 2 — arable land, 3 — forest, 4 — bush, 5 — natural grassland, 6 — wetland.

In general terms, the last century could be divided into three periods of landscape change. The first third is characterized by the process of unification, growth of evenness. During the next third the landscape became more divided into smaller units and more rounded in shape. The last thirty years have brought along the process of polarization, the division of land into two major groups, fields and forests, while the share of other land use types diminished (see RODOMAN 1974). At the same time, regional differences appear in landscape diversity as well as in dynamics of the diversity. North Estonia is even, rich in forests, moderately heterogeneous, with relatively large and simple contours and quite a simple structure (Fig. 6). It preserved its state from the very beginning of the century quite up to 1960's, the biggest changes having appeared during the last thirty years. South Estonia has much more complex structure, the contours are small and with long borders, the area as a whole is uneven, lowly heterogeneous, and, in general, returning to its former state after some decades of disturbances (Fig. 6). Central Estonia is the richest in fields, the landscape pattern is simple and even and still quite stable. West Estonia is a stable and even region with long borders, complex pattern, and moderate heterogeneity.

Comparing the rhythms of changes of both land use pattern and landscape diversity, some similarities could be found. Although the dependence of landscape diversity of land use was not proved, the main tendencies are almost the same.

To sum up, one can say that some diversity indices, like, *e.g.*, the edge index, indicate quite well landscape changes, while some others, like Shannon-Weaver index and Pielou's evenness, deal mainly with the number of patches, not with their area, and therefore do not suite well for landscape diversity analysis. Although significant changes having occurred in different regions in Estonia, landscape diversity in the whole territory of Estonia has remained at the same level for the whole time period investigated (see Fig. 7). Most probably, it seems like the inertia of the social system of Estonia as a

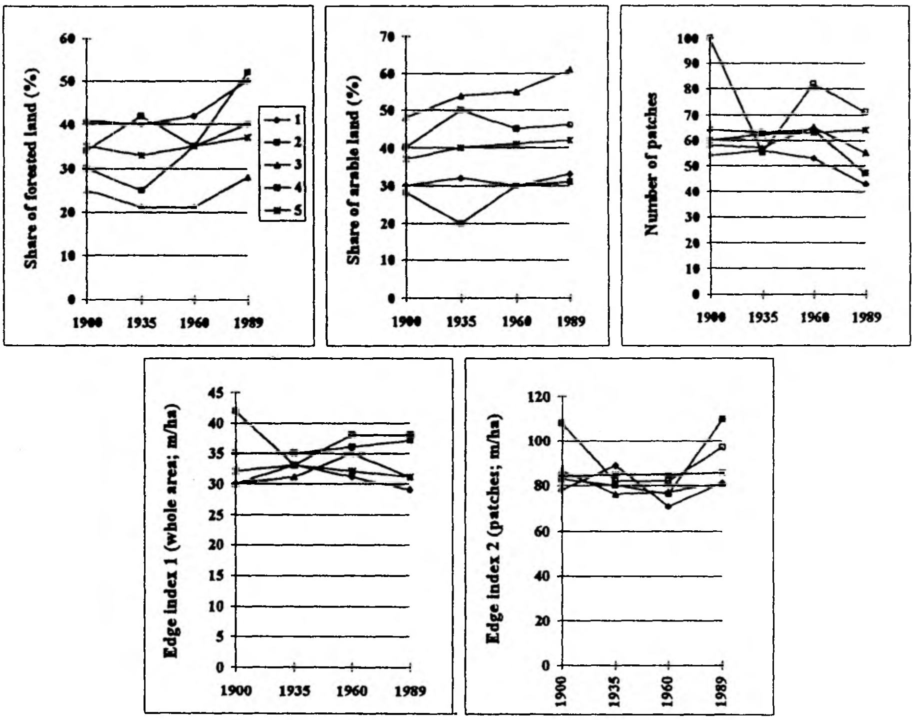

Figure 7. Dynamics of landscape diversity parameters in Estonia during the 20th century, averaged on the base of 30 test areas over the whole territory. 1 — North-Estonia, 2 — West-Estonia, 3 — Middle Estonia, 4 — South-Estonia, 5 — Whole Estonia (average values). Dynamics of landscape diversity parameters in Estonia during the 20th century, averaged on the base of 30 test areas over the whole territory. 1 — North-Estonia, 2 — West-Estonia, 3 — Middle Estonia, 4 — South-Estonia, 5 — Whole Estonia (average values).

rather sparsely populated country is so big that the system as a whole is easily able to compensate the amount of energy spent by men to change the landscape in its different parts. In other terms, land use marginalization in one region has been compensated by intensification in another.

5. ENVIRONMENTAL CONSEQUENCES

The main environmental consequences of landscape have a significant ecological background. In a broad sense they are: (1) loss of habitats, (2) species extinction and invasion of new species, (3) eutrophication of water bodies, (4) groundwater pollution, and (5) increase in the rate of vulnerability of ecosystems.

Loss of habitats is mainly caused by the decrease of the share of natural grasslands (Table 1) and land amelioration that has shifted the land-use activities from formerly arable lands in more high-lying areas to marginal areas (former semi-natural grasslands, depressions, wooded meadows, riparian and coastal meadows). Meadow communities,

Table 1. Development of land-use in Estonia during the 20th century (in 10^3 ha; after MANDER and PALANG 1994 and AGRICULTURE 1995)

Year	Agricultural land	Arable land	Natural grassland	Forest
1900	2978	1142	1836	796
1918	3092	1135	1792	995
1929	2749	1078	1625	726
1940	2652	1112	1540	873
1945	2455	979	1478	1037
1950	2497	949	1481	1021
1955	2175	968	1385	986
1960	2038	985	994	1462
1965	1851	1030	819	1582
1970	1643	1062	580	1722
1975	1560	1116	443	1793
1980	1500	1134	366	1902
1985	1479	1140	339	1915
1990	1461	1147	311	2012
1995	1450	1144	307	2016

often rich in species (690 species, some of them very rare, have been recorded in the meadow flora; KÜLVIK 1993) are beautiful patterns in Estonian countryside. Especially bright are wooded meadows with their dense herb layer rich in orchids and single oaks, ash and limes, *etc.* Some of former wooded meadows were cultivated into grasslands, others were afforested and a considerable number was overgrown with scrub. This has caused a loss of some species and, probably, a number of presently common species will become rare or die out in future: 83 plant species are in danger of extinction already (KÜLVIK 1993). Alvar meadows, the mostly treeless and meadow-like communities on limestone plateaus which are typical ecosystems of Scandinavia, have been also threatened. In recent years they have become overgrown with pine and juniper because sheep are not grazed in most of these areas any more. Formerly, sheep effectively controlled the growth of bushes and trees.

In the few decades, over 700000 ha of water-logged meadows, fens and traditional mires have been drained. As the agricultural use of these areas did not prove successful, a major part of this land is presently covered with young forests and shrubs of low value. Fortunately, due to the abundance of all kinds of mires (about 22% of Estonian territory is still covered with mires; PETERSON 1994), large areas of economic and/or scientific importance have been maintained.

Loss of species. At present, there are approximately 8600 plant and fungi species in Estonian flora, and approximately 18500 species of animals in Estonian fauna (PETERSON 1994). Due to habitat losses, seventy-seven formerly registered plant and species (among them, 17 *spp.* of vascular plants, 21 *spp.* of bryophytes, 1 sp. of algae, and 38 *spp.* of macrolichens) have become extinct during the last century (KÜLVIK 1993). A significant loss (35%) of local nesting ornithofauna of a polder territory in South Estonia has been observed because of the habitat loss (MANDER *et al.* 1989). In another case study from South Estonian and Lithuanian moraine landscape was investigated that in isolated woodlots the plant species diversity has been influenced by nitrogen loading from adjacent farms and intensively fertilized fields (MIKK and MANDER 1995).

Likewise, invasion of new species and increase of local populations has been observed for many organism groups. A typical example are plants like adventive flora elements and weeds. Likewise, another well documented tendency is an increase in population size of some mammals (*e.g.*, beaver, wild boar, moose, roe deer, brown bear, wolf, lynx and otter; KÜLVIK 1993) and birds (*e.g.*, white stork, great cormorant, mute swan and herring gull). On one hand, it is caused by regional changes of environmental conditions, but, on the other hand, it is a result of landscape changes. For instance, increase in forested areas and polarization/marginalization of the landscape (concentration of agriculture and other economic activities in centres on one hand, and extensification of economic activities in marginal areas on another) have created better living conditions for beaver, brown bear, lynx, otter, and wild boar. Also, formerly well regulated hunting played an important role in population increase of roe deer and moose. Last three years, however, showed a significant decrease in population of these two species.

Eutrophication of water bodies and groundwater pollution is mainly caused by very intensive use of mineral fertilizers in last decades, concentration of agricultural production into big farm complexes, and land amelioration. In Central and South Estonia about 60% of dug-wells and shallow bore-wells are contaminated with nitrates (NO_3 concentration >45 mg l^{-1}; METSUR 1993, see also MANDER *et al.* 1994a). Also, during and after land amelioration activities, losses of nutrients into groundwater and surface water bodies increases significantly. However, the collapse of collectivized farming system during the recent years has been followed by a significant decrease in use of mineral fertilizers and land amelioration activities, *e.g.*, the mean annual application of mineral fertilizers (N, P, and K) and organic fertilizers in Estonia was drastically dropped during the last four-five years: from 0.11, 0.06, 0.93, and 1.03 million tons of N, P, K, and organic fertilizers, accordingly, in 1987 to 0.073, 0.047, 0.078, and 0.43 million tons in 1994, respectively (Fig. 8). As a main consequence of these changes, the nutrient load of rivers, lakes and coastal waters has been decreased significantly. For instance, long-term investigations on nutrient cycling carried out in the Porijõgi River catchment, South Estonia, demonstrate a highly significant increase in both nitrogen and phosphorus losses. The mean annual runoff of TIN, NH_4-N, NO_3-N, and total-P was reducing from 16.0, 1.15, 14.8, and 0.33 kg ha^{-1} in 1987 to 2.4, 0.43, 2.0, and 0.22 kg ha^{-1} in 1994, respectively (Fig. 9, right part). In the same time, the share of set-aside arable lands (fallow), forested lands, seminatural grasslands, and wetlands (amortized drainage areas) was increasing from 1.7, 40.0, 6.7 and 3.4% to 12.5, 44.5, 10.2, and 3.7%, accordingly. In opposite, the percentage of arable lands showed a significant decrease: from 41.8 to 22.5% (Fig. 9, left part). Beside the significant land-use changes, the fertilizers application in this watershed was dropping in the same tempo like in the whole Estonia.

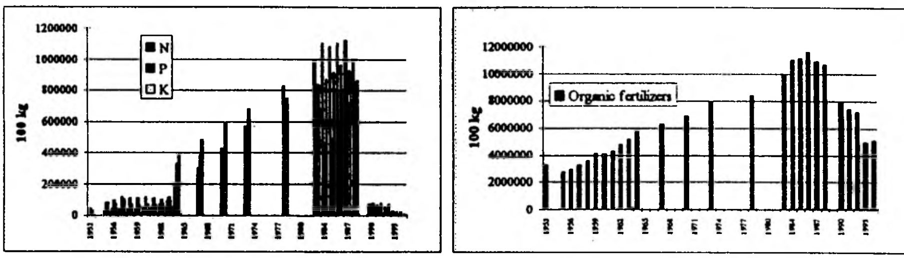

Figure 8. Application of fertilizers in Estonia in 1953–1994.

Increasing rate of vulnerability of ecosystems. This phenomenon is mainly characterized by the appearance of the first signs of damage caused to forests and lakes by acid rain. At present, in about 3200 ha of forest such damage has been detected. Likewise, a decrease in both average age of needles and radial increment of coniferous trees is probably a result of acidification. In opposite, in the oil-shale-industry region of North-East Estonia, the alkaline ash depositions from big power plants, cement factory and other industrial sources essentially disturb the natural acidic bog ecosystems. One of the consequences of such a disturbance is the significantly less intensive growth of sphagnum mosses.

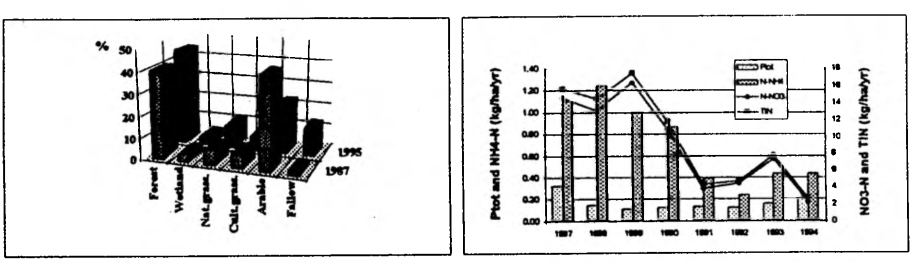

Figure 9. Dynamics in land-use pattern (left part) and nutrient runoff (right part) in the Porijõgi River catchment, South Estonia. TIN — total inorganic nitrogen.

6. ECOLOGICAL NETWORK

A network of ecologically compensating areas (also, the ecological network, see Fig 10) can be regarded as a subsystem of the anthropogenic landscape — an ecological infrastructure — which counterbalances the impact of anthropogenic infrastructure in the landscape, and also preserves the main ecological functions in landscapes: (1) to accumulate material and human-induced energy dispersion, (2) to receive and render harmless all unsuitable wastes from populated areas, (3) to recycle and regenerate resources, (4) to provide wildlife refuges and to conserve genetic resources, (5) to serve as a migration-tract for biota, (6) to be a barrier, filter and/or buffer for fluxes of material, energy and organisms in landscapes, (7) to be a support-framework for regional settlements, (8) to provide recreation areas for people, and, consequently, (9) to compensate and balance all inevitable outputs of human society (MANDER *et al.* 1995b).

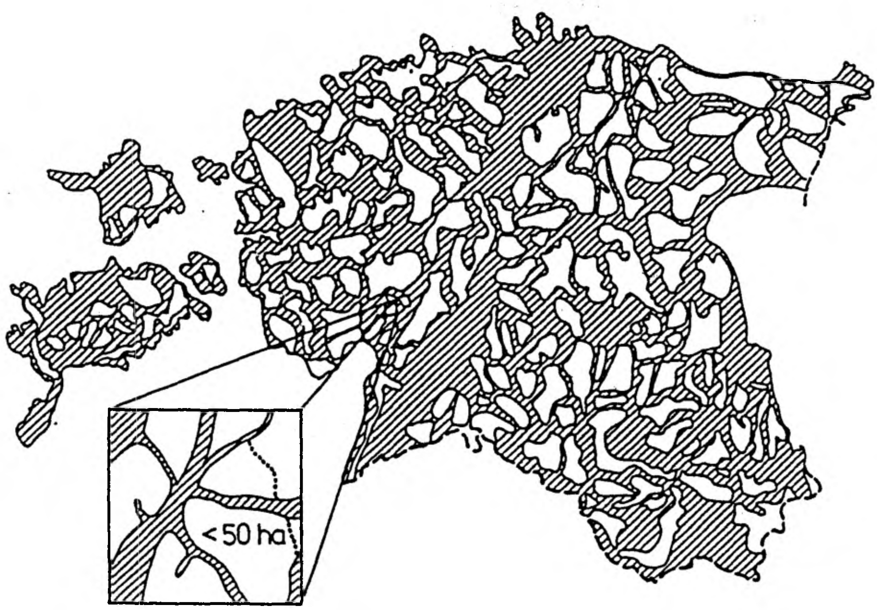

Figure 10. Network of ecologically compensating areas (ecological network) of Estonia.

These functions are all time-dependent and could break down with continuing anthropogenic load. Therefore, the ecological network is functional only when combined with additional measures of environment protection and nature conservation. Ecologically compensating areas combined with areas of intensive human activities form a strongly polarized (nonbalanced) system that can reduce entropy and increase order of self-regulation of the region. However, to level differences between these two poles (see RODOMAN 1974), buffering areas are of great importance.

A network of ecologically compensating areas is a hierarchical system with the following levels: (1) core areas, (2) buffer zones of core areas, corridors and stepping stones, and (3) nature development areas that support resources, habitats and species (see BALDOCK *et al.* 1993). According to the Law on Protected Areas, Species and

Natural Monuments from May 1994, there are five main types of nature protection areas which can be considered as core areas of the ecological network in Estonia (PETERSON 1994; see Table 2).

Protected areas	Number	Total area (ha)
National Parks	**4**	**120940**
State Nature Reserves	**5**	**63400**
Reserves, ***incl.***	**237**	**209539**
Landscape Reserves	77	93400
Mire Reserves	32	96799
Botanical Reserves	50	6800
Botanical-Zoological Reserves	16	7100
Ornithological Reserves	13	2100
Water Reserves	18	2900
Geological Reserves	12	440
Nature Park	**1**	**44200**
Programme Areas, ***incl.***	**2**	**1865900**
West-Estonian Archipelago Biosphere Reserve	1	1560000 (land: 404000 ha; "core zones": 13600 ha)
Pandivere Hydrological Reserve	1	305900
Protected Natural Objects, ***incl.***	**≈3260**	**≈8500**
Single elements of landscape (karst areas, waterfalls, outcrops of Paleozoic sediment rock, *etc.*)	119	600
Erratic boulders and stone fields	264	
Parks	542	6500
Primeval trees and tree groups	537	
Archeological sites	≈1800	≈500

In addition to protected areas, all large forests, wetlands (mires, bogs, swamps, coastal wetlands) lakes and rivers, natural grasslands and other large natural communities belong to the ecological network. In some cases ecological farms (in 1994, 31 farms were licensed) and even former Soviet military bases in forests and mires could be supporting areas (nature development areas, corridors, stepping stones) for the ecological network.

The size of network components serve as another criterion of the network's hierarchy with three levels: (1) *macro-scale*: large natural core areas (>1000 km^2) separated by buffer zones and wide corridors or stepping stone elements (width >10 km); (2) *meso-scale*: small core areas (10–1000 km^2) and connecting corridors between these areas (*e.g.*, natural river valleys, seminatural recreation areas for local settlements; width 0,1–10 km); (3) *micro-scale*: small protected habitats, woodlots, wetlands, grassland patches, ponds (<10 km^2) and connecting corridors (stream banks, road verges, hedgerows, field verges, ditches; width <0,1 km).

In Estonia, there is one main "ecological axis" which represents the macro-scale ecological network: the large forest and mire zone (phytogeographically known as *Estonia intermedia*; see Fig.1) extending from Lahemaa National Park in the north to the coast of the Gulf of Riga. Other major axes are not as compact and consist of meso- and micro-scale compensating areas. Ecologically compensating areas of all levels comprise about 55% of Estonia.

The land use changes during the 20th century have remarkably influenced the ecological network in Estonia. Except the core areas, the whole network, especially the seminatural meadows and forests serve as buffering area, *e.g.*, during the intensification of agricultural activities their area decreases and vice versa, they expand when the activities are less intensive. At present, the last tendency appears which allows to forecast the expansion of buffer zones of core areas and nature development areas that should support biological and landscape diversity.

CONCLUSIONS

(1) The main trends in Estonian land-use dynamics have been a decrease in agricultural land (from 65% in 1918 to 30% in 1994) and an increase in forested areas (from 21 to 43%, respectively).
(2) After political collapses the main agricultural activities have been shifted from the western part of Estonia to the eastern part. This pendulum-like movement is caused by the geopolitical location of Estonia.
(3) Land-use changes, the concentration of agricultural production, land amelioration, and the oil-shale based industry in north-eastern Estonia have caused the main ecological disturbances and a great polarization of rural landscapes
(4) Concentration of agricultural activities has been a main reason for eutrophication of water bodies and groundwater pollution. Nevertheless, the decreasing agricultural activities during the last 3 years have caused a slight improvement of water quality in inland waters and aquifers.
(5) Land amelioration has shifted the agricultural activities from the former arable lands to marginal areas (natural grasslands, wetlands). It caused an essential disturbance of the stabilized nutrient cycling in landscapes.
(6) The increase in mineral fertilizer use and intensive land amelioration during the last three decades have been essential factors in eutrophication and groundwater contamination by nitrates. However, the end of collectivized farming system in recent years has seen a significant reduction of mineral fertilizer use and land amelioration.
(7) A well-developed network of ecologically compensating areas consisting of nature protection areas, forests, mires, meadows and coastal waters, has been formed during a turbulent development. This network, a relatively low population density and a high polarization rate of the territory have maintained a major part of biodiversity. Nevertheless, extinction of wooded meadows and alvar meadows could be guided with a significant loss of species. It is very important to maintain and enhance the ecological network during privatization.
(8) The next important step will be connecting the network of ecologically compensating areas in Estonia with the European Ecological Network (EECONET) system; therefore, an optimization of the ecological network on different hierarchical levels, using various criteria, is needed.

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LANDSCAPE
AND
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Landscape diversity changes in Estonia

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Abstract

This paper discusses landscape diversity dynamics in Estonia during the 20th century. The analysis of maps from four different time periods in terms of 12 diversity indicators shows that landscape diversity changes in Estonia are minor. Still there remain some regional differences. A principal component analysis indicates four types of diversity, namely, shape of the patch, 'classical' diversity, land use, and number of units, which explain 80% of the whole variability of landscape change. © 1998 Elsevier Science B.V.

1. Introduction

Changes in landscape diversity have become a popular for discussion amongst landscape ecologists. Many works (O'Neill et al., 1988; Li and Reynolds, 1994; Riitters et al., 1995) have focused on different diversity indices and their statistical properties. Others have tried to investigate the different effects of landscape changes (e.g., Lipsky, 1995; Metzger, 1995; Seiler and Eriksson, 1995; Gustafson and Gardner, 1996). Forman (1997) has produced an extensive summary of current knowledge about landscape diversity. Furthermore, land use changes in Estonia have also been discussed, using both cadastral data (Kasepalu, 1991; Mander and Palang, 1994) and series of historical maps (Mander et al., 1994). Peterson and Aunap (1997) have also followed changes in agricultural land tenure from 1987 to 1995 using Landsat imagery. This paper summarises this work, describing the changes in landscape diversity in Estonia in the 20th century.

Geographers and landscape ecologists have differing views on landscape and its diversity. It is often described as the diversity of geographical spaces and their environmental systems (Leser and Schaub, 1995). In this paper, diversity is defined by differences in land use. The study provides a historical overview of landscape diversity change, based on analysis of old map series. For 56 test areas, several diversity indices were computed. This provides opportunities to trace both spatial and temporal changes. In addition, it enables one to decide about the functioning of the ecological infrastructure, the basic idea behind modern nature conservation. It also suggests to landscape planners scenarios for optimising future landscapes.

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2. Data and methods

2.1. Test sites

The study was carried out on 56 test sites all over Estonia (Fig. 1). These sites were randomly selected provided all landscape regions (according to Varep, 1964) were represented. In addition, to avoid possible additional distortions, the location of the test sites on a single map sheet was considered. The area of each test site was 1954 ha. Altogether these test sites cover about 2.5% of the territory of Estonia (87 930 ha). The maps of the test sites were scanned, digitized and transformed/analyzed using the MapGrafix 3.5 software on Macintosh computers.

2.2. Maps available

Landscape diversity changes on these test sites were followed on maps from four different time periods:

1. Russian topographic map sheets (scale of 1 : 42 000) dating from 1896–1917, later referred to as '1900';
2. Topographic map sheets (scale 1 : 50 000) published by the Topo-Hydrographic Department, Estonian Army, in 1935–1939, later referred to as '1935'. However, not all the territory of Estonia was covered by maps of this series (Jagomägi and Mardiste, 1994). this may cause minor errors in the parts of the analysis concerning the 1930s;
3. The 1960 land use map of Estonia (scale 1 : 50 000);
4. Topographic map sheets (scale 1 : 50 000) issued by GUGK in Riga in 1982–1990 and later referred to as '1989';

2.3. Delimitation of land use categories

On these maps, eight categories of land use were determined: (1) settlements; (2) waters; (3) fields; (4) grasslands; (5) bushes and brushwood; (6) forests; (7) mires; and (8) quarries and wastelands. Roads, watercourses, ditches, hedgerous, and ecotones served as borders between different patches. Unfortunately, an approach like this leaves the possibility that differences in generalisation, the work habits of the map compilers, etc., may influence the obtained data. Nevertheless, the use of such old maps is often the only method to reconstruct past land use.

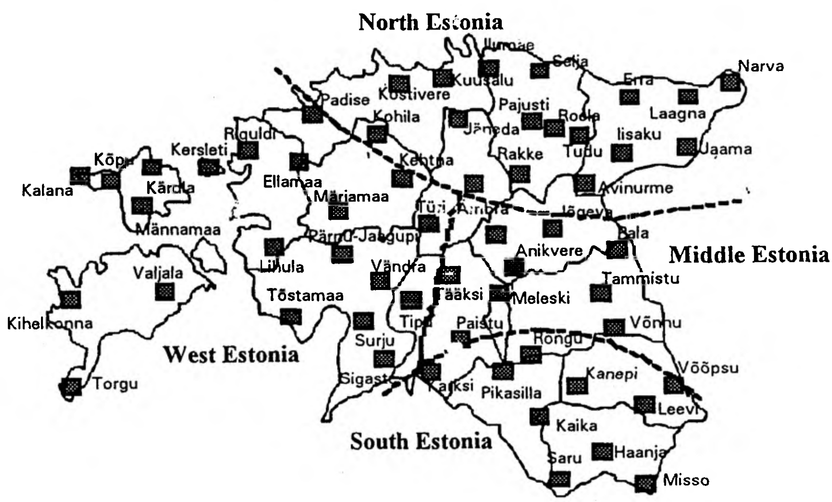

Fig. 1. Location of test areas.

2.4. Diversity indices

Based on the area and the perimeter of the delimited patches, several diversity indices were computed.

1. Heterogeneity after Shannon-Wiener (see Bastian, 1994): $H = \Sigma(n_i/N)\log(n_i/N)$, where n_i is the number of patches of type i, N being the total number of patches.
2. Evenness after Pielou (1966, 1975): $e{=}H/\log S$, where S is the number of types (H – heterogeneity after Shannon–Wiener).
3. Edge index (after Jagomägi and Mander, 1982): $I{=}\Sigma[(L)/A]$, where I is the length of ecotones, A being the area of the patch.
4. Complexity (Patton index, Patton, 1975): $T{=}4\pi A/p^2$, where p is the perimeter of the patch.
5. Curvature: $P{=}p/2(\pi A)^{-2}$

The indices 3, 4, and 5 were initially computed for the whole test site (indicated by (1) in the text) and then as the average of all patches in the test site (indicated by (2) in the text). Number of patches, share of forests, share of fields and number of land use types were also used to describe the diversity of each test site.

The statistical analysis methods like χ^2-test, dispersion analysis, Kruskal–Wallis test and principal component analysis were used. The analysis was carried out with Statgraphics 3.0 and CANOCO software packages. Significance levels in the χ^2-test and dispersion analysis was set at 0.05.

3. Results and discussion

Earlier studies (Mander and Palang, 1994, Mander et al., 1994) have demonstrated that the land use changes in Estonia during the 20th century have been significant. During this period, the proportion of forests has increased three-fold (from 14% to 42%), while the portion of land in agricultural use has diminished from 65% to 30%. Moreover, the driving forces behind these changes have also varied. For instance, the political system has changed four times from 1900–1990, each time bringing new and different land use policies. Presumably, these changes have also induced changes in landscape diversity.

Surprisingly, no temporal change in landscape diversity indices appeared when the country as a whole was considered. The average values and standard deviation of almost all measured indices are very stable (Table 1). Only four indices out of eleven show statistically significant changes (Table 2). Firstly, the proportion of forests has increased throughout the whole time period. This coincides with the land use data describing the whole country (see, e.g., Mander et al., 1994). Secondly, both heterogeneity and evenness have decreased to 1989, compared with the earlier dates. Finally, the average edge index was higher in 1960 than in 1900 or in 1989.

We also tried to identify regional differences in landscape diversity change. For this purpose, Estonia was divided into four regions. The results of this analysis are presented in Table 3. Comparing these numbers, one can note that the southern Estonian test sites have higher values for edge indices. This can be

Table 1
Average values and standard deviations of measured landscape diversity parameters

Index	Average	1900	1935	1960	1989
Number of patches	64±25	63±22	69±32	62±21	61±22
Edge index (1)	145±80	140±76	164±96	123±58	151±80
Edge index (2)	52±28	52±36	52±27	53±25	52±26
Heterogeneity	0.55±0.13	0.57±0.12	0.56±0.10	0.54±0.11	0.53±0.16
Evenness	0.74±0.14	0.75±0.13	0.77±0.12	0.76±0.13	0.69±0.17
Arable land (%)	35±19	39±18	31±17	33±20	39±21
Forest (%)	39±20	33±19	36±20	37±19	47±20
Complexity (1)	0.50±0.03	0.49±0.03	0.49±0.03	0.50±0.03	0.50±0.04
Complexity (2)	0.63±0.13	0.62±0.10	0.66±0.15	0.60±0.11	0.65±0.14
Curvature (1)	1.54±0.08	1.54±0.07	1.55±0.07	1.52±0.07	1.54±0.09
Curvature (2)	1.28±0.13	1.28±0.12	1.26±0.14	1.31±0.14	1.26±0.13

Table 2
Changes of diversity indices timewise

Index	χ^2-test	Dispersion analysis	Dispersion homogeneity	Kruskal–Wallis test
Number of patches	Normal	No difference	Homogeneous	
Edge index (1)	Normal	1900 and 1989>1960	Homogeneous	
Edge index (2)	Normal	No difference	Homogeneous	
Heterogeneity	Normal	1989 smaller	Homogeneous	
Evenness	Normal	1989 smaller	Non-homog.	
Arable land (%)				No difference
Forest (%)				Increasing
Complexity (1)	Normal	No difference	Non-homog.	
Complexity (2)	Normal	No difference	Homogeneous	
Curvature (1)				No difference
Curvature (2)	Normal	No difference	Homogeneous	

Table 3
Changes of diversity indices regionwise

Index	Dispersion analysis	Dispersion homogeneity	Kruskal–Wallis test
Number of patches	No difference	Homogeneous	
Edge index (1)	No difference	Non-homog.	In south Estonia higher
Edge index (2)	Differs	Non-homog.	In south Estonia higher
Heterogeneity	No difference	Homogeneous	
Evenness	No difference	Non-homog.	No difference
Arable land (%)			In central Estonia higher, in west Estonia lower
Forest (%)			In west Estonia higher
Complexity (1)	No difference	Non-homog.	In west Estonia higher
Complexity (2)	Differs	Non-homog.	In west Estonia higher
Curvature (1)			In west Estonia lower
Curvature (2)	Differs	Non-homog.	In west Estonia lower

explained by the hilly landscape of that part of Estonia. As relief varies, so do the edges of patches. On the contrary, the very plain relief of western Estonia results in larger patches, a bigger share of forests, and higher complexity and lower curvature.

Separate test sites, however, have undergone remarkable changes (see Fig. 2). Some of them have lost most of their diversity during this century, others have become more diverse, and some have experienced only minor fluctuations. However, these changes tend to compensate each other. In other words, while one test site lost its diversity, mainly due to intensification of human impact or abandonment, an opposite process took place somewhere else.

Principal component analysis enables four axes, explaining 80% of the total change, to be defined (Fig. 3, Table 4). Clear differences between the axes indicate that four different diversities have been measured. The first axis describes the diversity of the shape of the patches, being highly correlated with curviture (index 1: r=0.73, index 2: r=0.89) and having a high negative correlation with complexity (index 1: r=−0.67, index 2: r=−0.88). The second axis has a strong positive correlation with edge indices (index 1: r=0.84, index 2: r=0.87) and a somewhat lower negative correlation with heterogeneity (r=−0.68) and evenness (r=−0.65). The third axis concentrates on the changes in the share of land use types (share of fields r=−0.78, share of forests r=0.67). Finally, the fourth explains variations in the number of types and patches (r=0.71 and 0.85, respectively).

A similar ordination procedure was applied to all test sites. In theory, test sites with similar geographical locations and/or similar field/forest ratios should change in a similar way. However, nothing like this

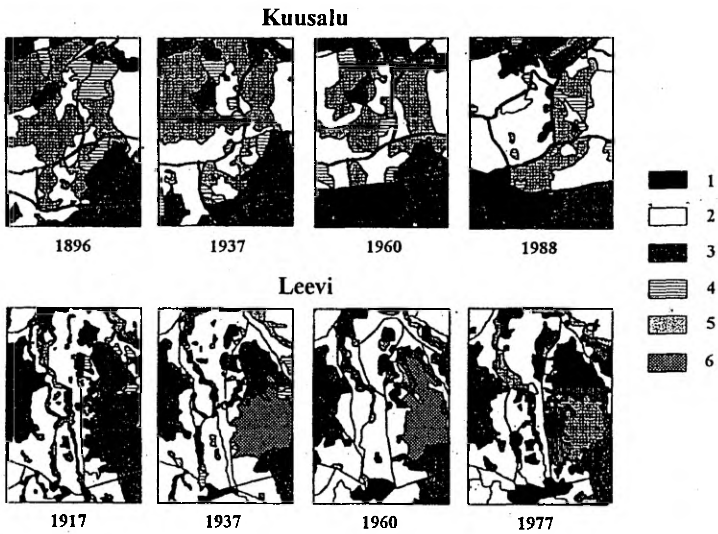

Fig. 2. Landscape dynamics in Kuusalu, Harju County, north Estonia and in Leevi, Võru County, South Estonia. 1, settlement; 2, arable land; 3, forest; 4, bush; 5, natural grassland; 6, wetland.

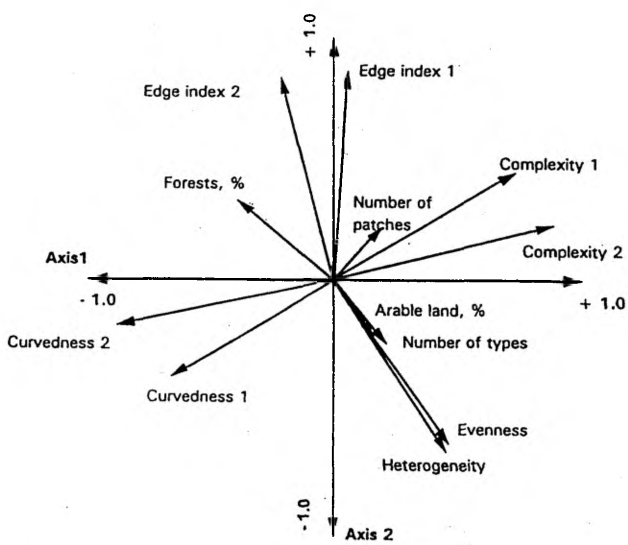

Fig. 3. Ordination scheme of landscape diversity indices, plotted as a result of principal component analysis.

Table 4
Results of principal component analysis

Index	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalue	0.2740	0.2523	0.1519	0.1265
Number of types	0.1634	−0.2188	0.1609	0.8513
Number of patches	0.1906	0.2339	−0.4100	0.7077
Edge index (1)	−0.2305	0.8363	−0.0231	0.1662
Edge index (2)	0.0472	0.8667	−0.1979	0.1214
Heterogeneity	0.4572	−0.6792	0.2911	0.3892
Evenness	0.4652	−0.6446	0.2324	−0.1586
Arable land (%)	0.2127	−0.2419	−0.7790	−0.1687
Forest (%)	−0.4033	0.3339	0.6608	0.0310
Complexity (1)	−0.6648	−0.3769	−0.4587	0.1558
Complexity (2)	−0.8845	−0.1796	0.1936	0.0861
Curvature (1)	0.7256	0.4467	0.3610	−0.0296
Curvature (2)	0.8863	0.2325	−0.1678	−0.1083

exists in reality. The changes in the test sites are rather chaotic, being mostly fluctuations along the complexity–curvature axis, without any clear tendency either in time or in space. An explanation of such behavior could be 'insufficient' human influence: the test site changing when the human activities become more intensive and returning to its initial state when the human influence becomes lower again.

Summarising the results of this analysis, the most unexpected outcome is that despite all kinds of land use changes landscape diversity has remained stable. Thanks to the low population density, Estonian landscapes have had the space to buffer change. Land use dynamics do point towards some overall shift in landscape diversity. This shift has occurred, but only in certain places, while at other places an opposite shift has happened, thus keeping the average diversity stable. The reason for this is that the population of Estonia is so sparse that often, when land is reclaimed, it is quickly abandoned due to the lack of suitable management. This observation is one more suggestion supporting the argument that the so-called network of ecologically compensating areas (see Mander et al., 1995) is still functioning.

4. Conclusion

The analysis has shown that despite the large changes in land use pattern, landscape diversity changes have been minor. Also that regional differences appear only for certain indices. The indices used measured different kinds of diversity, altogether describing 80% of the variability. In this, the 'classical' indicators like the edge index, Shannon–Wiener's heterogeneity and Pielou's evenness cluster in one group.

Although the parameters used in this analysis do not allow a determination of significant landscape diversity changes to be made, one may presume that on a higher hierarchical level these changes may be more easily traceable (using, e.g., satellite imagery), especially on uplands and islands, where land use changes are greatest. Therefore, there is a need to improve the analysis of landscape diversity by using different parameters and technologies.

Acknowledgements

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IV

Mander, Ü., **H. Palang,** J. Jagomägi 1995:
Landscape change and its impact on ecological network: case of Estonia.
Landschap, 2–3, 27–38.

Ecological networks in Estonia

Impact of landscape change

Ülo Mander, Hannes Palang and Jüri Jagomägi

The current paper gives an overview of the network of ecologically compensating areas in Estonia. It explains the network's components' functions and hierarchy, as well its formation and principles of design. The paper also includes the results of two separate studies undertaken in order to follow land use and landscape diversity dynamics in Estonia. As the development of the ecological network is closely connected with the dynamics of land use, these studies will assist in the understanding of the history of the network's formation as well as its possible changes.

Ecological networks in Estonia

Background

In accordance with new nature conservation and agricultural policy in Europe, ecological network serves as the basic concept. The network includes, first, 'protection and enhancement of the most important habitats ('core areas') and, second, the maintenance of landscape features that facilitate the dispersal and migration of species' (Baldock *et al.*, 1994) as well as compensate for various anthropogenic impacts on ecosystems. On the European level, the EECONET programme is an attempt to apply this concept (Bischoff and Jongman, 1993). In many European countries, programmes are under way to protect and enhance the most important ecological systems as the main element of a broad nature-conservation and environment-protection strategy, as is illustrated in this special issue of LANDSCHAP.

In Estonia, a concept of 'the network of ecologically compensating areas' (or, 'compensative areas network'; Mander *et al.*, 1988) has been developed since the early 1980s.

Components, functions and hierarchy

The network of ecologically compensating areas (later, also the ecological network) can be observed as a subsystem of the anthropogenic landscape - an ecological infrastructure - which counterbalances the impact of anthropogenic infrastructure in the landscape. Also, the ecological infrastructure guarantees the realisation of the main ecological functions in landscapes. The term 'compensating' is given a broad meaning by the authors, and ecologically compensating areas are related to following functions: (1) to save material and energy, mainly energy in the dispersion of which people are involved, (2) to secure and make harmless all that is unsuitable

Ecologically compensating area
Ecological infrastructure
Landscape diversity
Land-use change
Ecological network

for populated areas (polluted water, air and solid wastes), (3) to recycle and regenerate resources, (4) to provide refuges for wildlife populations, and conserve genetic resources, (5) to serve as a migration-tract for biota, (6) to be a barrier, filter and/or buffer for fluxes of material, energy and organisms in landscapes, (7) to be a support framework for the system of settlements in the region, and, consequently, (8) to provide recreation areas for people; (9) to compensate and balance all inevitable outputs of human society. Of course, all these functions are time-dependent and can collapse in conditions of continuing anthropogenic load. Therefore, the concept of ecological network is rational only in combination with other measures of environment protection and nature conservation. Ecologically compensating areas combined with areas of intensive human activities form a strongly polarised (non-balanced) system that has the ability to reduce entropy and increase the degree of self-regulation of the region. However, to level differences between these two poles, buffering areas are of great importance.

Despite the fact that the ecological network of Estonia was brought up already in the early 1980s (Jagomägi, 1983) and was accepted among the first analogous systems in Europe (Baldock *et al.*, 1994), the Estonian nature conservation legislation has not yet fully supported it. Nevertheless, new laws on nature conservation and environment protection in Estonia (Act on Nature Protection, 1990; Order on Protection of Coastal areas, 1992; Forest Act, 1993; Act on Protected Areas, Species and Natural Monuments, 1994; Act on Protection of Coastal Areas, 1994) leave enough place to handle buffer zones of protected areas and all natural/semi-natural ecosystems outside protected areas as elements of the ecological network (see Peterson, 1994).

The ecologically compensating areas' network is a hierarchical multilevel system. Also, the EECONET concept proceeds

Protected areas in Estonia

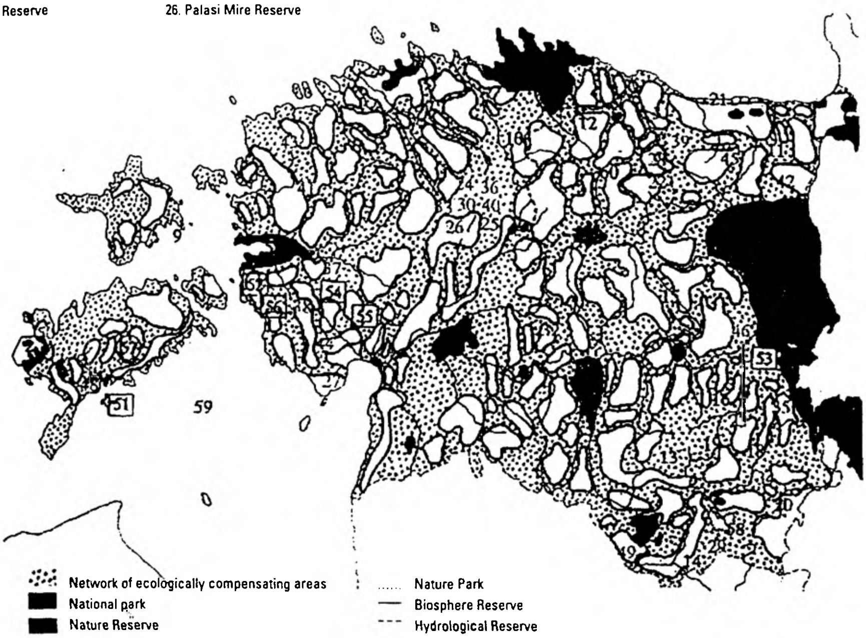
- **4 National Parks (totalling 120,940 ha),**
- **5 State Nature Reserves (63,400 ha)**
- **237 Reserves, inc.:**
  - 77 Landscape Reserves (93,400 ha)
  - 32 Marsh Reserves (96,799 ha)
  - 50 Botanical Reserves (6,800 ha)
  - 16 Botanical-Zoological Reserves (7,100 ha)
  - 13 Ornithological Reserves (2,100 ha)
  - 18 Water Reserves (2,900 ha)
  - 12 Geological Reserves (440 ha)
  - 1 Nature Park (44,200 ha)
- **Programme Areas**
  - West-Estonian Archipelago Biosphere Reserve - 156,000 ha (of which 404,000 ha is land and 13,600 ha make up 'core zones')
  - Pandivere Hydrological Reserve - 350,900 ha.
- **1,462 Protected Natural Objects, inc.:**
  - 119 single elements of landscape (karst areas, waterfalls, outcrops of Palaeozoic sediment rock, 600 ha)
  - 264 erratic boulders and stonefields
  - 542 parks (6,500 ha)
  - 537 primeval trees and tree groups
  - 1,800 archaeological sites.

from that understanding. Considering the functional hierarchy, the following levels can be pointed out: (1) core areas, (2) buffer zones of core areas, corridors and stepping stones, and (3) nature development areas that support resources, habitats and species (Baldock *et al.*, 1994). According to the Law on Protected Areas, Species and Natural Monuments (1994), there are several types of nature protection areas which can be considered as core areas of the ecological network in Estonia (figure 1).

In addition to the protected areas, all large forests, wetlands (marshes, bogs, swamps, coastal wetlands) lakes and rivers, natural grasslands and other large natural communities are supposed to belong to the ecological network. In some cases, ecological farms (in 1994, 31 were licensed) and even former Soviet military bases in forests and marshes may be considered supporting areas (nature development areas, corridors, stepping stones) for the ecological network.

Another criterion to the hierarchy of the ecological network is the size of network components. At least three main hierarchy levels could be put forward:

1. Lahemaa National Park
2. Vilsandi National Park
3. Karula National Park
4. Soomaa National Park
5. Matsalu National Reserve
6. Viidumäe National Reserve
7. Nigula National Reserve
8. Endla National Reserve
9. Hiiumaa Islets Landscape Reserve
10. Kõrvemaa Landscape Reserve
11. Kurtna Landscape Reserve
12. Neeruti Landscape Reserve
13. Otepää Landscape Reserve
14. Paganamaa Landscape Reserve
15. Vooremaa Landscape Reserve
16. Valley of the River Ahja
17. Valley of the River Pirita
18. Valley of the River Võhandu
19. Tilleorg Valley
20. Valley of the River Piusa
21. Glint of Saka-Ontika-Toila
22. Luusaare Mire Reserve
23. Valgesoo Mire Reserve
24. Mahtra Mire Reserve
25. Piiumetsa Mire Reserve
26. Palasi Mire Reserve
27. Lindi Mire Reserve
28. Tudu-Järvesoo Mire Reserve
29. Kellamäe Mire Reserve
30. Loosalu Mire Reserve
31. Sämi-Kuristiku Mire Reserve
32. Parika Mire Reserve
33. Keava Mire Reserve
34. Meenikkunu Mire Reserve
35. Meelva Mire Reserve
36. Laukaso Mire Reserve
37. Aela-Viirika Mire Reserve
38. Tuhu Mire Reserve
39. Sirtsi Mire Reserve
40. Avaste Mire Reserve
41. Marimetsa Mire Reserve
42. Agusalu Mire Reserve
43. Läänemaa Mire Reserve
44. Nätsi-Võlla Mire Reserve
45. Muraka Mire Reserve
46. EmajõeSuursoo Mire Reserve
47. Käina Bay
48. Lake Linnulaht
49. Wooded Meadows of the River Koiva
50. Wooded Meadows of Tagamõisa
51. Broad-Leaved Forest of the Abruka Island
52. Wooded Meadows of Virtsu-Laelatu-Puhtu
53. Primeval Forest of Järvselja
54. Oak Wood of Mihkli
55. Hump of Virussaare
56. Bog of Nehatu
57. Meteorite Craters of Kaali
58. Haanja Nature Park
59. West-Estonian Archipelago Biosphere Reserve
60. Pandiverre Hydrological Reserve



• **Figure 1**
The network of ecologically compensating areas (spotted) and protected areas (as core areas of the ecological network) in Estonia. Main cities are marked in black. Protected areas shown after Peterson, 1994

- the macro-scale network: large natural core areas (>1000 km²) with their buffer zones and wide corridors or stepping stone elements (width >10 km) between them;
- the meso-scale network: small core areas (10-1000 km²) and corridors between these areas (e.g. natural river valleys, semi-natural recreation areas for people around settlements; width 0,1-10 km);
- the micro-scale network: small protected habitats, woodlots, wetlands, grassland patches, ponds (<10 km²) and corridors (-stream banks, road verges, hedgerows, field verges, ditches; width <0,1 km) between them.

In the case of Estonia, there is one main 'ecological axis' across the territory, which represents the macro-scale ecological network. It is the large forest and marsh zone (phytogeographically as Estonia intermedia; Lippmaa, 1935; see also Külvik, 1993; Mander & Palang, 1994) beginning with the Lahemaa National Park on the north coast of Estonia and going over large bog and forest areas (Kõrvemaa Landscape Reserve, Soomaa National Park, Nigula Nature Reserve, Nätsi-Võlla Marsh Reserve) up to the coast of the Gulf of Riga. Another two major axes could be found. The first of these is the marsh and forest zone on the eastern border of Estonia, that begins with large bogs and forests in the northeastern part with Kurtna Landscape Reserve, Muraka Marsh Reserve and Agusalu Marsh Reserve, and goes along the shore of Lake Peipsi - including Emajõe Suursoo Marsh Reserve - up to Haanja Nature Park, Karula National Park and Otepää Landscape Reserve in moraine-hilly areas of southeast Estonia. The second is the zone of very mosaic landscapes of forests, grasslands and wetlands across the southern part of Estonia. It begins with moraine-hilly areas in southeastern part and continues over Soomaa National Park and Matsalu Nature Reserve up to the West-Estonian Archipelago Biosphere Reserve. These two axes are not so compact and consist of several meso- and micro-scale compensating areas (figure 1). Altogether, ecologically compensating areas of all hierarchical levels cover about 55% of the territory of Estonia.

Table 1 • Development of land-use structure in Estonia during the 20th century (in 103 ha)

Year	Agricultural land	Arable land	Natural grassland	Forest
1900	2978,0	1142,0	1836,0	795,6
1918	3092,0	1135,0	1792,0	995,0
1929	2749,0	1078,0	1624,8	725,7
1940	2852,4	1112,1	1540,3	872,7
1945	2454,6	978,6	1477,9	1036,8
1950	2496,5	949,4	1481,0	1021
1955	2175,1	968,3	1385,4	985,8
1960	2037,6	985,2	993,7	1461,6
1965	1851,0	1030,4	819,4	1582,0
1970	1643,2	1062,4	580,3	1722,0
1975	1559,6	1116,3	443,3	1793,0
1980	1500,1	1133,9	366,2	1901,9
1985	1478,8	1139,9	338,9	1914,7
1990	1431,3	1147,1	284,2	2012,2
1992	1430,4	1147,8	282,6	2019,0

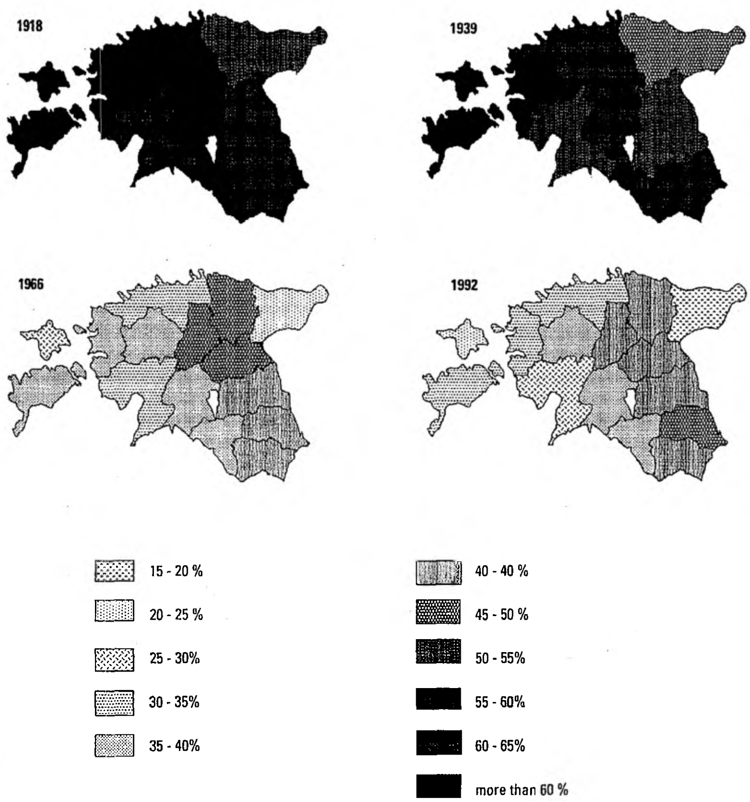
Historical formation of the network

Land-use changes

The current network of ecologically compensating areas has been formed during centuries of human impact on the nature. Its present state is mainly shaped by the human activities of the last century, during which the impact was the strongest.

Significant trends in land-use dynamics are found in Estonia during the 20th century. The most important changes have been a decrease in the percentage of agricultural land from about 30,000 km^2 in the beginning of century to 14,300 km^2, and an increase in the share of forests from about 7,960 to 20,190 km^2 (table 1). The share of agricultural land has diminished mainly due to the decreasing area of natural pastures and grasslands - from 18,360 to 2860 km^2, respectively. On the other hand, a wave-like (pendulum-like) shift could be observed in the land-use change: after political collapses, the share of agricultural land decreased in the western part of Estonia and increased in the eastern part, and the other way around, during the period of independence, the main development occurred in the western part (figure 2; see also Mander & Palang, 1994). It looks like the consequence of a huge 'gravitational' influence from the East.

The main driving factors for this development were (1) land reforms (1919, 1940, 1989) and two World Wars; (2) collectivisation and deportation of about 60,000 people to Siberia in 1941 and 1949 (a most significant decrease in the share of agricultural land took place during the first ten years of collectivisation; see also Mander & Palang, 1994); (3) urbanisation; (4) formation of a broad and strictly controlled Soviet boundary zone on the coastal areas that significantly limited all civil activities on islands and on the coast; (5) concentration of agricultural production, and (6) land amelioration. Also, natural



• **Figure 2**
Dynamics of the share of agricultural land in Estonia (arable land plus grasslands).

conditions play an essential role: e.g. in the eastern part that mostly coincides with the Upper Estonia (Varep, 1964; Arold, 1993), the conditions for intensive agriculture are better than in the western part (mainly coincides with Lower Estonia). This explains the concentration of agricultural production in eastern and central Estonia, but could also be one of the reasons for the internal shift described earlier (Mander & Palang, 1994).

Landscape diversity changes

Land-use changes become more evident if we look them trough the prism of landscape diversity changes. Landscape diversity changes are followed on 30 test areas (20 km^2 each) chosen in the territory of current Estonia (Palang, 1994). The investigation was carried out analyzing maps from different times: from the beginning of the century, the 1930s, 1960s, and 1980s. Land use served as the basis for differentiating landscape units. Areas and perimeters of these units were measured and, based on these, several diversity indices - heterogeneity (Shannon-Wiener index; see Bastian, 1994), evenness (after Pielou, 1966), complexity of contours, 'cavityness' (irregularity) of contour borders, edge index - were computed.

The results of the investigation are pre-

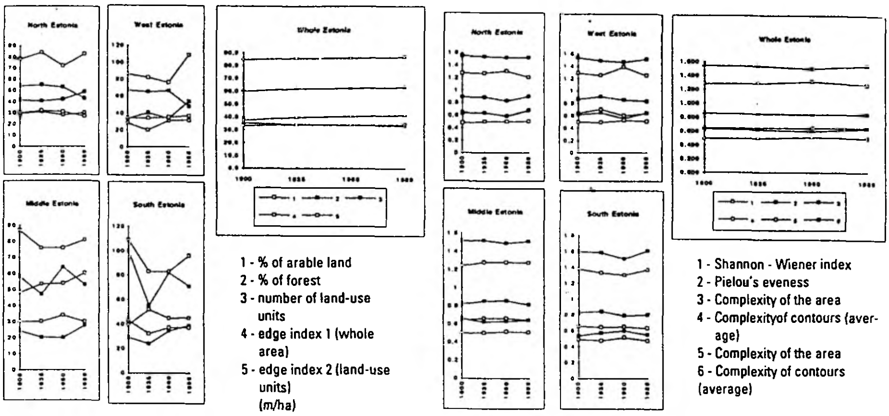


Figure 3 • Dynamics of different landscape diversity characteristics (mean values of 30 test sites).

sented in figure 3. They show that although the changes having occurred on some test areas are rather big, landscape diversity in Estonia in general has remained at the same level for the whole time period investigated. Landscape diversity changes having occurred in one test area are compensated by an opposite change on another test area. One still can find differences both in spatial distribution and dynamics of landscape diversity pattern.

The general conclusion of the study could be that up until now the ecological network has been able to fulfil its main function - to compensate human impact. Although land-use changes during the century have been essential, they have not led to major landscape diversity changes. However, polarisation effects could be found, especially during the last 30-35 years. As a result the ecologically compensating areas have become increasingly contrasted compared with the intensively used lands.

Ecological consequences of landscape changes

The main ecological consequences of landscape changes are as follows: (1) loss of habitats, species extinction, and invasion of new species; (2) eutrophication of water bodies and groundwater pollution; (3) increase in the rate of vulnerability of ecosystems.

Loss of habitats

Loss of habitats is mainly caused by the decrease of the share of natural grasslands (table 1) and land amelioration that has shifted the land-use activities from former arable lands in more high-lying areas to marginal areas (former semi-natural grasslands, depressions, wooded meadows, riparian and coastal meadows). Meadow communities, often rich in species (690 species, some of them very rare, have been recorded in the meadow flora; Külvik, 1993), form beautiful patterns in the Estonian countryside. Especially bright are wooded meadows with their dense herb layer rich in orchids and single oaks, ash and limes. Some of the former wooded meadows were cultivated into grasslands, others were afforested, and a considerable number were overgrown with scrub. This has caused a loss of some species and, probably, a number of presently common species will become rare or die out in future: 83 plant species are already in dan-

ger of extinction (Külvik, 1993).
Alvar meadows, the mostly treeless and meadow-like communities on limestone plateaus which are typical ecosystems for Scandinavia, have been also threatened. In recent decades they have become overgrown with pine and juniper because of the abandonment of sheep grazing that controls the growth of bushes and trees.
In just a few decades, over 700,000 ha of water-logged meadows, fens and traditional marshes have been drained. As the agricultural use of these areas did not prove successful, a major part of this land is presently covered with young forests and shrubs of low value. Fortunately, due to the abundance of all kinds of marshes (about 22% of Estonian territory is still covered with marsh; Peterson, 1994), large areas of economic and/or scientific importance have been maintained.
Due to drainage, intensive felling, and air pollution, some forest types (such as swampy common alder forests, boreonemoral hardwood-spruce forests, and alluvial river-bank forests) are currently rare or on the verge of extinction (Külvik, 1993).

Loss of species.

At present, there are approximately 8,600 plant and fungi species (approximately 3,400 spp. of fungi, 2,500 spp. of algae, 780 spp. of lichens, 500 spp. of mosses, 44 spp. of pteridophytes, 4 spp. of native gymnosperms, and 1,400 spp. of native angiosperms) in Estonian flora, and approximately 18,500 species of animals (about 17,600 spp. of invertebrates, including 14,400 spp. of insects; 480 spp. of vertebrates, including 3 spp. of cyclostomata, 721 spp. of fish, 11 spp. of amphibians, and 5 spp. of reptiles; 330 spp. of birds, and 65 spp. of mammals) in Estonian fauna (Peterson, 1994). Due to habitat losses, 77 formerly registered plant and species (among them, 17 spp. of vascular plants, 21 spp. of bryophytes, 1 sp. of algae, and 38 spp. of macrolichens) have become extinct during the last century (Külvik, 1993).

A significant loss (35%) of local nesting ornithofauna of a polder territory in southern Estonia has been observed because of changing the ecological network (Mander *et al.*, 1989). Another case study explains that in isolated woodlots, plant species diversity has been influenced by nitrogen loading from adjacent farms and intensively fertilised fields (Mikk & Mander, 1995).

New species

Invasion of new species has been observed for many organism groups. A typical example are plants such as adventive flora elements and weeds. Likewise, another well-documented tendency is an increase in population size of some mammals (e.g. *Castor fiber, Sus scrofa, Alces alces, Capreolus europaeus, Ursus arctos, Canis lupus, Felis lynx, Lutra lutra*; Külvik, 1993) and birds (e.g. *Ciconia ciconia, Phalacrocorax carbo, Cygnus olor*, and *Larus argentatus*). On the one hand, this is caused by regional changes of environmental conditions, but, on the other hand, it is a result of landscape changes.

Eutrophication

Eutrophication of water bodies and groundwater pollution is mainly caused by the very intensive use of mineral fertilisers during the last decades, concentration of agricultural production into big farm complexes, and land amelioration. In central and southern Estonia about 60% of dug-wells and shallow bore-wells are contaminated with nitrates (NO_3 concentration >45 mg l^{-1}; Metsur, 1993; Mander *et al.*, 1994). Also, during and after land amelioration activities, losses of nutrients into groundwater and surface-water bodies increase significantly (see Mander *et al.*, 1989). However, the collapse of the collectivised farming system during recent years has been followed by a significant decrease in the use of mineral fertilisers and land amelioration activities (see Mander & Palang, 1994). As a main consequence of these changes, the nutrient pollution load of rivers, lakes and coastal waters has been decreased significantly.

Vulnerability

Increasing rate of vulnerability of ecosystems. This phenomenon is mainly characterised with the appearance of the first signs of damage caused to forests and lakes by acid rain. At present, such damage has been detected in about 3,200 ha of forest. Likewise, a decrease in the average age of needles of coniferous trees (the average age of pine needles is only 2.1 years in northeastern Estonia, and 2.8 years in southern Estonia; the corresponding value in non-plugged areas would be 4-5 years; Külvik, 1993) is probably a result of acidification. In the oil-shale-industry region of northeast Estonia, alkaline ash depositions from big power plants, cement factories and other industrial sources essentially disturb the natural acidic bog ecosystems.

Design of ecological network and landscape changes

Due to turbulent times of privatisation, the problems of maintaining, (re)designing and developing the ecological network are becoming very actual. In the case of changing the network or increasing the anthropogenic load, it is very important for Estonia to follow the principles of the sustainable utilisation of EECONET (e.g. principles of careful decision making, avoidance, translocation, compensation, public participation, restoration and (re)development, but also the precautionary principle - the 'polluter-pays' principle - and principles of best available technology and best environmental practice) that will be implemented through the European Biological and Landscape Diversity Strategy (EECONET Declaration, 1993).

To (re)design and develop the network of ecologically compensating areas, there are different maps available for physical planning in Estonia. The topographic maps at scales of 1:10,000, 1:25,000, 1:50,000 and 1:100,000 from the Soviet period (last corrections made in 1970-1985) are old and do not represent land-use changes. Old topographic maps (1:42,000) from the beginning of this century, and (1:200,000) from the period of the Republic of Estonia between two World Wars (1930-36) are still useful for some purposes (e.g. the location of former farms and households in the countryside). The new base map (1:10,000) and other series of topographic maps will be produced by various institutions and companies, both state-owned and private. Various thematic maps are useful for solving different specific questions related to the (re)developing the ecological network. Geological maps (Palaeozoic, Quaternary, geomorphologic, hydrogeological), climatic maps, soil maps, peatland maps, map of waters, vegetation maps, forest maps, land-use maps, and road maps, all in different scales and from different years, should be mentioned among them.

The current map of the network of ecologically compensating areas was compiled in 1982 on a scale of 1:100,000 using almost all topographic and thematic maps available at that time. This map was a perspective scheme until the year 2000, and it took into account all other important perspective plans for Estonia. More detailed schemes (1:25,000) of ecological network were made in 1983-1985 for environmental conflict areas (oil-shale-based industrial area of northeast Estonia and the capital city Tallinn with its suburbs and hinterland), and protected areas (West-Estonian Archipelago).

Due to essential socio-economic changes during the last five years, there is a need for the next round of ecological network design. In this case, a very important problem will be the optimisation of the network on different hierarchical levels.

Optimisation of the ecological network on different hierarchical levels

Considering the data provided in this paper and the ecological network map (figure 1), it could be said that Estonia has enough compensating areas at the national level. From the point of view of fragmentation, Estonia nowadays looks more like forest land than a land with old agricultural traditions. The land-use pattern seems to consist of small open fields in the forest, rather than woodlots in the matrix of agricultural land. Therefore, the classical MacArthur-Wilson theory of island biogeography does not fit Estonian agricultural landscapes (Mikk & Mander, 1995). However, on the local level, there are big differences between different regions. For instance, in the vicinity of cities (Tallinn, Tartu, the northeast Estonian industrial area) and in Pandivere Hydrological Reserve, the expansion and enhancement of the ecological network is necessary. At the same time, in southern-Estonian hilly areas or on alvars and wooded meadows of west Estonia, the expansion of forest - owing to decreasing agricultural activities - has damaged the ecological and recreational potential of these areas. Thus, the ecological network should be optimised.

The most relevant general objectives for optimisation on each hierarchical level are: (1) compensation, (2) polarisation, and (3) connectivity.

The principle of compensation means that all changes to the ecological network caused by human activities must be compensated through the creation of qualitatively equal amount of biotopes to support the biodiversity and the local material cycling equilibrium (e.g. the forestation of clear-cut areas, recultivation of open-pit mines, restoration of wetlands, rivers, and lakes, etc.). With the present economical situation, the compensating principle is not very realistic. Nevertheless, considering the increasing exports of wood and peat, as well as the increasing importance of local bioenergy resources, the compensating activities should be undertaken by the state and local authorities.

The landscape polarisation concept provides functional contrasts between land-use units. Typically, there is a spatial distance between the most contrasted units, such as centres of human activity (towns, industrial complexes and intensively managed agricultural fields) as one pole, and large natural areas (i.e. protected areas) as another. To smooth out the contrasts, especially if the spatial gap is small, various transitional (buffer) ecosystems (e.g. buffer zones for rivers, lakes, wetlands, and protected areas, green belts for towns) must be maintained and (re)established. In general, landscape polarisation is an objective process that supports the normal functioning of human-influenced landscapes. However, it must be regulated using the buffers.

The importance of connectivity between ecosystems increases significantly with the spread of human-made infrastructure (roads, energy transmission lines). At the present time, there is a sufficient connectivity between ecosystems in Estonia at all hierarchical levels. However, due to the planned re-establishment of a traffic system that Estonia badly needs for balanced regional development, the rate of biotope isolation will increase. Therefore, mitigating and compensating measures such as bridges and tunnels for the migration of animals will become normal in practice of infrastructure construction.

There are not many examples for the optimisation of the ecological network in literature. Proceeding from the broad sense of ecological compensation, Kavaliauskas (1989) proposed a complex of indices measuring the optimality of landscape structure (i.e. ecological network). It contains partial indices for its 'bio-, psycho-, techno-, economo- and humanitaro-ecological conditions'. Unfortunately, it was only a theoretical approach, not supported by practical application. The EECONET concept mainly applies to the optimality of the network from the point of view of species migration (EECONET Declaration, 1993; Baldock *et al.*, 1994). We consider that both ecological and social criteria should be taken into account during optimisation. According to the hierarchy of the network, the optimisation criteria are combined differently for various hierarchical levels:

- for the macro-scale compensating areas, the criteria for optimal size and connectedness are mostly determined by material, energy and organism flows on regional and continental levels (transport, deposition and ecosystem buffering capacity of SO_2, NO_x, heavy metals and other pollutants; ecosystem capacity to stabilise CO_2 - O_2 balance, migration of birds, fish and mammals; regeneration capability of renewable resources);
- at meso-scale, the criteria are both ecological (see macro-scale criteria, plus self-purification of water in rivers, lakes and coastal seas, groundwater protection aspects) and social (e.g. recreational potential of the area);
- most works have been carried taking into account the optimisation of landscape structure at the micro-scale on which the biggest variety of criteria could be used; for instance, buffer zones parameters for rivers and lakes (Knauer & Mander, 1989; Mander, 1993; Mander, 1994), buffer zones for groundwater (Wohlrab, 1976) and forest islands in agricultural landscape (Ivens *et al.*, 1988); also, most work on the physical and socio-economic planning of regions apply to this hierarchical level.

At present, the parameters of optimality of the ecological network in Estonia at macro-and meso-scale will be worked out.

Conclusions

1 A well-developed network of ecologically compensating areas consisting of nature protection areas (protected areas cover about 23% of Estonian territory), forests, marshes (22%), meadows and coastal waters, was formed during the turbulent development of last century. This network, a relatively low population-density (34 people per sq. km) and a high polarisation rate of the whole territory have maintained a major part of biodiversity. Nevertheless, the extinction of wooded- and alvar meadows could result in with a significant loss of species. It is very important to maintain and enhance the ecological network during privatisation.

2 The main trends in the dynamics of the ecological network based on the land-use variations in Estonia have been a decrease in the percentage of agricultural land (from 65% in 1918 to 30% in 1994) and an increase in the share of forests (from 21% to 43%).

3 Land-use changes, the concentration of agricultural production, the land amelioration, and the oil-shale-based industries in northeastern Estonia have caused main ecological disturbances and the increased polarisation of rural landscapes.

4 A significant increase in the use of mineral fertilisers and intensive land amelioration during the last three decades have been essential factors in the eutrophication of water bodies and groundwater contamination with nitrates. However, the collapse of the collectivised farming system during recent years has been followed by a significant decrease in the use of mineral fertilisers and land amelioration activities.

5 The next important step will be connecting the network of ecologically compensating areas in Estonia with the EECONET system; therefore, an optimisation of the ecological network on different hierarchical levels, using various criteria, is needed.

Summary

Ecological network in Estonia
Impact of landscape change
Ü. Mander, H. Palang and J. Jagomägi
Landschap 12/3

The article overviews the state and formation of the network of ecologically compensating areas in Estonia. The network is based on nature conservation areas, forests, marshes, meadows, and coastal waters, still covering more than a half of the territory of Estonia. The formation of the network has been influenced mainly by land-use changes, but also by other economical activities. Although the changes in land use have been significant during the last century, the network has managed to retain most of its bio- and landscape diversity. The analysis of land-use change shows a tendency of forest increase and agricultural-land decrease during the whole century. This has resulted in several ecological consequences (loss of habitats, species extinction, and invasion of new species; eutrophication of water bodies and groundwater pollution; increase in the rate of vulnerability of ecosystems), but at the same time landscape diversity characteristics have remained at the same level throughout the entire century. This means that up until now the ecological network is still able to compensate to some extent for human activities. However, current societal changes, especially concerning land privatisation, have raised the need for a new round of (re)design and optimisation of the ecological network. In this, compensation, polarisation, and connectivity are the main principles to be followed.

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V

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Ecological network and road network: The case of Estonia

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Abstract

This paper discusses the interaction of the road network and ecological network in Estonia. The problems are studied on two levels. First, the fragmentation of the ecological network encompassing the whole country is described. Currently the ecological network can compensate the effects of road traffic. Secondly, the meso-scale effects are characterized. Here roads have a twofold role in the landscape. Finally the article tries to give a vision for the nearest future.

Introduction

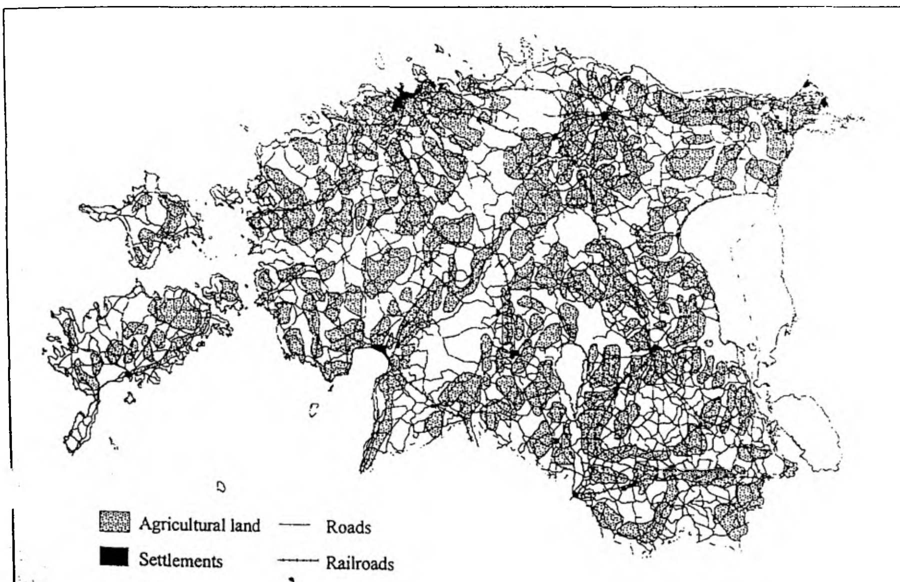
Differently from most of the Western European countries, Estonia can be handled as one large habitat. There are two reasons for such a conclusion. First, more than a half of the country is still or again in more or less natural state. Secondly, the existing natural and seminatural areas still form a connected network, with its nodes and corridors. This network of natural areas, also called the network of ecologically compensating areas or even the ecological infrastructure (Jagomgi 1983, Mander et al. 1995), has served as the basic idea for the nature conservation activities.
Another network, the road network, is superimposed on the network of ecologically compensating areas. Although the intensity and timing of traffic using these infrastructures (the traffic of cars on the roads and the traffic of animals through the ecological infrastructure) differ in great extent, problems occur when these two networks cross. The problems are often manifold and multileveled.
The current paper presents a geographical, multi-scale approach to the problem of landscape fragmentation. It concentrates on landscape change on two levels. First, changes on macro-level will be discussed. Secondly, landscape diversity shift on local level will be considered.

Macro-level: Ecological Network and Human Infrastructure

The development of the ecological network could be deduced with the help of land use statistics during the 20th century (Mander & Palang 1994, Mander et al. 1994). Differently from most of the European countries, increase in the share of forests is one of the main tendencies in land use during the whole century. It has risen from a mere 13-14% in the beginning of the century to some 45% in the early nineties. At the same time, the share of agricultural land shows a tendency towards decrease, down to

30% in the early nineties. Mostly this decrease is caused by diminishing area of natural grasslands, formerly used as pastures or haymeadows, now either cultivated or abandoned and afforested. Nowadays, natural or semi-natural areas - forests, brushwood, and natural or seminatural grasslands cover about 52% of the territory of Estonia.
Another important feature is that these (semi)natural areas are still interconnected. The whole country looks more like consisting of several islands of agricultural lands and settlements in the ocean of forests. This provides animals the space and possibility to migrate from one end of the country to another. In addition, the intensity of agricultural production is also relatively low, compared to Western Europe, and consequently species like hare, roe deer, but also many birds, feel comfortable on agricultural lands, as well. The main features of the ecological network are displayed in Figure 1.

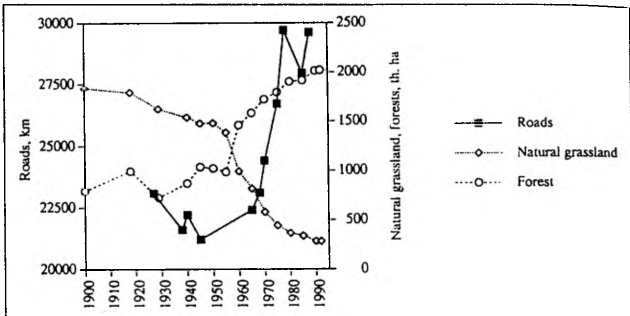
Figure 1.
Ecological network and infrastructure



On the other hand, the development of the road network has been slow but constant. As the population density is relatively low in Estonia - only about 33 persons per sq. km - the density of road network has also remained low. The main framework of the major roads was already formed before 1940, from 1960's onwards the existing roads have only been improved and a few new roads have been built. Figure 2 shows the development of human infrastructure from the beginning of the 20th century. The density of roads has increased from 0.49 $km*km^{-2}$ in 1927 to 0.66 $km*km^{-2}$ in 1989. The total length of roads has increased from 23,083 km in 1927 to 29,625 km in 1989. Of these, only a half (14,797 km) are public roads. In 1990, the average traffic density on major roads was as low as 2,000 -

5,000 vehicles per day, only in dual carriageway sections near Tallinn it was 8,000-12,000 vehicles per day (Laving & Valma 1992). As the increase in the number of cars in Estonia is the quickest in Europe, in 1995, as an estimate, these numbers should be multiplied by 2.

Figure 2.
Development of natural areas and road network



Problems occur when these two networks cross. According to Mardiste (1992), animals were involved in at least 3,377 traffic accidents in 1985 - 1990, most of these having happened in intersections of roads with ecological network. In 1990's, the pattern has remained the same. On one hand, the number of cars has increased significantly, on the other hand, the area of (semi)natural areas has increased, providing the animals more space to live on.

Meso-level: Local Fragmentation

On this level, the role of roads in fragmentation is twofold. First, the roads may split habitats into smaller pieces. However, in Estonian conditions, fragmentation itself is not the most important factor of habitat deterioration. Instead, the spread of pollution from the roads, invasion of new (especially plant) species supported by transport, and several other side effects play the major role. On the other hand, greater massifs of forests or fields can also be obstacles for some species migration. In this case, a road passing through such an area functions as a corridor, attracting animals to use the verges for moving from one place to another. Often these animals may mix the verge and the road. This can only add to the number of traffic accidents. To illustrate these problems, landscape diversity changes can be used. The former small field roads of the 1930's were removed during the amelioration campaigns in 1960-1970's and consequently large fields appeared instead of the former complex pattern of small fields and baulks. In this kind of landscape, the roads (which in Estonia have usually quite wide verges and often also snow-protection hedges on both sides) together with amelioration ditches provide the animals the only possibility to pass through agricultural lands. Also the spruce hedges are often a brilliant nesting place for birds and smaller animals. In forest areas, a road passing it opens a free space for light and in turn enables some new habitats for plants that need more light for growing. Often this results in thick brushwood following the road-sides. At the same time investigations (e.g. Mikk & Mander 1995) show that the surrounding matrix of agricultural lands is not a significant isolation factor for plant species dispersion. In spite of clear tendency towards polarization, the dimensions of arable lands in Estonia still remain relatively small. Normally the distance between two (semi)natural patches in agricultural landscape does not exceed 0.5 km. Also, soil and relief conditions support the maintenance of natural and seminatural patches. The number of plant species in these areas mostly depends on factors other than isolation, *e.g.* area of the patch, disturbance and biotope heterogeneity (Mikk & Mander 1995).

The Policies

Until present, the problem of interaction between infrastructure and ecological network has not had a high priority in the Estonian research and policy. Research has been carried out into the effects of roads on the neighboring areas (spreading of pollutants, counting killed animals, etc.), but mostly this has been casual and not systematic. Consequently, no special measures have been foreseen to mitigate the possible problems. Usually the main issue is that the big animals (elks, roe deer, wild boars, once or twice even a bear) appearing on the road provide danger for the drivers. However, in 1960-1970's, a huge lobby was made under the general heading of landscape care to guarantee the right placing of the roads in the landscape. Certain rules of good practice were worked out and often these were followed by the road builders. These rules included issues like: the road should not cut the wetlands, but pipes should be built in the road to let the water pass; hedges should be planted along the road to form a barrier against the snow, but also against pollutants and noise, etc. Often these unwritten rules are still valid today. Currently, the ecological network somewhat compensates the influence of the road network. For the next several years, such a compensation could continue. The current tendencies in the state policy let us presume that the expansion of (semi)natural areas will go on for some more years, and at the same time main attention in the field of infrastructure will be focussing on upgrading the existing roads system rather than on building new connections. Considering this, one might state that landscape and habitat fragmentation due to development of infrastructure on country level is not a significant problem yet. However, the problem may gain new dimensions. These may include the need for building by-passes for animals, fences to isolate the most dangerous places, etc. Where, what and how to build are the questions that will be asked in the next decade.

Conclusions

1. Although rather great changes in land use and infrastructure have taken place since the beginning of the century, landscape fragmentation due to infrastructure is not yet a very serious problem for Estonia.
   One reason for this is the expansion of forests that has partly compensated the influence of infrastructure. However, the growth of traffic intensity and renovation of main roads in the nearest future may give the problem a new dimension.

2. On local level, amelioration has replaced the former complex matrix of arable land and natural habitats with more monotonous massifs of fields and forests. Although there remain regional differences, the general tendency towards such polarization can be found all over Estonia. However, the formed massive arable lands do not obstruct the migration of species.

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POSSIBILITIES FOR SUSTAINABLE LAND USE PLANNING

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1. INTRODUCTION

Together with recent political changes, the need for sustainable land use planning has become more and more evident in Estonia. This is supported also by the ongoing reprivatisation of land and restoration of private ownership, which together with the decline of agriculture, change considerably the existing land tenure system. These point to the necessity to reconsider the existing ideas about how to organise nature conservation in the country. Finally, the first round of physical planning on the county level should come to an end in 1998.

The present paper tries to indicate some possibilities for solving the most burning conflicts of land use planning. As the value-based approach to nature conservation is still the most understandable for the larger part of nature conservationists and planners, the paper takes this for the basis. It describes the different values found in the landscape and tries to assess these values on the example of West Estonian alvars. Finally, an example of a sustainable land use plan for the Lõu alvar in Saaremaa is given.

2. LANDSCAPES AND VALUES

There are tens of definitions of the term *landscape* and almost as many understanding of the values a landscape can have. These definitions have often been subject to investigations (see, e.g., Keisteri, 1990). Usually the different understandings refer to landscape as something descriptive, classifying or systematic, but increasingly often project-oriented approaches to the term appear. In these, landscape is defined in a more narrow context.

Speaking of landscape in the context of land use planning, one of the possible ways to handle the term is the one proposed by Emmelin (1996) who denotes landscape as *the visual sum of objects and processes in a given locality at a given time*. An important idea in this definition is that landscape is understood not as a static phase of a locality, but as a process continuing through time. As land use planning affects these processes, one can speak about many *future* or *potential landscapes* (Emmelin, 1996) dependent on the policies and planning that are applied to the particular locality. Consequently, future landscapes are the products of the policies and/or planning that are applied on the landscape that exists today.

Similarly, the lists of values one can find in a landscape vary considerably. Usually people talk about ecological, economical, and cultural-aesthetical-social values. Boyce (1995) indicates 6 classes of benefits a consumer can get from a forested landscape. These are aesthetics, habitats, fuelwood, timber, cash flow, and biological diversity. Jones (1993) goes further and provides a more thorough classification of landscape values, which will be used in the purposes of the current work.

Jones distinguishes between three groups of values (Tab. 1) associated with the landscape as a resource. Economic values represent the different material benefits one can get from landscape. Landscape has also a value for non-economic or amenity activities, such as seeking for some kind of experience. Finally, Jones points out the security value of a landscape, providing defense or demarcating territoriality.

Tab. 1 Landscape values after Jones (1993)

ECONOMIC VALUES	AMENITY VALUES	SECURITY VALUES
Subsistence value	Intrinsic ecological value	Defense value
Market value	Recreational & aesthetical value	Demarcation value
Utilitarian-ecological value	Scientific & educational value	
	Orientational & identity value	

3. PRINCIPLES FOR SUSTAINABLE LAND USE

Sustainable development is defined as a development that meets the needs of the present without compromising the ability of future generations to meets their own needs (WCED, 1987). Applying this definition to the landscape, the current land use should provide preconditions for future landscapes in a way that the values of those future landscapes are not compromised. In other words, the task of sustainable land use planning is the optimisation of the use of different landscape values.

Often economic values are considered to be the only important values. To increase these, new technologies have been introduced to improve the soil properties, to lower the ground water level, to make the landscape pattern more convenient for bigger machines. Usually this has been done in the expense of amenity values. Areas with the highest economic values are intensively used. Those with extremely high amenity values are sometimes protected. As a landscape is a process, protecting landscape means sustaining the process, maintaining the technology that has created the landscape. Both abandonment and intensification lead to a change in values, and not always this change is towards increase.

Numerous examples show that together with new technologies the landscapes have gone through a considerable change. In Estonia, the small-scale mosaic of the 1960's has been replaced by large-scale polarised pattern of fields and forests by 1990's (Mander - Palang, 1994). In Mecklenburg-Vorpommern and Brandenburg, Germany, some 20 % of agricultural land has been abandoned in the 1990's (Breitfeld et al., 1992). In Sweden, land use has intensified in a few concentrated areas during the last fifty years, while large areas were marginalised (Ihse, 1996). In the Czech Republic, concentration of agriculture has simplified the landscape structure: instead of complex patterns we see only large monotonous units (Lipsky, 1996).

Sustainable land use planning means optimising the use of landscape values not only in the protected areas, but also outside these, on the whole territory. Not surprisingly the best solution to this optimisation task is the maximal landscape diversity. Large monofunctional territories do not always enhance the maximal landscape values. Ecological networks, as designed in many countries, is one idea how to maintain ecological values over large territories. Establishing guidelines of good practice, as proposed in the draft versions of the Estonian act on landscape protection, is another.

4. HOW TO IMPLEMENT: THE CASE OF LÕU ALVAR

The following part summarises an attempt to influence the land use planning on one of the most interesting and also specific areas in the biggest of the Estonian islands, Saaremaa.

4. 1 Alvars

Alvars are among the most unique units of vegetation and landscape from the floristic, ecological and developmental point of view. They spread on a very limited area of Silurian and Ordovician limestones in Estonia, Sweden and some parts of Finland. They occur where limestone bedrock reaches the ground or is covered by thin soil formed in the process of weathering of the limestone. Their vegetation consists of calcicoles and xerophytic. Usually alvars are seminatural communities where human influence has played an essential role. The look of most of alvars is formed by the occurrence of junipers *(Juniperus communis).*

The peculiarity of alvars is determined by the diversity and extremity of environmental conditions and by the fact that during the centuries they have been subjected to human action, mainly grazing cattle. As a result, steppe-like plant communities with abundance of rare and relic plant species and landscape units of very specific character have been formed.

Tab. 2 Values of the alvars

Value group	Judgement of value	Expression of value
ECONOMIC VALUES		
Subsistence value	*very low*	Using the resources of alvars as the means of subsistence
Market value	*low*	Everything (wood, juniper berries, sheep, limestone, land etc.) for sale
Utilitarian ecological value	*medium*	Using and preserving the landscape simultaneously
AMENITY VALUES		
Intrinsic ecological value	*very high*	Preservation of biodiversity
Scientific and educational value	*very high*	Creating possibilities for scientific and educational works, observing and learning nature and natural processes, preserving biological and landscape diversity
Aesthetic and recreational value	*high*	Possibilities for satisfying some mental needs; establishing possibilities for recreation
Orientational and identity value	*medium*	Possibilities for perceiving existence and identity values, identifying with nature; preserving the historical structure of landscapes
SECURITY VALUES		
Defence value	?	?
Demarcation value	?	?

4.2 The values of alvars

Due to their extreme environmental conditions, the economical values of the alvars are usually low or very low (see Tab. 2). At the same time, their amenity values are among the highest among the Estonian landscapes. However, these high amenity values have not always been appraised. Several attempts have been undertaken to increase the economic values, most common is the practice to plant pine forests or to use the alvars as quarries for limestone and gravel. During the last decades, due to amenity values, alvars have attracted scientists, birdwatchers and nature tourists to spend time here.

4.3 The Lõu alvar

The Lõu alvar is situated in the South-Western part of the island of Saaremaa, on the western coast of the Sõrve Peninsula. The whole area is interesting from geological, pedological, botanical as well as from recreational point of view.

As on the Lõu alvar all different types of alvars are present, it is the most representative and unique of all alvars in Estonia. Therefore it deserves a special status which should aim at conservation of the alvar as a seminatural community typical to the coastal areas of Estonia. Because of the interaction of peculiar ecological and developmental factors, conservation of alvars is rather complicated. Since they react comparatively easily to various impacts, including the land use changes, there is a need for a special sustainable protection regime. For maintaining alvars it is not enough to designate the area as a strict reservation, on the contrary, it requires certain management intervention.

The presence of all alvar types (some of them very rare) is the most remarkable and valuable feature of the area. The growing conditions for plants vary considerably within the area. Consequently the plant communities are mosaic. and of very high species diversity. In all, on the alvar there have been recorded about 400 vascular plant species, many of which are rare or endangered. The Lõu alvar is of great value as a habitat for at least 100 lichen species which include many rare ones. The endemic *Cetraria alvarensis* is considered to be the most interesting of them.

The area is also of great importance as the breeding, wintering and migration place for many birds. Therefore it is designated as an internationally Important Bird Area.

The Kaugatuma and Lõu cliffs are the typical outcrops of bedrock of the Kaugatuma horizon, deposits of numerous fossils as well as the habitats for several rare plant species.

It is hard to overestimate the potential of all these values to create possibilities for recreation and ecotourism. The facts that for many Estonians alvars are symbols of our islands and something like tracks of the lifestyle of our forefathers as well as they are of great interest for scientists indicate the identity and scientific and educational value of Lõu alvar.

The best way to protect above mentioned values seems to be the establishment of Lõu landscape reserve. In accordance with the Act on Protected Nature Objects the landscape reserve is an area with specific natural or cultural landscape formed in order to maintain the nature conservation, cultural or recreational values. A landscape reserve is divided into special and limited management zone. The restrictions and limitations applicable in these zones and the obligations of all persons are defined by the law and the protection rule.

As in the case of Lõu landscape reserve the major aim is to protect the uncommonly rare representativeness of various alvar types the main consideration taking into account in planning the zonation of the area is to guarantee sufficient conservation of all alvar types. Acting like this, the uniqueness of the area will be maintained.

The special management zone embraces at least partially every alvar type. The rare and more vulnerable types belong completely into the special management zone. Nevertheless, most of the area falls into the limited management zone. Thus it is more profitable from the point of view of economic, public, touristsę as well as local communitiesę interests.

Since most of the area represent seminatural communities, in achieving the purpose of conservation it is compulsory to carry out the activities (mowing, grazing, clearing the shrub and tree layer, re-establishment of stone fences) which would guarantee the maintenance or restoration of appearance and species composition of the area. So, essentially we deal with a maintained protected area. At the same time the protection regime should exclude any activity endangering the natural conditions, appearance of the landscape and protected plant and lichen species.

People are allowed to stay everywhere in the reserve except within the special management zone in cases enacted with the protection rule. In addition to territorial restrictions, residing within the reserve is regulated also seasonally since there are periods of drought when the area is extremely fragile.

Camping and making fire is allowed only in special places. Driving motor-vehicles outside the paths is strictly prohibited. It is allowed to drive motor-vehicles only for inspection, rescue and scientific work which are carried out in accordance with the order enacted by the Government.

Forestry is carried out in accordance with the principles of nature protection presuming that the maintenance of biodiversity and landscape appearance is guaranteed. Hunting animals and collecting plants, fossils and other nature objects is forbidden.

5. CONCLUSIONS

One possibility to understand landscape is to handle it as a process. It is the result of human activities in the past, and present planning and policies are shaping the future landscapes. Several values are associated with landscape. Traditionally economical values have been the most important, while amenity and security values have been in the background. However, with time the important of these is growing. As the values and valuations may differ in time and in context, a sustainable land use should not harm the future values of a landscape. Therefore the authors argue for an optimised use of landscape values, which in turn asks for maximised landscape diversity.

West Estonian alvars serve as An example of such optimised use of landscape. As they are seminatural areas, they ask for management and conservation at the same time. This is a good reason for sustainable planning, i.e. optimising the use of different values. Instead of increasing the probable economic benefits through e.g., planting forests, one should take better advantage of the amenity values like aesthetics, ecological diversity, and symbolic value.

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SLOVENIAN RURAL AREAS IN THE LIGHT OF LANDSCAPE VULNERABILITY

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1. INTRODUCTION

The indicators of industrial and urban pollutions of environment rank Slovenia among the moderately degraded European countries. Exceptions to the foregoing statement are represented by the heavily polluted basin-valley subalpine ecosystems which are also marked with only moderate self-purifying capacities (Plut, 1995; Špes, 1996). Yet, some recentmost investigations have also exposed agricultural sources of environmental pollution, which are manifested, above all, in rural areas, especially in the supbannonian part of Slovenia. To evaluate the extent and the level of pollution of individual ecosystems (agrarian and urban-industrial), a complex methodology for investigating landscape vulnerability has been elaborated, proceeding from a ratio between the self-purifying capacities of environment and the actual pollution (Špes et al., 1996).

2. BASIC FEATURES OF SLOVENIAN RURAL AREAS FROM THE ASPECT OF ENVIRONMENTAL POLLUTION

Rural areas stretch over two thirds of Slovenian territory, where a gross fifth of the population of Slovenia lived at the beginning of the 90's (Ravbar, 1995). Basic features as to production conditions in Slovenia are as follows (Rednak - Vovk, 1995):

1) A great percentage of forests (over 50 %);
2) Intensely agitated landforms and a great percentage of karstic surface;
3) A great percentage of meadows and pasture lands.

VII

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LANDSCAPE CONSERVATION AND ITS PERSPECTIVES IN ESTONIA

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ABSTRACT

The current article focuses on the past, present and future of landscape conservation in Estonia. First a brief history of landscape conservation is given. After that the current situation in landscape protection is described. The third part of the article addresses the changes in land use and landscape diversity having occurred during the 20th century. The last part of the article defines the main tasks of landscape management for the next decades. These include handling landscape as a process, paying more attention to sustainable use of landscape values, using landscape planning and EIA as tools for landscape management, creating an environmental GIS to support decision-making in planning and EIA, and implementing ecological networks as the basic concept of landscape management.

Keywords: landscape management, values, landscape planning, ecological networks

INTRODUCTION

Nature conservation and also landscape conservation have undergone a long way in Estonia. However, the political and economical changes of the recent years have forced also nature conservationists to rethink the basics. How to face private ownership of land? How to carry out nature conservation activities outside protected areas? Which is the place of landscape conservation in nature conservation policies?

The current article outlines one vision about how landscape conservation could develop in Estonia. It starts with giving an overview of the development of landscape conservation in Estonia in the past, then describes the present situation. Further, landscape changes having occurred in the country during the last century are discussed. Finally, the major part of the article outlines the perspectives and tasks for landscape conservation.

1. The past of landscape protection in Estonia

The first protected areas in Estonia were established in the beginning of the 20th century. In 1910 the first bird sanctuary was created on the Vaika islets near the island of Vilsandi, off the west coast of Saaremaa. In 1924 the first protected areas were established in Kastre-Peravalla, Harilaid, Abruka broad-leaved forest and in yew tree habitat in Tahkuna. The first Nature Conservation Act was passed in 1935. By 1940, there were 47 nature reserves in Estonia (Randla, Sillaots, 1997).

During the Soviet period nature conservation activities based largely on the third Nature Conservation Act which was passed on July 11, 1957. Following this, the Estonian Council of Ministers issued a regulation about establishing 4 state nature reserves — Matsalu, Nigula, Viidumäe and Vaika — and 28 other protected areas (then prohibited areas). The same regulation also created a state institution for nature conservation, Nature Conservation Board (headed by V. Telling, V. Voore and H. Luik). This Board initiated management of landscapes through legal instruments (regulation demanding to approve activities changing the appearance of landscape), planning (functional zoning), and distribution of guidelines for landscape care (the first of these was compiled by H. Kontor in 1966). To bring some examples of activities of those times, one can mention the first application of functional zoning in north-eastern Estonia (Luik, 1966), zoning of recreational areas (Eilart, 1964) and creating green corridors in Tartu and its surroundings (Parker, Eilart, 1969).

In 1970's the ideas of functional zoning were widely used in different project institutes, such as RPI Põllumajandusprojekt and RPI Maaehitusprojekt, lead by V. Pallok, A. Kerge, M. Vihalem. The latter supported the development of the concept of ecological planning, initiated by J. Jagomägi and A. Raik at the Chair of Physical Geography, University of Tartu. In 1980's, the third guidelines for landscape care were drafted, but they were never approved. Finally, in 1990 all previous experience of nature conservation activities was summarised by the Act on Nature Conservation.

2. The situation in present

Before 1994, 1 biosphere reserve, 1 national park, 1 water protection area, 5 state nature reserves, and 57 protected areas of different categories were established at state level. The number of various protected areas, usually smaller ones, established at county level was even up to 4 times higher. The total number of protected natural monuments with size up to 100 hectares was 1,462.

In 1995, according to the Act on Nature Conservation Objects (passed on June 1, 1994), a principal estimation and inventory of the protected areas network has been commenced. The aim of the work, carried out in parallel to Land and Property Reform, is to optimise and improve the protected areas network by selecting the most valuable ones out of up to 500 protected objects (protected areas and large natural monuments) and determining their protection categories according to the new classification settled by the Act on Nature Conservation Objects.

Preliminary results of the ongoing revision show that there will be 2 programme areas (West-Estonian Archipelago Biosphere Reserve and Pandivere Water Protection Area), 4 national parks (Lahemaa, Karula, Soomaa, Vilsandi — defined by the Act on Nature Conservation Objects), about 55 nature protection areas and over 160 protected landscapes in Estonia. Currently about 438,800 ha or approximately 10 per cent (excluding the West-Estonian Archipelago Biosphere Reserve) of Estonia is under protection. The strict protection regime applies to about 1 per cent of the territory only, and the aim is to increase this figure to up to 5 per cent by the year 2010 (ENES, 1997).

3. Landscape changes of Estonia during the last century

Earlier studies (Mander & Palang 1994, Mander et al., 1994) have demonstrated that the land use changes in Estonia during the 20th century have been essential. During this period, the share of forests has increased three-fold (from 14 to 42%), while the portion of land in agricultural use has diminished from 65 to 30%. Moreover, the driving forces behind these changes have also varied. For instance, the political system only has changed four times from 1900–1990, every time bringing along new and different land use policies. Presumably, such changes have also induced changes in landscape diversity.

However, despite all kinds of land use changes landscape diversity has remained stable (Palang *et al.*, 1997). Thanks to the low population density, Estonian landscapes have had the space to buffer the change. The land use dynamics point towards some overall shift of landscape diversity. The shift has happened, but only in some places while in other places an opposite shift has happened, so keeping the average diversity stable. The reason for this is that the population of Estonia is so sparse that often once reclaimed lands where abandoned quite soon, due to the lack of management abilities. This is one more hint that the so-called network of ecologically compensating areas (see Mander *et al.,* 1995) is still functioning.

4. Perspectives for landscape management

The following part of the article aims at outlining the perspectives for landscape management. The word *management* is used instead of *protection* or *conservation*, as conservation is understood by the authors as one way of landscape management.

4.1 Landscape as a process

Usually, when people start talking about landscape they have in mind something static, visible, touchable. Landscape is often understood as something static, a physical appearance of a place at given time. For them landscape is stable, not changing in time, but changing in space.

Landscape is to great extent a result of human activities. In addition to natural processes, such as, *e.g.*, erosion or vegetation growth, anthropogenic processes occur. The latter may include forest cutting, road building, agriculture, grazing, etc. The processes are not the same all the time, but tend to change. Natural processes have their own rhythms, while human processes are shaped by different land use policies. Logically, different land use policies shape different landscapes. Derived from this, landscape can be defined as *the visual sum of objects and processes in a given locality at a given time* (Emmelin, 1996). An important idea in this definition is that landscape is understood not as a steady-state phase of a locality, but as a process continuing through time. As land use planning affects this process, one can speak about many *future* or *potential landscapes* (Emmelin, 1996) dependent on the policies and planning that are applied to the particular locality. Consequently, future landscapes are the products of the policies and/or planning that are applied on the landscape that exists today.

So landscape is rather a process or a set of processes continuing through time. The landscape we have today is the result of processes, both human-steered and natural, that have occurred in the past. The present landscape might have had different part alternatives, different ancestors that have been turned into the current landscape. These histories we can only restore using old maps, photos or descriptions, and based on these, assess the success or failure of the past policies.

Similarly, the present landscape has several future alternatives. Depending on the policies that are applied on the landscape, the latter will change. The choice between these alternatives depends on the current policies, decisions, planning. The decision we make today do not influence the landscape of today but that of tomorrow. Usually people idealise the old, but at the same time they shape a new landscape which differs drastically from that old ideal. Therefore, land use planning appears to be the key issue in shaping the future landscapes.

4.2 Landscape as a resource

Landscape is also a resource that has different values. Usually people find ecological, economical, and cultural/aesthetical/social values in the landscape. Boyce (1995) indicates 6 classes of benefits a consumer can get from a forested landscape. These are aesthetics, habitats, fuelwood, timber, cash flow, and biological diversity. Jones (1993) distinguishes between three groups of values (Table 1) associated with the landscape as a resource. Economic values represent the different material benefits one can get from landscape. Landscape has also a value for non-economic or amenity activities, such as seeking for some kind of experience. Finally, Jones points out the security value of a landscape, providing defence or demarcating territoriality.

Table 1. Landscape values after M. Jones (1993)

ECONOMIC VALUES	AMENITY VALUES	SECURITY VALUES
Subsistence value Market value Utilitarian-ecological value	Intrinsic ecological value Recreational & aesthetical value Scientific & educational value Orientational & identity value	Defense value Demarcation value

Ranking of these values has been changing together with the development of agriculture, technology and society. People tend to appreciate the past of the landscapes while they are constantly reshaping the same landscape into a more modern one that meets better the needs of some new technology. At the same time, values attached to the landscape and valuations of the landscape are the driving forces while planning the land use.

Often economic values are considered to be the only important values. To increase these, new technologies have been introduced to improve the soil properties, to lower the ground water level, to make the landscape pattern more convenient for bigger machines. Usually this has been done in the expense of amenity values. Areas with the highest economic values are intensively used. Those with extremely high amenity values are sometimes protected. As a landscape is a process, protecting landscape means sustaining the process, maintaining the technology that has created the landscape. Both abandonment and intensification lead to a change in values, and not always this change is towards increase.

A question arises whether landscape is a recoverable resource or not. The way to the answer lies through investigating the landscape values. Some of the values are easily recoverable, while the others can be depleted. From this, the demand for sustainable landscape or sustainable land use could be derived. The current land use should provide preconditions for future landscapes in a way that the values of those future landscapes are not compromised. In other words, the task of sustainable land use planning is the optimisation of the use of different landscape values (Palang, Kaur, 1997).

4.3 Landscape Planning

The previous subchapters have already outlined the tasks of land use planning. Firstly, planning should guarantee the optimal use of landscape values so that none of them is depleted. Secondly, planning should make the choices between the future alternatives of landscape so that the landscape will meet the needs for that technology and society.

The importance of landscape planning and landscape management is currently especially stressed because of the specific political situation of Estonia. On one hand, the country has not yet finished demolishing of the Soviet land ownership system. The land reform is still continuing, only a small share of all lands has been privatised. On the other hand, the starting negotiations and the future joining the European Union will mean that the EU legislation and policies will be applied to Estonian landscapes as well. This bring along not only policies that differ from the current ones, but as well changes in valuations. All this means that the country has to be extremely careful and clarify its needs, values and valuations in the field of landscape, in order to maintain these during the turbulence of the years of changes.

Thorough landscape analysis or inclusion of landscape aspects in the EIA procedure, creating an environmental GIS and using it to base the decisions upon, and planning and implementing the Estonian ecological network or network of compensating areas shall be the major tasks for landscape management during the following years.

4.4 Need for information in planning

Different data sets, registers, maps, all containing environmental data, exist in Estonia. The environmental information is stored on different media, in different format, with different degree of generalisation. In other words, the information is unmanageable. A solution would be an environmental GIS that would enable the transfer of information form those who gather it to the decision-makers in form that is understandable for them. This GIS should not be an aim by itself, but rather a tool that would assist in analysing different values of landscape, thus creating preconditions for increasing the quality if environmental decisions. The GIS should aim at organising the environmental information enabling to carry out economical, ecological, and aesthetical analyses of field, forests, and water areas, thereby supporting the quality of environmental decision-making. The GIS should be able to integrate different databases and analyse the data spatially. The efficiency and quality of work and decisions of a planner, environmental specialist, decision-maker depends largely the availability of information and technical possibilities they possess. The GIS should be unable in everyday work.

4.5 Ecological network

Estonia was among the first countries in Europe where basic principles of landscape planning and the network of compensating areas (Jagomägi, 1983, Mander *et al*, 1995) were developed. The elements of now widely used concept of ecological networks are found in the works dealing with management of natural resources (J. Eilart, J. Jagomägi, H. Luik, A. Raik, V. Ranniku). J. Jagomägi and A. Raik developed the concept of ecological planning, from which the idea of Estonian ecological network emerged — then called the network of ecologically compensating areas (Jagomägi, 1983). These areas were defined as subsystem of cultivated landscape which compensates and buffers human impacts, or, to be more precise, influenced the flow of matter, energy and information through the landscape as obstacle, accumulator, filter, and buffer (Jagomägi *et al.*, 1988).

Furthermore, this approach is on good congruence with several European policy directions (Pan-European Biological and Landscape Diversity Strategy, etc.). Similar approach serves as the basis for nature conservation in many countries, such as Lithuania, Slovakia, and the Czech Republic. For Estonia, the main attention should be turned to applying the concept in conditions of private land property, but also implementing it through planning in all levels. Applying ecological networks is also connected with several other initiatives, such as NATURA 2000. Again, creating and implementing of environmental GIS systems in different levels is the main precondition for this.

However, the schemes worked out some 15 years ago do not fully satisfy the needs of landscape planning today. The basic principles for planning the ecological network should be thoroughly discussed and the methods renewed. It is about the last time to start with environmental regional planning that would enable to define the structure of the ecological network. The first attempts in this field are already on their way on the initiative of the Jõgeva county government and the Saaremaa Centre of the West Estonian Biosphere Reserve.

Until now there is no direct legal support to the ecological networks. However, some indirect hints can be found in the Act on Planning and Building and the Act on Sustainable Development. Much more is to be expected from the National Environmental Strategy of 1997 and, based on this, National Environmental Action Plan due to be ready in 1998. In the latter, a whole chapter is dedicated to the conservation of biological and landscape diversity, where ecological network is one of the main ideas.

5. CONCLUSIONS

Although Estonian landscape conservation has had a glorious history, the changing political circumstances demand rethinking the basics. The system that functioned so well during the Soviet times does not fit into the new capitalist conditions.

This article offers several new ideas that should be applied in landscape management. First, landscape should be understood as a process changing in time, and conservation should focus on directing this process rather than trying to preserve the appearance. Second, landscape has several values, and the task of landscape management is to optimise the use of these values in a way that none of these is depleted. Third, landscape planning and inclusion of landscape aspects in the EIA procedures are among the best ways of coping with the aforementioned tasks. Fourth, information should be made available for the planners, for what environmental GIS should be created. Finally, the principles of ecological networks should be considered as the main idea of landscape management in Estonia during the next decades.

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VIII

Palang, H., Ü. Mander 1999:
Predicting the Future of Estonian Rural Landscapes:
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PREDICTING THE FUTURE OF ESTONIAN RURAL LANDSCAPES: ANALYSIS OF ALTERNATIVE SCENARIOS

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Abstract

The article outlines five scenarios for future development of Estonian rural landscapes. It gives a brief overview of land use changes in Estonia during the 20th century and, based on these, scenarios have been developed. First, it discusses the possible landscape effects of the *Eesti 2010* scenarios developed at the Institute of Future Studies. Of these scenarios, only one predicts increase in the agricultural land compared to 1992. However, none of these scenarios take into account the joining of Estonia to the EU that influences the future options considerably. Second, extrapolation of the trends of 1945–1989 to 1990's and beyond has been used to create the zero-scenario. According to this, the area of agricultural land would have decreased significantly, arable land would have remained almost stable, still with slight decrease, and forest would have increased. Finally, the actual land use in 1990's still follows the trends of the Soviet time. Natural grasslands seem to recover, arable land remain stable, agricultural land is diminishing and the increase of forests has stopped.

Key words: scenarios, land use change, Estonia

1. Introduction

Recently, many research papers have been published (Kasepalu 1991, Mander and Palang 1994, Mander *et al.* 1994, 1995, Peterson and Aunap 1998, Palang *et al.* 1998) that describe land use and landscape diversity changes in Estonia from the beginning of the 20th century till 1990's. The main tendencies of landscape change, according to these studies, have been the increase of forest land from 21% in the beginning of the 20th century to 47% in the beginning of the 1990's and the decrease in the share of agricultural land from more than 65% to 32% during the same period. The ecological consequences of these changes include losses of habitats and species, introduction of new species, and eutrophication, among others. At the same time, landscape diversity indices show no significant change if generalized over the whole territory, but the smaller the territory, the greater the changes are. This leads to a conclusion that despite all the changes, the country as a whole is still able to compensate at least some of the change.

However, until now the research has concentrated on describing the change in the past, rather than providing forecasts for the future. At the same time, predicting future land use by creating scenarios is becoming increasingly popular. Scenarios have been developed to predict the visual impact of agricultural policies in Norway (Jones and Emmelin 1995), or to study the impact of CAP on land use in Europe (Meester 1995), to bring some examples.

The present paper summarizes the first results of a greater study undertaken to predict the possible future of Estonian landscapes. It concentrates on the changes of agricultural land use in 1990's. First, the article tries to assess the possible landscape impact of the four scenarios (Raagmaa and Terk 1997) created to forecast the development trends of the Estonian society till 2010. Second, it tries to answer what would have happened to the land use if the Soviet system would have continued. Finally, it compares the extended trends of the Soviet period with the real changes of 1990's.

2. Material and methods

Land use data is derived from Estonian official statistics, as used also in previous works. Based on this, trends of were calculated for four land use categories. Simple and second order polynom regressions were used for calculations. For each land use category, three time periods were used. Long period indicates the whole Soviet era from 1945–1989, medium period encompasses the period 1955–1989, short period the time 1966–1989. The year 1989 was chosen as the end of the Soviet period because starting from 1990 private land ownership was re-allowed in Estonia. After that moment also statistical data becomes less reliable, as it is often based on generalizing sample data over a larger territory, instead of overall data collection as practiced earlier. Using three time periods also have several reasons. The longest period includes all the impact of the Soviet time, starting with collectivization of agriculture in late 1940's, two campaigns of land amelioration in late 1950's and early 1970's. The medium period excludes the most turbulent years in the beginning of 1950's, the short period focuses on the recent development of the established Soviet agricultural system.

One way to understand landscape is to define it as the visual expression of the sum of objects and processes in a given locality at a given time (Emmelin 1996). According to this, present landscape is a result of processes having occurred in the past, while the present landscape in turn forms a basis for future landscape. However, there is not one, single future landscape. There is rather many potential landscapes the emergence of which depend largely on policy decisions. The mechanism of landscape change is explained in Figure 1.

As seen from the figure, landscape change is a constant process. The degree of changes depends on the policy options, the prevailing attitude in the society, the culture if you wish. Landscape values include life-supporting (ecological), aesthetic, economical values. Understanding that landscape values have changed and changes of valuations cause changes in policies. These in turn may lead to socio-economic changes, thus generating further changes in landscape values. Also, socio-economic changes may lead to changes in valuations and attitudes which induce new policies.

Scenarios can be generated using two techniques (Harms 1995). Forecasting scenarios project current trends or expectations onto future. Backcasting scenarios design possible alternatives and confront them with the present situation. In this paper, both backcasting and forecasting techniques have been used. The *Eesti 2010* scenarios use backcasting to describe the four possible alternatives, while the zero-scenario bases on forecasting technique.

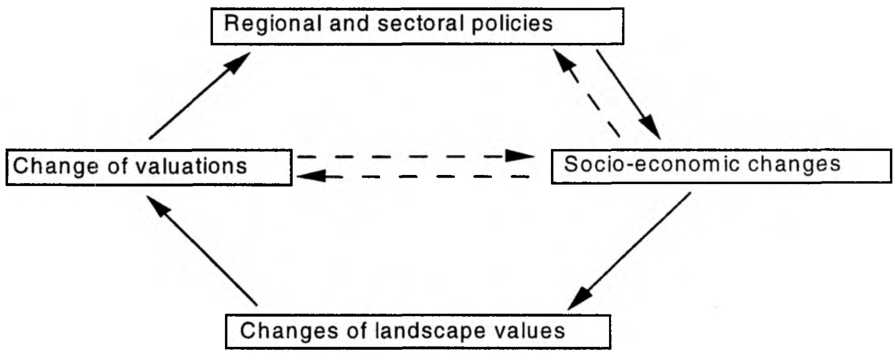

Figure 1. Cycle of landscape change at regional level

The options for future landscapes discussed in this article base on two considerations. First, the history of the landscape has been taken into account. This includes the changes in land use having occurred during the 20th century. And the future of the landscapes is dependent on this history. Second, a small country like Estonia is not free in its choices, which have to be in line with developments outside the country. However, these scenarios do not take into account the possible joining of Estonia to the EU. Also, the extrapolation of the current trend or zero-scenario has been used in analysis. This shows the future of the landscape if 'nothing happens' or, in other words, current processes continue.

3. Results and discussion

3.1 Driving forces for change

The main reasons for land use changes have been both political and economical. Collapse of the Soviet Union brought along privatization. In 1992, the former collective farms were demolished and the slow land reform took its start. By now, it is far from being finished, and all policies, as much as they exist, are directed to solve the ownership problems rather than regulate land use (Kevvai 1997). At the same time, economic crisis meant that the market for agricultural products went down, lack of finances to renew technical equipment and buy fertilizers combined with the appearance of cheaper exported products have caused the increase of set-aside lands.

3.2 *Eesti 2010* scenarios: outlines and possible landscape effects

The Institute for Future Studies have developed four scenarios to outline the possible development of Estonia till 2010 (*Eesti 2010*; Raagmaa and Terk 1997). Table 1 gives the main features of these scenarios. These scenarios base on the assumption that some options are still open for the country. However, as the process of scenario-development started in 1995, these scenarios do not take into account the influences departing from the possible joining of Estonia to the European Union. Still, as the scenarios are used as official document in planning, assessment of their possible impact is necessary. The following tries to outline the possible landscape effects of these scenarios.

First, the ***Southern Finland scenario*** shows the future of the country as similar to that of southern Finland. In addition, transfer of production and also investments from Finland to Estonia is foreseen. This brings along a further decline in agricultural land use and least environmental pressure, compared with the other scenarios. In landscape structure, this means maintenance of large intensively managed fields in Central and North Estonia, where the soil fertility is the highest. At the same time, in other parts of the country, less land is necessary for agriculture, which becomes grassland. In former natural grasslands, the current natural succession continues and the area decreases. More areas become overgrown by first bushes and later forests, while the current stands are gradually being felled and new trees planted.

In the *Capital region*, concentration of settlement and use of numerous household plots create a high diversity of agricultural land. At the same time, area of grasslands, forests and even fields will decrease, due to the increasing needs for land under buildings and infrastructure. In *North Estonia*, the tendency of 1980's towards polarization continues. The fields, now used either by local or foreign landlords, become larger, still existing small villages are gradually abandoned, as are the still existing fields around those villages. These get overgrown and supplement the natural areas. Similar tendency happens in *Central Estonia*, where, however, the change is somewhat slower. *West Estonia* lives off tourism, agricultural lands are abandoned. Thanks to the further decrease in agriculture, the formerly managed wooded and coastal meadows receive no management and the high natural values of these get lost. However, together with the increase of tourism, some most valuable spots that occur in the protected areas receive sufficient management, financed from the tourism income, and are shown as examples. *South East Estonia* goes back to the 1930's with high diversity of landscape consisting of tiny spots of fields and forests. The large forests having grown here during the last decades of the Soviet regime are felled and new trees planted. Due to the decrease of population, increasing number of small plots are being abandoned. *North East Estonia* also moves towards polarization, but here the agriculture continues to serve the needs of the local large towns, while extensive natural areas are taken under oil-shale mines and peat production fields.

The ***Transporter*** scenario insists on continuing the tendencies of 1980's. In general the share of agricultural land increases, production becomes more intensive, causing in turn higher pollution. Also in regions the tendencies of the 1980's continue. In the *Capital region*, new roads increase the fragmentation of landscape, more fields and also forests are taken under building. *North Estonia* becomes more and more polarized, with large monoculture fields and large forests. At the same time, large areas, both fields and forest will be lost under the planned phosphate mine. *Central Estonia* follows the same route, only somewhat slower again. *West Estonia* becomes underdeveloped, with abundance of left houses, abandoned fields and overgrowing grasslands. *South East* also continues the tendency towards higher diversity, with greater share of fields and forest, both scattered in small patches evenly over the region. *North East*, in turn looses more lands under mines.

The ***Military Info-oasis*** scenario predicts somewhat greater changes. As agricultural production in this case concentrates on fulfilling the needs of domestic market, it becomes more extensive, more land is set aside from agricultural production, and change of specialization to milk increases the share of cultivated grasslands within the agricultural lands. Use of alternative fuels will affect several bogs that will be used to extract peat. In general the tendencies of 1990's continue. The *Capital region* stays as it is, only the building of new roads increases the fragmentation of landscape. *North Estonia* looses some of its agricultural land to nature development, which in turn becomes fragmented by the new roads. In *Central Estonia*, development concentrates around Tartu and Jõgeva, while in other parts of the region agriculture decelerates and gives way for nature development. *West Estonia* becomes more forested, small farms deal with supplying themselves. *South-East* Estonia sees some growth in agriculture, as new military installations and bases provide market possibilities. At the same time, the share of closed areas, used for military purposes, increases. *North-East Estonia* faces similar military situation, while decrease in population leaves ever larger space for nature.

Finally, the ***Great Game*** scenario forecasts the largest changes. As this seems to be the desired option for future, it foresees a highly innovative and technologically advanced society. However, it also forecasts decrease in forests and natural areas in general, more land is used for generating biomass as fuel. Intensive agriculture cause higher pollution load, and to compensate this, buffer strips are often created around water bodies. The share of fields decreases slightly compared with 1992, as does the share of forests which are used more intensively. Landscape becomes more polarized. The *Capital region* sees the most active building which means that less land is left for agriculture and forests. In *North Estonia* agriculture becomes more intensive, fields grow bigger and more regular, old villages are restored and new villas built in the countryside. Thanks to this landscape becomes more diverse than it was before the independence. However, intensive agriculture and spreading population can cause conflicts with nature conservation. *Central Estonia* sees similar growth in agriculture and population, polarization increases, but in general the proportion of land use remains the same. In *West Estonia*, tourism brings income that is also used for managing areas with high natural values, thus helping to maintain these. Wood industry puts some pressure on forests, as does peat industry on bogs. In land use, the share of agriculturally used land decreases further. In *South-East Estonia*, agriculture increases somewhat compared to the current situation. Nature stays extensive and natural, share of forests increases, natural grasslands are extensively used. In *North-East Estonia*, industry takes more land from fields and forests, while tourism puts more pressure on natural areas, especially on the northern coast of Lake Peipsi.

3.3 The zero-scenario: trends of the Soviet period

Figures 2–5 display the calculated trends for continuation of the Soviet land use for the years 1990–2005. Also, the actual land use in 1990–1996 is given. The trends were computed using simple and polynomial regression tools of typical statistical computer software. The r-square values of the regressions are given in Table 2. In all cases the polynomial regression describes polynomial regression well land use rends that is demonstrated by the high r^2 values (0.828–0.983; $P<0,05$). Of these four land use categories, arable land has been the most stable throughout the whole Soviet period and therefore the forecast seems most exact. Although linear trend indicate a continuous increase in the acreage of arable land, in reality it follows the polynom pretty well. It seems to be one more argument telling that the share and location of fields in Estonia remains stable regardless of any major political fluctuation. The land may have been set aside as a fallow for some years, but it is not written off so easily. However, the estimations of the amount of set-aside land vary considerably, reaching from 22.5% to 27–31% of all arable land in 1995 (Kevvai 1997). On the other hand, the area of natural grasslands has decreased the most during the Soviet period, and all linear trends predict the disappearance of natural grasslands altogether, the difference being the time when the last natural grasslands ceases to exist. In reality, however, the tide seems to be turning and the acreage of natural grasslands remains stable. As agricultural land is the sum of arable lands and natural grasslands, the trend of it also depends on the changes of these two. The area stays almost stable during the last years. With forests, linear trends predict continuous increase while polynomial trend say forest land has reached its peak and will start decreasing soon. Surprisingly, the actual change follows the polynomial regression trend, the reason being the boom in forest industry and reluctance of land owners to plant new trees on the felled areas.

3.4 Regional changes

Table 3 presents the shares of arable land, natural grassland and forest in the land possessed by agricultural users in 1991–1995.

The decrease in arable land has been the greatest in Central and South-East Estonia, while in other regions it the changes are less. At the same time, natural grassland has remained almost stable. Taking into consideration the slight but constant increase in the share of forests one may come to the conclusion that in regions the tendencies having occurred in the agricultural landscape during the whole century, still continue. The only exception being the share of natural grasslands that reached bottom in late eighties and starts recovering again. However, the latter often means decrease in their ecological value. The reason for this is the natural succession of natural grasslands. Often grasslands need some kind of human management, usually annual mowing. In the beginning of 1990's this was seldom done, and the grassland became overgrown (Kukk and Kull 1997). At the same time, some of the fields are abandoned, letting the natural vegetation take over. As a consequence, new natural grasslands appear, replacing the overgrown ones, thus keeping the total area stable.

Conclusions

1. Both backcasting and forecasting techniques are suitable for predicting the future of Estonian landscapes.
2. The *Eesti 2010* scenarios have described four alternatives for the future of Estonian landscapes. Of these scenarios, only one predicts increase in the agricultural land compared to 1992. However, none of these scenarios take into account the joining of

Estonia to the EU that influences the future options considerably. Therefore, the need for further studies in this field is apparent.

3. The continuation of the trends in land use prevailing during the Soviet era would have left Estonia without natural grasslands by mid-1990's, while the area of agricultural land would have decreased significantly, arable land would have remained almost stable, still with slight decrease, and forest would have increased.
4. The actual land use in 1990's still follows the trends of the Soviet time. Natural grasslands seem to recover, arable land remain stable, agricultural land is diminishing and the increase of forests has stopped.

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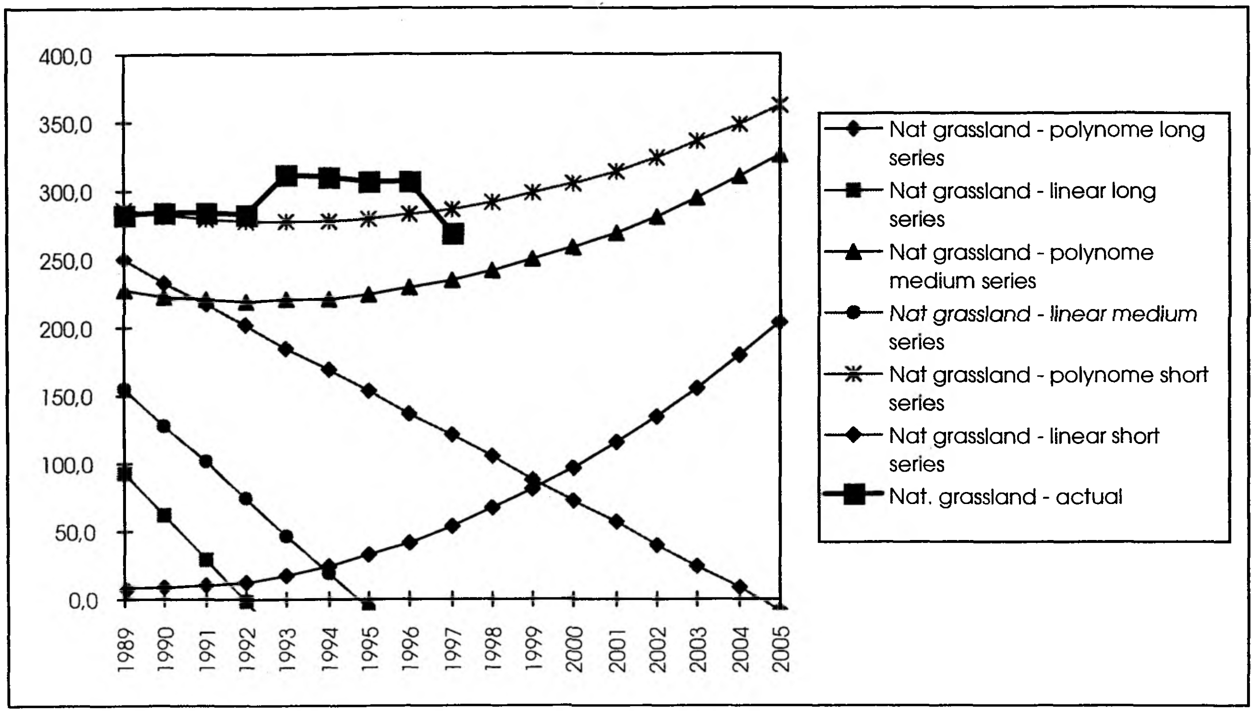

Figure 2. Continuation of trend for the Soviet period, natural grasslands (10^3 ha).

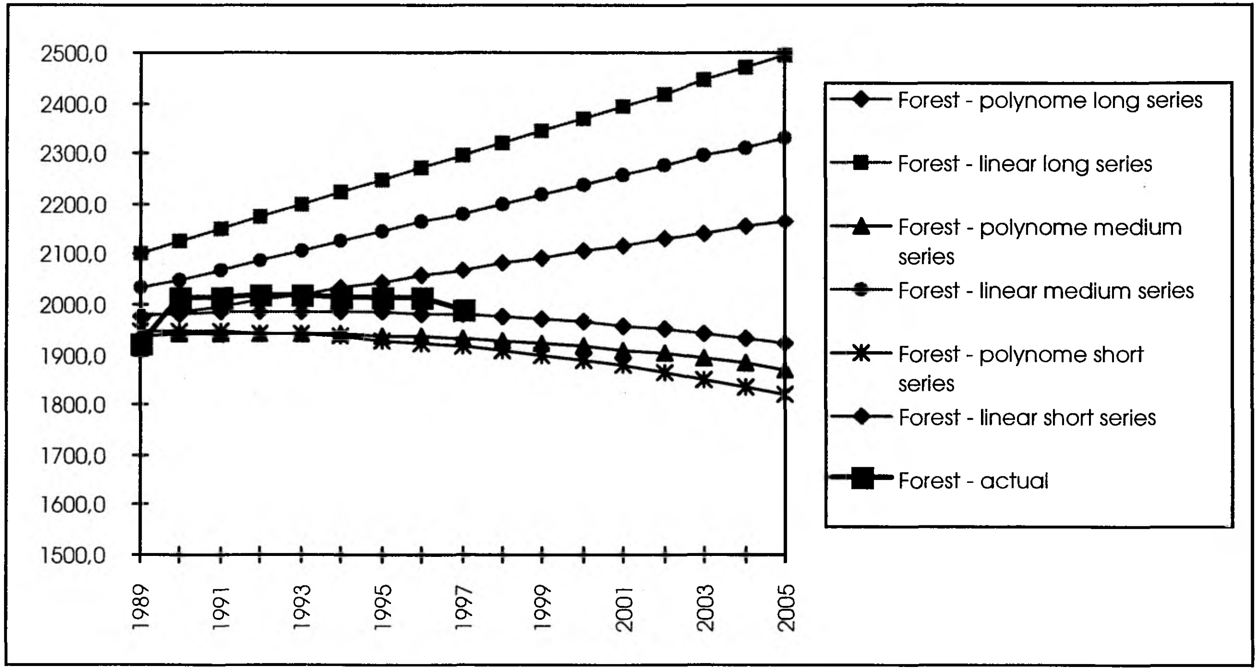

Figure 3. Continuation of trend for the Soviet period, forests (10^3 ha).

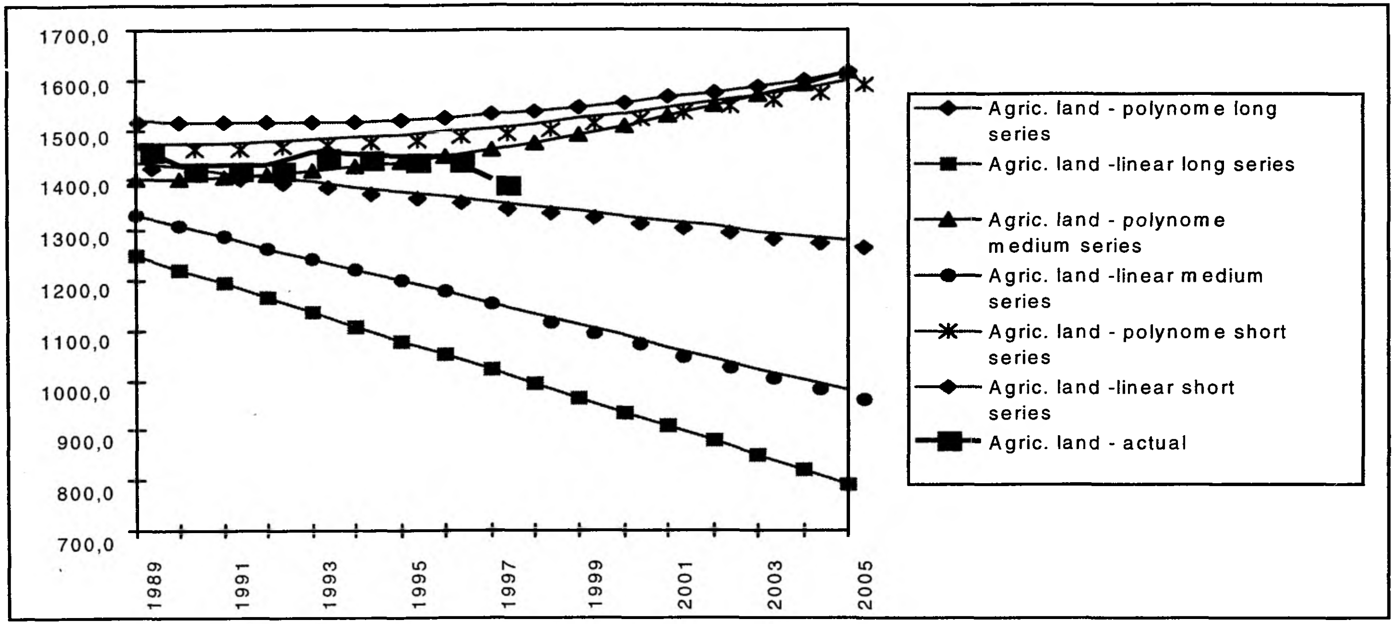

Figure 4. Continuation of trend for the Soviet period, agricultural land (10^3 ha).

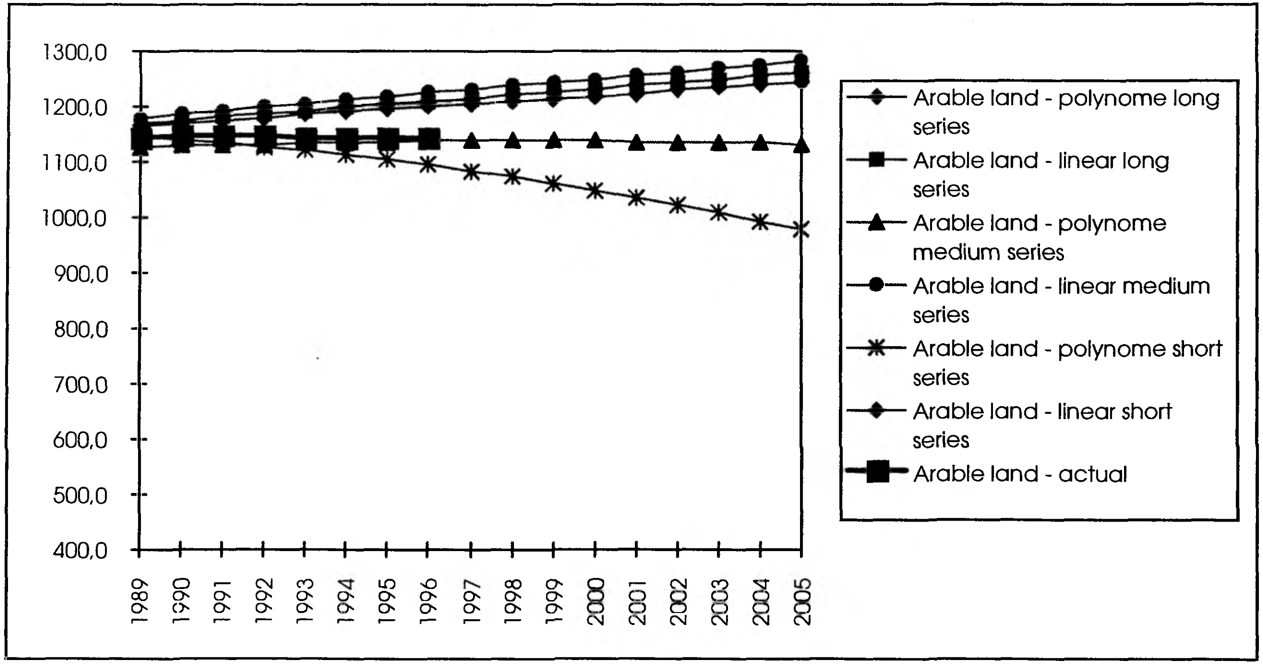

Figure 5. Continuation of trend for the Soviet period, arable land (10^3 ha).

Table 1. Main features of the *Eesti 2010* scenarios (after Raagmaa, Terk, 1997)

Region/Scenario	Southern Finland	Transporter	Military info-oasis	Great game
Country in general	• Fields compared to 1992 — 84% • Somewhat more active agricultural land use, both intensive and extensive • Differences in environmental policies between communities • Least pressure on environment • Hunting and nature tourism combined with ecological farming • Investments and transition of agricultural production from Finland to Estonia • Increase in agricultural output, decrease in labor force	• Fields compared to 1992 — 112% • Increase in agricultural land use • Increase in agricultural non-point pollution • More factories and main roads • More garbage • Probable phosphate mining • Problems with settlement in NE, SE, CE	• Fields compared to 1992 — 70% • Decrease in industry and agriculture • Closed areas for military purposes • Extensive agriculture • Production for domestic market • No new oil-shale mines • Phosphate mining • Local fuel used in power generation • Specialization on milk • Increase in farms dealing with natural economy	• Fields compared to 1992 — 95% • Increase in agriculture • Introducing new species and genes • Decrease in protected areas • Decrease in forests • Buffer strips around water bodies • Biomass as energy supply • Decrease in oil-shale mining • More intensive use of forests • Increasing polarization of land use
Capital region	• Small household plots • Concentration of settlement	• Increase in building — more land needed • More roads	• Least growth • More roads	• Rapid growth in building — less land for agriculture and forestry

North Estonia	• Less changes • Abandonment of small villages	• Most intensive agriculture • Some building	• Decrease in agriculture • More roads	• Increase in agriculture • Restoration of old buildings and villas • Non-point pollution • Contrasts in nature conservation
West Estonia	• Tourism • Wood industry	• Tourism, mainly Russians • "Blended isolation"	• More forestry • More natural economy	• Tourism • Wood industry • Peat industry in Pärnu
Central Estonia	• Decrease in agriculture • Land used by large domestic and foreign-owned farms	• No changes in agriculture • Domination of large farms	• More investments in Tartu and Jõgeva	• Increase in agriculture • Concentration of population
South-East Estonia	• Decrease in agriculture • Natural economy	• Increase in agriculture following the Soviet standards	• Military objects • Increased market	• Stable and natural nature • Increase in agriculture • Introduction of new plants and technologies
North-East Estonia	• No changes • Agriculture serves the needs of local towns • More lands under mines.	• No changes • Agriculture serves the needs of local towns • More lands under mines	• Military objects • Decrease in population • Large space for nature	• More industry • High tourism pressure

Table 2. r-square values of regressions of the land use trends

	Long period		Medium period		Short period	
	Polynomial	Linear	Polynomial	Linear	Polynomial	Linear
Agricultural land	0.956	0.906	0.960	0.870	0.978	0.906
Arable land	0.917	0.917	0.976	0.939	0.983	0.828
Natural grassland	0.979	0.916	0.969	0.923	0.981	0.937
Forest	0.969	0.926	0.976	0.932	0.939	0.890

All the values are highly significant (P<0,05).

Table 3. Land use of agricultural producers — percentage of total land.

	Natural grassland				Woodland				Arable land			
	1991	1993	1994	1995	1991	1993	1994	1995	1991	1993	1994	1995
Estonia total	9.6	9.6	9.6	9.6	28.1	32.1	32.2	32.3	44.2	43.6	43.6	43.4
Capital region	12.3	12.3	12.2	12.3	26.1	32.6	32.6	32.8	41.6	41.1	41.0	40.8
North Estonia	7.9	8.0	8.0	8.0	27.9	31.6	31.8	31.9	49.3	48.7	48.6	48.6
Central Estonia	7.3	7.3	7.3	7.4	29.2	29.5	29.6	29.8	50.9	50.0	49.9	49.6
West Estonia	12.0	12.0	11.9	11.8	25.7	33.0	33.1	33.3	34.1	33.7	33.8	33.7
North-East Estonia	11.9	11.8	11.8	11.8	28.0	35.7	35.7	35.8	40.8	40.0	39.9	39.8
South-East Estonia	9.4	9.4	9.3	9.4	31.4	33.6	33.6	33.8	46.1	45.4	45.3	45.2

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Peamised uurimisvaldkonnad. Maastike ja maakasutuse dünaamika Eestis. Ülikooli diplomitöö "Mentaalsed maastikud, nende kujunemine ja sõltuvus looduslikest teguritest". Magistritöö "Eesti maastike mitmekesisuse ja maakasutuse dünaamika XX sajandil". Olen juhendanud viis bakalaureusetööd TÜ geograafia instituudis (Kadi Jürimäe "Vormsi kultuurmaastik 20. sajandil" 1995, Egle Kaur "Maastiku väärtused kaitseala planeerimise alusena" 1997, Aarne Luud "Maastiku mitmekesisus ja ökoloogiline väärtus" 1997, Tambet Kikas "Puhkealade looduskaitselise planeerimise võimalustest biosfääri kaitsealal" 1998, Anu Haugasmägi "Taluturism Eestis Saaremaa ja Haanja näidete varal" 1998).

Organisatsiooniline tegevus. Olen *Infra Eco Network Europe* (IENE) Eesti asekoordinaator, Eesti Ökoturismi Ühenduse (EÖÜ) juhatuse liige, Rahvusvahelise Maastikuökoloogia Assotsiatsiooni (IALE), Eesti Geograafia Seltsi (EGS), Õpetatud Eesti Seltsi (ÕES) liige.

Keelteoskus: eesti keel emakeelena, väga hea inglise keel, väga hea vene keel.

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