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Change in agriculturally used land and related habitat loss: A case study in eastern Estonia over 50 years

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Abstract. This study investigates land use changes on an area of 128 km^2 in Jõgeva County, eastern Estonia, by comparing landscape types in a vegetation map from the 1950s with the land use structure described on the Estonian Basic Map produced in 2002. We concentrated in particular on changes in agricultural land, but also changes of both species-rich and species-poor habitats were studied. The most widespread process was forestation, which reduced the total area of arable land by 21% and of grassland nearly by 4%. During the 50 years the land use of 90% of the forest land area, 46% of the arable fields, and only 11% of the grasslands had remained spatially stable. The extremely high spatial turnover of grasslands is due to loss of historical meadows and wooded meadows. This suggests a decreased habitat quality of present grasslands. Most of the new agricultural land was created on species-rich grasslands and species-poor fens. Forest expanded mostly on species-rich grasslands and fertile arable land.

Key words: land use changes, land abandonment, agricultural land, grasslands, forestation, vegetation map.

INTRODUCTION

Land use changes are affected by very different processes: intensification and extensification of agricultural practices, marginalization and abandonment of agricultural land, development of infrastructure, pressure from tourism (Calvo-Iglesias et al., 2006). Various complex social, economic, and political factors implicate land use changes (Nikodemus et al., 2005). Many studies concern the results of the abandonment of arable land (i.e. the agricultural land under different crops) and the reforestation process (Bürgi & Turner, 2002; Calvo-Iglesias et al., 2006; Gellrich & Zimmermann, 2007; Tasser et al., 2007).

The natural overgrowing and forestation of open habitat areas are among the primary processes that caused landscape change in Europe during the 20th century. The rationalization of agriculture in the middle of the 20th century led to the intensification of land use, but on the other hand also to the abandonment of traditional agricultural land and to natural forestation (Strijker, 2005; Henle et al., 2008). The area of forests has increased in Europe by 10% in the last

40 years, the proportion of agricultural land has fallen by 11%, and the area of permanent pastures has decreased by 11% (European Environmental Agency, 1995). For example, in the last 50 years semi-natural communities have largely disappeared in Sweden due to the development of economically oriented agricultural landscape. More recent changes include a general reduction in agricultural land and in grassland and an increase in conifer plantations (Ihse, 1996). Changes in landscape structure have been shown to have a clear impact on the biodiversity of insects (Sepp et al., 2001; Schneider & Fry, 2005).

Several changes occurred in Estonian landscape in the 20th century, but the general trend is reduction in agricultural land and increase in the area of forests. At the beginning of the 20th century an intense change of forest land to agricultural land took place (Jõgiste et al., 2005). The proportion of forest land had by then decreased to less than 30%. However, between 1918 and 2000, agricultural land area shrank from 65% to 30% (Peterson & Aunap, 1998; Mander & Reintam, 2001). In the same period, the area of forest land increased from 21% to 52%. All this happened as a result of the combined effects of land reform, population deportations, collectivization of agriculture, and urbanization. Changes in the political system, of which there were four in Estonia during the 20th century, also had an effect (Palang et al., 1998). One of the major changes in land use occurred after World War II, when the process of forestation of abandoned agricultural lands began. In addition to the natural successional process, forest was also planted on former fields (Jõgiste et al., 2005). However, the relative importance of planting and natural forestation process has not been recorded.

The most recent processes in the Estonian landscape concerning the agricultural land use are forestation, abandonment and subsequent overgrowing of grasslands with shrubs and young trees, expansion of old-fields at the expense of abandoned arable land, and reduction in the proportion of arable land (Aaviksoo & Meiner, 2001). Peterson & Püssa (2001) estimated that 15–30% of the former arable land was lying abandoned between 1985 and 2000. Between 1995 and 2005 the area of arable land in Estonia fell by 283 000 ha, but the area of managed grasslands increased by 126 000 ha. Until 1999 the area of arable land increased, but since 2000 it has begun to fall again (Statistics Estonia, 2006).

When grasslands are abandoned and become forested, their vascular plant species richness generally declines. The reduction in species richness is associated with the length of time after abandonment. The speed of decrease in the total number of species might depend also on tree cover (Pykälä et al., 2005). However, the abandonment and following succession of grasslands are still more preferable than intensifying their management with the help of fertilizers, pesticides, etc. (Jongman, 1996; Strijker, 2005).

Vegetation maps are good sources of information for investigating land use changes. Geo-botanical mapping of Estonian vegetation began in 1934. It was concluded after World War II, from 1948 to 1955. Vegetation units were defined and mapping took place across the whole of Estonia (Laasimer, 1965). Information was gathered on the species composition and dominants of the vegetation units as well as on environmental conditions (relief, soils, hydrological regime). The information is sufficient for classifying the different vegetation units as species rich or species poor.

In this study we analyse the changes in the agricultural land. We aim at giving the spatial persistence and extent of the agriculturally utilized land where management change has taken place. We describe the extent of the agricultural land created since the 1950s. We asked about the contribution of natural and semi-natural habitats in the creation of agricultural land. We will also ascertain the extent of the land use changes regarding species-rich and species-poor communities (forests, grasslands, fens) by comparing the map of vegetation from the middle of the 20th century with the map depicting land use in 2002. In addition, our goal was to assess the spatial extent of forestation processes embracing both natural forestation and forest planting.

MATERIAL AND METHODS

Study area

The study area is located in eastern Estonia, in Jõgeva County, mostly in Saare Municipality but partly also in Kasepää and Pala municipalities. The soils are less fertile than in neighbouring areas. The main crops of the arable lands are cereals (wheat, barley, rye) and in recent years, also oilseed rape. The area was defined on the basis of one grid square (128.2 km^2) of the vegetation map drawn up at the beginning of the 1950s. The size of the study area was 11.1 km × 11.6 km. The area includes two major settlements (Voore and Saare), the former in the south (341 residents) and the latter in the south-west (206), and ten dispersed villages, each with 50–70 residents (Valla lühitutvustus. http://www.saarevv.ee/index.php?lang=est&main_id =93,95 (visited 10 Jan. 2007)).

Data

Vegetation map

A topographic map of 1 : 42 000 scale dating from 1896–1917, but later referred to by the single year of 1900 (Palang et al., 1998), was used as the mapping base of the vegetation map of the 1950s. The vegetation units within a grid square (128.2 km^2) were always mapped and described by the same recorder; thus no bias in the data is expected. The classification of vegetation used for mapping relied on the classification by Lippmaa (1937).

For mapping the vegetation, all the different vegetation units were traversed and identified in the field and their plant communities were described. The vegetation units were demarcated on the map during the fieldwork. The number of replications of vegetation analyses per vegetation unit was related to its area: one vegetation analysis plot per each 0.25 km^2 of a vegetation unit was described. The plot size varied between open habitats and forest-like biotopes. A vegetation plot encompassed a 100 m^2 area of the tree and shrub layer in forests and wooded meadows. The plot size used for the grass layer in forest and in meadows varied from 4 m^2 to 10 m^2. Species composition was determined by recording all species and their abundance on a five point scale.

Because of the scale of the map used for vegetation mapping, vegetation units do not have very clearly defined borders. However, this applies to the whole study and thus the error is the same all over the study.

Classification of arable lands and grasslands on the vegetation map of the 1950s

The agricultural lands consist of two differently managed types: arable lands and grasslands. The arable lands are used for cultivating various crops, while the grasslands produce forage for livestock. However, in the vegetation mapping the (natural or) semi-natural grasslands and cultivated grasslands were not separated. The latter are usually fertilized and cultivated with heycrops in Estonia. Compared to semi-natural grasslands, the cultivated ones have much lower species diversity (Sammul et al., 2003).

Arable lands are classified on the vegetation map according to their soil types. For this purpose soil samples were taken from each arable land and the soil profile and acidity level were recorded. This made it possible to determine what kind of forest or fen type could have grown in the place of the arable land earlier. In the study area arable lands of four types of origin were distinguished: those created from (1) mixed spruce, spruce, and fresh boreo-nemoral deciduous forests; (2) pine forests on sandy soil; (3) calcium-poor mires; and (4) pine forests on poor paludified soil.

Meadows and wooded meadows were grouped into six vegetation unit types: (1) species-rich meadows, (2) species-poor meadows, (3) dry species-rich wooded meadows, (4) dry species-poor wooded meadows, (5) paludified species-rich wooded meadows, and (6) paludified species-poor wooded meadows.

Estonian Basic Map

The source of information on the current land use in Estonia is the Estonian Basic Map, which in digital form is at a scale of 1 : 10 000. The Basic Map was constructed from aerial photographs. We used the Basic Map to compare the current land use with that depicted on the vegetation map from the 1950s. In our study area the aerial photographs were taken in 2002. The Basic Map provides information about the location and size of the following land-use types: grasslands (including cultivated and natural grasslands, which cannot be distinguished), fens, forests, young forests, arable lands, scrubland, and other open areas. Young forests are defined as areas covered with young trees (<4 m) whose cover is more than 30%. The same rule applies to clearings (clearings are defined as young forest). For assessing the spatial extent of forestation we used both of the land use types of the Estonian Basic Map: forest and young forest. Scrubland is defined as an area with at least 50% coverage of shrubs. The coverage of trees in the scrubland must be less than 30%, otherwise it classifies as forest (Estonian Land Board, 2003).

Map analysis

To compare the current and historical land use, the vegetation map of the study area was digitalized. All analysis of the map was performed using Mapinfo (7.5, MapInfo Corporation), mainly by map layer querying for different vegetation units. The queries were used to delimit land use types within the study area and find their aggregate areas. The subsequent work included the analysis of qualitative and quantitative changes. The overlaps of areas of every historical vegetation type with the current land use type layers on the Basic Map were determined. The areas of the overlaps were identified and the percentage change for every vegetation unit was calculated. It is important to point out that the mapping scales of the two maps are different. This affects the results but the impact is the same all over the area.

Management changes in arable land and meadows

The arable land and meadows were divided into four categories according to data of the 1950s: arable land on fertile soil, arable land on infertile soil, species-rich meadows, and species-poor meadows. The change of land use in these four categories by 2002 was described and the proportions of land use types in 2002 were compared using χ^2-test.

RESULTS

General changes in land use

It appears that in the 1950s arable land accounted for almost half of the land (Fig. 1). Various grasslands made up over a tenth of the studied area. By 2002 the share of arable land had fallen by 20.7% and that of grasslands by 3.5% (Fig. 2).

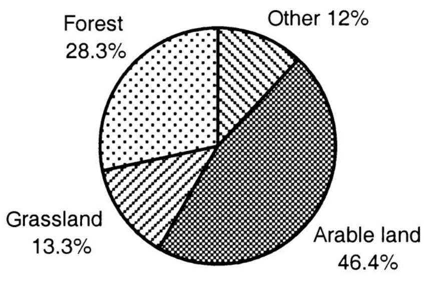

Fig. 1. Land use in the 1950s.

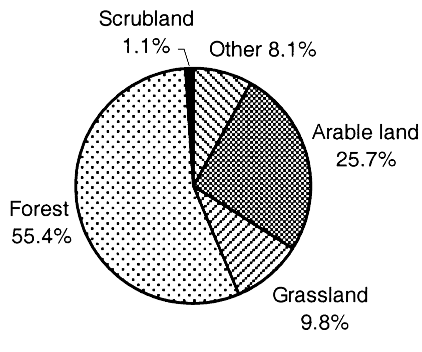

Fig. 2. Land use in 2002.

Over the 50 years the forest coverage had grown by almost a half. Of the land that was forested in the 1950s 90.4% was forest land at the same place in 2002. Of the arable land 46.4% had remained arable land and 11% of the grassland was grassland in 2002.

Changes in agriculturally used land

The percentage coincidence of the historical and current land use types distinguished on the vegetation map and the Basic Map is presented in Table 1. In all, 46.4% of the total area of the historical arable land had retained its former agricultural function, i.e. had remained arable land or had been converted to grassland. About 20–40%, depending on the type of arable land, had overgrown with forest, with young forest making up 3–8%.

The changes in species-rich and species-poor grasslands and fertile and infertile arable land are shown in Table 1. Comparison of the mean values of transition of the four groups revealed that the changes were not random (χ^2-test, $p < 0.001$). Of fertile and infertile arable land quite equal parts had remained arable land or turned into forest. Major differences were observed in changes into grassland. The proportion of arable land that had changed to grassland was larger on infertile soil than on fertile soil. More of species-rich grassland had turned into forest compared to species-poor grassland. The changes in agricultural land use are depicted in Fig. 3, which shows the proportion of grassland and arable land.

Creation of new agricultural land

Arable land

New arable land, totalling 526.5 ha, had been created almost everywhere in the area. These areas are mostly near villages. Some historical fen areas were arable land in 2002. In all cases, fens had been taken into use partially (primarily fen margins) and as a result of amelioration. Of species-rich vegetation types grasslands and of species-poor types fens gave the largest percentage of the new arable land (Table 2). The changing of different habitats to arable land was not random ($p < 0.01$).

Grassland

Another type of agricultural land the change of which we were interested in was grassland. During the about 50 years under study, 359.6 ha of grassland was formed. It includes both natural and cultivated grasslands. The creation of grasslands was affected in part by human settlement and the growth of villages. Larger grasslands were most often created near settlements and close to major roads. Table 3 demonstrates that grasslands were created almost equally at the expense of species-rich and species-poor communities (forests and fens). If we consider the total area of the respective vegetation types, then species-rich communities

Table 1. Territorial transition of the land use of the 1950s (four types and their subtypes) into the land use types in 2002 (%)

Vegetation types in 1950s	Vegetation types in 2002								*p*-Value
	Arable land	Forest	Young forest	Grass-land	Minero-trophic swamp	Scrub-land	Other open area	Roads and buildings	
1. Arable land (fertile soil)	47.9	27.6	3.0	0.9	12.7	1.2	3.6	3.2	<0.001
2. Arable land (infertile soil)	41.0	35.0	7.1	9.6	1.2	0.6	4.5	1.0	<0.001
Arable land created from species-poor fen	40.9	38.5	4.9	7.9	2.5	0.6	4.0	0.7	
Arable land on sandy soil	40.8	33.3	7.8	10.6	0.4	0.6	4.9	1.5	
Arable land on peaty soil	44.6	17.4	26.2	11.4	0.0	0.0	0.3	0.05	
3. Species-rich grasslands	10.0	68.5	8.9	7.6	0.4	0.9	2.9	0.8	<0.001
Species-rich open grasslands	2.6	47.1	18.6	21.9	0.9	0.8	7.3	0.9	
Dry species-rich wooded meadows	17.3	61.9	5.6	8.5	0.2	1.7	3.3	1.6	
Paludified species-rich wooded meadows	5.4	79.2	9.5	3.5	0.4	0.2	1.5	0.3	
4. Species-poor grasslands	8.5	50.3	2.5	16.0	0.2	6.3	13.7	2.5	<0.001
Species-poor open grasslands	10.0	50.1	2.8	18.2	0.5	2.7	14.1	1.6	
Dry species-poor wooded meadows	7.5	48.6	2.3	13.6	0.0	12.5	13.8	1.8	
Paludified species-poor wooded meadows	4.1	59.8	1.4	13.8	0.0	0.0	11.3	9.5	

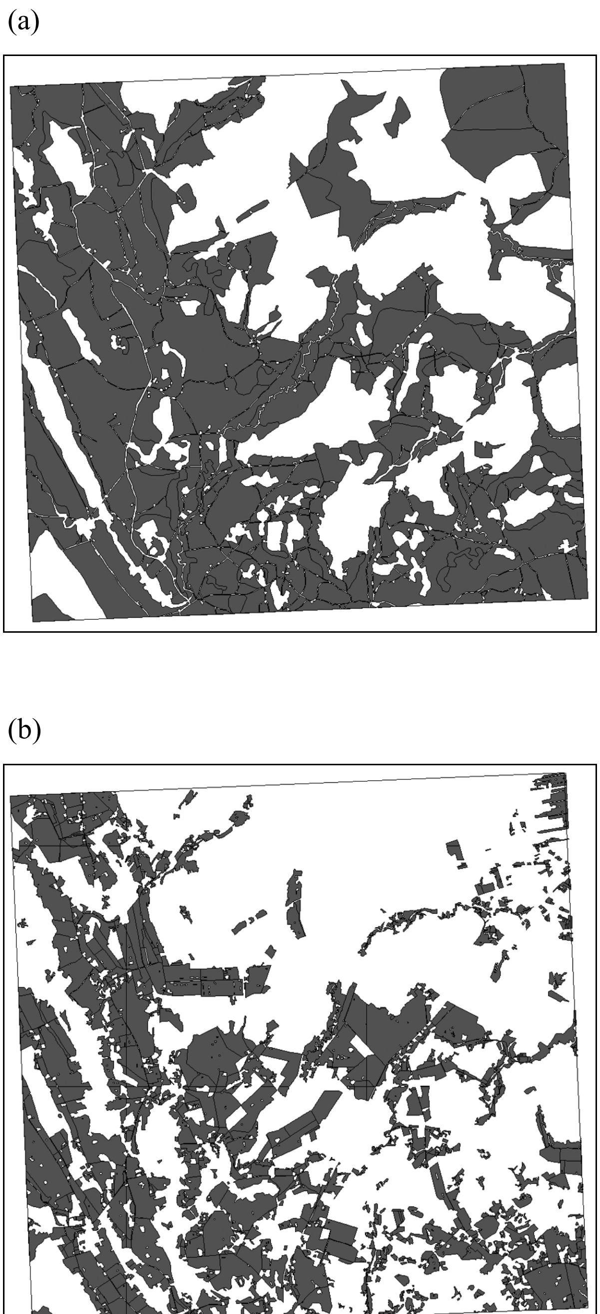

Fig. 3. Distribution of agricultural land (grey) and forest (white) in the 1950s (a) and in 2002 (b). 1 : 150 000.

Table 2. Conversion of vegetation types into arable land: change in relation to the total area of new arable land and in relation to the total area of the vegetation type (%)

Vegetation type in 1950s	Percentage of total area of new arable land	Percentage of total area of vegetation type
Species-rich types:		
Fen	5.8	22
Grassland	16.5	10
Forest	2.7	6
Species-poor types:		
Fen	17.4	14.4
Grassland	11.4	8.5
Forest	15.2	3.9

Table 3. Conversion of vegetation types into grassland: change in relation to the total area of new grassland and in relation to the total area of the vegetation type (%)

Vegetation type in 1950s	Percentage of total area of new grassland	Percentage of total area of vegetation type
Species-rich:		
Forest	12.1	2.8
Fen	18.2	29.7
Species-poor:		
Forest	14.2	2.5
Fen	20.9	11.8

form a greater part, especially in the case of fens. A significant difference ($p < 0.001$) is visible in the changing of different types of forests and fens to grassland. Table 3 shows that a large proportion of the grassland was formed from fens. We can find new agricultural land all over the study area (Fig. 4).

Forestation processes

Analysis of the new forested areas reveals that many of them are areas located next to existing forest (Fig. 5). At the same time, there are areas where forest appeared in the middle of a field. The less fertile areas were mostly situated near roads and were relatively large pieces of land. Forestation had occurred primarily at some distance from houses. Out of species-poor meadows and wooded meadows, those located in riversides had partly become forested by 2002, especially in the northern part of the study area, away from larger human settlements. Small patches of young forests had developed evenly over the whole study area. In many cases logged areas had become forested.

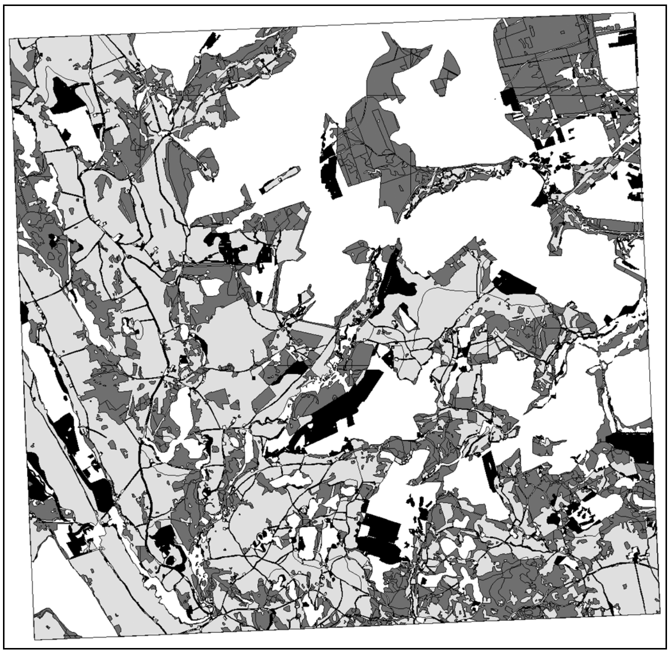

Fig. 4. Changes of agricultural land (1 : 120 000). Light grey – agricultural land throughout 50 years; dark grey – abandoned agricultural land; black – new agricultural land; white – forest.

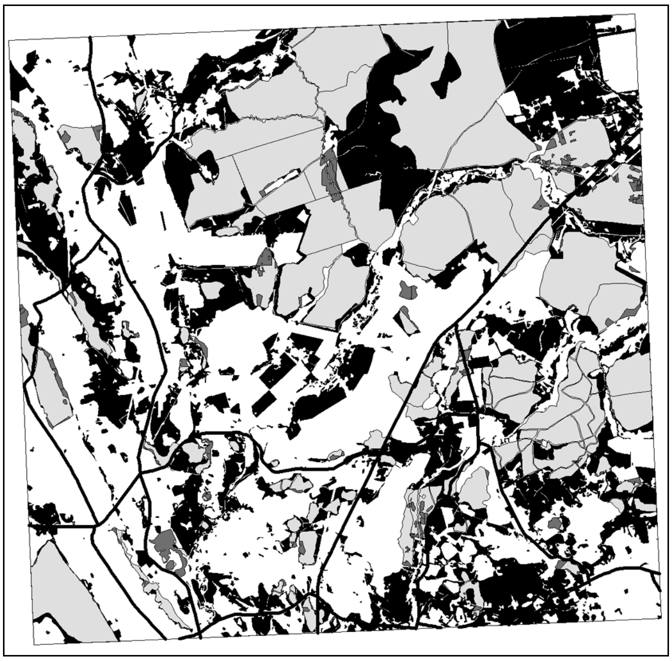

Fig. 5. Forestation and lost forest in the study area (1 : 120 000). Light grey – forest throughout 50 years; dark grey – lost forest; black – new forest compared to the 1950s; white – agricultural land.

Forestation had taken place on 669.9 ha of species-rich grasslands (incl. wooded meadows) and on 373.8 ha of species-poor ones. In addition, 1504.5 ha of fertile arable land and 442.6 ha of less fertile arable land had become forested. Analysis of different arable land and grassland types changed into forest indicated that the proportions of different types were not random ($p < 0.001$).

DISCUSSION

Forestation is the main process that caused changes in the agriculturally used land in the study area. Even a brief look at the maps of land use patterns reveals that the forest coverage significantly increased over 50 years. The proportion of forest almost doubled in the area. Tullus (2000) and Mander & Reintam (2001) observed the same trend for the whole country.

In the study area there are numerous arable fields where natural overgrowing can be observed. As the number of overgrowing arable fields is quite large and these did not show up yet as young forest on the 2002 Basic Map, the proportion of young forest will increase. Moreover, overgrowing has been hastened by the dissolution of a farming cooperative in 2000. The fields abandoned at the end of the 1990s and at the beginning of the new millennium need to be further investigated. The incidence and degree of overgrowing should be ascertained in order to study the processes in recent history. Many areas have ceased to be managed because there is no longer an economic need for that.

The forestation process is not so intensive near the larger settlements as on the land between the smaller settlements where the arable lands and grasslands are no longer managed and have begun to overgrow. In addition, the afforestation of arable land received financial support in 2005 and 2006 (from the Estonian Agricultural Registers and Information Board), as a result of which less fertile arable lands were planted with forest trees. Some effect of this support mechanism is already discernible, but its spatial extent and distribution need further recording.

Positive effects of the abandonment and natural forestation of arable land are considered to be the stabilization of soils, carbon sequestration, and a temporary increase of biodiversity (Gellrich & Zimmermann, 2007). However, as a result of the expansion of forest area, a great loss of species-rich grasslands was observed on the area. No managed wooded meadows had preserved in the study area: by 2002 all of them had become overgrown. Abandoned grasslands that begin to overgrow with shrubs become poorer in species than traditionally managed grasslands (Jongman, 1996; Öckinger et al., 2006; Gellrich & Zimmermann, 2007). Hansson & Fogelfors (2000) reported the change of wooded meadows to woodland in 15 years. An Estonian study recorded the onset of shrub overgrowth 4−6 years after the cessation of agricultural production (Lauringson et al., 2000).

The area of grasslands decreased only by 3.5%. However, only 11% of the grassland was located at the same place as 50 years ago. This shows that the area of valuable permanent semi-natural grasslands has decreased considerably, and probably so has the species richness. In this study we described only two time slots, and due to scarcity of data we could not analyse changes in detail in between these two. The selection of land for creating new agricultural land had a rather clear trend. The border areas of forests and fens were taken into use, and sites close to villages and major roads were often preferred. Fens were the most suffered habitat type, their area considerably decreased due to creating new arable land. Therefore further analysis is needed to see if the abundance of different species inhabiting fens has declined. As biodiversity is a very important topic in the EU, in the Action Plan (Commission of the European Communities, 2006) "Halting the loss of biodiversity by 2010 – and beyond" different actions are recommended.

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Põllumajanduslikult kasutatud maa muutused 50 aasta vältel ja sellega seotud elupaikade kadumine Ida-Eesti näitel

Silja Kana, Tiiu Kull ja Merit Otsus

On käsitletud maakasutuse muutusi 128 km^2 suurusel alal Jõgevamaal Ida-Eestis. Uuritav ala asub peamiselt Saare vallas. Kaardianalüüsi abil on keskendutud põllumajanduslikult kasutatud maa muutustele, võrreldes 1950. aastatel koostatud taimkattekaardi ja 2002. aasta andmetega Eesti põhikaardiga, samuti põllumajandusliku maa ning lisaks liigirikaste ja liigivaeste kooslustega toimunud muutustele. Peamine protsess antud alal on metsastumine. Selle tulemusena on põllumaa osakaal vähenenud 21% ja rohumaade osakaal peaaegu 4%. Viiekümne aasta jooksul on 90% metsadest, 46% põllumaast ja 11% niitudest säilinud oma ajaloolisel kohal. Rohumaade suuremahuline ümberpaiknemine on tingitud ajalooliste niitude ja puisniitude kadumisest. Seega võib eeldada, et praeguste rohumaade kvaliteet elupaigana on vähenenud. Uus põllumaa 1950. aastatega võrreldes on tekkinud põhiliselt liigirikaste rohumaade ja niitude ning liigivaeste sooalade arvelt. Põhiliselt on need külade lähedal paiknevad alad. Pindalaliselt on metsastunud rohkem liigirikaste niitude ja viljaka mullaga põllualad.