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GIS ASSESSING TRADITIONAL AND MODERN AGRICULTURAL LAND USE/LAND COVER CHANGE

A case study 1959-2005: Rekijoki, Somero, SW-Finland

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Finland’s rural landscape has gone through remarkable changes from the 1950’s, due to agricultural developments. Changed farming practices have influenced especially traditional landscape management, and modifications in the arable land structure and grasslands transitions are notable. The review of the previous studies reveal the importance of the rural landscape composition and structure to species and landscape diversity, whereas including the relevance in presence of the open ditches, size of the field and meadow patches, topology of the natural and agricultural landscape.

This land-change study includes applying remote sensed data from two time series and empirical geospatial analysis in Geographic Information Systems (GIS). The aims of this retrospective research is to detect agricultural landscape use and land cover change (LULCC) dynamics and discuss the consequences of agricultural intensification to landscape structure covering from the aspects of landscape ecology.

Measurements of LULC are derived directly from pre-processed aerial images by a variety of analytical procedures, including statistical methods and image interpretation. The methodological challenges are confronted in the process of landscape classification and combining change detection approaches with landscape indices. Particular importance is paid on detecting agricultural landscape features at a small scale, demanding comprehensive understanding of such agroecosystems. Topological properties of the classified arable land and valley are determined in order to provide insight and emphasize the aspect the field edges in the agricultural landscape as important habitat. Change detection dynamics are presented with change matrix and additional calculations of gain, loss, swap, net change, change rate and tendencies are made. Transition’s possibility is computed following Markov’s probability model and presented with matrix, as well. Thesis’s spatial aspect is revealed with illustrative maps providing knowledge of location of the classified landscape categories and location of the dynamics of the changes occurred.

It was assured that in Rekijoki valley’s landscape, remarkable changes in landscape has occurred. Landscape diversity has been strongly influenced by modern agricultural landscape change, as NP of open ditches has decreased and the MPS of the arable plot has decreased. Overall change in the diversity of the landscape is determined with the decrease of SHDI. Valley landscape considered as traditional land use area has experienced major transitional changes, as meadows class has lost almost one third of the area due to afforestation. Also, remarkable transitions have occurred from forest to meadow and arable land to built area. Boundaries measurement between modern and traditional landscape has indicated noticeable proportional increase in arable land-forest edge type and decrease in arable land-meadow edge type. Probability calculations predict higher future changes for traditional landscape, but also for arable land turning into built area.

KEYWORDS: Aerial photos, Agricultural landscape, Change matrix, Landscape boundaries, LULCC, Markov’s probability, Rekijoki valley

TURUN YLIOPISTO
Matemaattis-luonnontieteellinen tiedekunta
Maantieteen ja geologian laitos

ROOSE, MEELI: PERINTEISEN JA NYKYPÄIVÄN MAATALOUSMAAN KÄYTÖN MUUTOSTEN ARVIOINTI PAIKKATIETOMENETELMIÄ HYÖDYNTÄEN.
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Suomen maatalousmaisema on muuttunut huomattavasti 1950-luvulta lähtien maatalouden kehityksen myötä. Maataloustoimintojen muutokset ovat vaikuttaneet erityisesti perinteisen maiseman hoitoon, ja muutokset maatalousmaan ja niittyjen maanpeiterakenteissa ovat olleet huomattavia. Aiemmat tutkimukset painottavat maatalousmaiseman rakenteen tärkeyttä lajien ja maiseman monimuotoisuuden kannalta. Tässä tutkimuksessa tähän lukeutuvat myös avo-ojat, pelto- ja niittylaikkujen koko sekä luonnonmukaisen ympäristön ja maatalousmaiseman välinen topologia.

Tässä maiseman muutostutkimuksessa sovelletaan kaukokartoitusmateriaalia kahdelta ajanjaksolta sekä paikkatietoanalyysejä. Retrospektiivisen tutkimuksen tavoite on havaita maatalousmaisemassa tapahtuneita maankäytön ja maanpeitteen muutoksia sekä pohtia maatalouden tehostumisen vaikutuksia maisemarakenteeseen maisemaekologian näkökulmasta.

Tietoa maankäytön ja maanpeitteen muutoksista on saatu esikäsitellyiltä ilmakuvilta useilla metodeilla, kuten tilastollisilla menetelmillä ja ilmakuvatulkinnalla. Tutkimuksen metodiset haasteet liittyivät maisemaluokitteluun sekä muutosanalyysien ja maisemaa kuvaavien indeksien yhdistämiseen. Erityistä huomiota on kohdistettu maatalousmaisemaelementtien havainnoimiseen pienellä mittakaavalla, mikä vaatii hyvää ymmärrystä maatalousekosysteemeistä. Maatalousmaiseman reunaelementtien tärkeyttä lajien elinympäristöinä on painotettu maatalousmaan ja laakson topologisia ominaisuuksia havainnoimalla. Muutosdynamiikkaa on esitetty muutosmatriisilla sekä laskemalla luokiteltujen maisemaelementtien lisääntymistä, vähenemistä, lokaation vaihtumista, nettomuutosta ja muutosnopeutta. Muutosmahdollisuutta on arvioitu Markovin todennäköisyysmallin avulla ja esitetty muutosmatriisilla. Muutosten spatiaalista näkökulmaa on puolestaan tuotu esille kartoilla, jotka kuvaavat maisemarakennetta sekä muutosten spatiaalisuutta.

Tutkimus osoittaa, että Rekijokilaakson maisemassa on tapahtunut merkittäviä muutoksia. Maatalousmaiseman muutos on merkittävästi vaikuttanut maiseman monimuotoisuuteen, kuten avo-ojien lukumäärän vähentyminen ja viljeltyjen peltoalojen keskimääräisen koon pienentyminen todistavat. Shannonin diversiteetti-indeksin pienentyminen kuvastaa maiseman monimuotoisuudessa tapahtunutta kokonaismuutosta. Niittymäinen maanpeitealue on pienentynyt lähes kolmanneksella metsittymisen seurauksena, minkä vuoksi perinteisen maankäytön alueena pidetty laaksomaisema on kokenut suuria muutoksia. Lisäksi huomattavia muutoksia on tapahtunut metsäisestä maanpeitteestä niityksi sekä viljelymaasta rakennetuksi alueeksi. Reuna-alueiden analysointi modernin ja perinteisen maiseman välillä on osoittanut viljelymaan ja metsän välisten reuna-alueiden huomattavaa suhteellista lisääntymistä, kun taas viljelymaan ja niittymaan väliset reuna-alueet ovat vähentyneet. Todennäköisyyslaskelmat ennustavat suuria perinteisen maiseman muutoksia, mutta myös viljelymaan muuttumista rakennetuksi alueeksi.

ASIASANAT: Kaukokartoitus, Maatalousmaisema, Muutosmatriisi, Maisemareunat, Maankäyttö, Maanpeite, Markovin todennäköisyys, Rekijokilaakso

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1 Introduction

Land use and land cover changes (LULCC) are constantly altered by natural forces and human activities. Driving causes of LULCC are interaction of society (i.e., cultural preferences, tourism), economy (i.e. demand for specific products, financial incentives), development programs (i.e. agricultural programs, development of infrastructure, forestry) and biophysical processes (i.e. environmental conditions, air pollution, water resources) (Calvo-Iglesias et al. 2006; Nikodemus et al. 2005; Skånes & Bunce 1997). Important factors are also temporal dynamics such as population growth or succession and the dynamics of evolutionary change (Pickett & Cadenasso 1995). To explain past patterns of landscape and forecast future patterns it is required to assess the driving forces behind LULCC. Scientific investigation of the causes and consequences of LULCC integrates both natural and social sciences (Barnsley et al. 2001; Fu et al. 2008).

Interest in landscape studies is encouraged by critical need to assess the impact of rapid, broad spatial scale changes in our surroundings (Turner et al. 2001: 1). The subject of terrestrial transformation detection has important role in many applications involving land: e.g. in assessing the rate of forestry, coastal change, urban sprawl, wildlife management and conservation, agricultural landscape change, and in modeling of natural hazards (Wijanarto 2006). Landscape ecological studies imply that spatial relationships are essential part of land-use planning, decision making of creation or protection of sustainable landscapes (Turner 1989). Comprehending the landscape change allows understanding the infrastructure and rural areas development – shaping of the surrounding regions (Tiitu 2011). The concepts and tools of landscape ecology have been increasingly integrated in biodiversity conservation and ecological restoration (Fu et al. 2008).

There is available noticeable amount of studies made about agricultural and rural landscape, and impact of the landscape change to social-economic systems and biological diversity. Management of the forest and agricultural systems, where diverse and complex semi-natural habitats are often replaced by virtual monoculture on the more intense level, emerges several aspects for agricultural landscape studies from ecological perspective (Skånes & Bunce 1997). Agricultural landscape structure has clear impact for species diversity, as loss of landscape heterogeneity is studied to be a key factor affecting species richness decline in Europe (Benton et al. 2003). Removal of the open drainage from the arable land causes landscape homogenization, as the number of landscape patches reduces and production area increases (Hietala-Koivu 1999, 2002, 2003; Hietala-Koivu et al. 2004; Hovi 2012; Marja et al. 2013). Habitat loss and fragmentation affecting landscapes connectivity and level of isolation, is considered to be primary issue of modern landscape changes (Wiens 1997; Hanski 1999; Bruun 2000; Luoto 2000; Krauss et al. 2003; Tiainen et al. 2004). The importance to preserve specific agricultural landscape elements such as open drainage has been noted (Marja et al. 2012). Landscape change studies surveying human-modified areas are commonly integrated with more ‘natural’ neighborhood. Rekijoki valley’s research of the effects of traditional land management has proposed the combination of low coverage of trees and continued grazing to be beneficial to local plant species richness (Pykälä 2003; Luoto et al. 2003a).

Great deal of attention has been given to wildlife-edge relationships. Kuussaari et al. (2007) survey applying boundaries classification, have highlighted the significance of semi-natural grasslands and open forest edges adjacency for species richness in farmland with relatively intensive agriculture. Researches concentrating on the agricultural land edge properties facilitate often GIS related analysis, like neighborhood-defined approaches of indices and functions (Roose et al. 2007). Many researches on field margin ecology have focused on different taxes, including pollinators (e.g. Lagerlöf et al. 1992; Meek et al. 2002; Kleijn & Verbeek 2002). Krauss et al. (2003) has paid attention on distinguishing specialist and generalist species, and determined that decreasing of the patch area significantly changes specialist species density (i.e. those which can thrive in narrow range of environmental condition, like some meadow species in traditional landscapes). Many surveys have concluded that day butterflies benefit from sufficient natural vegetation in the both intensive and extensive agricultural landscape, implying to the positive effects of natural patches in the managed landscapes for habitat diversity (Thomas & Hanski 1997; Pykälä 2007; Kivinen et al. 2008). Those possibly remnant vegetation patches are emphasized to be crucial in agri-environmental schemes to enhance biodiversity in an otherwise depleted agricultural landscape (Duelli & Obrist 2003). Habitat area is the most important predictor of butterflies' diversity – smaller habitat areas generally support fewer species (Grauss et al. 2003). Agrolandscape ecology must be evolved to develop and manage agriculture in a sustainable and cost-effective manner for future generations (Barrett 1992).

In the 19th century Finland's regions serving farming practices were perceived as three main areas: Western Finland with its field cultivation, Eastern Finland's slash and burn cultivation, and livestock production in Northern Finland. Pastures and arable land were made by clear-cutting, burning forests and flooding. The main livestock product was milk, meat and manure (i.e. fertilizer for arable land). Herd's winter food was cut from natural open areas, or from burn-beaten areas (Soininen 1974). Generally, agriculture in Finland may be divided into two main branches, arable farming and animal husbandry. The cow has been by far the most important farm animal in Finland (with climax in 1960s) and the horses were considered largely as working animals (Varjo 1977). Winter wheat and spring wheat have been typical crops of Southern Finland, where it has been the major source of bread cereal (Varjo 1977). Improved transport communication and export caused fell in market prices of grain products in the world markets and in the 1930's price of milk products increased rapidly. At the same time, the wood industry expanded in Finland and forest's value increased (Voutilainen et al. 2012). As financial profit from milk products was in rose, farm practices needed to increase hay making in order to feed livestock and produce more milk-products (Jutikkala 1958: 433).

The second period of land use intensification emerged in the middle of the 20th century as cultivation practice changed markedly: the nutrient scarcity was replaced by fertilization, high level acidity was eliminated with liming, moistness was balanced with drainage, and developing machinery and plant and animal breeding was introduced (Luoto 2003). The intensified agricultural practices resulted in overproduction of cereals and milk-products by the 1960's, which derived to field reservation system, leaving fields uncultivated and reforested. In the end of 1980's it was obligatory for every farmer to maintain part of the cultivated area as fallow land, which was enhancing the meadow and pasture habitats during 1991-1994 (Pitkänen & Tiainen 2000). Agricultural reform caused the abandonment of low input land uses, traditional agricultural land and the natural deforestation. By the 1980's Finnish agricultural practices mainly concentrated on the crop cultivation or livestock production. From the 1990's to 2005 it has been noted that the area of extensive agricultural land has increased mostly because of arable land abandonment and increase in fallow land.

Finnish rural environment has had some decline in biodiversity in past couple of decades (Tiainen et al. 2004). On the one hand, not-disturbed and non-plowed agricultural habitats contributing to the structurally diverse landscape has positive impact for several species. Though, it is noted that increase in such environments and fields transforming to forested areas, concludes to landscape homogenization and finally suffering of species diversity (Ihse 1995). Decline in intensive pasturing, due to overproduction of milk products, in 1960's caused decline in meadow and pasturing area's. The amount of ditches banks has decreased averagely all over the monitored area, mostly in the South-Finland (Hietala-Koivu 1999). Presence of ditches in agricultural landscape enhances species diversity as important elements for species dispersal and habitat. Since 1995, when Finland joined EU, the agro-environmental policy has centered on the agro-environment payments part-financed by the EU. Through the measure under this it has been possible to influence the relationship between agriculture and the environment. The main change was the production support to area subsidies and specific environmental protection schemes were granted (e.g. field margins buffer zones along waterways) (Luoto 2003; Pitkänen & Tiainen 2000; Hyvönen et al. 2010)

Finnish agriculture as a whole is regionally evenly dispersed. The reasons behind this can be found in historical, societal and political factors, and tight connections between agriculture and surrounding land and natural circumstances (Voutilainen et al. 2012). Agricultural landscape is significant part of Finnish nature, consisting approximately 2,3 million hectares of arable land (Statistics Finland 2011: 157-159). The role of agriculture varies a great deal between regions (Voutilainen et al. 2012). Cultivated land, as the natural-based source of livelihood in Finland is distributed based on the climatic and geographical factors (soil, light, nutrients, acidity): in coastal zone of 100 km fields form one third of the whole area, in inner land 10% of the whole region and in northern part of Finland under 5% of the whole territory (Tiainen et al. 2004; Varjo 1977). In southwest Finland there is almost 300 000 ha of arable land (Statistics Finland 2011: 157-159). The amount of farming practices has decreased almost half from 1990’s and significantly the average amount of land per one farm has risen from 17 ha to 37 ha. Today fields has subsurface drainage and only in few places, fields are traditionally drained with parallel ditches about 1m wide and situated 10-20m apart (Marja et al. 2013).

Geographic information systems (GIS) provide technological advance for ecologists, geographers and environmentalists for storing, analyzing and displaying spatially distributed data of remote sensed material in interdisciplinary investigations. The availability of remote imagery has made it possible to study spatial pattern over large areas and its change through time (Turner et al. 2001: 10). Additional tools like spatial statistics and global positioning systems are applied as complementary techniques (Farina 2007: 313). Remote sensing exists as an important observation and measurement tool for analysis of landscape ecological relationships and characteristics without disturbing the surrounding environment (Pelletier & Quattrochi 1991). Some of the important applications of remote sensing are environmental assessment and monitoring, global change detection, agriculture, nonrenewable and renewable natural resources, topographic mapping (Sabins 1996: 1; Schowengerdt 2007: 2). Using aerial photography and spatial analysis in retrospective studies is a precise and beneficial method of monitoring transitions of land-use and land-cover over a given period of time (Käyhkö & Skånes 2006; Käyhkö 2007; Käyhkö & Skånes 2008).

2 Aims of the study

This study aims to identify and analyze land use and land cover changes (LULCC) in in Rekijoki valley area’s rural landscape composed of local settlement and agricultural practices distributed over 200 hectares. Land use and land cover (LULC) is classified over the period of 1959 and 2005, in total 46 years. Monitoring procedure is executed with applying fine-scale spatial categorization on the patch level; measuring landscape pattern, LULC dynamics and assessing featured calculations.

Detailed aims of the research are the following:

1. allocation and general pattern of changes;
2. detects changes in edge character between arable land and valley area;
3. probability predictions for future changes.

It is assumed based on previous surveys that farming practices has reached to bigger extents, fields mean size has increased with overall growth in arable land - agricultural landscape is changing towards homogenization. Also, one expects to detect some evidence on restoration efforts in the valley area, as the region under question has received instructions for additional management, including mowing or deforesting the valley area. Because of this, important results for the thesis outcome is the assumption that the managed meadows area whether has expanded or overgrown.

3 Concepts

3.1 Agricultural landscape

There are many different interpretations of term landscape depending on the phenomenon under consideration. Most landscape ecologists consider landscape simply as a spatially heterogeneous area whose spatial extent varies depending on the organisms or processes of interest (Wiens & Milne 1989; Wu & Levin 1994; Pickett & Cadenasso 1995). For example, from a wildlife perspective, one might define landscape as an area of land containing a mosaic of habitat patches (Dunning et al. 1992). Definitions of landscapes include an area of land containing a mosaic of patches or landscape elements (McGarigal et al. 2002), which are the focus of the emerging discipline of landscape ecology (Forman & Gordon 1986: 11; Zonneveld & Forman 1990; Wiens et al. 1993). Landscapes are the mosaics where the mix of local ecosystems or land uses is repeated in similar form over a kilometers-wide area (Forman 1995: 13).

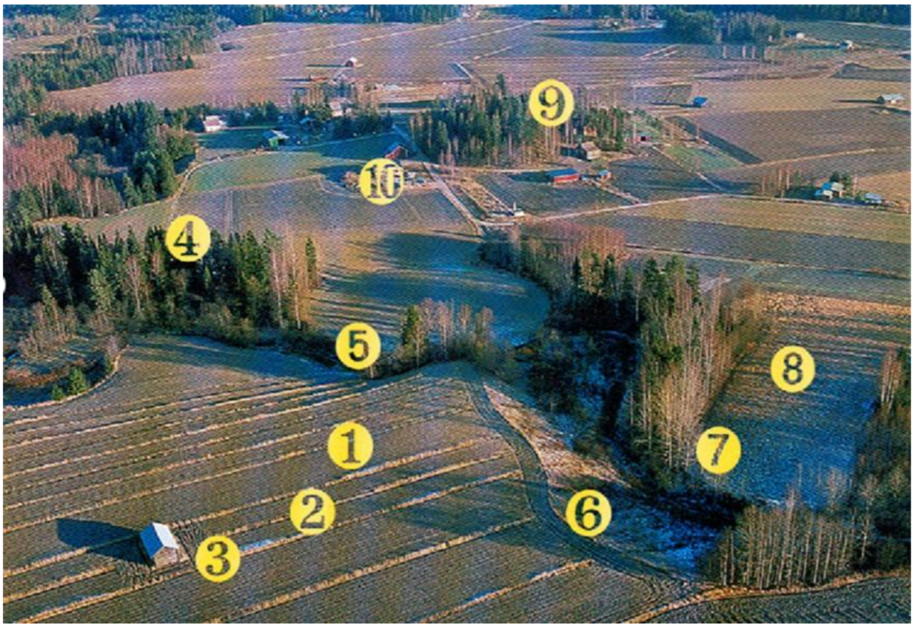

Figure 1. Agricultural landscape mosaic. Numbers from 1 to 10 refer to the different elements of rural landscape: 1) patch 2) open ditches 3) barns 4) remnant forest patch 5) corridors between two remnants 6) buffer zone 7) field edge 8) grassland 9) stony forested patch 10) farms area (photo: Tapio Heikkilä).

According to Forman (1995) landscapes are conceived as mosaics of three components: patches, corridors and a matrix. Patches are homogeneous, nonlinear area that differs from surrounding. Corridors are defined as strips of particular patch type differing from adjacent area and connecting patches. Agricultural landscapes consist of cultivated fields, field boundaries, semi-natural grasslands, built area, forest and stony islands in the fields (Luoto 2000; Tiainen et al. 2004). There is variety of elements that make up a agricultural landscape (Figure 1). The field patch is the smallest section of rural space and corresponds with a farming unit (Lepart & Debussche 1992). A farm as a conception, consist of area with main building and side buildings specialized to arable farming, machine-park and utilized agricultural area (at least one hectare) or livestock (Statistics Finland 2011: 268).

Agricultural landscape creates with forests, human settlement, rivers and lakes (watercourses) a rich landscape mosaic (Tiainen 2004; Luoto 2000; Urban et al. 1987). Landscape elements comprising ecological infrastructure (e.g. field margins, forest islands, wetlands) are important habitats for natural flora and fauna (Bengtssön-Lindsjö et al. 1991). The ecological functions of the small habitats have become an important issue for discussion among plant ecologist and zoologist. It is commonly believed that road verges and other linear structures function as corridors for dispersal of grassland plant species between natural habitats in the rural landscape. Field margins within arable cropping systems provide a potential method of improving farmland biodiversity by increasing the availability of semi-natural habitats. Field margins are considered as non-cropped strips of land at the edge of arable fields (Woodcock et al. 2005).

From the ecological perspective, agricultural environment is made of natural ecosystem, which humans have modified with agricultural activities. The position of agriculture from the ecological perspective may be based on the interrelationships between the different branches of agriculture and land use. Agriculture has traditionally been managed at the agroecosystem level and judged based on the crop yield. Olson & Francis, (1995) have defined agroecosystem as '*integrated social, economic, and ecological systems designed to provide specific commodities and services and having hierarchical structure with multiple spatial and temporal scales*'.

Agricultural management at the landscape level needs to be implemented based on the concepts of sustainability, hierarchy theory, and landscape diversity (Barrett 1992). The interactions among spatial elements, that is, the flows of energy, materials, and species among the component ecosystems form the function of landscapes (Forman & Gordon 1986: 11). Well-understood concepts about patch sizes, landscape connectivity, and edge effects must be complemented by considering ecological roles of the matrix and landscape ecology (Lindenmayer & Fischer 2006: 150).

Agricultural landscape changes

Land use change in the agricultural landscape is a complex phenomenon, and various types of change studies with markedly different outcomes could be identified. Change studies depend on the magnitude and abruptness of the change (Hobbs 2000). Agricultural land use involves the most dramatic and (mostly) irreversible transformations of land cover. According to Houghton (1991) seven broad types of agricultural land use change could be indentify: 1) conversion of natural ecosystems to croplands; 2) conversion of natural ecosystems for shifting cultivation; 3) conversion of natural ecosystems to pasture; 4) abandonment of cropland; 5) abandonment of pastures; 6) harvest of timber; 7) establishment of tree plantations. Arable land transformation processes occurring affects overall habitat connectivity, curvilinearity, circuitry, continuity, width and functions of the boundaries (Luoto 2000). Different aspects of spatial pattern in the landscape may be important for processes such as the movement patterns of organisms, the redistribution of nutrients, or the spread of natural disturbance (Turner et al. 2001: 95).

Agriculture broadly defined to include farming, fishing, grazing, and forestry plays a significant role in the management of land, water, and biological resources. Biodiversity has complex part in agricultural environment because agriculture is influenced tightly by natural impacts. It is obvious that potential effects of land use on biodiversity are most apparent in agricultural landscape. Development in agricultural production drives land-use changes, and thus controls the capacity of landscapes to preserve biodiversity. According to Skånes (1996) negative consequences follow when changes in land use reduce the amount and connectedness of natural areas. In a managed landscape, semi-natural habitat, such as field margins, hedgerows, ponds, represent important areas for many species (Duelli & Obrist 2003). The most plant species rich habitats in agricultural landscape have been found on the margins of field and forest, as well field and road verges (Kuussaari & Heliölä 2004). Disappearance of certain landscape elements led to the formation of residual small biotopes, such as road verges and ditch banks (Skånes 1980). Habitat loss and fragmentation arguably pose the greatest threats to biological diversity (Swihart & Moore 2006).

The decline of species associated with arable farmland has been well documented. Changes in landscape structure have been shown to have a clear impact on the biodiversity of invertebrates (Sepp et al. 2004; Schneider & Fry 2005), birds (Gregory et al. 2004). In a changing landscape where land abandonment occurs, the spatial distribution of species is dependent on their biological characteristics and the pattern of land use. Plants, carbides and spiders are used as biological types to exemplify the consequences of abandonment in a grassland area (Burel & Baudry 1995). The species composition and abundance is determined by landscape structure (Sepp et al. 2007). Maintaining semi-natural habitats is key for preserving plant species richness and persistence of rare plants in agricultural landscapes (Baker 1989; Hansson & Fogelfors 2000; Duelli & Obrist 2003; Pykälä 2003; Luoto 2004). Compared to poor ecosystem, diverse ecosystem is more balanced and can withstand disturbances, like insects invasion (Pitkänen & Tiainen 2000).

3.2 Heterogeneity

Simplest approach to convey spatial patterns is to ignore spatial variation and treat space as homogeneous (Wiens et al. 1995) (Figure 2). Accordingly, there are two ways to introduce spatial complexity: patch-matrix and mosaic. Spatial heterogeneity occurs in mosaics, where objects are aggregated, and forming distinct boundaries. A land mosaic may contain only patches, or may also contain corridors (Forman & Moore 1992; Forman 1995: 4).

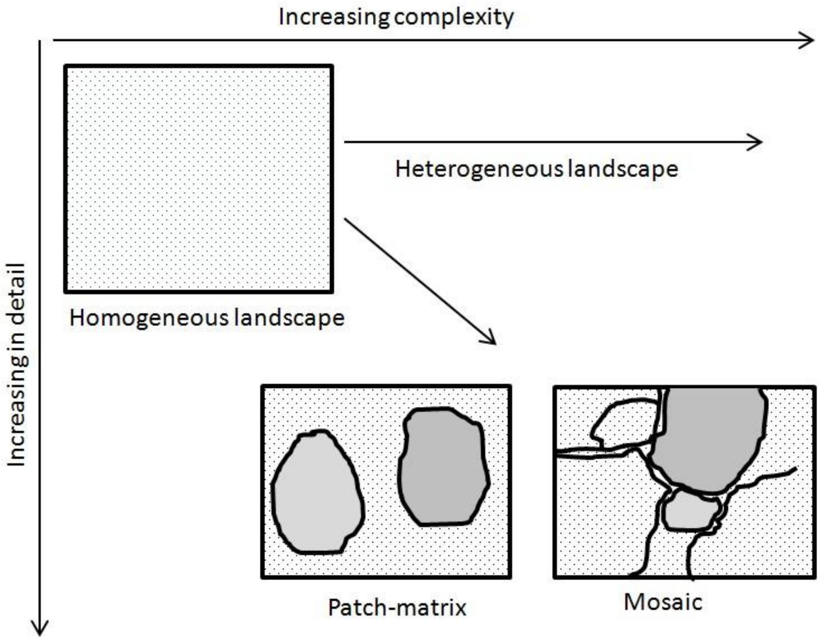

Figure 2. Spatial pattern in landscape ecological theory. Homogeneous landscape is changing to more heterogeneous as complexity raises. As features are added to the landscape one could discuss about ‘patch-matrix’ and ‘mosaic’ entities. Adapted from Wiens et al. 1995.

Spatial heterogeneity is termed as tendency of geographic places and regions to be different from each other (Longley et al. 2011: 101). Landscape is always spatially heterogeneous (an uneven, non-random distribution of objects), that is always has structure (Forman 1989: 173). Landscape heterogeneity is related to the extent to which a landscape viewed from the air is characterized by a diversity of environmental gradients or patch types. Diversity is central to holistic and cultural landscape studies (Antrop 2005). In heterogeneous landscape, structural complexity is high, when different vegetation types occur side by side offering different types of niches that can be used by different organisms; therefore supporting more species

(Lindenmayer & Fischer 2006: 146). Spatial heterogeneity has an important influence on a wide range of ecological patterns and processes (Schindler et al. 2007). Improving heterogeneity within and between arable land patches is recommended as key step towards ecological restoration. Fragment heterogeneity is also important part of habitats spatial characteristics. Greater microclimatic and vegetation variation in the more heterogeneous habitats allows individuals persist under severe weather conditions (Kindvall 1996). Spatial data exhibit an increasing range of values, hence increased heterogeneity, with increased distance (Longley et al. 2011: 101). Landscapes are heterogeneous because of interactions among the landscape elements. In agricultural landscapes the landscape elements such as pastures, cultivated fields, barns, ditches, vary markedly in structure from one another, resulting in a high degree of landscape heterogeneity (Zonneveld & Forman 1990). Different habitat types available in the heterogeneous landscape enhance species persistence to survive (Lindenmayer & Fischer 2006: 30).

3.3 Landscape fragmentation

An integrated view of the spatial characteristics of habitat fragments and their ecological consequences improves our ability to predict the outcomes of land conversion. In ecology, island biogeography theory and metapopulations dynamics support studies of habitat fragmentation (Collinge 1996). Ecological researches have commonly noted interpretation that the probability of local extinction increases as fragment size decreases, that is species richness declines as fragment area decreases (Collinge 1996). Landscape fragmentation is associated with three main ecosystems threats: loss of habitat, reduced habitat patch size, and increased isolation among habitat patches (Zeng & Wu 2005), which is why landscape fragmentation is considered to be Earth’s natural ecosystems main danger (Wilcove et al. 1986).

3.4 Connectivity

Connectivity refers to the degree to which patches of a given natural habitat are joined by corridors into a network of linkages. This affects the ease with which species can move among vegetation patches in the landscape (Botequilha Leitão et al. 2006: 12). Landscape connectivity may be defined as a degree of a landscape to facilitate or obstruct the exchange of matter (organisms, energy, material, information) among landscape elements. (Wu 2013). There are several types of features that contribute to landscape connectivity. Linear landscape elements such as ditch banks can act as ecological corridors (allowing species movement) when they connect fragmented areas – habitat patches – to each other (Dennis & Fry 1992; Forman & Gordon 1986: 131). Attributes of the corridors (width, length, location in the landscape) are influencing the use of such corridors by wildlife (Lindenmayer & Fischer 2006: 128). The line corridor species are highly affected by adjacent matrix characteristics, such as human activities, or wind and soil present (Forman & Gordon 1986: 132).

Connectivity is as a measurement of how connected or spatially continuous a corridor, network, or matrix is (Forman & Gordon 1986: 591). Those two concepts refer to the structural connectivity (e.g. the fewer gaps, the higher the connectivity). Functional or behavioral connectivity therefore are considering how connected an area is for a process, like an animal moving through different types of landscape elements (Forman 1995: 38). Ecological studies of habitat fragmentation term the ‘corridor’ generally as linear landscape element composed of native vegetation which links patches of similar, native vegetation (Collinge 1996). Connectivity can be categorized in three different types: habitat connectivity, landscape connectivity, and ecological connectivity. Habitat connectivity is concentrated more on species, connectedness between patches of suitable habitat. Human perspective is perceived when one discusses about landscape connectivity – connectedness of landscape patterns of vegetation cover in the landscape. It is important to emphasize, some species perceive the landscape connectivity being low and other taxas connectivity being favorable. Higher levels of landscape connectivity as perceived by humans will not always directly correspond to higher levels of habitat connectivity for a given individual species (Lindenmayer & Fischer 2006: 121-124). Quantifying physical connections linking vegetation patches, sizes and shapes of the patches assists connectivity researches (Schtickzelle & Baguette 2003). Lack of landscape connectivity can have negative impacts on assemblages: unoccupied vegetation patches (i.e., by pollinators, birds, plants). When landscape (matrix) provides connectivity, extinction risks because of foraging problems decrease (Laurance 1991).

Corridors may also provide shelter, reduce water and wind erosion and enhance the aesthetic appeal of a landscape. Linear elements, like those for surface water movement (i.e. ditches in the agricultural landscape), have a concentration of weedy generalist species in a narrow area, and serve as a major filter to movement between adjacent patches, thus minimizing unwanted movements across large patches (Forman 1995: 439).

3.5 Edge

Wherever two or more different habitat types abrupt, they form an edge, or ecotone (Sisk 2007: 152). Matlack (1993) has described the edge of a vegetation patch as a marginal zone of altered microclimatic and ecological conditions that contrasts with its interior. As most commonly perceived, ecotone is a ‘tension’ between two adjacent habitats and is generally considered as change in vegetation structure. Edges could be classified according by their origin – natural or human-derived (Luck et al. 1999). Some ecotones are created by disturbance (e.g. fire, human activities) and others occur as edaphic boundaries (e.g. soils, hydrology, and climate) (Johnston et al. 1992). Agricultural landscapes often exhibit abrupt changes in land cover, i.e. sharp edges between areas serving as potential habitat for wildlife. Natural habitats are sensitive to influences from surrounding cultivated areas, such as fertilizer runoff and invasion of agricultural weeds. This is especially an issue for small fragments, where much of the fragment is exposed to edge-effects. Edge-based landscape metrics are effective measures of landscape fragmentation capturing important aspects of landscape fragmentation (Zeng & Wu 2005).

An edge could be characterized considering spatial relationships with surrounding landscape (Forman 1995: 86). An edge, border and boundary can have different meanings and functions, however considered spatially adjacent (Figure 3).

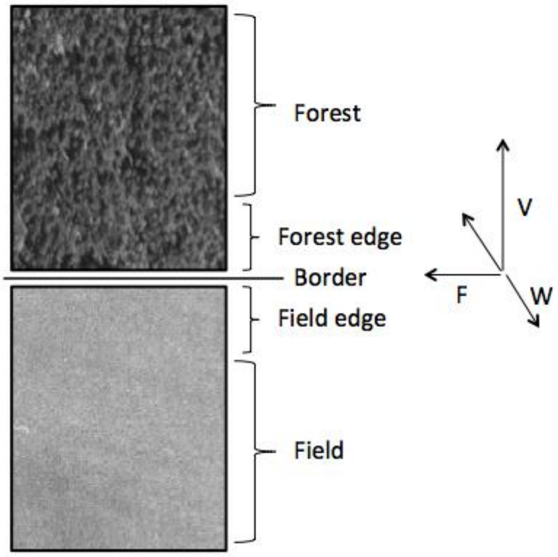

Figure 3. Spatial relationships of boundary, border, and edges in the forest-field edge structure. The boundary zone incudes edges on both sides of borderline. Width (W), verticality (V), and from (F) are measureable parameters characterizing the boundary (adapted from Forman & Moore 1992; Forman 1995: 86).

Edge effects exist where transformed areas are adjacent to natural areas. Lindenmayer & Fischer (2007: 168-169) have classified edge effects broadly to biotic and abiotic processes. Abiotic edge effects are microclimatic, such as increased temperature or light, or humidity changes, altered fire ignition, and wind pronounce. Biotic factors affect ecological communities through boundary, like diseases, weeds and predators, altered levels of insect activity, altered invertebrate community composition, and lowered rates of fledging success among birds. Forest edges typically contain more shade-intolerant species than the interior (Ranney et al. 1981). More weedy vegetation at the edge attracts generalized animals. In managed landscapes, changes in the size and spatial configuration of remnant forest patches may have important ramifications for species that utilize these patches (Burgess and Sharpe 1981). High-contrast (‘hard’) edges, such as those between forests and grasslands, leads to more to more intense interactions, than low-contrast (‘soft’) edges, such as those between different grasslands (Yahner et al. 1989).

Edge effect is related to the matrix and other landscape units. The negative effects of edges on biodiversity have become well recognized (Murcia 1995). Edge-sensitivity species are among those at particular risk in heavily modified landscapes (Lehtinen et al. 2003). Several species lives on the border zone of arable land and forest, and through this, field’s impact may reach deep in the forest (Tiainen et al. 2004). Elevated nest predation is often observed in agricultural landscape where there is high-contrast with surrounding landscape (Andrén 1992). Important landscape features correlating with the distribution of bumblebee species have been found in the length of ecotones between agricultural land and different forest types (Roose et al. 2007).

The shape of vegetation patches and distance from the edge follows form and function principle. The rounded from, with a minimal perimeter-to-area-ratio, is important in conservation biology. In contrast, a convoluted boundary with a high perimeter-to-area ratio is characteristics for systems with considerable interchanges of energy, meaterials, or organisms with the surroundings (Forman & Gordon 1986: 177). Changes induced by habitat edges markedly influence the ecological processes in the patches. Linear patches are more prone to effect than elliptical or circular ones (Reading et al. 1996). Geometric shape of a discrete habitat fragment influences the extent to which edge effects permeate the habitat interior. Shape can be described most simply by calculation of the perimeter/area ratio for habitat fragment. Human activity tends to linearize boundaries between habitats and simplify the complex shapes of habitat fragments (O’Neill et al. 1988).

3.6 Traditional rural biotopes

Traditional rural biotopes are areas which have been created by traditional livestock farming. These biotopes are used to be mowed and grazed, but occasionally also cleared, burned or flooded (Alanen & Pykälä 2004: 192). Traditional rural biotopes include various types of meadowland, moorland, wooded pastures, and areas of woodland cleared for shifting cultivation (Heikkilä 2011). Society has learned to appreciate the traditional biotopes in last decades, although disappearing of them has been known for long (Haeggström et al. 1995: 107-109). In 2005-2006 there was only 45 % (1548 ha) of the significant biotope areas managed in southwest Finland. Construction and eutrophication have also had a part in accelerating the disappearance of traditional rural biotopes (Alanen & Pykälä, 2004: 198-202; 209).

3.7 Change detection

There are many reviews of change detection methods and remote sensing technology for mapping and monitoring of LULCC available and each one has variations depending on the imagery type, final purpose, and the type of change to be discovered. There is a spectrum of ways to consider landscape change, ranging from simple and readily interpretable, to more complicated and less interpretable. Different change detection procedures have their own merits and no single approach is optimal and applicable to all cases (Lu et al. 2004). Temporal change detection task is to compare minimum of two time sets of imagery to identify changes. The results of a comparison can be, for example, polygon, line or point features of LULC, representing size, shape and spatial position, occurring in the temporal horizons in question (Feranec et al. 2007). Land cover change detection recognizes two forms: 1) conversion from one land cover category to another (e.g. from forest to arable land) and 2) modification within one category (e.g. from deciduous forest to conifer forest). These two forms of change have implications for the methodology used to describe and classify land cover. According to Coppin et al. (2004) several approaches have been developed for digital change detection identification by remote sensing data application: bi-temporal change detection methodologies (same area at two points in time) and multi-temporal (several time intervals with multiple imagery) trend analysis.

Landscape ecology in not only concerned of the question that how much there is particular component in the landscape, but also how it is arranged and how the pattern has changed (Turner et al. 2001: 4). In landscape changes research, finding out whether the terrain’s pattern is different at time t + 1 than it was at time t, is one of the main purposes. Generally said, change is alteration in the structure and function of ecological mosaic over time (Forman & Gordon 1986: 11).

3.8 Transition matrix

LULC datasets may be compared between time periods using geographic information systems (GIS) to map and measure LULCC in variety of scales. The advantage of GIS techniques is ability to manage different LC maps by means vectorial operations like ”intersect” and “union”, in order to easily evaluate the amount of change (Petit & Lambin 2001). The most common method of examining change is to overlay maps representing the spatial distribution of a variable of interest at two different time periods. This technique is widely used within both the raster GIS environment (Lo & Shipman 1990) and the vector GIS environment (Ahern et al. 1990). The overlay method is also used to construct change maps, which are easy to interpret visually (Schlagel & Newton 1996). One way to summarize landscape change is to count the landscape, on a category-by-category basis, in which a polygon consists of changed cover types if certain time interval. A concise way of summarizing these tallies the so-called change matrix, where for N cover types is an NxN matrix. When calculating change, an image *changes from* one land cover type and *changes to* another. This matrix reflects the size of the images and changes from type *i* to type *j* over time interval (Fichera et al. 2011). In addition, the matrix can be used to identify changes that are unlikely to occur (e.g. urban area changing to a forest).

Scientists can analyze transition matrix at several levels. To monitor total change in landscape it is useful to observe two pairs of components: net change and swap, as well as gross gain and gross losses. The diagonal numbers of matrix indicate the persistence of a category. The persistence is used to compute gross gain and gross loss, which show the change quantity, respectively. At the most general level of information, the *total row* in change matrix lists the quantity of each category at time 2 and the *total column* lists the quantity of each category at time 1. The difference between the two is termed *net change*. A lack of net change does not automatically indicate a lack of change on the landscape. Change can occur in such way that the location of a category changes, while the quantity of category remains the same. This type of change consisting allocation is termed *swap*. Mostly, only quantity of the net change is documented, which makes it important to account for swap in analysis (Pontius 2004).

Land use change from one period to another is a basis to project future changes. Method for modelling landscape changes is first-order Markov chain. The method is based on probability that a given piece of land will change from one exclusive state to another (Aavikson 1995). The future state of a system can be modeled on a basis of the immediately preceding state, by developing a transition probability matrix of land use change per category from time 1 to time 2. Markov chains are adaptable to many applications; hence they are centrally important to theoretical probability (Reddy et al. 2009).

4 Methodological framework

The human landscape is most common scale of research activities and the study of landscape change is an important component of landscape ecology. This study is based on the principles of the landscape ecological science and wears theories and models originated from this framework.

4.1 Landscape ecological theories and models

Many disciplines have contributed to the development of landscape ecology in the past few decades (Turner 1989; Wu & Hobbs 2007: 3; Fu et al. 2008). Contemporary landscape ecology is interdisciplinary science, hence relationship between organisms and their environment involves a myriad of biology, physiochemical, and geospatial process (Wu & Hobbs 2007: 271; Fu et al. 2008). Ecological concepts, theories, and methods come from a number of different branches of practices, including botany, zoology, evolutionary biology, genetics, physiology, soil science, physics, chemistry, geography, meteorology, climatology and remote sensing (Wu & Hobbs 2007: 280). Landscape ecologists represent a diversity of disciplinary backgrounds and landscape ecology gathers people who are interested in landscapes from different aspects – e.g. from the hard-core spatial ecology to the landscape history, aesthetics, and design.

In landscape ecology, three landscape characteristics, structure, function, and change are considered (Turner 1989; Zonneveld & Forman 1990; Forman 1995: 5, Botequilha Leitão & Ahern 2002). Landscape ecology studies both, the fundamental ideas concerning those characteristics, and their application, that is, the use of these principles in the formulation and solving the present matters (Forman & Gordon 1986: 11).

Ecology is generally defined as the study of the interactions among organisms and their environments (Forman 1995: 19). In the subject as a whole, landscape ecology can be seen primarily as a means of dealing with spatial patterning and heterogeneity and building this on the foundation of ecosystem, community and population ecology

(Turner et al. 2001: 2; Risser et al. 1984; Urban et al. 1987; Wiens et al. 1993; Pickett & Cadenasso 1995). Landscape ecology is perceived as scientific underpinning for spatial planning and management of landscapes, particularly in human-dominated settings (Turner 1989). Today, the most widely used definition of landscape ecology is simply the study of landscapes, explicitly focused on the relationship between spatial pattern and ecological processes on the hand and nature-society interactions on the other hand over a range of scales (Pickett & Cadenasso 1995; Turner et al. 2001: 2; Turner 2005; Wu & Hobbs 2007: 281). Socioeconomic factors, such as prices of agricultural or forestry products, are increasingly considered in contemporary landscape ecology that emphasizes the driving mechanisms and environmental impacts of landscape change (Turner & Gardner 1991: 10; Fu et al. 2008). Landscape ecology provides much of value for those wishing to conserve or manage the planet and its inhabitants.

GIS have contributed to emerge of landscape ecology (Turner et al. 2001: 9). Remote sensing techniques are often used in inventory and mapping of natural capital, quantification of environmental characteristics, describing the flow of matter and energy in the ecosystem, and evaluating change and optional solutions for ecosystems management (Johnson 1969: 220).

Theories simplify a complex reality so that one can achieve some understanding and make reliable predictions. Most ecological theories incorporate assumption about cause and effect. When pattern observed in nature matches that contained in a theory, one can then look in the theory to have explanation for the observed pattern. Landscape ecology, as any other science, searches for solutions using theories that contribute to generating questions. Two landscape ecological theories that are emphasized through recent study are hierarchy theory and percolation theory:

Hierarchy theory

Spatial patterns and functional processes vary with level of scale, which enhances the understanding of the landscape ecology by combining empirical studies at different levels with the concepts of hierarchy theory (Allen and Starr 1982). When landscape's spatial heterogeneity is considered, the explicit treatment of scale becomes necessary and hierarchies emerge (Wu 2013). Landscape ecology is the science of studying and improving the relationship between spatial pattern and ecological processes on a multitude of scales and organizational levels. Natural systems are difficult subjects under research and they can be handled if they show particular kind of ordering (Atlan 1974). A landscape as a hierarchical concept is an operational system with each level containing levels below it. An important development of hierarchy theory has considered extrapolating information upscale (O'Neill 1995). This means, that the dynamics of the higher level cannot be represented by the same functional form as its components. The elements of hierarchical landscape are linked together with flows (e.g., movement of animals, gaps in forest stands, regional processes controlling local species richness), which are associated with the three main hierarchical linkages: (1) encompassing element at the next higher level, (2) close elements at the same scale, and (3) component elements at the lower level (Forman 1995: 9).

Complexity is a fundamental part of the hierarchy concept. The more components that are included in a system, the more complex the system becomes. Hierarchy theory refers, how a system of discrete functional units linked at two or more scales, operates. Also it useful because it requires explicit characterization of scaled relationships that exist between pattern of interest and ecological determinants of the pattern (Farina 2007: 64; O'Neill et al. 1986: 4). The hierarchy theory considers a system as a component of the larger system, which in turn, is composed of subsystems. In recent study landscape classification is one example of a hierarchical framework.

Percolation theory

Originally percolation theory was formulated to study the behavior of fluid spreading randomly through a medium and the subject has been intensively studied in the field of physics. In percolation concept, the effects of structural features of landscapes (e.g. boundaries, corridors) are mediated by movement (Wiens 1995). Percolation theory has been applied in the research of landscape boundaries (Gardner et al. 1992). The principal advantage of percolation theory is that it provides universal laws which determine geometrical and physical properties of a system (Berkowitz & Balberg 1992). Percolation theory deals with spatial patterns in randomly assembled systems, like clusters in the square lattice (Stauffer & Aharony 1992: 1-2).

The application of percolation theory to landscape studies has addressed a series of questions dealing with the size, shape, and connectivity of habitats as a function of the percentage of a landscape occupied by that habitat type. In the studies of landscape contagion effects, disturbances, forest fires, and pest outbreaks can be employed in view of percolation theory (Turner 1987). Percolation theory offers important insight into the nature of connectivity (or its inverse fragmentation) on landscapes (Gardner et al. 1992; Fonseca et al., 1996; Milne et al., 1996). A percolation model is a collection of points distributed in space, certain pairs of which are said to be adjacent or linked. Two basic types of percolation mechanism are conferred site percolation and bond percolation (Essam 1980). Site percolation involves a probability, that any site is open independently of the other sites, whereas bond percolation deals with paths, which connect certain pairs of sites (Turner et al. 2001: 18-19). Percolation theory has been used in assessing habitat fragmentation effects and the use of corridors as management tools (Wiens 1995). Percolation models describe the probability that an organism will move across a landscape composed of integrated elements as a function of relative proportions enhancing or restricting movement. In landscape ecology percolation theory is applied for example in preparing neutral models (Gardner et al. 1987). In this study percolation theory is considered in assessing the landscape connectivity questions and in orientating in the character of the forest-field boundary.

Landscape models

A landscape model can be defined as a conceptual tool that provides terminology and a visual representation that can be used to study how organisms are distributed through space (Lindenmayer & Fischer 2007: 36). Models provide a variety of valuable purposes in the researches, helping to identify problems and concepts more precisely and clearly, and to make predictions. However models should be regarded as methods to achieve a conclusion and should not be considered as goal unto themselves (Turner et al. 2001: 48-49). Models may be classified and described in various ways: deterministic or stochastic; dynamic or static; continuous or discrete time; mechanistic, process-based, or empirical models (Turner et al. 2001: 67). A model is spatial when the variables, inputs, or processes have precise spatial locations. A spatial model is needed when explicit position – what is present and how it is arranged – is an important determinant of the process being studied (Baker 1989). According to Turner et al. (2001: 54) spatial models are important in following conditions: spatial patterns being as independent variables in the analysis; predicting spatial variation and change of an attribute of interest through time; question involves sets of processes of biotic interactions that generate pattern.

Baker (1989) has categorized models of landscape changes as whole landscape model, distributional landscape model, or spatial landscape model, depending on the amount of detail included in the models. Forman (1995) has listed several spatial modeling types related to landscape pattern on the basis of techniques used. Some of the corresponding model's ideas regarded in the basis of this study are as follows: neighborhood models, network models, patch and corridor simulation models, patch dynamic models, economic land-use models.

Relationships between landscape pattern and measures of species occurrence can be captured by pattern-based landscape models. Common goal of such models is to reduce the complexity created by analyzing single species (Lindenmayer & Fischer 2006: 35). According to Lindenmayer & Fischer (2006: 31-34) three landscape models are used particularly frequently: island model; patch-matrix-corridor model; variegation model. The islands model conceptualizes landscapes as fragments of habitat patches surrounded by cleared landscape – analogous to oceanic islands in a sea (Haila 2002: 31). In such model, islands (patches) can be defined for all species, boundaries of the islands are distinguished and conditions on the islands are relatively homogeneous. There are several other theories developed from islands theory, such as wildlife corridors, nested subset and notion of vegetation coverage thresholds. Matrix is the dominant and most extensive part of the landscape with major control over landscape dynamics. Patch-matrix-corridor model is an extension of the island model. The matrix is important, because it provides habitat, landscape connectivity and native vegetation (Lindenmayer & Fischer 2006: 149). As previously described model has some simplifying assumptions for example not taking into account spatial continua of the landscape (edge effects), then variegation model is used (McIntyre & Barrett 2003). Variegation model takes into account small habitat elements, which might otherwise be classified as unsuitable habitat patches. It is used, when boundaries between patch types are diffused and differentiating them from the background matrix is not straightforward (Lindenmayer & Fischer 2006: 35). Elements of structural complexity that are particularly important to many species may be defined as “keystone structures”. These elements can be scattered trees, shrubs, wetlands, old logs, wetlands or many other (Tews et al. 2004).

There is a broad spectrum of approaches implementing models of landscape patterns and processes, and linking these models to GIS data is common. Models are necessary for landscape studies for several reasons: experimental manipulation of large landscapes often cannot be performed at the appropriate scale; experiments are expensive and logistically difficult, because of high cost and logistical difficulty involved (Turner 1989; Turner et al. 2001: 49). In landscape models, it is necessary to have a suite of models of different levels of complexity, and to understand the consequences of suppressing or incorporating detail (Levis 1992: 1960).

4.2 Landscape indices

Prerequisite to the study of landscape change are metrics - measurements designed to quantify and capture aspects of landscape pattern (Griffith et al. 2000; McGarigal et al. 2002). Analysis of landscape pattern and structure can consider a large number of metrics and the use depends on the interest of research (Haines-Young & Chopping 1996; Farina 2007: 315). The majority of researches use landscape metrics in biodiversity and habitat analysis. There are also many studies focused on relationship of landscape metrics with the evaluation of landscape pattern and changes therein (Uuemaa et al. 2009).

Landscape metrics attempt to capture three groups of phenomena: landscape configuration, composition and connectivity (Figure 4). Landscape composition refers to features related to the presence or amount of land cover types. Landscape configuration and connectivity refers to the spatial distribution of those land cover types and includes measures of the placement of cover types relative to one another, and measures of shapes (McGarigal et al. 2002). All metrics are effective in quantifying a certain component of spatial patterns: "patchiness", size, shape, composition, juxtaposition, and arrangement of landscape units (Peng et al. 2010; Lindenmayer & Fischer 2006: 189-190; Lausch & Herzog 2002).

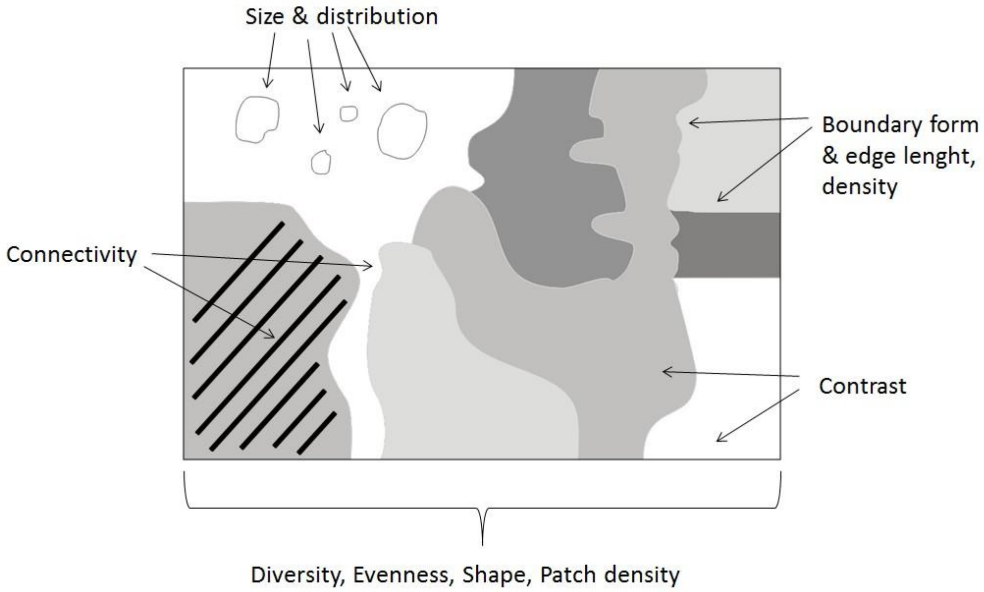

Figure 4. Landscape mosaic containing measurable parameters. Diversity, evenness, shape and patch density are parameters referring to whole landscape, whereas spatial configuration within the mosaic is determined with connectivity, size and distribution, boundary's properties and contrast (adapted from Wiens 1995).

According to recent study following metrics according to the landscape pattern measured were chosen: area/density/edge metrics, shape metrics, and diversity metrics. Within each of these groups, FRAGSTATS provides spatial statistics and metrics at the patch, class and landscape levels (McGarigal et al. 2002).

Landscape-level metrics are useful for an initial overall analysis, class-level metrics for a more in-depth analysis, and patch-level metrics for further detailed studies (Botequilha Leitão et al. 2006: 207).

According to Li & Reynolds (1994) spatial heterogeneity can be classified into five main components: (1) number of patch types; (2) proportion of each patch type; (3) spatial arrangement of patches; (4) patch shape; and (5) contrast between neighboring patches. Landscape metrics could be used for several monitoring purposes, including monitoring landscape structure and ecological functions. Consequently, landscape metrics are best understood as comparative measures of landscape condition. As each landscape metric provide only partial description of landscape pattern, it is efficient to use several metrics in combination to provide a more complete understanding of the pattern-process relationships under consideration. Particular attention should be given to the appropriateness of the map classification scheme, the scale of the landscape, and the digital data model (vector or raster) (Botequilha Leitão et al. 2006: 207).

Metrics should be used critically, being aware of their applicability and inherent limitations: they are most useful when they are properly framed by theoretical principles (Wiens 1999). Many landscape indices are highly correlated; they quantify a similar or identical aspect of landscape structure. For example, at the landscape level *patch density* (PD) and *mean patch size* (MPS) will be perfectly correlated because they represent the same information. Metrics are also scale dependent, making it difficult to compare results from different landscapes. Interpreting the results needs several knowledge of the landscape ecology, as the results do not necessarily link to land management prescriptions (Lindenmayer & Fischer 2006).

4.3 Issue of scale

Scale is level of spatial resolution perceived or considered. The perceived pattern of a landscape is influenced by the scale at which the landscape is represented. Understanding the range and sensibility of variability in landscape due to changes in scale and criticism to the appropriate use of landscape is important, as it has serious implications for the analysis and interpretation of landscape metrics (Gergel & Turner 2002: 101).

There is no single natural scale at which ecological phenomena should be studied; systems generally show characteristic variability on a range of spatial, temporal, and organizational scales (Levin 1992: 1943). Scale is important in several aspects of landscape ecology, from factors affecting individual organisms to continental plate tectonics and the evolution of floras and faunas (Turner et al. 2001: 8; Forman & Gordon 1986: 16). Irrespective of the landscape concept used, there are two major approaches to landscape ecology, reflecting differences in scale. The most common approach is the elucidation of the interactions among adjacent elements: *fine-scale* mechanisms. Fine scale refers to the pattern of a small area, where the differences between maps sizes and actual sizes are relatively low. The second approach focuses on the coarse-scale dynamics and behaviors of the elements as a whole. *Coarse scale* or *broad scale* refers to the pattern of a large area, where the differences between the map area and actual size is great. For example the use of satellite data enables change detection to be done over broad spatial scales.

New technologies and research techniques, such as geographic information systems and electronic databases focusing on spatial patterning and dynamics, integrate these approaches (Pickett & Cadenasso 1995; Forman 1995: 9). For example, plot experiment and laboratorial works are appropriate at fine scales, but broad scale studies (e.g. hurricanes, volcanic eruptions, earthquakes) are more proper in computer environment, where replication is possible. Insights gained at one scale could not necessarily be translated directly to another scale, hence attention should be focused directly on the scale at which a phenomenon of interest occurs (Turner et al. 2001: 9). Since spatial scales are important, temporal scales inevitably are, too. Spatial scale is closely related to temporal scale for a particular phenomenon i. e.: at the microscale, (natural and human disturbances affecting the species), or at the macroscale, (regional climatic changes affecting displacement of ecosystems). Hence the landscape, with its heterogeneity and causative mechanisms, would be a single distinct recognizable level of spatial scale (Forman & Gordon, 1986: 16-17).

The image interpretation element texture has important function of scale. For example, in a large-scale aerial photograph (e.g. 1:500, it is able to distinguish between branches in the canopy of a stand of trees and describe it as coarse texture. When, the scale becomes smaller (e.g. 1: 5000), the tree crowns might coalesce and the texture becomes smoother (Jensen 2007: 137). Current studies analyses are based on fine-scale, supporting relatively detailed image interpretation.

4.4 Land use/land cover classification

The quantification of landscape pattern is useful for understanding the effect of pattern on ecological processes; and for documenting either temporal changes in a landscape or differences between two or more landscapes. Landscape patterns may be represented by categorical maps, where homogeneous patches exhibit relatively abrupt transition to adjacent areas (Gustafson 1998). In the studies on landscape patterns, the primary data mainly come from categorized maps, like vegetation, soil, and land use/land cover maps. There are specific challenges of using aerial photography, especially with respect to manual aerial photograph interpretation (Morgan et al. 2010).

Classification as an approach carried out for studying the interaction between human activity and the landscape is a crucial task because how a landscape is defined, characterized and classified can have significant effect on a wide range of land management decision and to the outcomes of the study (Lindenmayer & Hobbs 2007: 49; Farina 2007: 10). It is important to note that classification is an abstraction as it depicts a representation of the reality (di Gregorio & Jansen 2000b). Classification represents a relevant procedure in the study of the land mosaic, especially from the human perspective (Farina 2007: 10). Classification of landscape data is required for most spatial metrics to perform landscape pattern analyses (Turner et al. 2001: 133). It is relevant to interpret landscape patterns as precise as possible to avoid misclassification that causes errors in results of metrics calculations (Langford et al. 2006). The map must be classified in a manner appropriate to the application or the metrics will have little meaning (Botequilha Leitão et al. 2006: 56)

The important characteristics of image influencing the interpretation include scale, brightness and tone; image contrast, resolution and resolving power (Sabins 1996: 6-9). Classification principles change according to purposes, scale and means of investigation (e.g. interpretation of satellite imagery, field plot sampling or statistical methods), time and available financial resources (di Gregorio & Jansen 2002). Classifying landscapes as patches uses many approaches according the ones perceptive capacity (Farina 2007: 10), for example: structural patch (associations of vegetation), habitat patch (distinct plant community types), and corridor patch (narrow strip of land).

In some researches it is important to interpret land cover relating it to land use (natural, modified-cultivated or artificial). Still, there are principal differences between land cover (LC) and land use (LU). Land cover refers to the biophysical cover over the surface land, including water, vegetation, bare soil, glaciers, rocks and artificial structures, like cultivated vegetation and infrastructures (depicts the materials or resources). Land use is defined in terms of human activities or economic function, such as agriculture, forestry and building construction that alter land surface processes (illustrated how a piece of land is used). Land use dynamics are indicators of the land cover changes (Gomarasca 2009; Ellis & Pontius 2010; Lillesand et al. 2008: 213). Land cover may be observed directly (field work, remote observation), while land use monitoring is broader depending from different aspects and purposes: socio-economic purposes, managed or unmanaged land under observation, ownership issues. Ideally, land use and land cover information should be presented on separate maps. However, while land cover information can be directly interpreted from images, information about human activity on the land cannot always be inferred directly from land cover (Lillesand et al. 2008: 214).

Physiognomic attributes are relevant for identification of LULC classes (Feranec et al. 2007). The elements of image interpretation include: location, tone and color, shape, size, texture, pattern, shadow, height and depth volume, slope, aspect, site, and association (Jensen 2007: 131). These attributes vary depending on the study. In agricultural landscape studies, one have to identify and distinguish greenery, arrangement and share of areas of crops and agricultural land, relationships of grasslands with urban fabric, occurrence of dispersed cottages, permanent crops and natural vegetation, and irrigation channel network. Semi-natural areas characteristics relevant for researches are classified based on development stage and arrangement of vegetation (trees and bushes), and composition density. Conventional LULC maps are categorical, dividing land into categories of land use and land cover (thematic mapping) (Ellis & Pontius 2010).

Agricultural landscape consists of several types of different and distinguished ecosystems i.e. field, hedgerow, wood, main road, side road and farmyard. These ecosystems combine a cluster of ecosystems type, which are likely to find randomly from some other place in the landscape. The second cluster may differ from first cluster in means that farmyards are greater or fewer dirt roads are presenting other place (Forman & Gordon 1986: 8-9). These ecosystem clusters are recognized as landscape elements, which are usually identifiable in aerial photography and often each element type (i.e. woods, side road with margins, farmyard) is represented by one or more actual elements.

The boundary of a landscape element depends of the research objectives and may vary based on geographic, ecological, or administrative units (e.g. a river, a rural area, or a county) (Wu 2013). Ecotone's, as type of boundary, detection requires the ability to determine spatial change. Therefore, GIS can be used to quantify ecotone's length, fractal dimension, and distribution and to determine the location of boundaries. The purpose of delineating boundaries on aerial photos is to differentiate dissimilar patches in the landscape. For linear ecotones, such as those associated with streams or ditches, a GIS can be used to establish buffer zones of a given radius surrounding the line. Ecotones may by be recognized not only by spectral reflectance, but also by vegetation height, texture, and pattern. Boundary distinctness in a landscape is scale dependent. A boundary that is distinct at one scale may be obscure when examined at a coarser scale (Johnston 1992).

Crop-type classification is based on the premise that specific crop types can be identified by their image texture and tone. Successful identification of crops require knowledge of the developmental stages of each crop in the area inventoried. One presume the attributes of arable land according to the expected developmental status and appearance of each crop in an area throughout the year (Lillesand et al. 2008: 235).

5 Study area

The study area is situated in Somero municipality, southwestern Finland. Research’s coverage of 200 ha is part of river Rekijoki valley (Figure 5), covering part of Häntälä depressions and core of Talvisilta village, which lies at 60,58885°N-23,37964°E; 60,57103°N-23,37964°E.

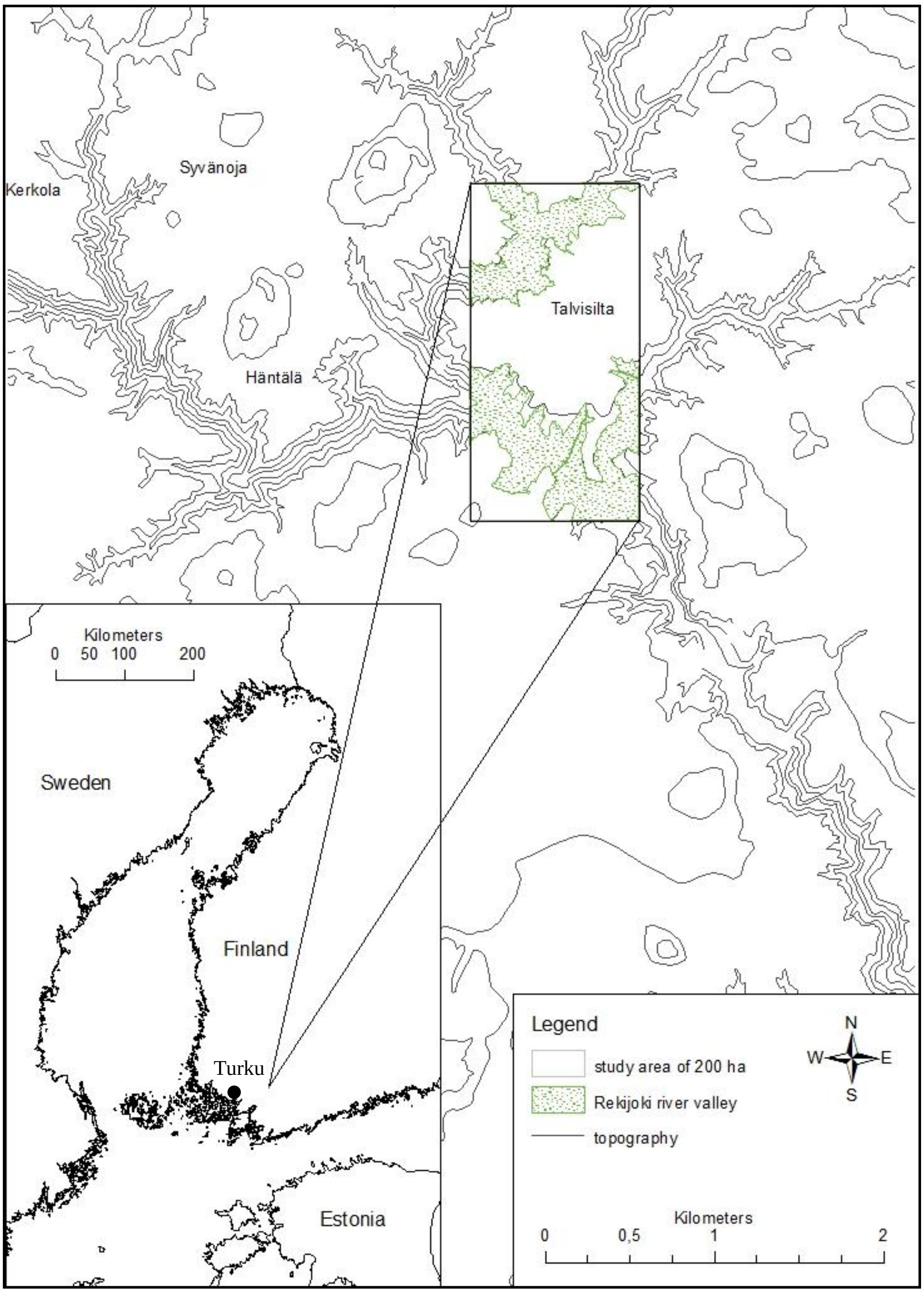

Figure 5. Location of the Rekijoki study area in SW Finland. Source National Land Survey of Finland (NLS).

Rekijoki valley contains extensive areas designated for nature conservation, providing protection for threatened habitats and species. V-shaped steep slopes are dominated by forests and semi natural meadows, which are remnants of traditional landscape. There is also a prosperous agricultural production in the region. Rekijoki river valley is considered as unique, exceptionally wide, and connected wholeness of cultural historic area (Ympäristöministeriö 1992; Lehtomaa 2000a).

5.1 Physical characteristics

Rekijoki river starting from the Reksuo swamp has carved deeply through steep-slope (30°) valley over thousands of years forming nowadays curved shape. In Talvisilta, Häntälä, Saarentaan and Syvänoja village's area, Rekijoki river and its branches (Aitaniitunoja, Syvänoja and Häntälänoja streams) from different directions have eroded the channels even to 30 m deep (Tarmio et al. 1967: 138; Ikonen et al. 2001), which makes the arable land up to 90 m above sea level (Lindgren 1960: 47). South-Finland's continental clay soil is usually about 9 m thick. In Häntälä, clay deposits are the thickest, maximally up to 77-80 m (Neuvonen 2006: 60; Haavisto et al. 1980: 30).

The mean annual temperature in southwest Finland during the period of 1981-2010 is measured between 4 and 5 º C and the annual average precipitation is between 650-700 mm (Finnish Meteorological Institute). Based on Northern growth zones, Rekijoki river valley is situated in south boreal growth zone. Rekijoki valley with its favorable location and climate is suitable area for agricultural practices compared to some other southern parts of Finland (Lounais-Suomen Ympäristökeskus 2008). More flat areas are under cultivation and valley slopes are used traditionally are pastures (Ympäristöministeriö 1999).

5.2 Flora and fauna in Rekijoki

Area’s flora is influenced by vicinity of coastline and inner land species. The generous herbarium depends largely of the traditional land use (Lounais-Suomen Ympäristökeskus 2008). Even if humans haven’t consciously spread them, they are dependent of human made habitats, ditches verges and old mansion’s yard lawns (Lindgren 1960: 51; 1955: 149). Dropwort (*Filipendula vulgaris)*, seen in vicinity of the stream and roadside in Talvisilta (Lindgren 1955: 150), is considered to be indicator of Iron Age settlement. Häntälä depressions are considered to be sort of nature collection over times. Unique geomorphology (landslides) and agricultural activity has influenced development of exceptional species. In Rekijoki valley area, some animal species are specialized specifically to use grass eating animals dungs as habitat, which are no more found in any place in Finland (Haarto et al. 2002). In the whole area could be found several wooded meadow species, which in near environment are rare, not seen even in the entire Somero municipality, like spring fumewort *(Corydalis solida)*. Valley has a powerful spring-effect, which can be seen in massive blossoming (Alanen & Pykälä 2004: 201; Torkkomäki 1998: 18-23, Kotula & Pykälä 2000: 22-23). Valley’s forests are generally coniferous dominated and recently developed, but not typical due to slopes unusual micro-climate, soil composition and hundreds of years continued pasturing. The dryness and dominant alders or junipers are difficult to succeed in vegetating efforts (Kontula & Pykälä 2000). In 1955, Lindgren has mentioned that wooded meadows are in low area proportion and deciduous trees are rare. Where there are no meadows or pastures, there it could be found grey alders (Lindgren 1960: 47-48). Grey alders are used as habitats by flying squirrel, whose population is protected in Rekijoki valley area.

Beside of rich selection of plant species, the area has also remarkable population of butterfly species; especially threaten ones (Ympäristöministeriö 1992). Clouded Apollo’s (*Parnassius mnemosyne*) only inner land population is situated in Häntälä depressions (Somerma & Väisänen 1994; Hæggström 1995: 133; Lounais-Suomen Ympäristökeskus 2008) It hasn’t been seen in any other Finnish inner land area and has been protected since 1976. Clouded Apollo’s population is considered to be only couple of hundred (Torkkomäki 1998: 47). The overgrowing of the meadows and traditional habitats is threat for butterflies' local extinction (Nieminen 1998). The caterpillars feed exclusively on *Corydalis* plant species (Heliölä et al. 2010). On the upper edges of the depressions rare mushroom species are found (Vauras 1998). Umbrella mushroom (*Macrolepiota excoriata*) habituating in three different pastures has been in recession since 1990-s.

5.3 Land use history of Rekijoki

Human activity and cattle grazing have shaped the valley landscape and also plant- and animal species composition over hundreds of years. Before early civilization landslides have kept the depressions slopes opened. Specific to the valley landscape is the mosaic pattern of old forest. These remnants have remained because of the difficulty of passing through the area. Open meadows, semi-open pastures on the slopes and wooded meadows have been survived extraordinarily long especially in Häntälä-Talvisilta area. As a result of developments in agricultural practices in the middle of 20th century, traditional meadows almost disappeared from South-Finland's countryside and amount of pastured area decreased substantially. This phenomenon raised aesthetical and bucolic value for the depressions and landscape that 'survived' from this time period (Torkkomäki 1998: 6–7). In Häntälä, natural pastures have still been unusually largely taken care of. Flatter area is in agricultural use and depressions slopes are used in traditional pasturing. Area has representative dense group of villages. South-Somero village association gathers four villages: Häntälä, Talvisilta, Syvänoja and Kerkola. Talvisilta village were first mentioned in the 1490's, which means it has civilization almost for 4000 years. In some places, traditional old buildings have remained which in turn raises the value of local cultural history (Ympäristöministeriö 1992; Lounais-Suomen Ympäristökeskus 2008). In Talvisilta, there could be still found some buildings from the 1800's (Lounais-Someron kyläyhdistys).

5.4 Management of Rekijoki valley

A traditional landscape, like all other types of cultural landscapes, helps to understand the local history. It is responsible to preserve old land use information and knowledge's, which in future could be unexpectedly important. If traditional agricultural landscapes would be destroyed or disappear, species, habitat biodiversity and landscape, impoverishment happens (Hæggström 1995: 103). According to the Southwest Finland national landscape conservation report (Lehtomaa 2000b) there are 39 nationally significant landscape conservation areas in Southwest Finland, which makes altogether 1613 ha. River Rekijoki valley arises clearly over others with its 788 ha. Valley's landscape in Häntälä and Talvisilta villages are considered to be regionally to be most significant part of this special landscape because of landscape and species diversity (Ikonen et al. 2001). Cattle grazing in Häntälä and Talvisilta villages have continued longer than in any Rekijoki river valley area. As stated by Ministry of Environment (1993), Häntälä pastures were named as *historically representative traditional-cultural landscape,* which should be maintained (Ympäristöministeriö 1993). In Rekijoki area, fragmentation of meadow's community due to decreasing pasturing can be noticed, hence to afforestation and natural overgrow in the 1970's and 1980's (Alanen & Pykälä 2004: 200-201).

In the 1990's the national value of the site became properly recognized (Ikonen 2002: 5). In 1995 Finnish Environmental Institute, South Somero village association, agricultural center Farma, Somero town, Finnish forest research institute METLA and Tapio Forestry have started Häntälä-Talvisilta project. The aims were to clarify and investigate the areas, plant and animal species and to compose nature conservation recommendations. On the basis of research, landowners were received instructions about general landscape preservation and maintenance of built village environment. Results of recovery were noticed already three years after forming the instructions: clearing the forested slopes was started and pasturing was increased from 1993-1998 up to four times. Since 1995, when Finland joined the European Union, the area of grazed patches studied in Rekijoki upper course has again increased as a result of a support scheme for the management of seminatural grasslands (Luoto et al. 2003b).

Cleared depressions raised also tourism value (up to 5000 visitors per year) and therefore nature trail for private sector were opened in 1997 (Torkkomäki 1998: 7; Kontola et al. 2000: 5). In the year 2000 (Kontola et al. 2000), conservation efforts were considered to be exceptionally good: over half of the meadows are pastured. The region has couple of hundreds hectares of old meadows, which have been managed traditionally (Lehtomaa 2000a). Association for Traditional Rural Landscapes in Southwest Finland was established in 2003, which arranges voluntary management actions, like mowing competition in 2004 (Ikonen 2004). River Rekijoki valley Natura 2000 site (1209 ha) comprises the core areas of Häntälä, Talvisilta and Rekijoki villages, altogether 253 ha. Consequently, the landowners' opinions, attitudes and awareness of the local traditional land use in the area are essential for both starting the management and being successful in it (Ikonen 2002: 5).

By means of species protection, it should be noticed Clouded Apollo's (*Parnassius mnemosyne)* and flying squirrel's (*Pteromys volans*) position in the environmental protection plan, as their reproduction and habitat areas are forbidden to destroy. Land owner and forest stakeholders in Rekijoki have received corresponding instructions (Ikonen et al. 2001). As so the key management goals of traditional rural biotopes in Rekijoki are: appropriately managed meadows and wooded pastures; re-introduction of species; nature friendly forest planning in the valley area; stakeholder activity in the management planning. In 2012, SW Finland's ELY-center finished report of the important places of flying squirrel and spring fumewort habitats. The aim was to monitor and to re-introduce species, like Clouded Apollo's caterpillars source of food (Ikonen 2012).

6 Materials and methodology

The methodological steps employed in this thesis are shown in Figure 6. The workflow commences with data elaboration (1), which included pre-processing of raw material and creating LULC (land use/ land cover) classification plan. Following step (2) involved database establishment consisting of aerial data vectorization, assigning attribute information, and performing overlay procedure. Finally, data analysis (3) encompassed LULC change analysis based on cross-tabulation matrix creation, transition analysis, landscape structural and compositional analysis using landscape metrics, and overlay analysis.

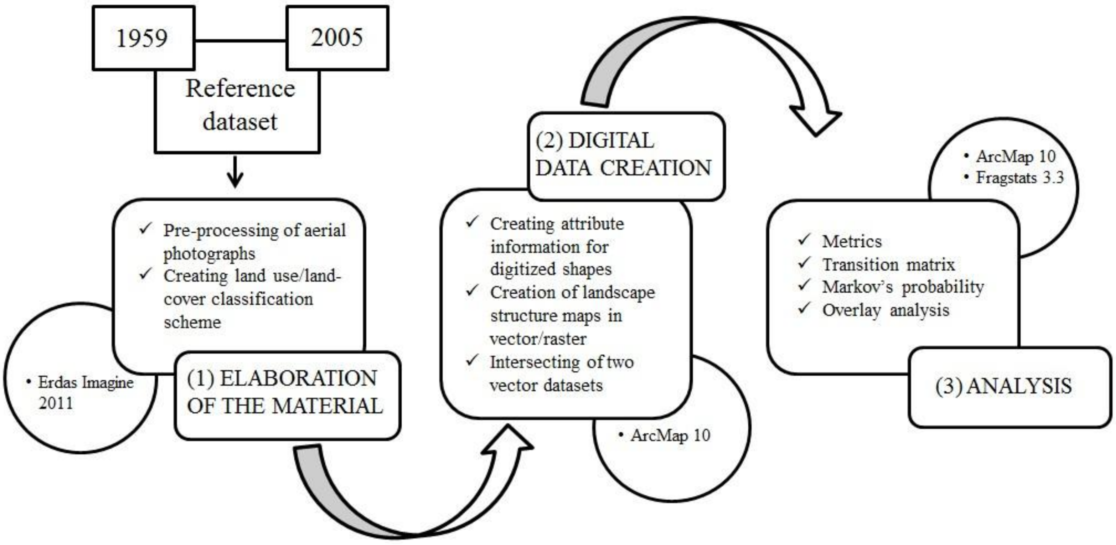

Figure 6. Flowchart of the data processing. Numbers 1-3 refer to the processing steps presented in this thesis. Datasets are distinguished with rectangular shape (▭). Software programs used in the study are presented in the rounded shapes (◯); descriptions of the work step are presented in the rounded rectangle (▢).

GIS programs put into effort were ERDAS Imagine 2011 (ERDAS 2005) (spatial data preparation), ArcMap 10 (ESRI 2011) (digitizing), and Fragstats 3.3 (McGarigal et al. 2002) (analysis).

6.1 Aerial photos and digital data creation

The study material consists of multi-temporal set of fine-scale digital panchromatic black-and-white aerial photographs, captured in spring 1959 and 2005, seen in Figure 7 and metadata presented in Table 1. Images were chosen from the time period between May and June in order to achieve adequate interpretation in next steps of the research. Raw data was received from the National Land Survey of Finland.

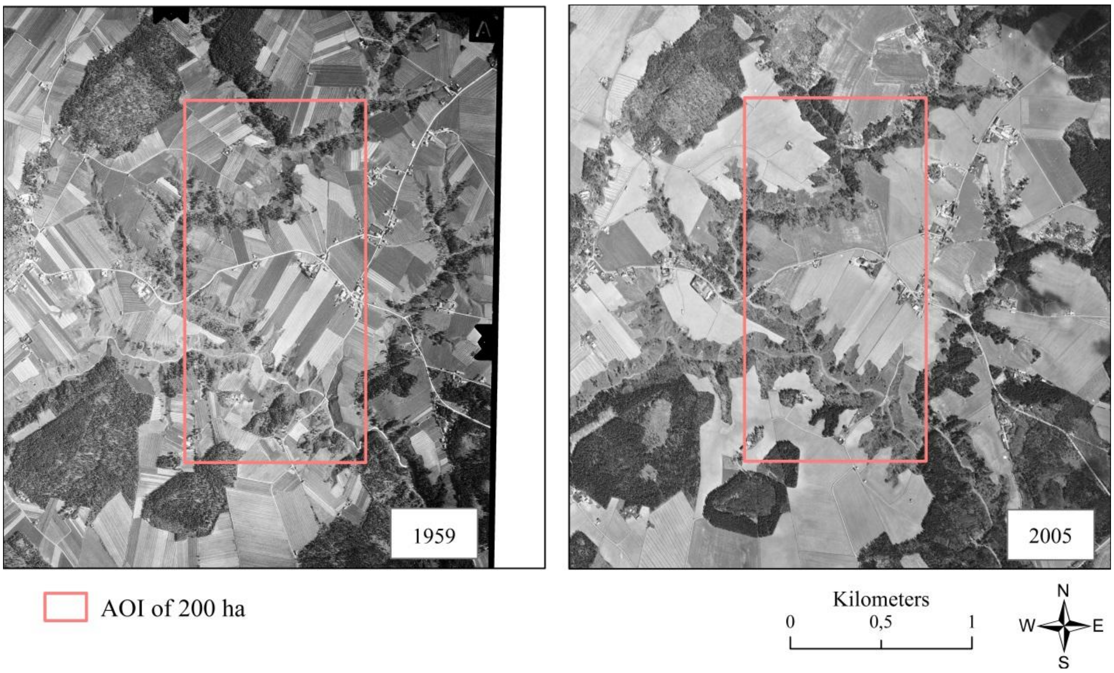

Figure 7 Two aerial images from 1959 and 2005. Area of interest (AOI) composes a core of two villages of Häntälä and Talvisilta in Rekijoki valley area, covering 200 ha.

Table 1. Characteristics of the study material.

Data	Acquisition date	Format	Scale	Source
Aerial image	1959	raster	1 : 10 000	National Land Survey of Finland
Aerial image	2005	raster	1: 31 000	National Land Survey of Finland
Reference map	2011	raster	1 : 10 000	National Land Survey of Finland

The aerial images were rectified and georeferenced in image-processing software ERDAS Imagine in order to create digital orthophotos. Materials have been georeferenced into Transverse Mercator projection, with datum Finnish KKJ, using

Finnish base map as reference material (Table 1). Surveyed reference points were chosen to be features e.g, building's roof corners and road intersections. A first-order polynomial and nearest-neighbor resampling technique were employed in the georeferencing process, and the image was resampled to a pixel resolution of 0,5 m. The primary area of interest was extracted for the further study process, with creating frame using ArcMap drawing tool (AOI in Figure 7). Landscape components were classified from the computer screen according to the classification plan (Table 3) comprising six main LULC polygon classes: arable land, forested area, open meadow, water body, built area, ditches, roads. Classification plan also represents sub-classes for selected main classes, that is *arable land* divided according to the land use (grassland, cereal, non-arable), *built area* distinguished based on the purpose of the building (barn or farm area), and *other* class containing three buffered linear elements of waterbody and roads. Visual interpretation was based on direct keys (Table 2): *tone, texture, shape, size*; as well indirect solution of identification, which is *association*.

Table 2. Elements and it's common descriptors in image interpretation process (Jensen 2007: 133).

Element	**Common adjectives**
Tone	• Gray tone: light (bright), intermediate (gray), dark (black)
Texture	• Characteristic placement and arrangement of repetitions of tone or color • Smooth, intermediate (medium), rough (coarse), strippled
Shape	• An object's geometric characteristics: linear, curvilinear, circular, elliptical, radial, square, rectangular, triangular etc
Size	• Length, width, perimeter, area (m^2) • Small, intermediate, large
Association	• Site: elevation, slope, aspect, exposure, adjacency to settlement, transportation • Situation: objects are placed in a particular order or orientation relative to another • Topography: there is often distinct topographic change at the boundary between two different landforms (Lillesand et al. 2008: 306).

The classification scheme is primary based on the main objective of the study i.e., assessing the landscape change detection in the agricultural land and surrounding valley area. Minimum diameter unit of interpretation is one meter (buffered ditches).

Table 3. Land-use nomenclature with 6 polygon classes, sub-classes, 3 line classes (first column), and keys (tone, texture, shape, characteristics) used in Rekijoki study area classification. Additional information column provides supplementary details of the class.

Polygon classes	**Sub-classes**	**Tone**	**Texture**	**Additional information**
1. Arable land	Grassland	Dark, grey	Coarse	Area under cultivation; non-arable area is counted as difficult plot in terms of agricultural activities (corner, stony patch, moist area), but still in the vicinity of the arable land, without clear purpose, or having poor quality on terms of yield production.
	Cereal field	Light, grey	Smooth	
	Non-arable	Dark	Irregular	
2. Forest	Forest	Dark	Coarse	Area with canopies, within valley area.
3. Meadow	Meadow	Grey	Coarse	Valley area with no canopies, under pasturing purposes.
4. Built area	Farms	Various	Irregular	Buildings and surroundings.
	Barns			
5. Ditches	Ditches	Dark	Smooth	Buffer shapefile feature (diameter of 1m).
6. Other	Waterbody	Grey, light	Smooth	Buffer shapefile feature (diameter 1m) and polygon.
	Main road			Buffer shapefile feature (diameter 4,5 m).
	Side road			Buffer shapefile feature (diameter 2,5m).
Linear classes	**Sub-classes**	**Tone**	**Texture**	**Additional information**
1. Ditches	Ditches	Dark	Irregular	Lines in the fields and on the edges of fields, roadsides.
2. Roads	Main road	Light	Smooth	Linear elements comprising infrastructure and classified according to the size and purpose of use.
	Side road	Light	Smooth	
3. Edge	Arable land – meadow Arable land – forest			Arable land bordering to forest or meadow.

Additionally, line classification containing linear landscape elements (ditches, road and edge) was devised (Table 3). In order to record margins topography in arable land classes (grassland and cereal) and valley (meadow and forest) boundary category *edge* was classified into sub-categories considering ecological point of view. Also *road* elements carried meaningful difference in the use purposes, as it was identified in the fields and farm areas, as well as main roads between villages.

The field patches were digitized as polygons in a way that ditches did not separate them into several smaller patches, unless there was not road or other type of crop dividing the patch. *Ditches* polyline were buffered, in order to calculate area covered by drainage. *Arable land* total area consisted land under agricultural practice without open ditches. Study area classes *forest*, *meadow* and *water body* are dominant only within study area's valley's environment.

6.2. Methods of data analysis

6.2.1 Landscape structure analysis

In order to analyze the landscape patterns and their implications to ecological processes, landscape metrics are used. Landscape ecological indices quantifying landscape structure were calculated using public domain software package FRAGSTATS raster version 3.3 (McGarical et al. 2002), in which landscape metrics were computed from two levels: class level and landscape level. The cell size used for raster analyzes was 1x1m. Core area and border zone were defined to 0 meters. The core set of landscape metrics, calculated at the class and landscape level, addressing the principal needs of recent study and describing the landscape structure and associated key processes are given as in Table 4 & 5. The outputs of FRAGSTATS data files were in ASCII format that were manipulated using commercial spreadsheet application MS Excel to convert metrics to other units. However, the distance- and area-based metrics computed in FRAGSTATS are reported in kilometers and hectares, respectively. Changes at arable land and valley (i.e. forest and meadow class) boundaries level (forest-arable or meadow-arable) were identified from manually digitized vector coverage in ArcMap 10.

Table 4. Five class level indices calculated in the research. Equation and description explained by MCGarigal et al. 2002.

Class metrics	**Equation**	**Unit**	**Range**	**Description**
Class area	$\mathrm{CA} = \sum_{j=1}^{n} a_{ij} \left(\frac{1}{10,000}\right)$	m^2	$\mathrm{CA} > 0$	The sum of the areas of all patches of the correspond. patch type
Class proportion	$\%\mathrm{LAND}\ \%\mathrm{arableLAND} = P_i = \frac{\sum_{j=1}^{n} a_{ij}}{A}$	Percent (%)	$0 < \%\mathrm{LAND} \leq 100$	The percentage the landscape comprised of the correspond. patch type
Number of patches	$\mathrm{NP} = n_i$	None	$\mathrm{NP} \geq 1$	The number of patches of the correspond. class type
Mean patch size	$\mathrm{MPS} = \frac{\sum_{j=1}^{n} a_{ij}}{n_i} \left(\frac{1}{10,000}\right)$	ha	$\mathrm{MPS} > 0$	Mean patch area of the class type.
Edge density	$\mathrm{ED} = \frac{\sum_{k=1}^{m'} e_{ik}}{A} (10,000)$	m/ha	$\mathrm{ED} \geq 0$	The sum of the lengths of all edge segments of the patch type, divided by the total area, multiplied by 10,000.

In means of spatial composition and configuration in current research metrics are grouped as composition metrics and configuration metrics as follows: class area (CA), class proportion (%LAND), number of patches (NP); and mean patch size (MPS), edge density (ED), landscape shape index (LSI), patch density (PD), Shannon’s diversity index (SHDI), Shannon’s evenness index (SHEI), respectively.

Class area (CA) is a measure of landscape composition; specifically, how much of the landscape is comprised of a particular patch class. *Class area* has an importance in ecological utility, as such. For example quantitative habitat loss is resulted by habitat fragmentation. In landscape changes research it is important to know, how much of the class type exist in the landscape. Additionally, class area is basis for many of the landscape metrics. Area metrics quantify landscape composition in absolute terms (hectares) (McGarigal et al. 2002).

%LAND is important to compute when one needs to quantify area in relative terms: percentage of total landscape area. At the class level %LAND calculates the percent of landscape occupied by each class type (McGarigal et al. 2002).

Metrics representing landscape configuration at the class level calculated in recent thesis are *number of patches* (NP) and *mean patch size* (MPS). *Number of patches* counts particular habitat type. Depending on the landscape context, amount of patches of a certain habitat type may affect a variety of ecological processes. For example, subdivided habitat (*number of patches* value of particular land cover class is respectively big) may be more resistant to the disturbances (e.g. disease, fire), and thus more likely to persist in a landscape than a patch type that is contiguous (Franklin & Forman 1987). The number of patches in a landscape can serve as index of spatial heterogeneity of the entire mosaic. A landscape with a greater number of patches has a finer grain: spatial heterogeneity occur at a finer resolution (McGarigal et al. 2002). Number of patches reveals landscape fragmentation process. If NP is too high it indicates that the patch class is highly fragmented (Botequilha Leitão & Ahern 2002).

Mean patch size (MPS) based on the *number of patches* is important tool for measuring landscape structure (Forman 1995). MPS calculates an area of each patch. Progressive reduction in the size of habitat fragments may be a key component of habitat fragmentation. Thus, landscape with a smaller mean patch might be considered more fragmented (McGarigal et al. 2002). NP and MPS should be used complementary since high NP and low MPS values reinforce and interpretation of a fragmented landscape condition (Botequilha Leitão & Ahern 2002).

Table 5. Five structural metrics on the landscape level calculated in recent study. Equation and description explained by McGarigal et al. 2002.

Landscape structure metrics	**Equation**	**Unit**	**Range**	**Description**
Landscape shape index	$\mathrm{LSI} = \frac{.25 \sum_{k=1}^{m} e''_{ik}}{\sqrt{A}}$	None	$\mathrm{LSI} \geq 1$	Equals the sum of the landscape boundary and all edge segments (m) within the landscape boundary involving the corresponding patch type, divided by the square root of the total landscape area (m^2), adjusted by constant for a square standard
Patch density	$\mathrm{PD} = \frac{N}{A}(10,000)(100)$	Number per 100 hectares	PD > 0	The number of patches in the landscape per 100 ha
TE	$\mathrm{TE} = \sum_{k=1}^{\acute{m}} e_{ik}$	meters	$\mathrm{TE} \geq 0$	The sum of the lengths of all edge segments.
Shannon's diversity index	$\mathrm{SHDI} = -\sum_{i=1}^{m} (P_i \ln P_i)$	None	$\mathrm{SHDI} \geq 0$	SHDI=0 when the landscape contains only 1 patch (i.e., no diversity). SHDI increases as the number of different patch types increases and the proportional distribution of area among patch becomes more equitable
Shannon's evenness index	$\mathrm{SHEI} = \frac{-\sum_{i=1}^{m} (P_i \ln P_i)}{\ln m}$	None	$0 \leq \mathrm{SHEI} \leq 1$	The observed Shannon's diversity index divided by the maximum Shannon's diversity index for that number of patch types.

On the landscape level, quantification in terms of the complexity of patch shape is measured with landscape *shape index* (LSI). In determining the nature of patches, landscape shape index measures the complexity of patch shape compared to a standard shape. In raster version of FRAGSTATS, patch shape is evaluated with a square standard: shape index is minimum for square-shaped patches and increased as patches become increasingly nonsquared-shape. LSI measures the perimeter-to-area for the landscape as a whole (McGarigal et al. 2002).

A landscape with greater patch density (PD) would have more spatial heterogeneity *Total edge* (TE) is an absolute measure of total edge length of a particular patch type (class level) or of all patch types (landscape level). Total amount of edge in a landscape plays and important role in ecological phenomena. Total class edge in a landscape is most critical piece of information in the study of fragmentation and spatial heterogeneity, as similarly the total amount of edge in the landscape. *Edge* *density* (ED) standardizes edge to a per unit area basis that facilitates comparisons among landscapes of varying size (McGarigal et al. 2002).

Diversity indices quantifying landscape structure are extensively used in a variety of ecological applications. The diversity of a system as measured by the number and types of diversity elements consist of two components: richness (the number of different types of classes of elements in a system) and evenness (the relative abundance of the different types or classes of elements) (Olson & Francis 1995: 14). Diversity indices influenced by richness component and applied in recent study are Shannon’s diversity index (SHDI). It is used as a relative index for comparing different landscapes or the same landscape at different times. Richness refers to the number of patch types present. As evenness indices correspond to the diversity indices, Shannon’s evenness index (SHEI) is second diversity index applied in this research. Evenness is expressed as the distribution of area among different patch types. SHEI is determined by the distribution of the amount of different land-use types in a landscape. LSI measures the complexity of landscape shape compared to a standard shape, using perimeter-area relationship. A basic arithmetic combination was used to compare the metric statistics to detect and locate land use and land cover changes (McGarigal et al. 2002).

6.2.2 Overlay analysis and database query

According to the results of manual digitizing it is aimed to compare vector LULC maps for 1959 and 2005. An intersect procedure determines spatial concurrence of landscape categories between two data layers. New data layer is generated based on the classification results.

Overlay can be defined as a spatial operation, which combines geographic layers to new information. In recent research, vector overlay is performed on polygon-on-polygon overlay. During this, the attribute data associated with each feature type is intersected and integrated to new composite maps. As so, three overlay maps for transition matrix, change detection, and Markov’s probability were produced to analyze and visualize spatial dynamics and distribution of the changes. Database query is the process of retrieving the attribute data without altering the existing data. Overlay is done using Boolean and relational operators. The function is performed by means of a conditional statement for queries. Boolean logical operators applied algorithms for use of this statement. Boolean operators select data records based on two or more attributes – analyses of spatial coincidence of input data layers : AND – intersection; OR – union; XOR – exclusionary or. Relational operators =, >, < conducted condition for each query. Example of Boolean operators to combine more than two conditions as shown in the Figure 8.

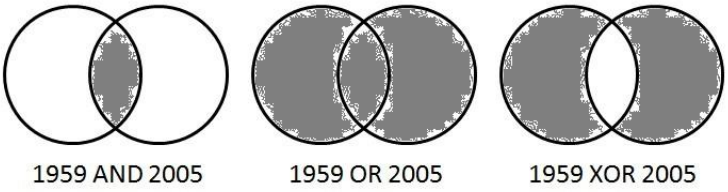

Figure 8. Venn diagrams used in this study representing Boolean operations. Adapted from Burrough (1986).

For better evaluation of change maps representation of landscape dynamics, comprehensive amount of information being displayed is selected (transitional dynamics, Markov's probability).

6.2.3 Transition matrix, gross gain, gross loss

Analyst module in ArcMap 10 was used to calculate cross-tabulation table as intention to measure the rate of land use change in two time intervals. New layer was produced, when two time layers were overlaid together. Map-to-map comparison provides a matrix of land transitions among categories. Reclassification tools and query selection was used to create matrix's attributes by re-grouping the dataset. Patches were coded by their dynamic course type (patch was defined by its land use history over time).

Two-dimensional table consist row and columns (Table 6). Rows shows the categories proportions from initial time and columns represent the categories proportions from a subsequent time. The notation P_{ij} (in the matrix represents the transition from the *i* patch type in 1959 to the *j* patch type in 2005. The diagonal elements (that is, *Pjj)* answers to the amount of land categories that showed persistence of class *j*.The minimal area of polygon change is 0,1 ha. Result of this matrix reflects also the size of the images.

Table 6. Land cover transition matrix.

	Time 2				Total time 1	Loss
	Category 1	Category 2	Category 3	Category 4		
Time 1						
Category 1	$\mathbf{P_{11}}$	P_{12}	P_{13}	P_{14}	P_{1+}	$P_{1+} - P_{11}$
Category 2	P_{21}	$\mathbf{P_{22}}$	P_{23}	P_{24}	P_{2+}	$P_{2+} - P_{22}$
Category 3	P_{31}	P_{32}	$\mathbf{P_{33}}$	P_{34}	P_{3+}	$P_{3+} - P_{33}$
Category 4	P_{41}	P_{42}	P_{43}	$\mathbf{P_{44}}$	P_{4+}	$P_{4+} - P_{44}$
Total time 2	P_{+1}	P_{+2}	P_{+3}	P_{+4}	1	
Gain	$P_{+1} - P_{11}$	$P_{+2} - P_{22}$	$P_{+3} - P_{33}$	$P_{+4} - P_{44}$		

The proportion of the landscapes P_{i+} allocated by category *i* in 1959, is given by (Braimoh 2006):

$$c_{i+} = \sum_{i=1}^{n} c_{ij} \qquad (1)$$

where *n* is absolute amount of categories. Likewise, the proportion of the landscape c_{+j} that is occupied by category *j* in 2005 is notated by:

$$c_{+j} = \sum_{j=1}^{n} c_{ij} \qquad (2)$$

The matrix is extended to calculate the gross gains and gross losses by category. The gross gain is derived by subtracting diagonal entries from the each category's column total. The gain row shows the amount of landscape that experienced a gross gain of class *j* between 1959 and 2005. The gross loss is derived by subtracting diagonal entries from the each category's row total. The loss column indicates the proportion of the landscape that experienced a gross loss of class *i* between 1959 and 2005.

6.2.4 Net change, swap, total change, persistence ratios

The land use change is analyzed through evaluation of gains and losses by classes.
To do that, absolute value of net change, swap, total change, and persistence ratios are calculated (Pontius 2004; Braimoh 2006; Manandhar et al. 2010). Net change is the difference between the gross gain and gross loss. The idea of swap, as a measurement of spatial reallocation, implies simultaneous gain and loss of the LULC category. The swap change equals the total change minus the net change. Equations 3 & 4 formalize the language of the absolute value of swap (S_j) and net change (D_j):

$$S_j = 2 \times \mathrm{MIN}\left(P_{j+} - P_{jj}, P_{+j} - P_{jj}\right) \tag{3}$$

$$D_j = MAX\left(P_{j+} - P_{jj}, P_{+j} - P_{jj}\right) - MIN\left(P_{j+} - P_{jj}, P_{+j} - P_{jj}\right) = \left|P_{+j} - P_{j+}\right| \tag{4}$$

If the gain is equal to loss (that is, net change is zero), then the swap is twice the loss or gain (Braimoh 2006).

Total change (C_j) for each category was calculated as either the sum of the net change and swap or the sum of the gains and losses (Eq. 5).

$$C_j = S_j + D_j = \mathrm{MAX}\left(P_{j+} - P_{jj}, P_{+j} - P_{jj}\right) + \mathrm{MIN}\left(P_{j+} - P_{jj}, P_{+j} - P_{jj}\right) \tag{5}$$

The annual rate of change is calculated by comparing the area under LULC class cover in the same region at two different times. The rate of change of different classes was derived from the compound interest law, suggested by Reddy et al. (2009).

$$r = \frac{\left[\ln(A_{t_1}) - ln(A_{t_0})\right]}{t_1 - t_0} \times 100 \tag{6}$$

Where, **r** is the rate of LULC change, and At_1 and At_2 are the categories area over time t_1 and t_2, respectively.

Gain-to-persistence ratio (Eq. 7), loss-to-persistence ratio (Eq. 8), and net change-to-persistence ratio (Eq. 9) were derived to evaluate the tendency of each LULC category to gain and loose from other categories:

$$g_p = \frac{gain}{persistence} \tag{7}$$

$$l_p = \frac{loss}{persistence} \tag{8}$$

$$n_p = g_p - l_p \tag{9}$$

6.2.5 Probability of changes

Theory development by Markov has been applied to model the probability of LULC changes cover from 1959 to 2005. Given the assigned LULC classes, a frequency table is developed where a count is made of the transitions from one class to another with a specified increment (Munsi 2010). A Markov model can be characterized by the transition possibility expression, which represents the conditional probability that the state of the system will be at the time **t**, given that at time the system is in state (Reddy et al. 2009). Generating probabilities of change between classes is accomplished by dividing each cell value by its row total. The result is the probability that a given class in date 1 will convert to another class in date 2 out of all possible changes (Wijanarto 2006). Markov process Equation 7 adapted from Munsi (2010):

$$P\{X_{n+1} = a | X_n = a_n, X_{n-1} = a_{n-1} \cdots X_1 = a_1\} = P\{X_{n+1} = a | X_n = a_n\} \tag{10}$$

A Markov chain is a random process where the following step depends on the current state.

7 Results

7.1 Landscape change

Class level

Overall results for landscape categorical classification, and changes in spatial configuration are presented with classified map (Figure 9).

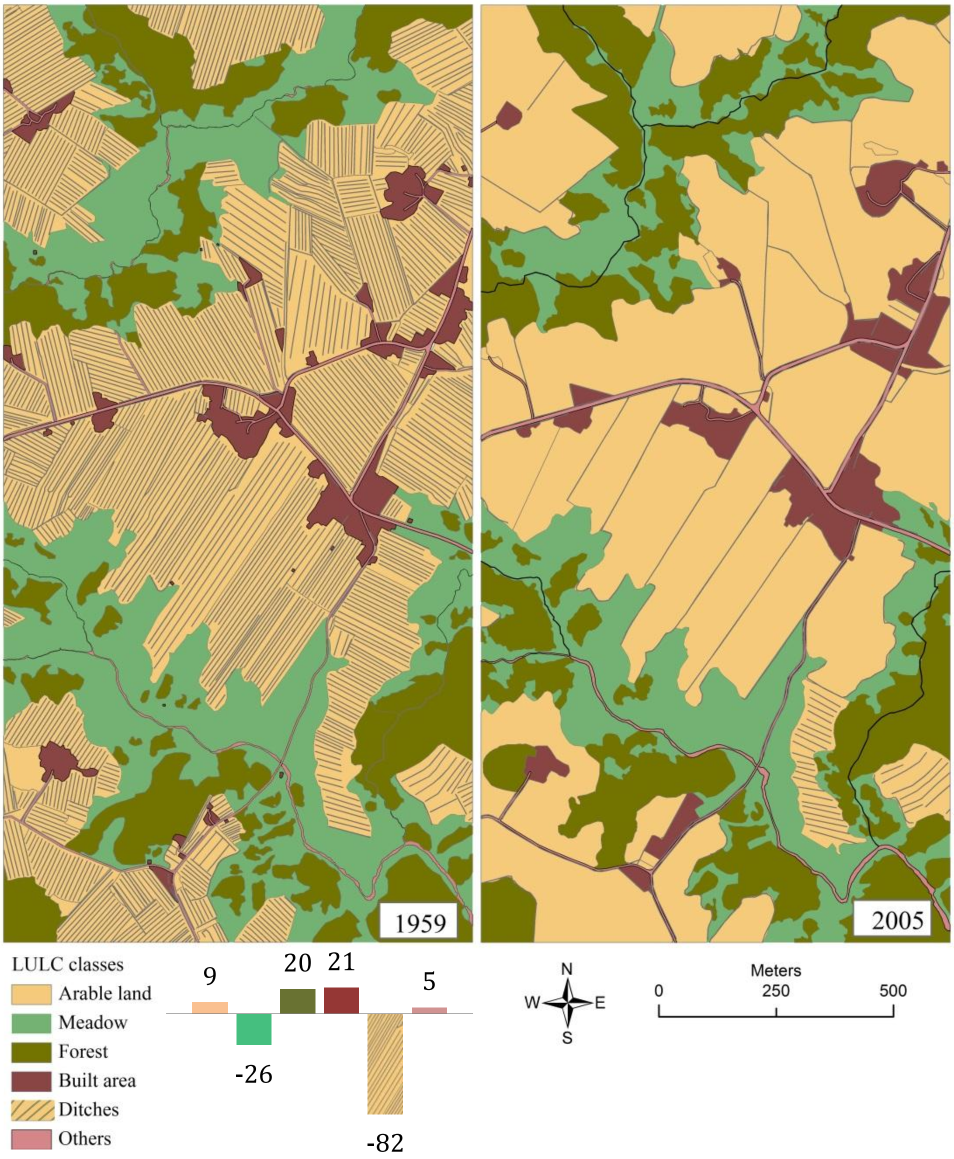

Figure 9. Land cover classification according to the generalized classification scheme representing LULC categorical changes in time period between 1959 and 2005. Overall change in class coverage's (%) is illustratively shown as diagram. Maps cover total of 200 ha in Häntälä-Talvisilta area.

In Rekijoki valley area, particular structural changes have been occurred in association with agricultural landscape in two time series. Six main LULC types classified were arable land, meadow, forest, built area, ditches, and other land (e.g. fallow, stony patch). Landscape structural and compositional metrics calculations at the class level are summarized in Table 7. Generally, arable land was the dominant LULC category during both study periods, covering 98,2 ha (49,1 %) in 1959 and 108 ha (54,9 %) in 2005. Additionally, arable land class was divided into three sub-classes (Figure 10) consisting three types of agricultural management: cereal growing, grassland and non-arable patches (e.g. fallow land, and stony patch). Farming land increased altogether 9 % (9,2 ha) from 1959 to 2005. Landscape structural indices revealed a notable fluctuation in arable land patch number (NP_{arable}) from 118 to 51 (-43%). Coalescence (average patch area increasing) process was evident (Figure 9 & 10) in landscape under cultivation, indicated by MPS_{arable}. Moreover, obvious change in agricultural land cover physical feature is disappearance of surface drainage class ditches (spatial transition presented in Figure 9) with gross loss of 82 %, which covers 8,4 ha ($CA/Change_{ditches}$). In 2005 (Figure 9), ditches are distributed mostly on the road-sides, and subsurface drainage system is surrounding the cultivated area. Only few arable land plots have been left with open drainage.

Arable land statistics for sub-classes (Table 8) indicate the extent of land dedicated to livestock food production or pasturing (grassland) has reduced 7 %. Also numbers of patches ($NP_{grassland}$) have lost 77 %. Non-arable land area ($CA_{nonarable}$) has decreased 30 %, but consist almost unnoticeable amount of the total arable land, as previously. Fields occupied by cereals have increased 16 % (12,5 ha) in area. MPS_{cereal} has increased outstandingly 73 % (2,4 ha) of the patch area, as also the overall mean size of the field plots have raised.

Due to field enlargement and loss in ditches class, edge density of arable land ($ED/Total_{arable}$) correspond loss of 85 % from 1959 to 2005. Also total edge ($TE/Total_{arable}$) has changed notably, in proportion of 81 % (Table 9). Both arable land sub-classes under active farming practices cereal land and grassland have gone through decrease in edge density (ED), 73 % and 92 %, respectively. Accordingly, total edge calculations, as well, indicate decrease of 64 % and 90 % in cereal and grassland classes. Non-arable patches have gained 31 % in total edge, whereas 14 % in edge density.

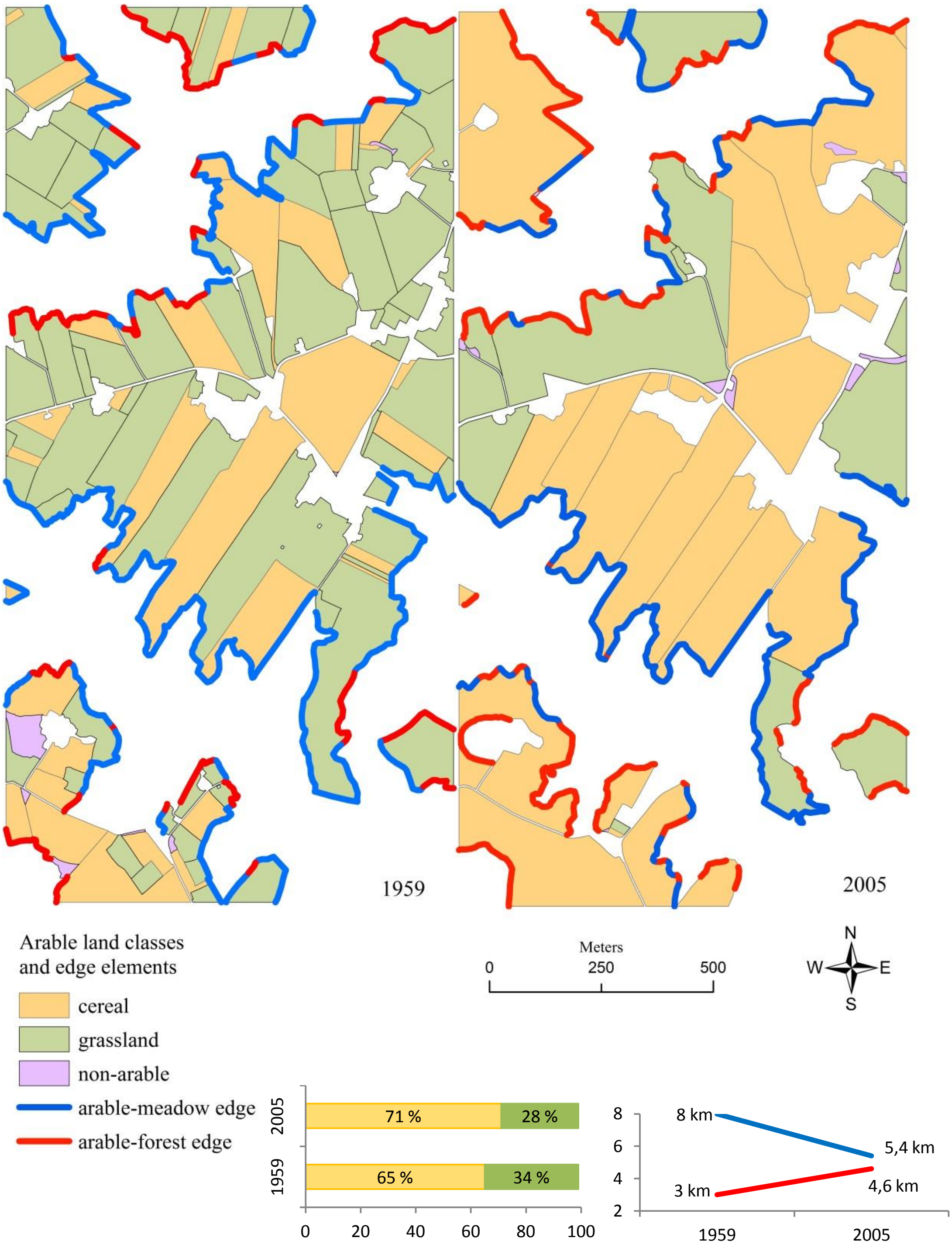

Figure 10. Map illustrating spatial distribution of the arable land categories and edge elements in 1959 and 2005, Rekijoki study area of 200 ha. Arable land neighboring to meadow strip’s length has been decreasing from 8 km to 5,4 km; accordingly neighboring to forest has increased from 3 km to 4,6 km. In 2005, cereal land use type has gained and grassland has lost proportionally in arable land coverage (100 %) compared to 1959.

Table 7. Landscape structural and compositional indices for the study area in Rekijoki for the years of 1959 and 2005.Overall results of the class type changes in classified categories: class area (CA) in hectares, class proportion (%LAND), numbers of patches (NP), mean patch size (MPS) in hectares and edge density (ED) in meters per hectare. Net changes of 1959 and 2005 are presented in absolute values and in percentages (parenthesis).

Categorical metrics	**CA (ha)**		**Change**	**%LAND**		**Change**	**NP (pcs)**		**Change**	**MPS (ha)**		**Change**	**ED (m/ha)**		**Change**
	1959	**2005**		**1959**	**2005**		**1959**	**2005**		**1959**	**2005**		**1959**	**2005**	
Arable	98,2	108,0	9,8 (9%)	49,1	54,1	5,0	118	51	-67 (-43%)	0,6	1,7	1,1 (65%)	1582,1	239,7	-1342,4 (-85%)
Meadow	47,0	35,0	-12 (-26%)	23,5	17,5	-6,0	27	44	17 (39%)	1,7	0,8	-0,9 (-53%)	189,8	170,2	-19,6 (-10%)
Forest	32,9	41,3	8,4 (20%)	16,5	20,7	4,2	58	52	-6 (-10%)	0,6	0,8	0,2 (25%)	114,3	138,0	23,7 (17%)
Farms	7,3	9,6	2,3 (24%)	3,6	4,8	1,2	27	18	-9 (-33%)	0,3	0,5	0,2 (40%)	53,2	48,5	-4,7 (-9%)
Barns	0,4	0,2	-0,2 (-50%)	0,2	0,1	-0,1	22	4	-18 (-82%)	0,0	0,1	0,0 (60%)	7,9	2,7	-5,2 (-66%)
Ditches	10,3	1,9	-8,4 (-82%)	5,2	1,0	-4,2	1024	122	-883 (-88%)	0,0	0,0	0,0 (0%)	1411,6	249,8	-1161,8 (-82%)
Main road	1,4	1,7	0,3 (18%)	0,7	0,9	0,2	1	1	0 (0%)	1,4	1,7	0,3 (18%)	27,5	27,5	0 (0%)
Side road	1,4	1,1	-0,3 (-21%)	0,7	0,6	-0,1	9	7	-2 (-78%)	0,2	0,2	0,0 (0%)	44,3	36,2	-8,1 (-18%)
Waterbody	1,1	1,2	0,1 (8%)	0,5	0,6	0,1	1	1	0 (0%)	1,1	1,2	0,1 (8%)	54,2	53,3	-0,9 (-2%)
Total landscape	200	200	-	100%	100%	-	1287	304	-983 (-76%)	6,1	7,4	1,3 (0,2 %)	3484,9	965,9	-2519,0 (28%)

Table 8. Arable landscape structural and compositional indices for the study area in Rekijoki for the years of 1959 and 2005. Overall results of the classified arable land categories cereal, grassland, and non-arable land: class area (CA) in hectares, class proportion (%arableLAND), numbers of patches (NP), mean patch size (MPS) in hectares. Net changes of 1959 and 2005 are presented in absolute values and in percentages (parenthesis). Colored symbols (●●●) are spatial reference from the fig. 10.

Arable land classes	**CA (ha)**		**Change**	**%arableLAND**		**Change**	**NP (pcs)**		**Change**	**MPS**		**Change**
	1959	**2005**		**1959**	**2005**		**1959**	**2005**		**1959**	**2005**	
● cereal	64,2 (65%)	76,7 (71%)	12,5 (6%)	65	71	7	36	23	-13,0 (-36%)	1,8	3,3	2,4 (73%)
● grassland	33,0 (34%)	30,6 (28%)	-2,4 (-6%)	34	28	-6	75	17	-58,0 (-77%)	0,4	1,8	0,9 (50%)
● non-arable	1,0 (1%)	0,7 (1%)	-0,3 (0%)	1	1	0	7	11	4,0 (-36%)	0,1	0,1	0,0 (0%)
Total arable land	98,2(100%)	108,0 (100%)	9,8 (9%)	100%	100%	-	118	51	-67 (-57%)	0,6	1,7	1,1 (65%)

Table 9. Edge metrics at the arable landscape level in 1959 and 2005 of the Rekijoki River Valley. Overall results of the classified arable land categories cereal, grassland, and non-arable land: total edge (TE) in meters, and edge density (ED) in meters per hectare. Net changes of 1959 and 2005 are presented in absolute values and in percentages (parenthesis). Coloured symbols (●●●) are spatial reference from the Figure 10.

Arable land sub-classes	**TE (m)**		**Change**	**ED (m/ha)**		**Change**
	1959	**2005**		**1959**	**2005**	
● cereal	103993	37513	67973 (-64%)	527,5	144,1	-383,4 (-73%)
● grassland	203659	20472	189064 (-90%)	1047,9	87,8	-960,1 (-92%)
● non-arable	1342	1945	602 (31%)	6,7	7,8	1,1 (14%)
Total arable land	308995	59930	-249065 (-81%)	1582,1	239,7	-1342,4 (-85%)

Next most abundant LULC class after arable land is valley area with forest and meadow categories. Forest area (CA_{forest}) has consistently increased from 32,9 ha to 41,3 ha, which makes overall gain of 20 %. Forest clumps (MPS_{forest}) has gained 25 % in mean area value. Loss of several smaller forest patches is clear, as number of patches ($N/PATCH_{forest}$) has decreased 10 %. Open area's land cover class (meadow) has decreased 26 %, which makes 12 ha. Meadow area have been segmented into greater number of smaller patches ($N/PATCH_{meadow}$ increases from 27 to 44) and mean patch size reveals that open areas have lost over half of the mean size of patch (-53 %).

Built area, consisting sub-classes farms and barns, have gained in total 21% of the area. More specifically, houses and yards of local settlement (CA_{farms}), have gone through enlargement of 24 % (2,3 ha). Markedly, growth in farms area is reflecting in NP_{farms}, as 9 smaller farm patches have been transformed to another class. The average size of the one farm settlement (MPS_{farms}) has grown 40 %. LULC class barns has lost half of the area (-50 %) and number of storage buildings (NP_{barns}) has decreased tremendously from 22 to 4 (-82 %).

Landscape level

Landscape level indices calculated for the time periods of 1959 and 2005 present study area's compositional changes (Table 10). In 2005, Shannon's diversity index

(SHDI), Shannon's evenness index (SHEI), landscape shape index (LSI), patch density (PD), and total edge (TE) indicate landscape change towards homogenization, as all values have decreased: SHDI has varied from 1,7 to 1,6 (-6 %); SHEI from 0,7 to 0,6 (-14 %), PD from 1107 to 596,5 (-46 %), and TE from 344088m to 96964m (-72 %). Landscape shape index (LSI) reveals that overall configuration of the land is becoming less complex, as the change in index value is considerable, decrease of 70 %. The evenness index decreases in correspondence with an increase of the number of patch types.

Table 10. Landscape level metrics calculated for the time period of 1959 and 2005: Shannons diversity index (SHDI); Shannon's evenness inde (SHEI); landscape shape index (LSI); patch density (PD); total edge (TE).

Landscape metrics	1959	2005	Change
SHDI	1,7	1,6	-0,1 (-6%)
SHEI	0,7	0,6	-0,1 (-14%)
LSI	61,9	18,3	-43,6 (-70%)
PD	1107,0	596,5	-510,5 (-46%)
TE	344088	96964	-247124 (-72%)

Landscape index PD is in correlation with SUM_{NP} (Table 7), as number of patches have declined as well, in amount of 76 % between two time periods.

7.2 Line elements and edge changes

Infrastructure has overcome some structural changes (Table 11), as sideroads have reduced 51% from its total length. Mainroad going through the core of the study area has remained same in lenght (2,2 km), but gained 18 % (0,3 ha) in area ($CA_{mainroad}$). Physical connectivity in the landscape by mean of human use has remained, as mainroad spatial location hasn't changed, but moving between fields has decreased (Figure 9). Edge density of the sideroad ($ED_{sideroad}$) has decreased 18 %, whereas edge density for main road has not changed (Table 7). Also, number of polylines of side road has been decreased with 2 and number of main road polylines has remained the same.

Table 11. Statistics of line elements of main road, side road, and ditches: length in kilometer (km), number of polylines (pcs), and average length in kilometers per polyline (km). Net changes of 1959 and 2005 are presented in absolute values and percentages (parenthesis).

Line elements	**Length (km)**		**Change**	**Nr of polyline (pcs)**		**Change**	**Avg. length (km)**		**Change**
	1959	**2005**		**1959**	**2005**		**1959**	**2005**	
Ditches	105,4	19,3	-81,7 (-77,5%)	1005	122	-883 (-88%)	0,1	0,2	0,1 (50%)
Main road	2,2	2,2	0,0 (0%)	1	1	0 (0%)	2,2	2,2	0 (0%)
Side road	3,5	1,7	-1,8 (-51%)	9	7	-2 (-22%)	0,4	0,2	-0,2 (-50%)
Total road	5,7	3,9	-1,8 (-32%)	10	8	-2 (-20%)	0,6	0,5	-0,1 (17%)

As mentioned in previous chapter of structural statistics, ditches class has gone through most obvious gross loss in area. When observing line elements, the number of polylines in ditches class has been cut 88 %, which is from 1005 to 122. What is more, average length of the ditches has gained 50 % (from 100 m to 200 m), which could be also explained with increase of $\mathrm{MPS}_{\mathrm{arable}}$. Changes in the topological relationships in the landscape are presented in the Table 12.

Table 12. Statistics of edge topology: length in kilometer (km), number of polylines (pcs), and average length in kilometers per polyline (km). Net changes calculated for number of polylines and average length of 1959 and 2005 are presented in absolute values and percentages (parenthesis). Net changes calculated for length 1959 and 2005 consist of absolute values (bold) and percentages relative to 1) absolute values of the lenght and 2) net change in compositional percentage. Colours 🟦 🟥 are spatial reference from the Figure 10.

Edge topology	Length (km)		Change	Nr of polylines (pcs)		Change	Avg. length (km)		Change
	1959	**2005**		**1959**	**2005**		**1959**	**2005**	
🟦 *Arable – meadow*	8,0 (72%)	5,4 (54%)	**-2,6** -33% in km -18% of composition	36	26	-10 (-28%)	0,2	0,2	0 (0%)
🟥 *Arable – forest*	3,0 (27%)	4,6 (46%)	**1,6** 35% in km +19% of composition	27	37	-10 (-37%)	0,1	0,1	0 (0%)
Total	**11,0 (100%)**	**10,0 (100%)**	**-1,0 (-9%)**	**63**	**63**	**0(0%)**	**0,2**	**0,2**	**0 (0%)**

The overall length of valley's edge to arable land from 1959 to 2005 has decreased 9 %. Boundary of arable land and meadow in landscape has remained dominant (72 % in 1959 and 54 % in 2005), as the line element's length has bigger value in kilometers compared to arable-forest line length, relatively. Though, during the study period arable-meadow boundary has lost 2,6 km (33 %) from the length, and the amount of dominance as edge type has reduced 18 %. Accordingly, arable-forest boundary has increased 1,6 km (35 %) in the length from 1959 to 2005, and raised its compositional abundance with 19 %. In 1959, the compositional distribution of the forest-arable boundary was ¼ of the whole length, which constituted minority from the total edge share. In 2005 the distribution of the length of the forest-arable and meadow-arable boundary of the whole length has equaled. The number of polylines of two topological classes have both lost almost one third of the polylines in 1959.

7.3 Transitional changes, swap, net change, change tendencies

Overlaying datasets of 1959 and 2005 resulted transition matrix, what were used to illustrate landscape change dynamics (Figure 11 & 12). The change detection cross-tabulation table was produced for change dynamics monitoring between two points in time (Table 13). Diagonal values in the matrix represent amount of the LULC category which have stayed persistent between two time periods. Rows display the categories of an initial time 1 and the columns display the categories of a subsequent time 2. As so, row totals indicate the amount (ha) of category in 1959 and the columns amount (ha) of category in 2005. The second value in the diagonal (marked as italics in parenthesis) represent the category's percentage of the persistence of the category's total value in 1959 (e.g. 93 % of the amount of arable land in 1959 did not experienced any change and stayed the invariable in 2005). The second value found in each row's off-diagonal cell, and marked as italics as well (5 values per each classified category) form a whole of 100 % (seen in column total 1959), which indicate the amount of area experiencing transition from 1959 to 2005 in percentages. As so, it could be interpreted, that 3,3 ha of arable land from 1959 has turned into built area in 2005, which makes 41 % of the total arable land in transition. The third number in italics below the other italic value recently explained, can be interpretative by similar principle, though calculation are based on total values in transition of column 2005.

Table 13. Transition matrix assessing observed transitions, gains and losses of six landscape categories in years 1959 (time 1) to 2005 (time 2). Numbers in bold are observed transitions (ha) from 1959 to 2005, second row in italics represents transitions in terms of losses and third row transitions in term of gains calculated in percentages. Built area class refers to farms and barns sub-class, and other land class refers to waterbody and roads.

	2005						**Total 1959**	**Loss** (in transition)
1959	Arable	Meadow	Forest	Built	Ditches	Others		
Arable	90,1 *(93 %)*	1,5	1,3	3,3	1,1	0,9	98,2	8,1
		19	*16*	*41*	*14*	*10*	100	*17*
		24	*8*	*77*	*61*	*36*	-	
Meadow	2,8	28,5 *(61 %)*	14,3	0,2	0,2	0,9	46,9	18,4
	15		*78*	*1*	*1*	*5*	100	*38*
	17		*89*	*5*	*11*	*36*	-	
Forest	2,0	4,0	26,6 *(81 %)*	0,0	0,1	0,2	32,9	6,3
	32	*63*		*0*	*2*	*3*	100	*13*
	12	*63*		*0*	*6*	*8*	-	
Built	1,5	0,0	0,2	5,4 *(71 %)*	0,1	0,4	7,6	2,2
	68	*0*	*9*		*5*	*23*	100	*5*
	9	*0*	*1*		*6*	*16*	-	
Ditches	9,8	0,1	0,0	0,4	0,1 *(1 %)*	0,1	10,6	10,4
	94	*1*	*0*	*4*		*1*	100	*22*
	58	*2*	*0*	*9*		*4*	-	
Others	0,7	0,8	0,2	0,5	0,2	1,5 *(40 %)-*	3,8	2,4
	29	*33*	*8*	*21*	*8*		100	*5*
	4	*13*	*1*	*12*	*11*		-	
Total 2005	108,0	34,9	42,6	9,7	1,9	4,0	200	47,8 ha in transition (24 %)
	-	-	-	-	-	-	*(152,2 ha persistent)*	*100*
	100	*100*	*100*	*100*	*100*	*100*	*76%*	
Gain (in transition)	16,9	6,3	16,0	4,3	1,8	2,5	47,8 ha in transition (24 %)	
	35	*13*	*34*	*9*	*4*	*5*	100	

*Interpretation of the table assisted in the first chapter of the recent section.

Overall persistence of the total landscape of 200 ha is 76 %, in other words 24 % of the study area exhibited transitions from one category to another. Spatial layout of the transition matrix, representing overall change occurring in the landscape is presented in Figure 11.

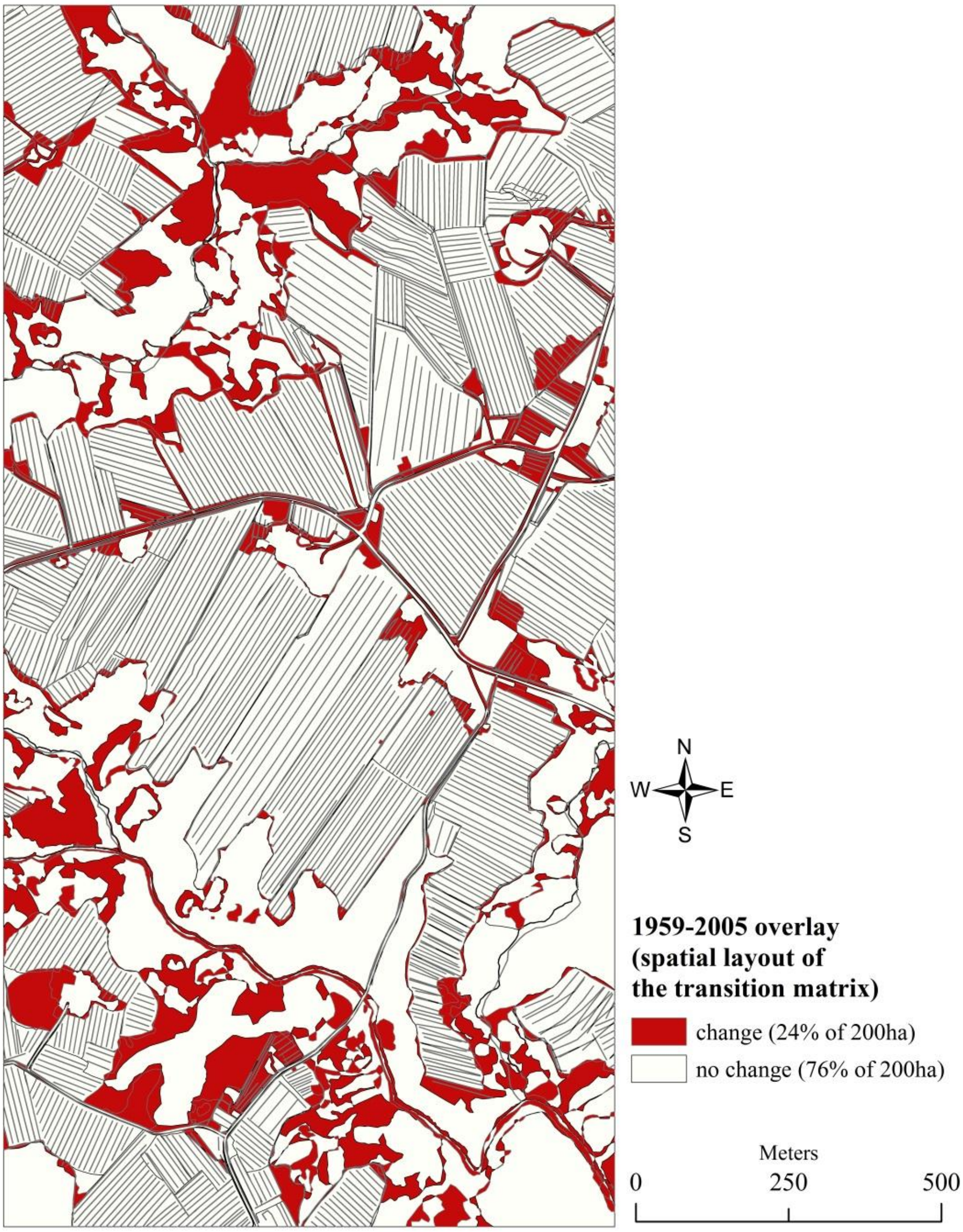

Figure 11. Map illustrating spatial distribution of the patches experiencing/not experiencing change between two time steps of 1959 to 2005, in Rekijoki valley study area of 200 ha. Red patches are the off-diagonal values and light colored patches are the diagonal values from the transition matrix.

In terms of an area (%), arable land category has experienced least transitions, when observing its 93 % of the farmland that has remained unchanged. Forest and built area follow with 81 % and 71 %, respectively. Ditches class has experienced highest amount of transition, as 1 % of the area stayed persistent. Spatial distribution of the landscape patches stayed persistent to changes is observable in the Figure 12.

Figure 12. Map illustrating spatial distribution of the diagonal values from the transition matrix between two time steps of 1959 to 2005, in Rekijoki valley study area of 200 ha. Arable landscape has stayed persistent to the transitions in the amount of 93 % of the categories total area; second most persistent is forest class with its 81 %. Most transitions have experienced ditches class, with its 1 % of persistence of the total area of ditches category.

When observing loss column in the transition matrix, meadow class covers 38 % (18,4 ha) of the total loss in 1959. Another major losses have occurred in ditches and arable land classes, 22 % (10,4 ha) and 17% (8,1 ha), respectively. One can point out following major transformations in terms of gross loss (ha) of the categories: meadow to forest (14,3 ha), ditches to arable (9,8 ha), and forest to meadow (4 ha). Most important relative change (%) in terms of losses per category (first number in italics) has been found ditches dynamics into arable land (94 %), followed by meadow transitions to forest (78 %) and forest to meadow (63 %). Built area follows with loss of 68 % of its total area in 1959.

Biggest gains, observed from gain row in total has occurred in arable (16,9 ha) and forest class (16 ha), as well as in meadow with its 6,3 ha. Accordingly, arable land and forest categories form 69% of the total gains in 2005. Biggest relative gains (%) according to the matrix (second number in italics) has occurred in forest gaining from meadow (89 %), meadow gaining from forest (63 %), ditches gaining from arable and arable gaining from ditches, 61 % and 58 % accordingly.

When observing off-diagonal values categorically, arable land turned mostly into built class (41 %), meadow to forest class (78 %), forest to meadow class (63 %), built area to arable land (68 %), ditches to arable land (94 %). Others class (e.g. waterbody, main road, side road) has experienced areal transitions mostly to arable, meadow and built class, altogether in 83 % of its total transition (areal amount of change, though, is moderate).

As dataset concluded numerous class dynamics on the patch level, it has been chosen to present transitional patches which covers area over 0,09 ha. Accordingly, most dominant changes in terms of the area (>0,09 ha) is presented in the Figure 13 & 14. As seen, transitions are in or adjacent to valley landscape: meadow turned into forest, forest turned into meadow, meadow turned into arable land, and forest turned into arable land. Furthermore, transition from arable land into built (farms area) is most visible in the arable landscape adjacent to human settlement. Also, it is noticed that transitions into arable land are situated mostly on the boundaries of the valley and arable land: patches are more like strip-shaped and narrow, with exceptions in the southern part of the study area, where couple larger orange and blue patches stand out (meadow and forest patch turned into arable land).

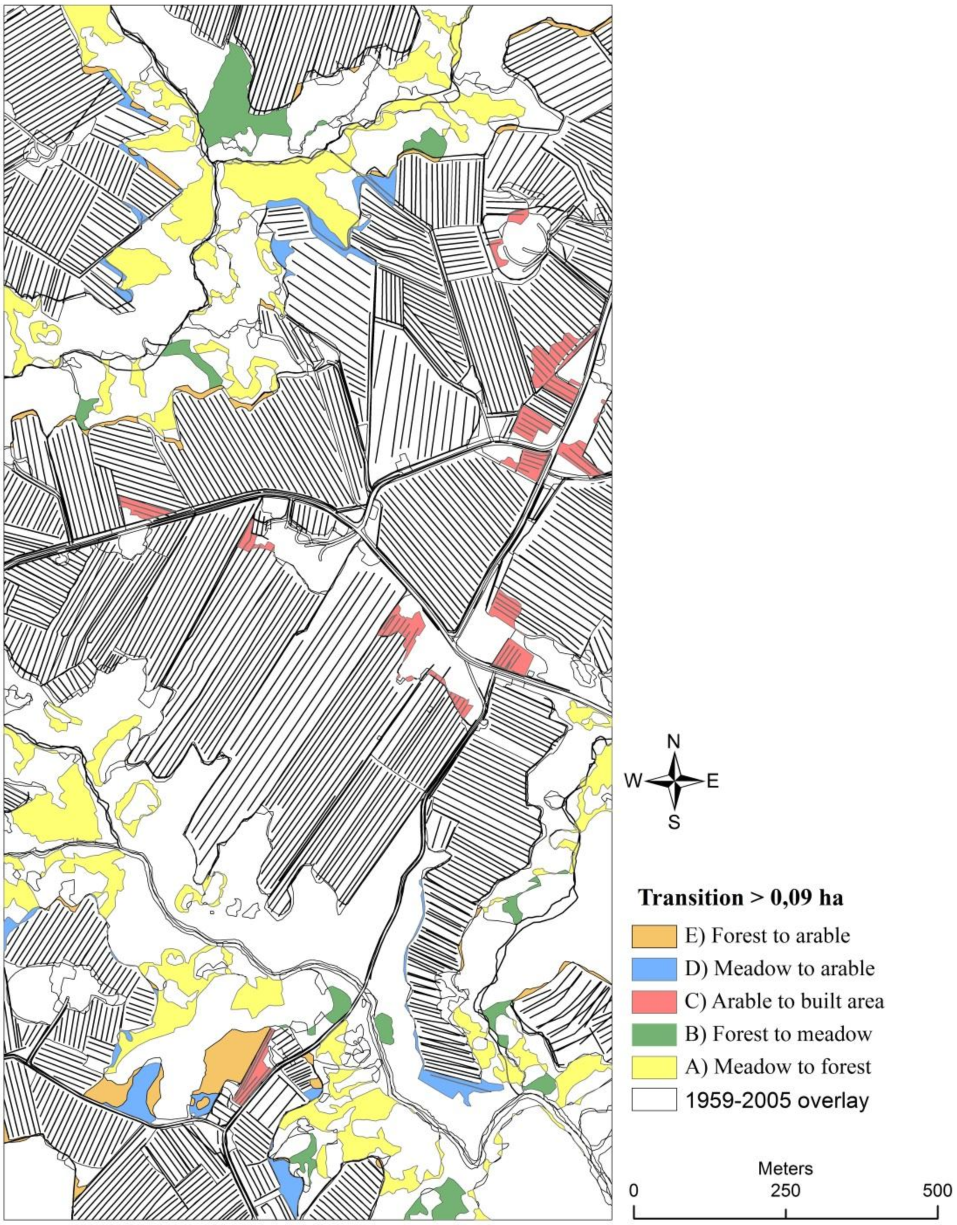

Figure 13. Map illustrating major (>0,09 ha) transition patches spatial distribution. Most remarkable dynamics from meadow to forest are indicated with yellow color, the second biggest areal change is colored green indicating transition from forest to meadow, third is red patches dynamics from arable land to built area; fourth is blue color indicating meadow dynamics to arable land; and last remarkable areal change is orange color indicating transition from forest to arable land.

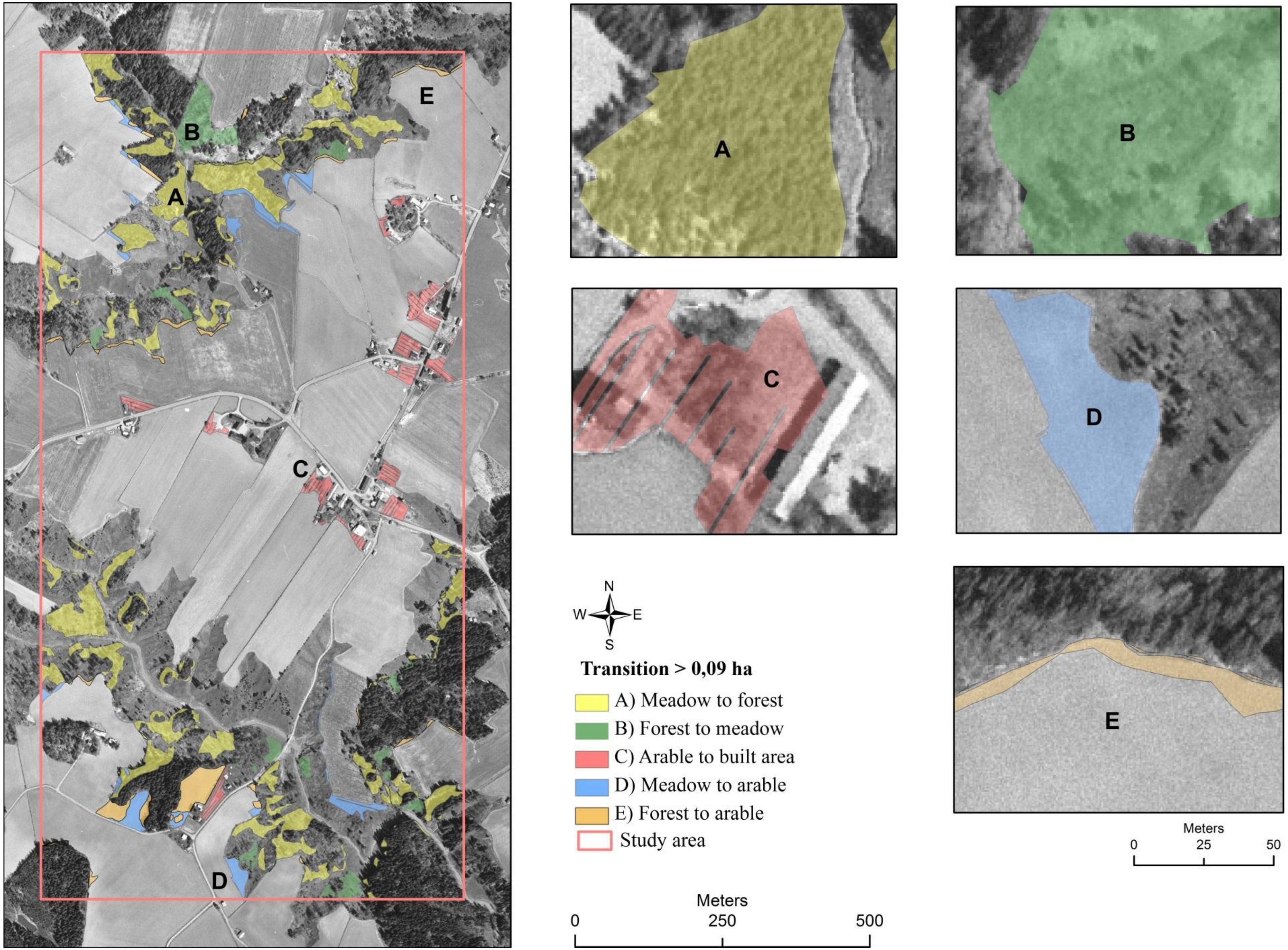

Figure 14. Map locating patch-based transitional changes of the land cover classes. Each patch presented in color considers area over 0,09 ha. Yellow color represents areal transition from meadow to forest (A); next biggest areal change is marked green indicating transition from forest to meadow (B); third transition is marked with red patches indicating arable land turning into built area (C); fourth and fifth transition indicated with blue (D) and orange (E) colors are meadow and forest classes transforming into arable land.

The map presenting transition (>0,09 ha) with additional aerial image on the basis as a reference for visual interpretation is presented in the Figure 14. For example, it is seen that what in 1959 has been meadow, is forested in 2005, coded with the element A. Contrastingly, element B shows the area of forest in 1959 that in latter time period of 2005 has been cleared and turned into open area (meadow). The expansion of anthropogenic activities is illustrated with the element C, as arable land has been replaced with farming building and its surroundings. Elements D and E are examples of arable land dynamics: larger meadow patch altered to arable farming and forest strips "smoothening" the arable land edge shape with transformation to field margin.

Gross gain and gross loss can include several contiguous elementary changes (Table 14). Calculations of net change, gain/loss and swap helps to decode transition matrix, as it might not be so apparent, how the category has changed (Pontius et al. 2004; Manandhar 2010). Major areal transitions have occurred in arable land, meadow and forest classes, beholden by total change calculation.

Table 14. Categorical areal (ha) changes of the landscape. Calculations, based on total gain and loss determining total change (C_j), swap (S_j) and net change (D_j). Relative results (%) for swap and net change are calculated from total change.

LULC category	**Gain**	**Loss**	**Total change (C_j)**	**Swap (S_j)**	**Net change (D_j)**
Arable	16,9	8,1	25,0 (100%)	16,2 (65%)	8,8 (35%)
Meadow	6,3	18,4	24,8 (100%)	12,7 (51%)	12,1 (49%)
Forest	16,0	6,3	22,3 (100%)	12,6 (57%)	9,7 (43%)
Built	4,3	2,2	6,5 (100%)	4,4 (68%)	2,1 (32%)
Ditches	1,8	10,4	12,2 (100%)	3,6 (30%)	8,7 (71%)
Others	2,5	2,4	4,9 (100%)	4,7 (96%)	0,2 (4%)
Total	47,8	47,8	95,7 (100%)	54,2 (57%)	41,5 (43%)

According to the net change, all categories have gone through definite change. Furthermore, swap indicates more exact dynamics of the category. Others class (e.g., waterbody and roads) has gone through swap-types change in the amount of 96 %, which means minimum value for net change (4 %). Also built area's swap and net change calculations reveals that 68 % of the built areas transitions comes from swapping process and 32 % of the total built area's change goes through net change. In means of area (ha) arable land has gone through swap and net change in the biggest amount. It is interpreted, that 35 % (8,8 ha)of the total gain in the arable land category in 2005 is originated from direct gain from the surrounding landscape. Meadow and forest change has general pattern that is characteristics for the total landscape, which is relatively high amount of the category (49 % and 43 %, respectively) experiencing net change. Ditches class transformation to another class is described in the amount of 71 % as net change (which in this term has loss implications, as gain is relatively small compared to loss), though, some part (30 %) experiencing also swap-type change.

The persistence indices (Table 15) were used to assess the persistence characteristics of the LULC in relation to gain, loss, and net change. When observing gain-to-persistence value, the ditches class has highest ratio of 18. Other class as well has g_p value over 1, which is 1,7. According to Braimoh (2006) it indicates that these two classes experience more gain than persistence.

Table 15. Gain-to-persistence (g_p), loss-to-persistence (l_p), and net change-to-persistence (n_p) ratios of the LULC classes.

LULC category	g_p	l_p	n_p
Arable	0,2	0,1	0,1
Meadow	0,2	0,6	0,4
Forest	0,6	0,2	0,4
Built	0,8	0,4	0,4
Ditches	18	104	87
Other	1,7	1,6	0,1

Also, when observing loss-to-persistence ratio, ditches and other class are having value over 1, which are 104 and 1,6, respectively. Similarlay (Braimoh 2006), it indicates that these classes have high tendency to be involved in landscape transformation process than rest of the landscape. Whe, observing net change ratio, then only ditches class has value over 1, which is 87.

7.4 Markov's probability, change rate

Markov's probability calculations are presented spatially in the map (Figure 15) and in the probability matrix (Table 16).

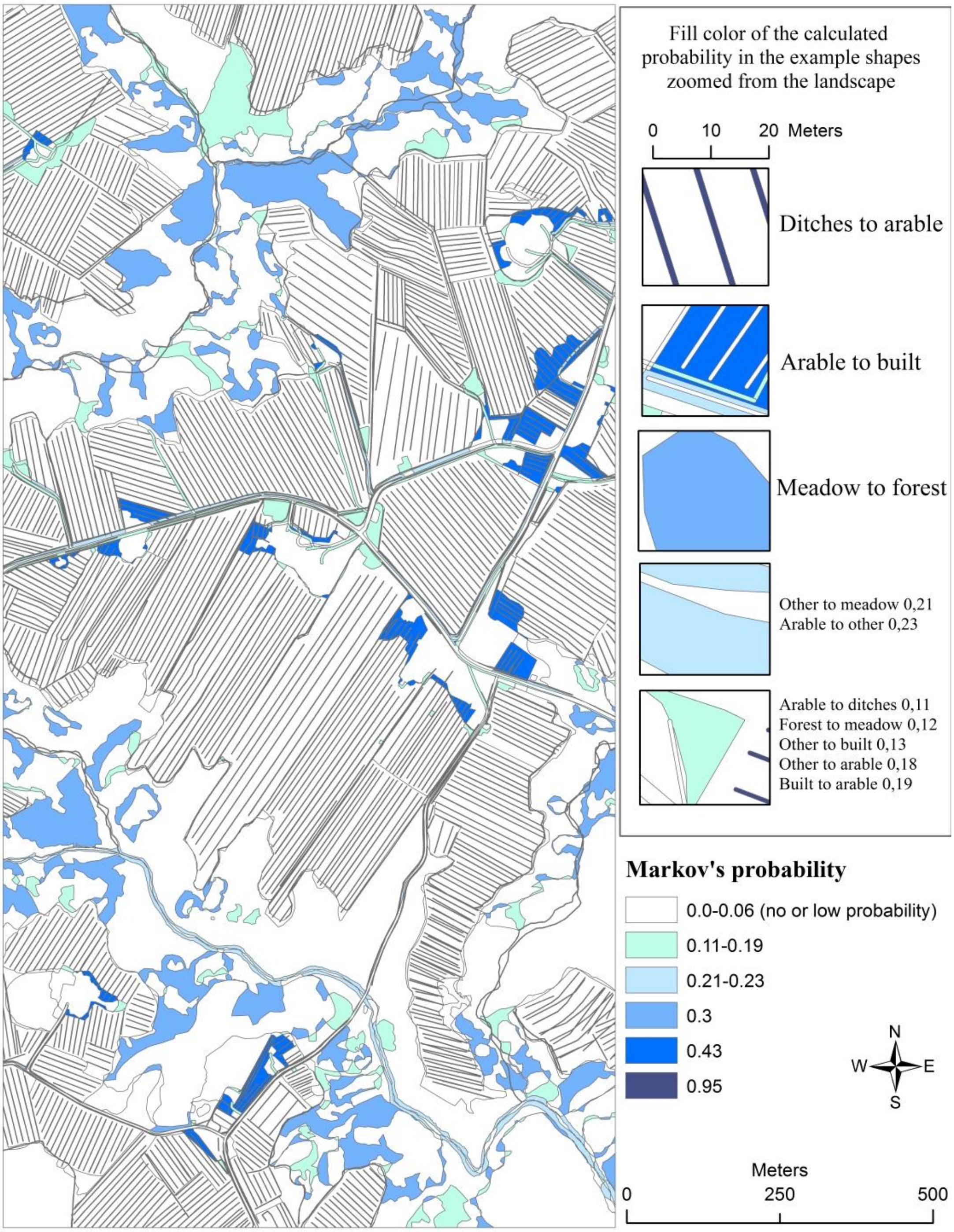

Figure 15. Visualization of the Markov's probability calculations of 1959 and 2005. Darker colors illustrates the major probabilities for the area to be modified into another LULC class.

Based to the present state of the class, Markov's transition matrix allocates probability that a LULC class will transform to another class in future. As seen from the map (Figure 15), spatial configuration of the probabilities are concentrated around human settlement. The valley landscape has middle level of bluish colors, indicating moderate (0,21-0,3) or small (0,11-0,19) probabilities to change to another class in the future. Areas with white color (0,0-0,05) are determined to go through any noticeable change in the future. Most outstanding conversion probability is for ditches to arable land (0,95) and arable to built area (0,43). Interpretation from the map is enhanced with zoomed layer of ditches, so it is visible, that ditches class is filled with darkest color.

Table 16. Markov's probability matrix for 1959 and 2005.

1959	2005 Arable	Meadow	Forest	Built	Ditches	Other
Arable	**0,92**	0,03	0,04	0,43	0,11	0,23
Meadow	0,06	**0,61**	0,30	0,00	0,00	0,02
Forest	0,06	0,12	**0,81**	0,00	0,00	0,01
Built	0,19	0,00	0,03	**0,70**	0,01	0,05
Ditches	0,95	0,01	0,00	0,04	**0,01**	0,01
Other	0,18	0,21	0,05	0,13	0,05	**0,38**

As seen from the diagonal values arable land and forest class has the highest values of resistance, 0,92 and 0,81 respectively. Built area and meadow class follow with the values of 0,70 and 0,61. Computed change rate comprehensively assists interpretation of trends of the each LULC class transitions (Table 17).

Table 17. Change rate of LULC classes.

Land-use class	1959-2005
Arable	0,19
Meadow	-0,65
Forest	0,56
Built	0,53
Ditches	-3,70
Other	0,09

Ditches class has decreased with the most intense rate (-3,70), followed by meadow class (-0,65). Forest and built classes are having positive values of 0,56 and 0,53, which can be interpreted as customary increasing rate. Rate values close to 0, like in arable and other classes, deflect low change of 0,19 and 0,09, respectively.

8 Discussion

In a landscape, three mechanisms create the pattern: heterogeneity (e.g. landscape patches), natural disturbance (e.g. fire, pests) and human activity (e.g. plowing fields and building roads) (Forman 1995: 5). The change detection analysis provides insight to ecosystem functioning and stability and puts forth the land use impacts. Comparing data collected at different times is a traditional way of change detection. Spatial extent and location of change is depicted with mapping procedures in GIS. Approach to create categorical map was based on manual data processing, supported with interpretation plan. As the study contains categorical analysis characterizing rural landscape, classification plan composes of arable land and featuring aspects, like ditches, storage buildings and areas occupied by farms. In this study spatial analysis of the two datasets based on transition matrix is applied in order to illustrate transition matrix, in means of spatial distribution of the changes (Figures 11-14).

Area of interest of this study represents both agricultural and natural landscape, as the location is in the middle of two local settlements and between valleys ‘branches’. Analyzes perspective is concentrated on the volume of human intervention in landscape: human landscape and semi-natural landscape. Human landscape consists of intensive agricultural land, built areas, and infrastructure. Semi-natural landscape is located mainly in valley area: consisting forest and open areas, influenced by extensive agricultural activities, like mowing and grazing, or foresting. This research is based on analyzing the change in landscape pattern calculating landscape metrics and computing transition matrix to make predictions and to apply change evaluation techniques. As objectives of the study were to monitor categorical changes and trends of the landscape change, the scale of the research was chosen to be on the patch and total landscape level.

Procedure quantifying the landscape pattern without considering process, failures to deal with change analysis (Li & Wu 2004). Therefore, structural and compositional metrics were chosen. Combining structural statistics and transitional calculations is an effective way to study rural landscape modifications.

When classifying habitat patches of the landscape, human perception was used in identifying, both in agricultural and natural landscape. This approach to determine landscape pattern is not considering habitat requirements, movement patterns and other ecological attributes of the local organisms − anthropocentric classification is applied. The use of ecological terms, like fragmentation and connectivity, are considered with concepts of landscape heterogeneity. Discussion is derived on the broad species-specific response and requirements to landscape condition: meadow species prefer open-areas, species using habitat corridors (ditches) to move in the landscape, edge species dependent on the edge property (forest or meadow). The patterns of landscape element assemblages are described in terms of connectivity, shape, edge density and structure. Researches focus both on whole landscape matrix and elements in the matrix. Additionally, discussion covers the topic of anthropogenic landscape versus natural landscape, upholded with topological aspect.

8.1 Agricultural landscape

In this study area arable fields are ranging of very different sizes and shapes (100m^2 to hundreds of hectares) ranging from small individual fields surrounded by forests to larger, contiguous farmland. Before the mechanization, smaller plots dominated landscape, managed mostly with horses. After development of farming practices in the middle of 20th century, when tractors and subsurface drainage were introduced, field plots average size increased.

In current research, agricultural developments have had important direct and indirect consequences to the local cultural landscape. Relationship between change and arable land is affected mostly by mechanical evolution. Immediate influence is noticeable in ditches area’s decrease of -82% (Table 7) and decline in number of ditches elements of 88 % (Table 11). According to the Statistics of subsurface drainage in Finland (2005) in 2005 there was 82% of the arable land installed with subsurface drainage in southwest Finland. Also, Hietala-Koivu’s (1999) spatiotemporal study of 39 years (1958-1997) have determined the tremendous fall of 91% in lenght of open ditches in study area situated in southwest Finland, as well. Not only the amount, but also spatial distribution of the drainage enhances the ease of farming. Today, open drainage is spatially distributed mostly on the field edges and road sides, compared to previous time step, when drainage had merely parallel distribution over the field. Ditches category has turned mostly into arable land (94% of the total *ditches* transition from 1959 to 2005 is to category *arable*,Table 13), resulting more effective and convenient cultivation possibilities. From the ecological point of view, the decrease in network of ditches on the fields reduces both landscapes' structural and functional connectivity.

The loss in movement and habitat strips for invertebrates or small mammals has negative effects for arable landscapes biodiversity, as spatial connectedness of landscape elements has impaired. Vegetated corridors may facilitate the movement of plants and animals among habitat fragments (Collinge 1996). Arable land's spatial heterogeneity is reduced with large-scale management, as the average patch size of arable land (Table 8) has gone through remarkable increase of 65%. When, exploring the arable land category at the crop level, average patch size of the cereal field and grassland has increased substantial 73 % and 50 %. Patch density calculated to arable land features the homogenization aspect, presenting the considerable decrease of 46 %. Diminishing of the smaller farms and storage buildings, having aesthetical meaning for the local culture, reflects the revenues of the mechanization in the agricultural landscape change process. The category *barns* have decreased substantially 82 % in the number of buildings and big amount of the area has transformed to arable land. Hietala-Koivu (1999), as well, has found especially barn class experiencing decrease in abundance (in 1958-1997, because fewer farms keep cattle and old hay barns are demolished.

Landscape comprises the major biophysical attributes, which influence its use. Steepness of the terrain and erosions may be one reason, why the Rekijoki valley area itself has stayed moderately or very little disturbed and therefore, low disturbance has become advantageous to natural diversity. Native ecosystems of forest and meadow in the Rekijoki study area have been transformed to agricultural field in very moderate amount. Such transitions occur only on the margins of the valley area, where interruption to adjacent land is easier; as landscape is relatively flat and getting steeper to the valley, because of slopes, is difficult.

River Rekijoki valley is situated in the south boreal growth zone, which makes the region, in terms of agricultural practice, placed in the suitable area with its longer growth period and climate compared to northern area in Finland. Main types of agricultural managing found were cereal croplands and grassland. The amount of non-arable land (low-productive small plots adjacent to agricultural land) was not considerable in terms of total area. When comparing arable land under crops in 1959 and 2005, 6 % of relative increase in area is noticed. Controversially, when observing grasslands amount, then it could be noticed relative decrease of 6 %. Cereal crops growing in SW Finland have become more popular managing type, indicated with the rise of almost 13 ha in total arable land dedicated to cereal crops from 64 ha to approximately 77 ha. More economic benefit from the landscape is gained, as the overall amount of crop yield per hectare has raised remarkably compared to previous times due to agricultural evolution, such as invention of chemical fertilizers and pesticides.

When exploring reasons for cereal and grassland land use fluctuations, Finnish agricultural history leads to many explanations. First of all, traditional hay making and grazing decline in the middle of 20th century , explains the grasslands areal decrease. Still, the cereal and grassland land use in the researche’s time steps of 1959 and 2005, may have been in systematical land use rotation (activities located also outside the study area’s frame), which was not discovered in fine-scale research. Alternatively, additional research about land use intentions (e.g. interviews) could have favored more advanced distinguishing of the seasonal rotation.

Arable land edge density’s remarkable decrease of 85 % leads to fewer interfaces with the surrounding landscape. It can mean less impact to natural environments, but oppositely also weaker contact between habitat patches in the landscape. That is to say, in the study area several dispersed cultivated patches under grassland and cereal land have merged into one patch. When compared with previous time, arable landscape is more difficult to pass in terms of disappearing habitat corridors.

Ecologically, population’s extinction probability increases when population connectivity decreases (Leigh, 1981). Also, the category side road, as linear feature in the agricultural landscape has decreased altogether 51 % from the total length. Diminishing of ditches and field roads to arable land might affect local pollinator butterfly species dispersal between vital vegetation patches providing food and shelter for worms – isolation reduces capacity to carry population. Species movement between habitat patches is important element in metapopulation dynamics (Wiens 1997). Though, disappearing of those linear elements providing habitat for unwanted species, prevents weed and pest invasion among remnant vegetation. From the regional habitat perspective, agricultural habitats (ditch verges and side road verges) have become more fragmented. Also the shape of patches within study area has changed more rounded shape, as identified with landscape shape index. Still, decrease of the human originated landscape elements, like barns and field roads, may reduce habitat diversity in the agricultural landscape.

As landscape becomes more homogenized, it becomes simpler, compared to more “natural” landscapes (Forman 1995). Overall homogenization of the landscape is affirmed quantitatively with calculating landscape indices SHDI and SHEI (table 4.6) at the whole landscape level, demonstrating the decrease of 14%. LSI indicates the vast change towards linearized landscape, as it decreases 70%.

8.2 Valley landscape

Landscape within the valley area has greater existence of microclimatic variation due to its aspect and angle of slope. Rekijoki valley’s area meadows serve as maintenance zones for certain plant and animal species, like butterflies, specialized in this area. The potential of the surrounding landscape on species richness is studied by the coverage of trees and monitoring the area of open-areas. Increasing cover of trees has negative effects on total species richness and that of rare grassland species in Rekijoki valley (Pykälä 2000). In this study, number of the smaller forest patches is decreasing, thereby increasing the average size of the remaining patches. The overall size of natural forest have increased 20% and the number of forested patches decreased from 58 to 52 (-10%), which means changes in the patterning of the forest category. The increase in the cover of trees after the end of grazing may be more detrimental to grassland plants than the lack of grazing per se (Pykälä et al. 2005).

Semi-natural areas (meadows) is determined to change towards degradation and fragmentation: approximately 12 ha (-26 %) of meadows area has transformed mostly (89 % of the *loss*, calculated in the transition matrix) to the forest class. It is assumed that certain butterfly population densities are in correlation with decline in habitat area (Krauss et al. 2003). Valleys meadow patterning is characterized with habitat subdivision, also defined as ‘fragmentation process’ (Forman 1995; Botequilha Leitão & Ahern 2002), indicated by the increase in number of meadow patches from 27 to 44 (39 %) and remarkable decrease in mean patch size of meadow from 1,7 ha to 0,8 ha (-53 %). Decreasing of the meadow’s mean patch size could be threatening both for the herbivorous biological diversity and invertebrates, as it is known that species richness if often found to be higher in large patches. Still, even those small patches are significant as a supplement too, as they may be used as stepping stones for species recolonization or species dispersal (Forman 1995: 439). Butterflies prefer open areas and increasing of forest environments could influence the existence negatively. Also, changes on spatial configuration and patterning of meadow patches in the valley have effects on physical connectivity. Meadow patches are getting more isolated, in due of forest overgrown.

Forman & Gordon’s (1986: 27) landscape change principle states that when undisturbed, horizontal landscape structure tends progressively towards homogeneity; moderate disturbance rapidly increases heterogeneity, and severe disturbance may increase or decrease heterogeneity. The loss of native vegetation is not permanent and unidirectional. Devoted sustainable landscape development restores local vegetation’s diversity and hence relieves susception to local extinction. Many ecosystems with high nature values in Europe depend on the continuation of specific forms of extensive agricultural land use (Strijker 2005) like cattle grazing (Pykälä 2007). Although livestock grazing leads directly to the loss of vegetation cover, it is linked to encroachment of cultural local vegetation. The spatial pattern defining valley of meadows surrounded by shrubs and moderate forest cover is maintained by interplay of sheep or cattle grazing and hay making. Meadow and forest areas with greater probability of transitioning to other land-uses should be taken into consideration for restoration effects. The loss of habitat is not definitely permanent and unidirectional problem. The conservation of natural and seminatural habitats, or the creation and maintenance of new seminatural areas, is the most promising way to enhance or restore species richness in agricultural landscapes (Duelli & Obrist 2003). Maintenance or restoration of a high diversity of vegetation types within habitat remnants may be essential to long term population persistence (Collinge 1996). Hypothetically, as the increase of the forest area would slow remarkably, there would be few gradual losses of meadow patches in the future.

Appropriate human intervention, like mowing or animal grazing has many beneficial aspects for wildlife and resource maintenance, as well as visual dimension valued by man-kind. The ecosystem development following abandonment may provide opportunities for the restoration of aspects of the native ecosystem and contribute to the achievement of the conservation outcomes in the region. Alternatively, socioeconomic consequences of land abandonment may lead to reduced income from tourism. The compensation of grazing and mowing has been of utmost importance in maintaining biodiversity in Europe, where humans have long suppressed natural disturbances (Pykälä 2007). In general, biodiversity and aesthetic properties are associated with heterogeneity in a landscape.

8.3 Edge between arable land and valley

Composition distribution of the edge type revealed that, the forest edge type has increased tremendously compared to meadow edge type, which in turn has lost almost the same amount (-18 %) of the length in total composition. When in 1959 forest edge consisted one fourth of the total edge between arable and valley area, then in 2005,the amount of forest edge to arable has increased to 46 % of the total edge length. Also, it is interesting to note out, that in the number of polylines of the forest adjacency to arable land, gradual loss of 36% is indicated. It concludes to the assumption that spatial patterning of the different edge types has undergone considerable change towards homogenization. Also Weng & Wu (2005) has noted that using edge segment density (number of polylines) for specific edge types is comprehensive information for characterizing fragmentation.

The structural edge changes are dependent mostly on the dynamics from meadow to forest within the valley landscape, and not as much because of conversions in the agricultural landscape. Arable land patches locations in respect to the other LULC categories have stayed mostly unchanged. The shape of the valley verge monitored from the map seems to be less devious, which explains the overall loss of 1 km (9 %) from the total edge length. Linear and rounded shapes has different influences for the edge attributes. Patches with highly irregular, convoluted boundaries will likely have greater exchange of nutrients, materials, and organisms with adjacent habitats (Collinge 1996). More simplistic edge curves and loss in meadow edges may affect the ecological flow and permeability between the agricultural landscape and valley, as well the microclimatic conditions. From another point of view, more rounded or compact form with minimal appendages (i.e., minimal perimeter-to-area ratio) is characteristics of systems where it is important to conserve natural resources, like organisms (Forman & Gordon 1986: 177). Forest edge is known to have different ecological functions compared to open area’s edge: forest edge becomes warmer, preserves more humidity, influences wind velocity and light penetration with its higher stand (Murcia 1995).

Characteristic ecotones are developed between temperate forests and cropland. The overlap zone or ecotone is narrow and composed mainly of intermixed species from both sides (Forman & Gordon 1986: 60-61). Edges of the agricultural land and single habitat patches in the valley area have meaningful relationship for edge species. The proportion of the meadow adjacent to agricultural land has decreased considerably, which may be concerning for population ecology (*conservation biology*). Populations of plants and animals in areas with bigger vegetational diversity may be less susceptible to local extinction (Kindvall 1996). Spatial scale of the changes are key issues associated with consideration of movement between habitats. The larger scaled changes may have important consequences in terms of survival for small mammals and flightless insect species. What constitutes loss of continuity of edge type and permeability for movement from the agricultural landscape edges to natural area is species-specific. Forest patches buffer the valley area, with keeping the suitable microclimatic conditions for plants. Forest edge to arable land also ‘protects’ from agricultural disturbances, like chemicals and noise. For agricultural land species, it might mean a growth of the natural barrier, isolation from natural landscape, which in turn affects foraging, reproduction.

Different ecosystem types (arable land adjacent to meadow/forest) could be investigated by extent of the the areas supporting the edge. When, for example, meadow edge to agricultural land has decreased, then it would also be useful to know, in what amount those meadow patches have been lost. Diminishing of the short strips of certain edge may influence markedly the total edge ecosystem. Also, Kuussaari (2007) has determined the significance of even small patches of semi-natural grasslands and open, sunny forest edges for species richness in modern farmland. Spatial arrangement or configuration of landscape elements are ecologically more important, than quantity (Forman 1995: 5).

8.4 Change trends

In means of areal coverage, forest, built and arable land classes have increasing trend to expand, while meadow and ditches class are indicated to have decreasing trend in areal growth. Change rate (-0,65) for the meadows category may be interpreted to be quite concerning, as it is well below under 0 compared to other categories. Ditches class change is considered to be one-time permanent transition, as tendency is extraordinary high, and spatial distribution has determined that possible changes are finite (the ditches remained on the sides of road and bordering fields will stay in the todays state). Spatial configuration of the vulnerability to future changes in the landscape is calculated with Markov’s probability (Table 16).

It is determined that, the tension of the change probabilities is concentrated nearby human settlement (value is 0,43-0,95) and then in the valley area (values between the interval of 0,11-0,43), pointing out that, changes occurring in intensive agricultural landscape are not as substantial as changes in extensive agricultural landscape. Extensive agricultural landscape, from the local perspective, has been part of the historical land-use in the study area. Depressions slopes have been used traditionally as pasturing area. In 1970s and 1980s, local valley structures were fragmented due to afforestation and natural overgrown (Alanen & Pykälä 2004: 200-201). Pasturing were started to be managed again in 1993-1998, supported by several regional and national institutions, which raised the areas of meadows coverage markedly (Lehtomaa 2000a). When observing the diagonal values of the Markov's matrix, it could be seen, that almost all the values for the six LULC categories are well over 0,50. When before it is mentioned the high rate and trend of the meadows category to decrease in coverage, then according to the probability observation, it is possible to evaluate with comparing the probabilities, that such concerns of meadows transitions has moderate trends. The exception of the value being well under 0,50 is noticed to be more in the *other* and *ditches* class.

When speaking of the overall state of the landscape, then patch density (PD) could be applied to make conclusions. According to McGarigal et al. (2002) landscape with greater patch density (PD) would have more spatial heterogeneity. As so, Rekijoki study area are noticed to have tremendous decrease of 46% in patch density, which can be interpreted as landscape's trend towards homogeneity.

8.5 Implications

Range of spatial and temporal complexities that characterize the magitude of edge effects could have been investigated with calculating the shape index for patches participating in edge characteristics, especially the meadow and forest patches.

Historical change detection studies are dependent on availability of remote sensing data. This research uses two datasets from time section of 1959 and 2005. Time sections represent different practices in agricultural history. In means of more detailed results of change rates and transition probabilities, some extra datasets between those two time periods could have enhanced the final assumptions. Also one possibility to endorse the inferences of the study would have been to choose several study area plots from more extent area. Nevertheless, individual regions are defined by degree of contrast and interaction with adjacent areas rather than by absolute size (Olson & Francis 1995: 8).

Research is based on digitizing and accuracy of the technique is dependent on the correctness of the adapted classifiers. Landscape structure must be identified in meaningful ways before the interactions between landscape patterns and ecological processes can be explored (Turner 1989). The minimum grain and extent of the classified element was determined by the smallest landscape feature eye could identify from fine-scale image, 0,5x0,5 m. Aerial photos pre-preparation consisted of georeferencing and setting the projection. Possible inaccuracies in pre-preparation process were avoided with achieving the appropriate values of GCPs (ground control points).

Transition matrix of changes has been examined in depth to discover possible anomalies, when observing the dynamics. As transition matrix lacks in capacity of discovering reallocation (Pontius et al. 2004), additional calculations of swap, net change and total change is made. Whereas categories' dynamics, transition matrix presents also categories persistence and gains/losses. Additional calculation for tendencies to persist and gain/loss, help evaluating the matrix's results. The rate of land use and land cover change is applied in order to calculate each categories value. Moreover, additional time steps during study period would have enhanced exploring the fluctuations in the change rate (Teferi et al. 2013).

In the study of edge characteristics, methods to investigate edge dynamics in the surroundings of the key biotopes enhances the understanding of the boundary functions (Käyhkö & Skånes 2006). In current study, boundaries of agricultural landscape and valley area are described with length and type (i.e meadow to arable: forest to arable). Using the buffer analyses in zoning approach, would have added transitional perspective to the boundaries study, as well.

Scant attention should be payed on that, the recent work implies on the desktop methods to change detection. It is important to understand the habitat requirements of organisms as part of determining the impacts of landscape change on them. Field work and determining the species compositions with samples would have had contributory effect to the study. Also, classified categories of boundaries having ecological relevance for analyzing valley habitats quality is based on assumption ‘how landscape pattern *may* relate to the given group of edge species’. Extrapolating accurate results of previous researches to small-scale studies remain questionable (McGarigal & Cushman 2002). Still, many of the background researches concentrate on the river Rekijoki valley area’s biodiversity and overall landscape structural changes in Finland.

9 Conclusion

Landscape ecology emphasizes broad spatial scales and the ecological effects of the spatial patterning of ecosystems. Changes in structural complexity of land cover occur as a consequence of human land-use practices, which are predominantly associated with agricultural development.

Historical land use and different agricultural production types have played an important role in influencing land-use pattern in Rekijoki study area. Mosaic structure of landscape elements has changed by the combined effect of processes. Socio-economic constraints, like changes in the importance of other cultivation sectors (e.g. cereal growing) and evolution in machinery, has played important role of the management of agricultural landscape in Rekijoki. Intensification of agriculture is obvious in the most productive lands. The overall results suggest that the ecological value of agricultural landscapes has homogenized. What is more, it is concluded that significant changes in the landscape structure/pattern and habitat diversity are caused mostly by natural overgrowing in the valley area and larger-scale agricultural activities in the arable land. Traditional land use change to another state was highlighted with five transitions in means of large extent in the area: meadow to forest, forest to meadow, arable to built area, meadow to arable, and forest to arable. Characteristic spatial arrangement of particular landscape is dependent on the steepness of the valley slopes. There hasn't been any tremendous transition from natural area to under agricultural land.

The critical issue of landscape change is not just the area of conversion but also the transformation or changes in ecological 'condition'. In ecology, habitat loss and isolation, caused by the process of land conversion, have been referred as 'habitat fragmentation'. Forest overgrown in valley area and arable land structural changes towards homogenization leads to loss in connectivity and habitat for invertebrates and butterflies. Abundance and configuration of landscape elements revealed that remarkable changes were decrease in the number of open ditches, substantial deprivation in patch density and the landscape change towards more linearized shape.

Rekijoki valley landscape diversity is a function of both historical events and current socioeconomic and ecological interactions.

Interface between two ecological communities was achieved with assigning topological attributes to the strips between two adjacent landscape categories of the edge and arable land. It is concluded that the trend towards more forested edges may have negative implications for the local invertebrates preferring open areas and permeability in the landscape matrix. However, the overall results of the edge length between agricultural landscape and valley area have experienced little change, which upholds the persistence of the traditional valley landscape adjacency to farmland.

We expect that landscape beauty, here a by-product of agricultural systems, can only be maintained if the specific landscape elements and their overall landscape structural pattern also have agro-ecological functions recognized by farmers. Finally we should also consider how useful the knowledge of ecological processes at the landscape level is for design that focuses on visual dimension of the landscape. There is significant relationship between ecological integrity and aesthetic constraints. Changes in the visual dimension of the landscape resulting from forest removal are viewed positively by most segments of society other than farmers.

As a final conclusion, it is assured that there has been a significant land cover change due to farming practices expansion: arable land area has increased; reduce in traditional agricultural activities have resulted overgrowing of the meadow patches, and forest edge has increased. Traditional management intervention in river Rekijoki valley was found to have some developments in the last decade. The restoration activities in the valley area, by means of cattle grazing and pasturing definitely helps to maintain the areal relationship between meadows and forests, in order to preserve traditional rural biotopes. Recognizing different landscape varying states is important for conservation strategies, whereas identifying which ecological processes are the most important for a given landscape species can be essential for developing effective mitigation strategies.

The datasets of Rekijoki valley landscape land use and land cover created during current study could be used in further retrospective investigations as a source of historical information. Underlying landscape dynamics analyses add important approach for management and protection plans, as it is precisely described where the changes have occurred.

Finally, devoting much of our attention to the land uses in traditional landscapes consisting of rare biotopes, one can reduce the negative ecological effects caused by inadvertent terrain altering, to biota and landscape heterogeneity.

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