National Environmental Research Institute
Danish Ministry of the Environment

Dynamics of Danish Agricultural Landscapes and the Role of Organic Farming

PhD Thesis

Gregor Levin

Roskilde University

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Abstract: This study explores relationships between organic farming and composition of agricultural landscapes. At national scale, results indicate that the conversion to organic farming significantly influences landscape composition in terms of increasing diversity of agricultural land uses and decreasing mean field sizes. Investigations of case areas point at few relationships between organic farming and landscape composition in terms of densities of different uncultivated landscape elements and in terms of field sizes. However, results at case area scale also indicate that differences in landscape composition between organic and conventional farms are strongly influenced by differences between the two farm types in terms of soil and slope conditions and in terms of farm size while organic versus conventional production only plays a secondary role.

Keywords: Organic farming, landscape composition, landscape change, farm size, Denmark

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Preface

This Ph.D. thesis was written at the Department of Policy Analysis, the National Environmental Research Institute (NERI) and at the Department of Geography, Roskilde University (RUC).

Supervisors for this Ph.D. thesis were Pia Frederiksen (NERI) and Jesper Brandt (RUC).

At NERI and RUC a Ph.D. is scheduled to three years. Of these three years one half of a year is devoted to the attendance of Ph.D. courses and one half of a year to providing services, including teaching.

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As Ph.D. student I was enrolled in the Research School for Organic Agriculture and Food Systems (SOAR). Furthermore, the study was part of a larger project on Nature quality in organic farming under the 2nd DARCOF research programme.

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Gregor Levin

June 2006

Summary

Agriculture manages about 2/3 of the Danish land area. As a consequence, agricultural land use consequently has a major influence on the appearance of the Danish landscape in terms of its spatial composition and structure. Alterations of agricultural practices always imply potential changes in landscape composition and structure. Qua its definition and ensuing standards, organic farming embodies a particular kind of agricultural production. Consequently, the conversion to organic farming implies potential changes in the spatial composition and structure of the landscape. As organic farming occupies approx. 6% of all agricultural land in Denmark, it is relevant to investigate potential effects of this conversion on the landscape. Furthermore, within the political and public spheres organic farming is widely expected or at least supposed to have a beneficial effect on agricultural landscapes. While principles of organic farming embrace the protection and management of uncultivated landscape elements as habitats for wild species, standards and rules do, at least in Denmark, only concern cultivation practices and animal husbandry. Furthermore, research on organic farming – landscape relations is scarce and results and findings of existing studies are often biased by inadequate methods, particularly due to very small samples and limited spatial and temporal scales.

Based on this background the central aim of this Ph.D. thesis is to elucidate relations between organic farming and spatial structure and composition of agricultural landscapes. Two major methodologies were applied. First, an analysis of Danish national agricultural registers from 1998, 2001 and 2004 aimed at investigating relationships between organic farming and landscape composition and structure in terms of crop diversity and field sizes. Second, an analysis for three case areas comprising 40 organic and 72 conventional farms aimed at investigating relationships between organic farming and landscape composition and structure in terms of field sizes and densities of different uncultivated landscape elements. This case area investigation was based on the interpretation of aerial photos from 1954, 1982, 1995 and 2002.

Analyses at national scale pointed at significantly higher crop diversities and smaller field sizes on organic farms. In general scale enlargement in agriculture with decreasing crop diversity and increasing field sizes characterised the period from 1998 – 2004. But conversion to organic farming weakened or even reversed this trend.

The case area analysis showed no significant direct relationships between organic farming and landscape composition. However, taking into account differences between organic and conventional farms with respect to other farm specific properties, the results at case area scale point at differences in landscape composition and changes in landscape composition between organic and conventional farming, which were influenced by differences in terms of farms size, soil conditions and topography.

On the basis of these results it is concluded that organic agriculture as a specific type of agricultural production is characterised by a ban on chemical fertilisers. Compared to their conventional counterparts, organic farmers therefore need to maintain nutrient balances by means of a more complex crop rotation, which implies larger crop diversity and smaller field sizes. This obvious effect of organic farming has a potential to counteract some of the negative influences of a continued scale enlargement in the agricultural sector, as it is being predicted in future scenarios.

Several authors argue that organic farmers due to their recognition of environmental issues are more active in landscape management inducing higher densities of uncultivated landscape elements on organic farms. Such relationship could, however, not be confirmed in this study. Differences in terms of farm sizes and soil and slope conditions lead indirectly to differences in densities of these uncultivated landscape elements between organic and conventional farms. However, differences in farm sizes as well as soil and slope conditions are not a direct consequence of organic farming standards and rules. It is thus argued that higher densities of uncultivated landscape elements on organic farms are not an outcome of organic farming as a specific type of agricultural production.

Sammenfatning

Landbruget forvalter omkring 2/3 af det danske landskab. Det betyder, at landbrugets arealanvendelse har en stor betydning for landskabets rumlige sammensætning og struktur. Ændringer i landbruget har altid medført en potentiel påvirkning af landskabet. På grund af regler og forskrifter repræsenterer det økologiske jordbrug en særlig form for landbrugsproduktion. Det betyder at omlægningen til økologisk jordbrug medfører potentielle landskabsændringer. Omkring 6 % af den danske landbrugsjord bliver i dag dyrket økologisk. Derfor er det relevant at undersøge om omlægningen til økologisk jordbrug medfører landskabsforandringer. Endvidere eksisterer der en generel forventning om, at økologisk jordbrug har en positiv indflydelse på landbrugslandskabet. Principperne for økologisk jordbrug omfatter beskyttelsen og forvaltningen af landskabselementer udenfor omdrift, som fungerer som levested for vilde dyr og planter. Danske regler for økologisk jordbrug omfatter dog udelukkende dyrkningspraksis og dyrehold. Desuden findes der kun meget få undersøgelser omkring sammenhængen mellem økologisk jordbrug og landskabet og resultaterne og konklusionerne fra disse undersøgelser er ofte begrænsede på grund af utilstrækkelige metoder.

Formålet med denne undersøgelse er at belyse sammenhænge mellem økologisk jordbrug og landbrugslandskabets rumlige sammensætning og struktur. Undersøgelsen blev baseret på to grundlæggende metodiske tilgange. I den første tilgang anvendtes nationale landbrugsregistre fra 1998, 2001 og 2004 til en undersøgelse af sammenhænge mellem økologisk jordbrug og landskabet i form af afgrødediversitet og markstørrelser. I den anden tilgang blev sammenhænge mellem økologisk jordbrug og landskabet undersøgt på baggrund af en analyse af luftfotos fra 1954, 1982, 1995 og 2002. Undersøgelsen blev udført i 3 undersøgelsesområder med i alt 40 økologiske og 72 konventionelle landbrugsbedrifter. Landskabets rumlige sammensætning og struktur blev undersøgt i form af markstørrelser og af tætheden af forskellige landskabselementer udenfor omdrift.

Analyser på nationalt niveau pegede mod betydelig højere afgrødediversitet samt mindre markstørrelser på økologiske bedrifter. Generelt har perioden fra 1998 til 2004 været karakteriseret af en skalaforstørrelse i landbruget, kendetegnet ved en faldende afgrødediversitet samt voksende markstørrelser. Men omlægningen til økologisk jordbrug har svækket og til en hvis grad endda vendt denne udvikling om.

Undersøgelserne i de tre områder kunne ikke vise nogen direkte sammenhæng mellem økologisk jordbrug og landskabets sammensætning og struktur. Dog kunne undersøgelsen vise, at forskelle mellem økologiske og konventionelle bedrifter med hensyn til bedriftsstørrelse, jordbundsforhold samt hældninger medfører forskelle i landskabet mellem de to bedriftstyper.

På baggrund af disse resultater konkluderes det at økologisk jordbrug, som en specifik produktionsform, er karakteriseret ved et forbud mod kunstgødning. Sammenlignet med konventionelle landmænd er økologi-

ske landmænd derfor tvunget til at opretholde jordens næringsstofbalance gennem en mere kompleks afgrøderotation. Dette medfører en større afgrødediversitet samt mindre markstørrelser. Denne klare effekt af økologisk jordbrug har også potentialet til at modvirke den negative påvirkning af den fortsatte skalaforstørrelse i landbruget, som fremtidsscenarier beskriver.

Flere forfattere argumenterer, at økologiske landmænd på grund af deres erkendelse af miljøproblemer er mere aktive i forvaltningen af landskabet og at dette medfører en større tæthed af landskabselementer udenfor omdrift på økologiske bedrifter. En sådan sammenhæng kunne denne undersøgelse dog ikke understøtte. Forskelle i bedriftsstørrelser, jordbundsforhold og i hældninger mellem økologiske og konventionelle bedrifter medfører indirekte en forskel i tætheden i landskabselementer uden for omdrift mellem disse to bedriftsformer. Men forskelle i bedriftsstørrelse, såvel som jordbundsforhold og hældning er ikke en direkte konsekvens af regler for økologisk jordbrug. Der argumenteres derfor for, at en høj tæthed af landskabselementer udenfor omdrift på økologiske bedrifter ikke er et resultat af økologisk jordbrug som en særlig produktionsform.

1 Introduction

Agricultural land occupies roughly 2/3 of the land area of Denmark. This dominance of agricultural land together with a very limited extent of larger natural areas imply that the majority of uncultivated natural and semi natural land is found as small patches embedded within cultivated land. Danish agricultural landscapes are thus a mosaic of cultivated, semi natural and natural land cover. Spatial structure and quality of these landscape elements and thus their conditions as habitats for wild species are highly influenced by farmers' decisions on land use practices and landscape management.

During history, alterations of agricultural practices have always had impacts on composition and structure of agricultural landscapes. Particularly since the 1950s increased economic subsidies for agricultural production led to a growing focus on production maximization, specialisation of agricultural production and consequently an increased significance of large scale agricultural production. Spatial scale enlargement in agriculture followed by the introduction of larger machinery necessitated the adjustment of the landscape to large scale production, resulting in the removal of numerous constraining landscape elements like field divides, hedgerows and ponds. Furthermore, a decreased importance of semi natural grasslands led to an increased abandonment. As a consequence a large part of these important nature types have gone into natural succession of vegetation and are today dominated by shrub and woody vegetation. This homogenization of Danish agricultural landscapes can be seen as one of the major threats to species richness in Denmark. Therefore, in the Danish context, nature protection and management are to a large degree tied to agricultural land use and its effect on landscape composition.

In Denmark organic farming has a history of several decades but the majority of conversion to organic farming took place during the 1990s and currently (2004) occupies roughly 6% of all agricultural land. In terms of environmental impacts, organic farming can be seen as an alternative to conventional farming. It is relatively well documented that the ban on chemicals in organic farming has a beneficial effect on the diversity of wild species on land in rotation and in edge biotopes. In addition, it is generally expected that organic farming also benefits landscape composition, including the extent of uncultivated natural and semi natural land cover. Consequently, organic farming has been put forward as an instrument to counteract the negative effects of conventional farming on landscape composition.

However, while principles for organic farming include the protection and management of uncultivated landscape elements, Danish rules and standards for organic farming do not specifically concern landscape composition including land outside rotation. A beneficial impact of organic farming on the landscape must thus be the result of differences within other parameters like cultivation practices, farm- and farmer types but also local or regional location of organic and conventional farms.

Only little research on the effect of organic farming on landscape composition exists and results and findings point into very different directions. In the light of this lack of research and due to the last five decades profoundly negative impacts of conventional agriculture, it is highly relevant to investigate if and how organic farming impacts composition of agricultural landscapes.

Based on this background, the central questions for this study are:

- Does landscape composition differ between organic and conventional farms?
- Is the conversion to organic farming followed by trends in changes in landscape composition, which differ from changes on conventional farms?
- How are differences in landscape composition and changes in landscape composition between organic and conventional farms influenced by other biophysical, socio-economical and production parameters, characterising the two farm types?

In order to approach these questions two major methodologies were applied.

First, an analysis at national scale of relations between landscape parameters and organic/conventional farming was performed on the basis of agricultural registers from 1998, 2001 and 2004. Second, an analysis of relations between organic farming and landscape parameters on the basis of aerial photos from 1954, 1982, 1995 and 2002 was applied for three case areas, including 40 organic and 72 conventional farms.

Framework for the thesis

This thesis consists of two main sections: A monograph and three papers. The main aim of the monograph is to present the background and relevance of the study, to discuss the theoretical considerations and to describe the applied methods and data. Finally, the monograph also gives a final conclusion where results and findings are put into a wider perspective. Since the monograph and the three papers are partly based on the same arguments, data and methods, it was unavoidable that some points are repeated in different parts of the thesis. The content of each chapter and paper is outlined below:

Chapter 2 gives the background for the study. Directions of change in Danish and other agricultural landscapes are reviewed and the potential effects of organic farming are discussed. Critical issues for an appropriate theoretical and methodological framework are outlined.

Chapter 3 describes the theoretical framework for the study. Approaches to the analysis of landscapes and of landscape change are discussed. Furthermore, theoretical approaches for the integration of multiple parameters are discussed.

Chapter 4 presents the methodological framework of the study. Firstly, on the basis of Chapter 2 and 3 considerations for the methodological framework are discussed. Secondly, the concrete methods applied in the study are described and opportunities and limitations are discussed.

Chapter 5 consists of the individual papers:

The central question in this study is the relation between organic farming and landscape composition. Thus, paper 1: *"Relationships between Danish organic farming and landscape composition"*, focuses on organic farming - landscape relations and on landscape changes following conversion to organic farming.

Analyses of this study point to significant relations between several landscape parameters and farm size. Therefore paper 2: *"Relationships between farm size and landscape composition in the light of landscape changes in Danish agricultural landscapes"* aims at investigating the role of farm size in relation to the landscape and landscape changes over the past 50 years.

The current study was part of a larger project on nature quality in organic farming. Paper 3: *"Structural development in Danish agriculture and its implications for farmland nature"* uses different results of this and related studies in order to discuss the future effects of a continued scale enlargement of agriculture on the landscape in terms of field structures and biotopes related to field structures.

Chapter 6 contains the final conclusions of the study. The main empirical results are presented and discussed in relation to the applied methods. Furthermore, results from all articles are used for a broader discussion of the current and future role of organic farming in the landscape. Finally recommendations for future research are outlined.

2 Background for the study

2.1 Agricultural change and dynamics of agricultural landscapes

Its dependence on land is one of the characteristics that distinguish agriculture from other production forms. Agriculture takes place in the landscape. The landscape's biophysical character influences land use decision making. Soil conditions, topography and structure and composition of the landscape affect the kinds of agricultural production, which are practicable. In contrast, agriculture itself affects structure and composition of the landscape. Farmers alter landscapes' physical characteristics to meet their production requirements. The emergence of agriculture, occurring at different times in different parts of the world, profoundly influenced landscape patterns. For central Europe it is stated that the appearance of agriculture began by the end of the last glaciation; a development that led to a more heterogeneous land cover through the introduction of new land cover types representing different stages of botanical succession (Duhme & Pauleit 1998). In comparison to pristine natural landscapes, relatively unaffected by human interference, this diversification of land cover led to the emergence of a variety of habitats and consequently to a growth in species richness. The high species richness found in central Europe can thus, at least partly, be subscribed to the diversifying effect of agricultural land use.

In addition to biophysical conditions, agricultural strategies are closely related to socio-economics, culture, politics and not least available technology. Whenever changes within these parameters occur they imply potential alterations in agricultural strategies and consequently changes in composition of agricultural landscapes (Burel & Baudry 2003). E.g. requirements for an increased agricultural production resulted in the Danish enclosure movement of the 18th and 19th century. Redistribution and concentration of agricultural land around the single farmsteads led to drastic changes in both land use and settlement patterns and profoundly influenced spatial composition of the landscape (Fritzbøger 1998). Similarly, from the 18th up to the 20th century increased demands for agricultural production together with technological innovations led to the reclamation of heaths and bogs. Particularly in western Denmark this resulted in drastic landscape changes from large continuous areas of open heaths and bogs, interspersed with tracks of arable land along watercourses to a largely cultivated landscape, with small remnants of fragmented heaths and bogs and larger tracts of forest plantations (Jensen & Reenberg 1980).

Throughout the 20th century agriculture-landscape relations have become increasingly dominated by the mechanisation and industrialisation of agriculture. Growing external inputs made agriculture less dependent on nutrient supply from its land base. Meanwhile, technological innovations increased options to alter the landscape through the removal of physical limitations in the form of e.g. constricting landscape elements. The disappearance of many uncultivated nature types like permanent grassland, heath-land and bogs exemplifies the drastic transformation of the Danish rural landscape during the last century (Agger & Brandt 1988, Brandt et al. 1994). After World War II the emphasis to increase self-sufficiency with cheap agricultural products led to a modernisation of western agriculture, which was brought along with increased subsidies for agricultural production at national and international level. This process was characterised by intensification of production through an increased use of external inputs and mechanisation of agriculture. Meanwhile, the agricultural production became increasingly concentrated on fewer and larger farms and single farms and regions specialised in one or a few products. This development of intensification, concentration and specialisation is well-documented for a number of western countries (Bowler & Ilbery 1997, Ilbery & Bowler 1998, Whatmore 1995) and has also been described for Denmark (Jensen 1984, Jensen & Reenberg 1986, Pinto-Correia & Sørensen 1995, Reenberg 1984). The desire to raise productivity per area unit together with the adoption of larger machinery increased demands for larger, uninterrupted fields and since the 1950s this has resulted in accelerated removal of constraining landscape elements like hedges, ditches or ponds. Meanwhile, formerly extensively used areas, like meadows or marshes, were no longer a crucial part of the production system and thus abandoned or converted into other, more profitable land uses like arable land or forest. The process of intensification of the arable land and removal of uncultivated landscape elements on the one hand and abandonment of extensively used land on the other was observed in many Western European countries like Brittany in France (Burel & Baudry 1990) in Belgium (Deckers et al. 2005), Great Britain (Haines-Young et al. 2003, Robinson & Sutherland 2002), Sweden (Ihse 1995), Finland (Hietala-Koivu 2002) and in Germany (Jedicke 1994).

Within regions dominated by agricultural landscapes, this development brought about considerable concern with the loss of important habitat functions for wild species. For instance in Denmark the lack of sizeable areas of undisturbed nature means that the diversity of wild flora and fauna is primarily found within the rural landscape (Agger et al. 1986, Brandt 1994, Ejrnaes et al. 1998). Wild species highly depend on habitat niches in the form of uncultivated natural or semi-natural landscape elements imbedded in the farmed land. The importance of these small biotopes as crucial habitats has been put forward by among others Benton et al. (2003), Bunce & Hallam (1993) and Jedicke (1994).

After the process of optimisation and maximisation, since the mid-1980s agriculture increasingly showed signs of a development where the main focus shifted from production optimisation to multifunctionality of land use comprising issues of nature quality, recreation and social and environmental sustainability (Kristensen 1999b). The reasons for this change are to be found in the political and economic sphere. Within the European Union (EU) agricultural overproduction and accelerating expenses for agricultural subsidies together with a growing societal focus on sustainability and claims for more environmentally friendly farming practices led to a general reconsideration of the aims of agricultural policies. As a consequence in the mid-1980s the environmental discourse was introduced in the agricultural policy, emphasising sector integration of the conservation of nature and environment. While in the beginning focus was on reduction of emissions of nutrients from agricultural production, later several regulations of agricultural policy related to rural development schemes have been introduced and focus on the conservation and restoration of farmland nature has increased. In Denmark, among others, support for grassland management, hedgerow planting and farm nature plans was introduced.

Also, in response to an increased awareness of the significance of habitats within agricultural landscapes, in 1992 the Danish nature protection law (Skov- og Naturstyrelsen 1992), was extended to include the protection of a number of natural and semi-natural habitat types, which are primarily characterised by small patches within the cultivated land[1]. However, results from a landscape monitoring system, established in the late 1970s, showed signs of a general stabilisation of the content of small biotopes even before the new legislation entered into force (Agger et al. 1986, Brandt et al. 1999). Also, the effects of agri-environmental schemes within the common agricultural policy (CAP) on landscape management can be perceived as a response to a growing awareness of the harmful effects of agriculture. Both Danish and EU-evaluations of these schemes point at considerable beneficial effects on nature quality (Direktoratet for Fødevare Erhverv 2003, Primdahl et al. 2003). However, the documented beneficial effect mainly concerns the management of semi-natural area like permanent grassland. Clear effects on landscape composition, e.g. on densities of hedgerows, were not found. Thus, until now, the role of the transformation of agricultural policy and legislation at national and international levels as driving forces for change in landscape composition are not very clear.

As a large part of agriculture within the EU still follows a trajectory of intensive high-yielding production, it can be assumed that the harmful effects of large scale agriculture will continue in the near future. Yet, evidences for the diversification of land use strategies have emerged (Ilbery & Bowler 1998, Kristensen 1999a, Kristensen 1999c). This diversification is illustrated by the increasing presence of part-time and hobby farmers within European and particularly Danish landscapes (Marsden 1995, Primdahl 1999). Also, the increased conversion to organic farming can be seen as an element of general agricultural transformation, where environmental consideration increasingly supplement optimisation of agricultural production as targets for agricultural land use. The effects of such transformation on composition of agricultural landscapes including extent of small uncultivated natural and semi natural landscape elements remains relatively unexplored (Tybirk & Alrøe 2001). Nevertheless, such agricultural transformation, including the conversion to organic farming, implies potential changes in the way farmers utilise land. Thus, equal to other land use changes, this may have a potential effect on composition of agricultural landscapes. The next chapter gives a short description of the development of organic farming at Danish and European scale and points at its potential effects on agricultural landscapes.

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[1] Protected areas include heaths, moors and bogs, meadows, salt meadows larger than 2500m² and lakes and bond larger than 100m². Furthermore, selected stream as well as cultural elements as grave mounds and dikes are protected.

2.2 Development of organic farming in Europe and Denmark

In Europe, organic farming has a history of more than 75 years. From the early 20th century improved insights within chemistry made the increased use of chemical inputs within agriculture possible and opened up for agriculture becoming broadly independent from natural conditions. However, the first negative signs of this development soon appeared in the form of e.g. over-fertilisation. As a response in 1924, in a course on biodynamic farming, Rudolf Steiner argued against a materialistic money-orientated worldview and hereby laid the foundation for modern organic farming. Since its start many different movements have characterised the development of organic farming. In the 1930s and 40s the first biodynamic associations (Demeter) were founded. In the 1940s organic farming with focus on "healthy and living soil" was developed in the UK and in the 1960s organic farming was further developed in Switzerland. A central element in all organic movements was the focus on the negative environmental effects of intensive conventional farming and the higher quality of organically produced food (Dabbert et al. 2003, Tress 1999, Willer & Yussefi 2004, Yussefi & Willer 2003).

In addition to environmental and food-quality aspects, the principles for organic farming also include economic and social aspects. In this perspective the principle aims of organic production and processing, as defined by the International Federation of Organic Agriculture Movements (IFOAM), characterise organic farming as a farming system based on a holistic approach embracing the ecological, economical and social perspectives of agriculture (IFOAM 2002).

Rising awareness of environmental issues through the 1960s and 70s led to an increased focus on alternative agricultural production forms, which in 1972 resulted in the formation of the IFOAM. But it was not until the late 1980s, when subsidies for organic farming were introduced, that a considerable conversion to organic farming within Europe began.

At present organic farming constitutes an important actor in European and particularly Danish rural landscapes. Since the beginning of the 1990s, organic farming developed very quickly within most EU member states (Figure 1). Ultimo 2004, in the EU 25, over 6 M hectares were managed organically by 155,000 holdings. This constitutes over 3.5 percent of all agricultural land (Organic Centre Wales 2006). There are substantial differences between the individual countries regarding the importance of organic farming and its development. In Austria, more than 11% of agricultural land is farmed organically whereas the country with the highest number of farms and largest number of hectares is Italy. However, some countries have yet to reach one percent. Since the 1990s the strongest growth is found within the Mediterranean region and Scandinavia. Denmark is one of the countries with the highest share of organic farming both with regard to share of agricultural land (5.9%) and number of farms (6.7%) (in 2004).

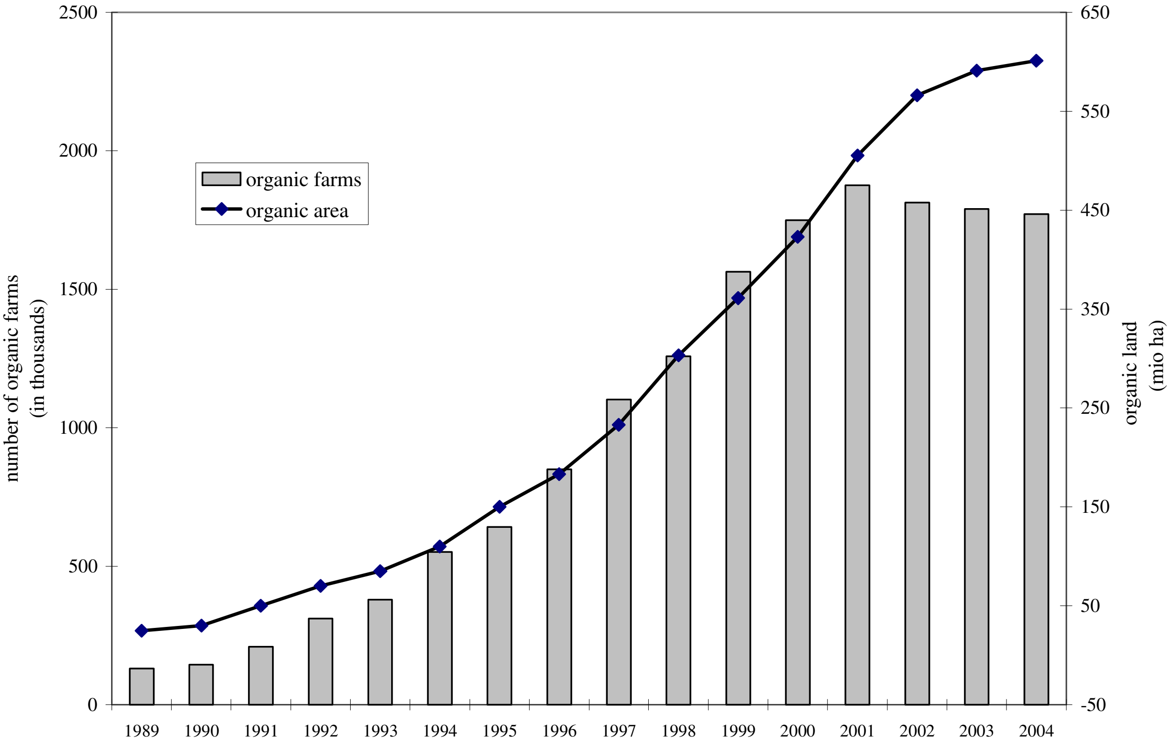

Figure 1: Development in organic farming in EU 25
Source: Organic Centre Wales (2006)

Figure 2 illustrates that at the Danish level the growth of organic farming is characterised by periods of rapid growth and periods of relative stagnation. Until 1987, organic farming remained a niche production, mainly driven by ideological convictions and awareness of environmental and food quality issues of a limited number of farmers, consumers and organisations. The Danish national association for organic farming, founded in 1981, was the primary actor for development and management of organic farming standards (Michelsen 2001a). In order to meet a growing demand for organic products, national standards together with a public certification and inspection schemes for organic farming were established in 1987. Also, at this time state subsidies for conversion to organic farming were introduced and in 1993 maintenance support for organic farming began. Accelerating growth rates from 1995 can be subscribed to national campaigns for organic products and strong promotion of the organic milk market including supplementary payments for organic milk by the large dairies. Additional support for organic crop- and pig production was introduced in 1997. However, the development in organic farming in Denmark after the millennial change is characterised by a relative stagnation and subsequent fall in the number of organic farms and in the area of organically farmed land. With respect to some products, particularly milk, production now exceeds demands and an increasing number of farmers convert back to conventional farming (Frederiksen & Langer 2003, Kaltoft & Risgaard 2004, Plantedirektoratet 2005).

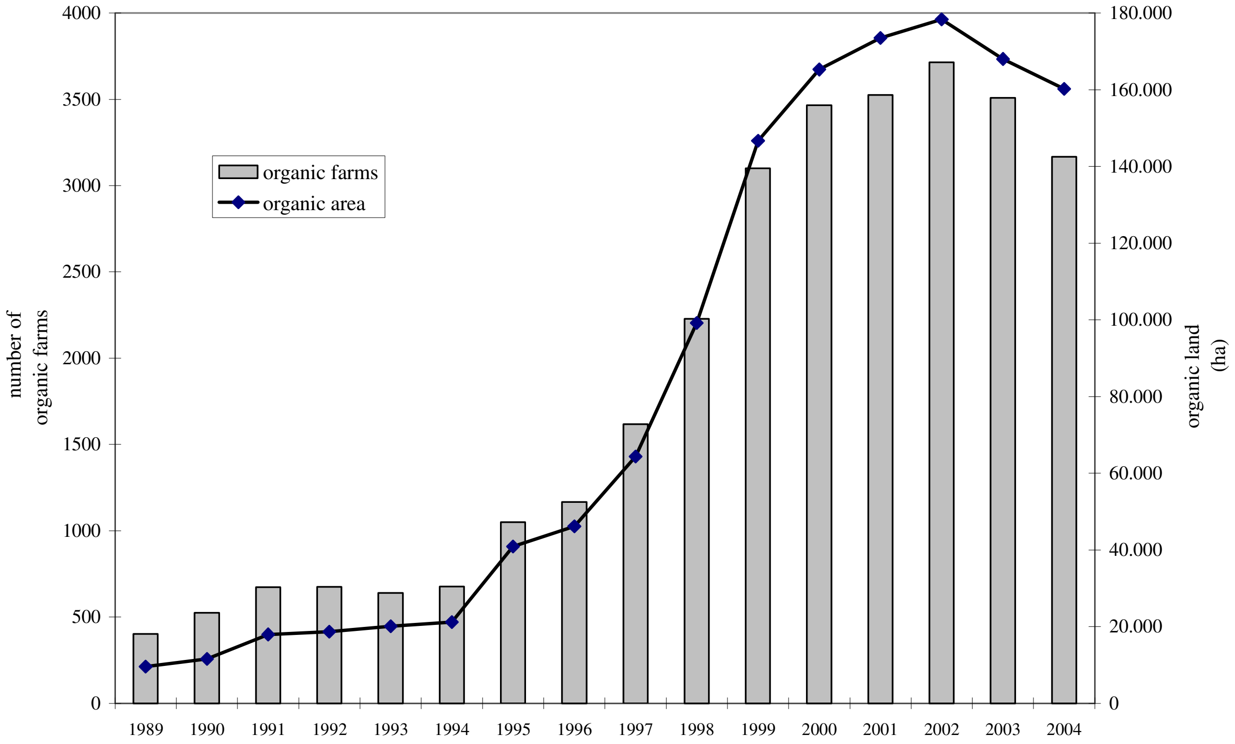

Figure 2: The development of organic farming in Denmark
Source: Statistics Denmark (2005)

The rapid growth in organic farming in Denmark during the 1990s must be understood in relation to a variety of factors at different levels. The growing societal awareness of the negative environmental impact of modern industrialised farming during the 1980s led to a rising demand for organically produced products and was followed by changes in the political agenda. This resulted in the implementation of environmental standards within the agricultural legislation at national and international (EU) levels. Emerging financial support for organic farming was one element in this new agricultural policy. The resulting economic advantages related to organic production can be seen as the most central driving force for the growing conversion to organic farming. This is not to underestimate the significance of other factors like farmers' growing awareness of environmental issues or agronomic challenges, which have been described in several studies (Ackermann 2003, Tress 1999, Tress 2002). But economic advantages nevertheless formed the precondition for the considerable growth in organic farming observed in Denmark and other European countries in the 1990s (Michelsen 2001a, Michelsen 2001b).

2.3 The impact of organic farming on the landscape

The reasons for the relevance and motivation to investigate impacts of organic farming on agricultural landscape are manifold. In the light of the considerable impact of modern farming on landscape composition, particularly since the early 1950s and a growing awareness of the negative effects of agriculture on the environment, it is relevant to elucidate if organic farming is a tool to counteract this development. Furthermore, as organic farming qua its definition and standards is different from conventional farming it also has a potentially different effect on the composition of agricultural landscapes. Finally, while research on organic farming – landscape relations is still scarce, there exists a general expectation for a beneficial effect of organic farming on landscape composition exists. Investigating organic farming in terms of its relations to and impacts on agricultural landscapes, this study aims at clarifying the validity of this expectation and form a contribution to the discussion of the role of organic farming in a landscape context at present and in the future.

2.3.1 Potential impacts of organic farming on the landscape

Potential impacts of organic farming on the composition of agricultural landscapes are described in detail in paper 1. In principle potential impacts are twofold. First, due to standards and rules, primarily in the form of the ban on chemicals, organic farming differs from conventional farming with respect to production practices. Differences in production practices may subsequently result in differences in landscape composition between organic and conventional farms. Second, organic and conventional farms may differ from each other with respect to several other parameters, which in themselves are related to or have an impact on landscape composition. Such parameters comprise the type of agricultural production, farmer types (e.g. hobby, part-time and full-time farmers) and farmers' attitudes towards e.g. environmental issues. Organic and conventional farms might also differ with respect to their local and/or regional location and consequently to local or regional biophysical properties, e.g. soil and topography. On the opposite, it could be local and regional biophysical properties, which influence farmers' decision to choose a particular setting. Furthermore, local and regional biophysical conditions might also influence farmers' decision to convert to organic farming or not.

Potential causes for relations between organic farming and landscape composition are thus manifold. Furthermore, different causes or parameters and their relation to the landscape will often be interrelated. E.g. type of agricultural production will often be related to the regional location. As a consequence, an adequate investigation of organic farming - landscape relations, necessitates theoretical concepts as well as methodologies, which are able to grasp these interrelations.

Paper 1 contains a detailed review of existing studies on organic farming - landscape relations. Results of these studies point into very different directions. In general the review signifies the necessity to evaluate results and findings with respect to applied methodologies. Several of the investigated studies use very small samples of only 2-6 farms from which general conclusions hardly can be drawn. Furthermore, in both sampling techniques and subsequent data analysis few studies take into account variations within other farm specific parameters in terms of biophysical properties, farm and production types or the local and regional location of the farms. It is thus difficult to evaluate if documented relations between organic farming and the landscape are biased by variations in other parameters. Finally, most of the studies investigate organic farming – landscape relations for only one point in time. Such narrow temporal scales obstruct findings on the impact of organic farming on landscape change.

2.4 Critical issues for the theoretical and methodological framework

On the basis of the background of this study, the central study questions and results and findings from existing investigations on organic farming – landscape relations, some major critical issues for an appropriate theoretical and methodological approach for the present study can be outlined.

- Land use and consequently its impact on landscape composition is influenced by a variety of often interrelated parameters. An appropriate theoretical approach and methodological framework must therefore be able to explore landscape composition and changes in these with respect to multiple parameters influencing farmers' land use decisions. Furthermore, applied methods should be able to investigate interrelationships between different parameters.

- Sample sizes and sampling methods are crucial. Small samples, particularly when not taking into account variations in other parameters can bias results and lead to false conclusions. Therefore, choice of sample sizes and sample methods should take into account such possible biases.

- Possible biases also need be considered in the design of the methodological framework.

- Finally, elucidating impacts of conversion to organic farming on changes in landscape composition necessitates a temporal dimension. Consequently, useful theoretical concepts and methods should embrace the option to examine landscape dynamics and their relation to farm parameters within an adequate temporal scale.

It may be a difficult task to incorporate all these issues in one study. However, in order not to draw false conclusions it is important, at least, to realise the advantages and limitations of theoretical and methodological approaches. In this regard the next chapters aim at outlining useful theoretical concepts and hence methodologies for this study.

3 Theoretical concepts

As argued in the previous chapters, relationships between agriculture and landscapes are highly complex and involve numerous, often interrelated parameters. Useful theoretical concepts should be able to embrace this complexity. It is important to stress that in the development of agricultural landscapes in time and space, human land use and thus human decision making and action form crucial parameters. In addition to natural science approaches, the analysis of agriculture – landscape relations therefore necessitates the inclusion of social science based approaches.

In this perspective the general concept of ecology and of ecosystems are discussed as approaches for the study of complex systems. Particular focus will be given to attempts to use the concept of ecology to embrace and integrate approaches from both natural and social sciences. As the landscape is the central focus of this study, the concept of landscape ecology will be discussed as a convenient approach. For the more practical implementation of theoretical approaches, a landscape concept with the landscape element or feature as interface between farmers' landscape decision making and the landscapes physical appearance in terms of spatial composition will be outlined.

Attempts to develop a grand unifying theory of e.g. human or landscape ecology certainly exist. However, within the context of this study, ecology, human ecology, political ecology and not least landscape ecology are treated as theoretical approaches or frameworks, which contribute with thoughts, ideas, notions and thus concepts that are relevant to the study of agriculture – landscape relations.

3.1 General ecology and the ecosystem concept

The term ecology was coined in 1866 with the German biologist Ernst Haeckel. It combines the Greek words oikos and logos and means the science of the habitat. Today, ecology can be divided into a professional/scientific and a more normative meaning, related to a politicization of ecology, which dates back to the late 1960s. In its scientific meaning, ecology is an area of academic inquiry that is often perceived as a subdiscipline of biology. Broadly, this scientific field of ecology deals with relationships between living organisms and their physiochemical environments. Since Haeckel, ecological studies have become increasingly more complex. The fields of ecological investigation gradually extended from the study of species in the context of the surrounding physical environment (Autecology) over the analysis of the structure and functioning of communities, including the understanding of trophic structures of ecological systems[2] (Synecology) to the consideration of complex systems integrating humans and their activities (Burel & Baudry 2003).

[2] E.g. prey-predator, plant-phytophage, etc.

In relation to the increasing awareness of the complexity of nature, A.G. Tansley introduced the concept of ecosystems in 1935 (Anker 2002). Instead of focusing on linear relationships between individual species and the abiotic environment through a reductionistic approach, ecosystem ecology intends to address interrelations between abiotic and biotic structures and functions at levels of organisation beyond those of the individual species (Müller 1997). Since the 1950s the development of the ecosystem concept was very much dominated by the work of E.P. Odum, who focused on the description of ecosystems through the analysis of flows of energy and matter. More recent work developed this energy approach further by introducing concepts from thermodynamics into ecosystem analyses (Jørgensen 1997, Lefroy & Rydberg 2003).

The essential feature of the ecosystem concept is that the dynamic relationships between its parts can not be understood from knowledge of the constituent parts alone. In this sense an ecosystem can be defined as any unit that includes all organisms and their interactions with the physical environment within a given area. A major challenge of the ecosystem concept is the delimitation of ecosystems into defined (spatial) units, which in theory can range from single atoms to the whole universe. In practice, however, the term has generally been reserved to units below the major world units. Furthermore, ecosystems have long been used as surrogates for natural systems, characterised by a homogeneous biocoenosis that developed in a homogeneous environment. If at all, human influences were mainly perceived as external disturbances, harmful to this natural balance.

3.1.1 Humans and human action as part of ecosystems

Central to general ecology and the ecosystem concept is the notion of the importance to address the complex and often mutual relationships between organisms and the environment. If the word "environment" is considered in its fullest meaning, it includes not only physical and biotic conditions but also components of the human sphere. As a consequence, relationships between humans and their surroundings must also embrace processes and influences linked to these human components (Steiner & Nauser 1993). Following the growing environmental consciousness, since the 1950s the focus of ecological research increasingly shifted towards understanding and management of impacts of human activities on natural systems (Worster 1993). Still, man was generally considered an external factor, causing disturbances of nature, but not being part of nature himself. To some extent this view has changed, and e.g. Müller (1997) puts forward that the most general feature and challenge of ecosystem ecology today is the integration of natural, social and human spheres.

Some attempts to incorporate humanity into ecology were, however, characterised by viewing human beings and their actions as analogues to other living organisms, implying that human individuals, groups and communities are phenomena that act and develop according to biotic factors and processes alone (Lawrence 2003). Yet, as Steiner & Nauser (1993) argue, human beings are very eminently social animals. Human-environment relations are thus highly influenced by this sociality, i.e. the kind of societal and cultural processes and norms that human populations form. Applying an analogy from biology to human-environment relations excludes these dimensions.

In spite of the weakness of general "biological" ecology to embrace humanity, the holistic and systemic concept of ecology and ecosystems proofed a valuable concept within other scientific spheres addressing human-environment relationships. There have been numerous instances of ecological concepts being used in other scientific fields. This adaptation of an ecological approach is illustrated by the emergence of various "ecologies". The concepts of human ecology, political ecology and not least landscape ecology can be seen as such attempts to overcome the binary between human and nature.

3.2 Human ecology

In contrast to general ecology, human ecology generally refers to the dynamic interrelationships between human populations and the physical, biotic, cultural and social characteristics of their environment (Lawrence 2003). The origin of the concept of human ecology dates back to the 1920's and has since occurred separately in a number of different disciplines with a scientific interest in human-environment relationships. Concepts of human ecology have been developed and used within such diverse scientific fields as sociology, anthropology, geography, psychology and medicine.

However, human ecology is still characterised by a lack of consensus about what it means. According to Steiner & Nauser (1993) this is to some extent unavoidable as there cannot be one single view on such a highly complex subject as the relationship between humans and the environment. Still, a common principle for a holistic framework of a human ecology perspective is the inclusion of human populations as an integrated part of the (human-) ecosystem, in order to embrace interrelationships with biotic, abiotic, cultural, social and individual human factors (Lawrence 2003). However, a critical issue is how to embrace all these parameters within one theoretical approach. Steiner & Nauser (1993) emphasise that as human ecosystems cannot be described adequately by one single view, but only by different complementary views, there cannot be one grand unified theory for human ecology. Therefore, rather than being interpreted as one grand theory, human ecology should be perceived a conceptual framework for the integration of different scientific fields in a transdisciplinary manner.

3.3 Political ecology

Another approach to, but by far from a coherent theory for the complex metabolism between nature and society, is the concept of political ecology. Its emergence in the 1970s is related to an increasing politicisation of environmental concern in that period and is therefore highly influenced by an environment and development discourse, the concept of sustainability, and the idea of international solidarity (Scott & Sullivan 2000).

Like other integrating approaches, political ecology seeks a holistic approach to environmental issues through the integration of multiple disciplines. However, what separates it from other approaches, e.g. human ecology, is its focus on societal structures as causes for as well as effects of environmental degradation. In this regard it focuses on human individuals or groups as the central agents whose actions must be understood in a broad political and economical context.

Mostly, political ecology approaches have been applied within a rural third world context. Earlier models primarily framed the problem of environmental degradation of the resource base for rural production in the third world around physical constraints, overpopulation, mismanagement and market failure. As a rejection to this model, particularly Blaikie (1985) and Blaikie & Brookfield (1987) amplified the need to focus on resource managers and households as the central agents. These agents' decision making in relation to resource use is perceived as responses to a variety of biophysical and socio-economic factors at different levels and scales. In reverse, these responses in resource use again affect biophysical (the environment) and socio-economic circumstances at all levels and scales. In this context political ecology has, among other things, been criticised for paying to little attention to the importance of biophysical parameters and thus not to provide an adequate theoretical concept to explore particular environmental outcomes or transformations. However, the concept of political ecology contains some considerations of interest to this study.

First, environmental degradation is seen as social in origin. Analytically, the centre-point of human environment studies is therefore the "land manager", whose relationship to nature can only be understood in a historical, political and economic context. In agricultural landscapes farmers, which are the main decision-makers for the use and management of the landscapes, can be equalled to "land managers". Second, the importance of considering the spatial dimensions of environmental issues is put forward. Such spatial accounting or multi-layer analysis enables explanatory linkages between decisions made at an often local scale to causes and effects at other spatial scales. Third, it is emphasised that local decisions are framed by external structures, embracing political and societal forces, often related to higher regional, national or international levels.

3.4 Landscape ecology

3.4.1 The emergence of landscape ecology

Similar to other scientific fields, landscape ecology attempts to apply the holistic concept of general biological ecology into a broader context. However, landscape ecology differs from e.g. human and political ecology as it already in its name defines the landscape as the central object of interest. Meanwhile, the landscape also constitutes a spatial framework for investigation.

The origin of landscape ecology as an emerging scientific discipline goes back to the German biogeographer Ernst Troll. In the late 1930s Troll underlined the necessity to link the spatial approach of geography with the process-oriented biology and emphasised aerial photo interpretation as an outstanding tool to combine the two approaches. According to Brandt

(1999) the goal for Troll was a broad marriage between geography and biology. In short, it combines geography's chorological approach, which addresses horizontal relationships between ecosystems, with biology's topological approach, which focuses on the functional vertical relations between the individual components in a landscape unit (Zonneveld 1995).

Since Troll, various scientists, geographers as well as biologists have adapted landscape ecological concepts. Throughout the 1950s and 1960s the development of landscape ecology was very much dominated by natural geography. Its geo-ecological approach attempted to unite different sub-disciplines into a landscape study through integrated structured studies within a chorological dimension. This approach was mainly used in the study of the ecological potential of vast landscapes in Eastern Europe, Canada and Australia (Burel & Baudry 2003).

The geo-ecological school was closely paralleled by a bio-ecological tradition, which had its origin within spatially oriented vegetation science. According to Brandt (1999) the two approaches have been combined into a geo-bio-ecological integration, and landscape ecology as an interdisciplinary approach, has furthered this integration into what Zonneveld (1995) calls an ecology of the landscape.

3.4.2 Landscape ecology as the study of spatial pattern and structure

Despite this development of landscape ecology in Europe, until the mid 1970s the term was largely absent from North American literature (Naveh & Liebermann 1994). However, following an increased recognition of the harmful effects of landscape fragmentation and in the wake of the theory of island bio-geography in the late 1960s (McArthur & Wilson 1967), particularly in the USA a school developed, giving special attention to the spatial aspects of landscapes. This school specialised in the investigation of landscapes' spatial structure and composition and their influence on the functioning of the landscape system with a specific interest in relationships between landscape structure and animal and plant populations. Important contributors to this development are Forman & Godron (1986), Turner (1987), Opdam (1988), Merriam (1989) and Risser (1989). Due to ever improving remote sensing and GIS[3] techniques, which led to increased accessibility and quality of spatial data sets, this spatially oriented approach still continues its development. The relationship between landscape pattern and species movement and dispersal remains a central issue. However, advanced spatial indices for pattern and structures of landscapes are also increasingly applied within more general fields, like landscape description, evaluation and for planning purposes (Brandt 1993, Dramstad et al. 2001, Frederiksen et al. 2004, Hehl-Lange 2001, Herzog et al. 2001, Hulshoff 1995). Very central to this spatial approach to landscapes is its opportunity to include the temporal dimension and in this manner to detect and evaluate dynamics in landscape pattern over time.

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[3] Geographical Information System

3.4.3 Landscape ecology as transdisciplinary science

Parallel to the quantitative spatial oriented landscape ecology, which to some extent can be seen as an internal specialisation within biology, a new perspective, focusing on landscape ecology as the integration of multiple landscape approaches, emerged. Zonneveld (1995) emphasises that in the study of landscapes a variety of attribute disciplines and methodologies, originating within the natural sciences, social sciences and humanities, must play an important role. "Together, integrated into a systems approach in the context of the landscape as an object of study, they form Landscape Ecology" (Zonneveld 1995:29). This implies that landscape ecology is not just "combining sciences" (multi-disciplinary), or "in between sciences" (inter-disciplinary), but integrating a number of (sub-) disciplines into transdisciplinary sciences (Naveh & Liebermann 1994).

This shift in the central focus of landscape ecology is clearly illustrated in the mission statement of the International Association for Landscape Ecology (IALE 1998), which states that:

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

The conceptual and theoretical core of landscape ecology has become distinct and recognised, effectively linking natural sciences with related human disciplines."

Further, the statement puts in front the following issues as core themes for landscape ecology:

- The spatial pattern or structures of landscapes, ranging from wilderness to cities,

- The relationship between pattern and processes in landscapes.

- The relationship of human activity to landscape pattern, process and change,

- The effect of scale and disturbance on the landscape

This definition of landscape ecology very clearly expresses the shift from just a combination between the chorological approach of geography and the topological approach of biology to a broad transdisciplinary science. Issues like the analysis of spatial pattern are still essential elements. Yet, the most central aim of landscape ecology is to provide a conceptual and theoretical approach, which enables to link natural sciences with the humanities in order to effectively embrace both biophysical and socio-economical aspects as well as interrelations between these in landscape studies.

Among others, the work of Naveh & Liebermann (Naveh & Liebermann 1994, Naveh 2000, Naveh 2001) played a significant role for the formulation of a theoretical foundation for this holistic approach to landscapes. Based on general systems theory and biocybernetics they argue for the Total Human Ecosystem (THE) concept, as the highest level of ecological integration, enabling the integration of what they call the biotechnogeosphere. However, in spite of the theoretical rationality of such meta-concept the practical integration of different disciplinary approaches and methodologies remains a major challenge for landscape ecology. Only through such integration in landscape studies, the whole really becomes more than just the sum of its parts. Similar to the concept of human ecology a major obstacle to transdisciplinarity within landscape ecology is that the flow of information is hampered by the scientific specificity within the different contributing disciplines.

However, what separates landscape ecology from other approaches to transdisciplinarity is that it by definition is tied to the landscape as a study object and framework (Moss 2000). The landscape as (spatial) connection between the different contributing disciplines can therefore, at least to some extent, help to overcome barriers between contributing disciplines and hence facilitate the link from a meta-approach to the practical application of landscape ecology. This, however, necessitates a definition of the landscape term, as well as a clarification of the spatial and temporal dimensions in which it is applied.

3.4.4 Defining the landscape

As a translation from the Latin word “regio” the landscape term appears for the first time in the early middle age in the Old High German language, meaning territory or region and usually being related to the spatial demarcation of the land property or tenure (Johnston et al. 2000). From the early 17th century, a more extensive landscape view, referring to the visual appearance or character of the land, evolved. This landscape perception, which is illustrated in the emergence of landscape painting in the 16th and 17th century, profoundly influenced general but also scientific landscape views up to today (Forman & Godron 1986).

It was in the 18th and early 19th centuries that the landscape appeared as an object or framework within science. Especially through the work of Alexander von Humboldt, who defined the landscape as the “total character of the earth”, the landscape term was extended to more than a comprehensive conception, realising the physical reality of the landscape (Tress 1999).

However, since Humboldt, the evolution of science was generally characterised by specialisation and fragmentation into separate scientific disciplines, and the complex landscape concept of Humboldt became dispensable. The landscape was perceived as consisting of single parts, which had to be analysed separately. It was not until the turn of the century that the more holistic landscape concept revitalised (Tress 1999).

A further step, embracing the functionality of landscapes, led to Carl Troll’s perception of the landscape as an ecologically functioning entity. He defined the landscape as a part of the earth’s surface, which through its appearance as well as through its location constitutes a definable spatial unit. Further, in his definition Troll included both the abiotic, biotic as well as mental or human sphere (Troll 1968). Troll’s accentuation of the spatial dimension of the landscape concept has been followed up by later definitions. Zonneveld (1988) defines the spatial character of the landscape as the “horizontal pattern of mutually related elements, the units of land", while Forman & Godron (1986) define the landscape "as a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout." Consequently, a general consensus exists saying that the landscape concept always contains a physical reality and thus a spatial dimension. Furthermore, processes and functions within landscape units are time dependent. Conceiving landscapes as functional units therefore implies the necessity of a temporal dimension. In this regard, along with structure and function, Forman & Godron (1986) point out "change, the alteration in the structure and function of the ecological mosaic over time", as a central characteristic of landscapes. Both the structure and the function of a landscape can appear very different at different spatial and temporal scales. Also the concept of heterogeneity is highly scale dependent (O'Neill 1988). Both biophysical and human disturbances as well as their effects on the landscape can be more or less time lasting and have very different spatial dimensions. Landscapes are thus highly dynamic in both time and space (Burel & Baudry 2003). Consequently, the inclusion of the temporal dimension has been central to the scientific landscape concept (Burel & Baudry 2003, Naveh & Liebermann 1994, Turner 1987, Turner et al. 2001).

3.4.5 The spatial and temporal dimension of landscapes

The progress landscape

In an article on society and nature, Hägerstrand (1993) presented his concept of the progress-landscape as a spatial and temporal framework for the integration of biotic, abiotic and human parameters and interrelations between them. As landscape he understands not only what can be visualised as such, but everything, which is present within a given spatial unit of land and, and furthermore, everything which moves in and out of this spatial unit within a given time period. In this definition Hägerstrand's landscape concept opposes to a more conventional static perception of landscapes. He argues that everything, from physical objects to human decision making and subsequent actions, has a spatial dimension. Here, he criticises an abstract view on social processes and human actions, which often ignores their spatial extent. Furthermore, Hägerstrand emphasises that everything within the landscape is dynamic. Everything is subject to succession or permutation, if not in space then in a temporal dimension.

The main argument for the concept of the progress-landscape is that it is in their physical presence in space and time that the different components of the landscape meet. Within the landscape framework everything is in contact with something else. Only by introducing their spatial and temporal dimensions and dynamics within the landscape is it possible to observe the points and areas of contact between the biophysical and human related components. Consequently, paying attention to spatial and temporal dimensions is crucial for the understanding of interrelations between the biophysical and human sphere and thus for the study of human-nature relations in general.

For Hägerstrand the progress-landscape primarily constitutes a useful approach to cope with some of the inconveniences within environmental management and planning. Even though his landscape concept is not particularly directed towards the scientific study of landscapes, generally his ideas fit very well into the holistic and transdisciplinary concept of landscape ecology, as it has been emphasised by e.g. Zonneveld (1995), Brandt (1999), Naveh (2000) and Burel & Baudry (2003). However, Hägerstrand himself realises that incorporating both spatial and temporal aspects of everything within a given land unit is in practice an impossible task. For him, it is first of all important not to ignore that everything has a physical dimension in space and time. However, for an actual implementation of this notion, a more practical concept or model, allowing the integration of the spatial and temporal dimensions of different phenomena is needed.

The concept of spatial and temporal hierarchy

A common notion of landscape definitions by e.g. Zonneveld (1995) or Forman & Godron (1986) is that landscapes constitute spatially definable units. Further, the different phenomena within a landscape unit are related to different spatial scales. An examination of relationships and interdependencies between different phenomena therefore necessitates the consideration of different spatial, but also temporal scales. Especially within the area of human-environmental interactions, which is central to the study of landscapes, a central issue is the relationship between micro-scale and macro-scale phenomena. Paying attention to interdependencies among scales can avoid two types of errors: First, the nature of a given phenomena or process may be obscured when observed at an inappropriate scale. Second, inadequate attention to scale dependency may lead to the misinterpretation of causes and effects (Reenberg 1998). The study of scaling issues is a major contribution of landscape ecology to ecological sciences in general and landscape studies in particular. Turner et al. (1989) propose a set of definitions relevant for the following discussion of scale issues:

Scale is the spatial or temporal dimension of an object or process (characterised by both grain and extent). Resolution is the precision of measurement (grain size). Grain indicates the finest level of spatial resolution possible with a given data set (e.g. pixel size for raster data). Extent measures the size of the study area or the duration of time under consideration. To extrapolate means to transfer information from one scale to another.

Some phenomena operate at large scales (e.g. global climatic change or national and international policies) while others are related to smaller, local scales (e.g. farmers' land use decision taking). Drawing in relationships between different phenomena, it becomes clear that large-scale processes may have an impact on local decision making, but meanwhile, local decisions and subsequent actions can form the foundation for large-scale trends. Figure 3 illustrates the scale dependency of different parameters in relation to the spatial configuration of agricultural landscapes. The figure is by far all embracing and it can be discussed whether the different parameters constitute effects or causes. However, what becomes clear is that different parameters are related to different, sometimes a range of, spatial scales. Structures and functions of landscapes will consequently be perceived differently at different spatial scales, making it crucial to decide upon appropriate spatial scales for study.

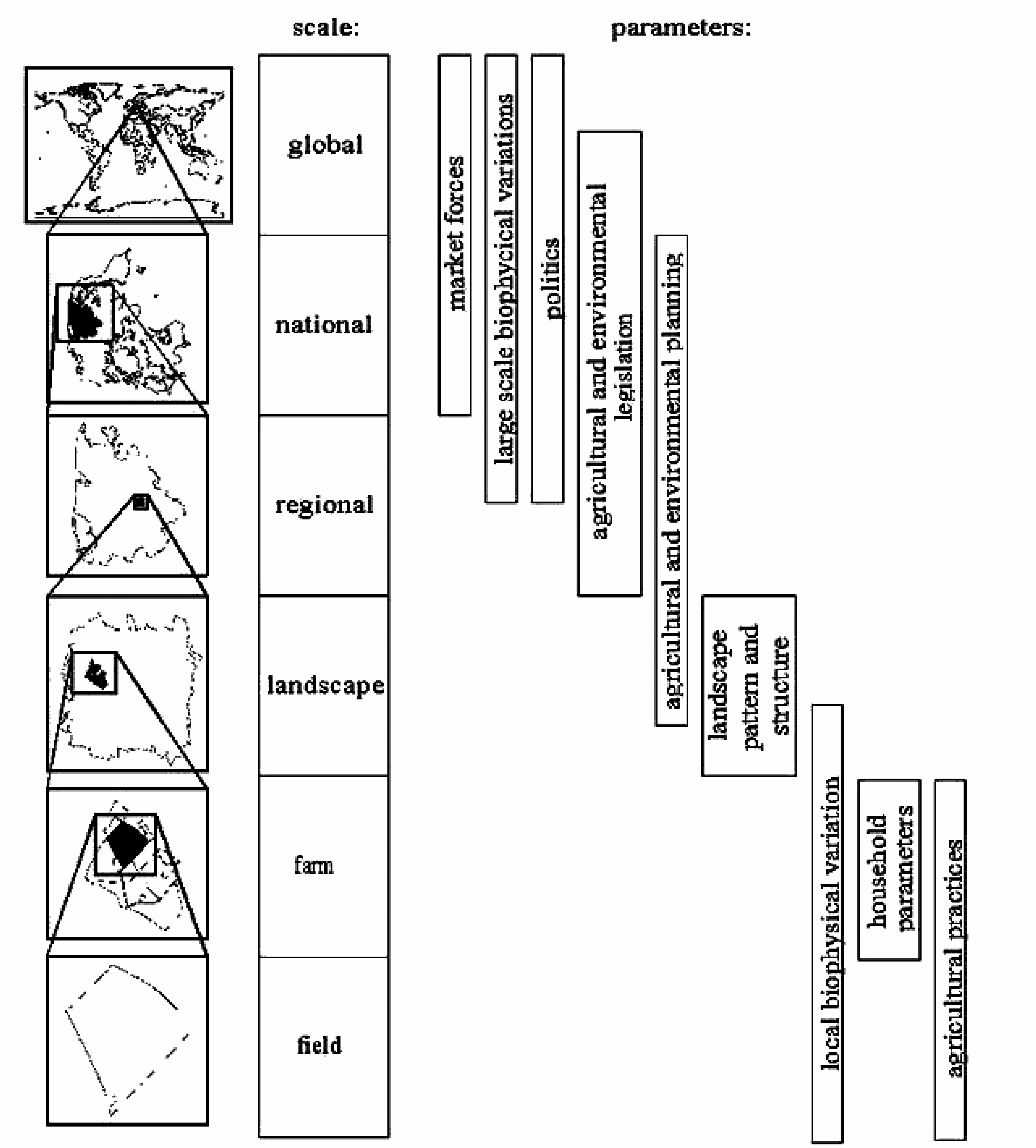


Figure 3: Scale dependency of different parameters in agricultural landscapes

Further, also the selection of temporal scale is known to highly influence the perception of phenomena and interdependencies between them (Burel & Baudry 2003, Reenberg 1998, Turner et al. 1989). For instance, observing annual variations in vegetation compositions presupposes a temporal resolution of less than one year. Meanwhile, geological processes and their effects on landscape structure are only discernible at much broader temporal resolutions of maybe thousands of years.

Turner et al. (1989) discuss how phenomena and processes that occur at a variety of temporal and spatial scales can be handled analytically. A crucial issue is the identification of processes of interest and the parameters that affect these at different scales. In this regard a major challenge is to develop a framework, which is able to translate or extrapolate information across temporal and spatial scales.

In several contexts the notion of a spatial and temporal hierarchy has been proposed as a relevant conceptual framework for the analysis of landscapes and their dynamics (Burel & Baudry 2003, Naveh & Liebermann 1994, Turner et al. 2001, Zonneveld 1995). In a review of the theoretical literature related to holism, Naveh & Liebermann (1994) present their ecological perspective on the concept of hierarchy. They stress that a hierarchy is not simply an order of ranks on a linear scale, but should rather be seen as a living three, a multi-layered, stratified, outbranching pattern of an organisational system, dividing into subsystems of lower order (Figure 4). This perception conforms to their earlier presented transdisciplinary concept of the Total Human Ecosystem (THE). They suggest the THE to be the apex of the ecological hierarchy in which the levels present organisms (1), populations (2), communities (3), ecosystems (4) and finally the THE (5). Different disciplines correspond to the respective levels in the hierarchy. For example population ecology and human ecology correspond to levels 2 and 5, respectively. These subdisciplines are, in turn, linked through integrative approaches like bioecology or landscape ecology.

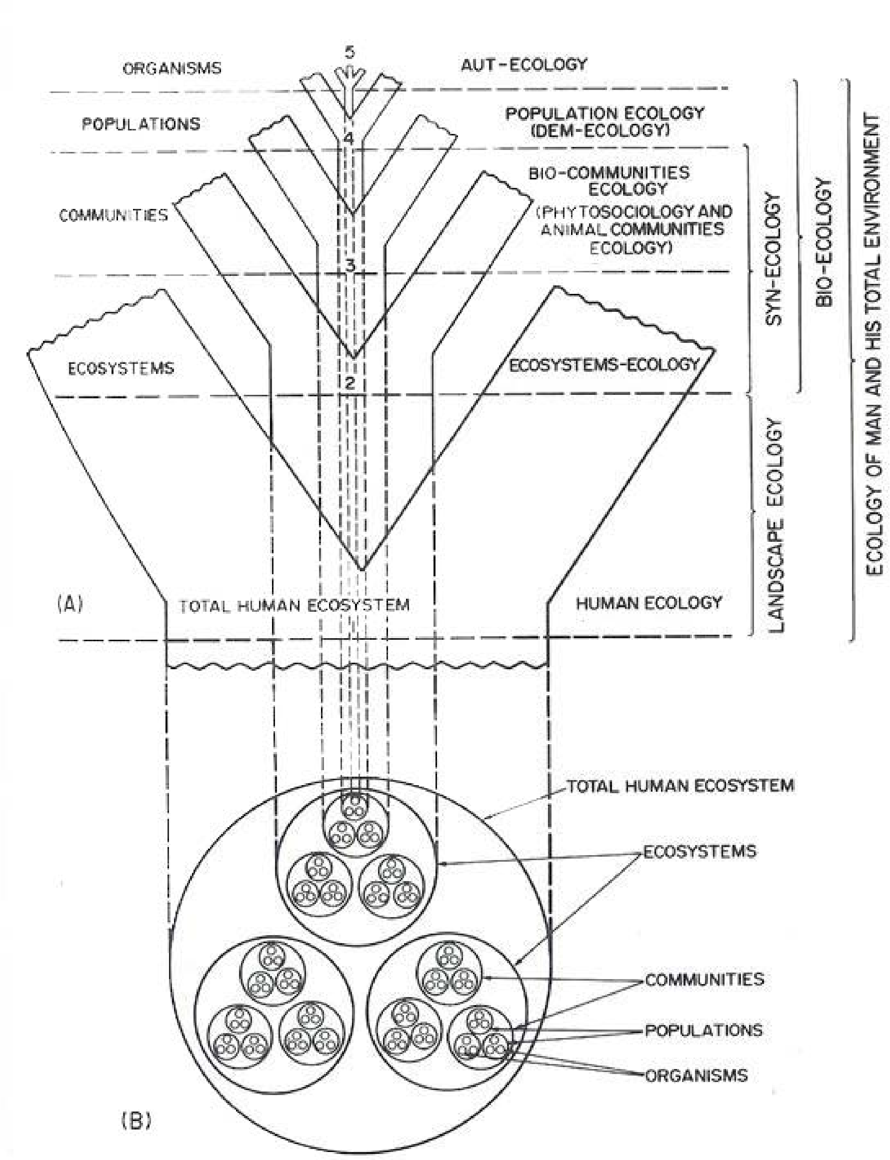


Figure 4: A hierarchical framework for landscape studies
Source: Naveh & Liebermann (1994)

Through its focus on the integration of different disciplines the hierarchy concept is not just a theoretical, but largely also an analytical or methodological approach. Considering spatial units or phenomena as parts of a hierarchy, such an approach makes possible the examination of interactions between various, e.g. socio-economical and biophysical phenomena at different scales in the landscape. In this context Reenberg (1998) argues for the landscape as a "nested hierarchy", where lower levels are characterised by smaller spatial and temporal scales (fine-grained pattern and rapid turnover times). Higher levels are characterised by larger spatial and temporal scales. By "nesting" information on the different phenomena to the respective spatial scales, this information can be used at these scales without violating its integrity. Furthermore, such a concept also allows for the "translation" or extrapolation of information between scales.

3.5 Linking together landscape management and landscapes' spatial composition

In the above section numerous issues, relevant and important to this study have been presented. However, as such these concepts are very broad and difficult to apply directly to the current study. In the next section a more concrete conceptual framework directed to the study of agriculture – landscape relations will be presented. This framework will also form the basis for the development of an applicable methodology.

3.5.1 The landscape as a mosaic of landscape elements

Although the multi-facetted holistic approach to the landscape term includes physical, biological but also cultural, social and economic aspects, the spatiality of the landscape and thus its physical appearance remains crucial. Furthermore, as the central subject of interest in this study is the spatial composition of the landscape, an appropriate landscape concept or model is necessary. The mosaic landscape (Forman & Godron 1986, Zonneveld 1995) can be seen as a useful concept or model for most Danish agricultural landscapes. This landscape concept (illustrated in Figure 5) consists of a matrix, which in Danish agricultural landscapes mainly is composed of agricultural land cover and patches, which are smaller elements of other, often uncultivated land cover. Corridors are line elements, e.g. hedgerows, connecting patch elements together and/or splitting up the matrix of cultivated land. The spatial arrangement of matrix, patches and corridors imply the composition of the landscape. The composition of the landscape can be defined as the amount of different entities (e.g. different land cover types). Spatial composition also embraces the spatial structure of the landscape, which can be defined as the spatial appearance (e.g. size and form) of different elements as well the spatial relationships between different elements (e.g. connectivity and isolation) (McGarigal et al. 2002).

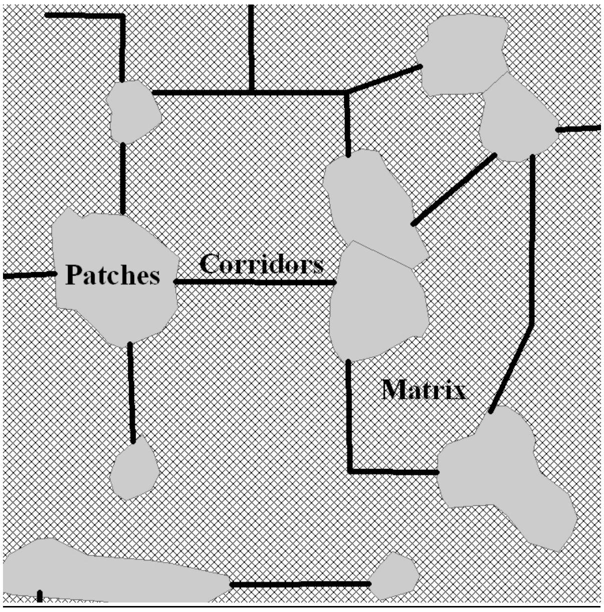


Figure 5: The concept of the mosaic landscape

3.5.2 The landscape element as "linking feature"

In the above outlined landscape concept the landscape element is central to landscapes' spatial composition. Therefore, when studying agriculture's impact on the landscape, it makes sense to focus on the landscape element as a central feature of analysis. Figure 6 illustrates the central role of the landscape element in agricultural landscapes. Extent and form of the single landscape elements at a local spatial scale influence the landscape's composition at larger scales. According to the spatial-biological approach within landscape ecology, spatial composition is critical to conditions for flora and fauna at local scale. Conditions for flora and fauna are also directly affected by the biophysical conditions (e.g. degree of disturbance) characterizing the single landscape element.

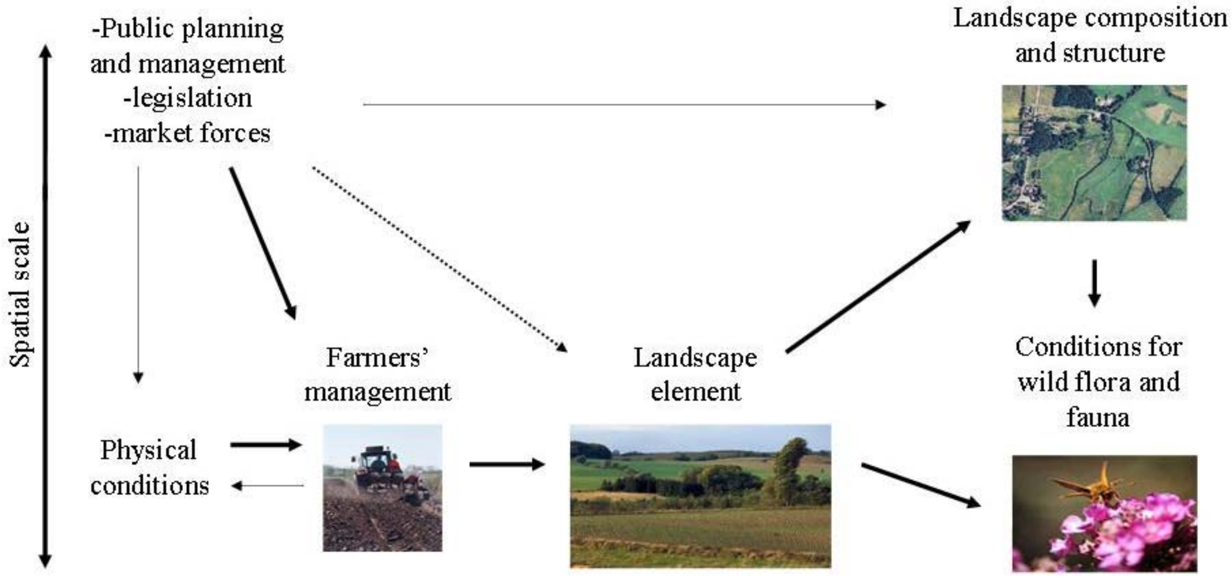


Figure 6: The landscape element as "linking feature"

The relevance of the landscape element as a central feature of analysis does also concern more practical opportunities for the landscape studies. Landscape elements are relatively easy to register on the basis of different data sources like aerial photos, different maps and existing statistical material. On the basis of such registration it is thus possible to quantify the spatial extent and form of landscape elements and hence to quantify landscape composition. If data exist for more than one point in time, it is also possible to analyse dynamics of landscape elements over time. Finally, with a certain spatial reference, it is possible to spatially relate landscape elements to other spatial information like the location of farm units or physical properties.

The focus on the landscape element is also relevant with respect to the investigation of agriculture's impact on the landscape. Effects of agriculture on the landscape, its composition and thus conditions for wild species, are usually the result of farmers' decision making and management at the scale of the landscape element. While e.g. merging together plots of agricultural land or planting a hedgerow does affect landscape composition, the actual physical change is carried out at the scale of the landscape element. To some extent, public planning and management does involve direct decisions about the management of landscape elements, e.g. in terms of plans for the re-establishment of specific nature types. Equally, public management and planning might also influence the physical conditions of the land, e.g. by raising ground water levels. However, particularly in agricultural landscapes, the physical implementation of such plans is generally performed by the single farmer or land owner. Consequently, it is his or her decision making and physical implementation at local scale that affect landscapes' conditions for flora and fauna at larger scales.

3.5.3 Farmers' decision making as central link

Farmers' agricultural practices and thus the effects on the landscape are influenced by numerous factors. According to Brandt et al. (1999) factors influencing on farmers' decision making can be grouped into the physical environment, technology, socio-economy, politics and culture. These factors can furthermore be grouped into external factors, e.g. policies and regulations, which the farmer cannot directly influence and internal factors, e.g. personal values, attitudes and ambitions, which are imbedded in the farmer as individual (Antrop 2000). Together, external and internal factors form a frame or room of manoeuvre within which the farmer can carry out his agricultural practice and thus his landscape management (Marsden & Munton 1991, van der Ploeg 1994). Central to the concept of the farmer as actor is that it is the farmer's individual decision making within the given room of manoeuvre that finally determines his decision making on land use and thus landscape management.

Figure 7, attempts to outline this concept. The figure is not all embracing as it was intended to focus on relationships between agricultural land use and the landscape. The land use and landscape management characterising a farm unit is the result of farmers' decision making in relation to different farm specific properties. These properties are themselves influenced by a number of both internal and external conditions, which make up the room of manoeuvre for the farmer. Also these conditions and the properties characterising the farm unit are linked together through farmers' decision making. This means that it is the single farmer's decision on basis of e.g. his values, prices for agricultural products and the location of the farm that determines whether the farm is managed organically or conventionally. Farmers' decision making as the link for external and internal parameters to farm properties and from farm properties to land use is in the Figure illustrated by the ring surrounding farm properties.

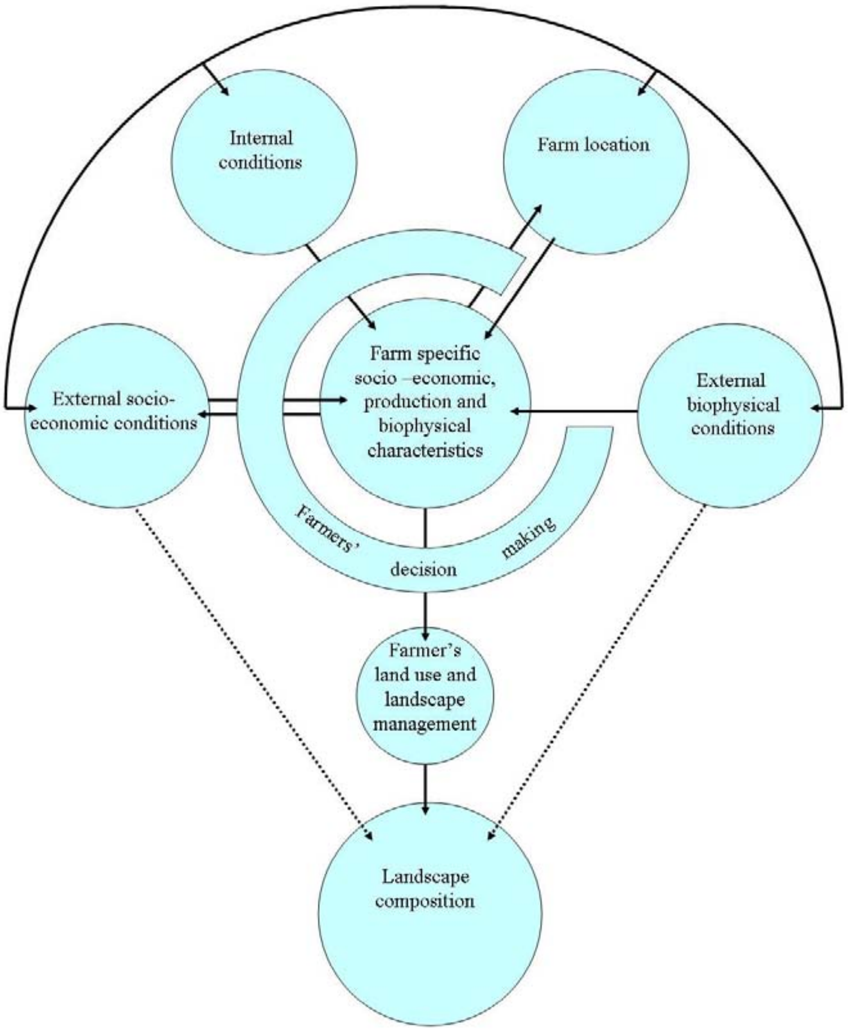


Figure 7: A conceptual framework for agriculture – landscape relations

External biophysical conditions determine soil and slope properties on the farm. In contrast to other conditions, the farmer can usually only change these conditions through decisions about the location of his farm unit. Recognising the importance of the location of farm units, the Figure includes farm location as an own parameter.

Different external and internal factors are often interrelated. E.g. public planning will often be related to biophysical conditions. Similarly, farmers' attitudes and values will often be linked to external factors like politics but also to internal factors like his age, educational background etc.. This complexity of interrelations between different parameters is in the figure illustrated by the arrows linking the different parameters together.

3.6 Critical issues for the methodology

The above presented concept of the mosaic landscape, the concept of the landscape element as the linkage between farmers' decision making and the composition and structure of the landscape as well as the concept of farmers' decision making as central link between external/internal parameters, land use and land use's impact in the landscape provide a useful frameworks for the current study of agriculture's impact on the landscape. The two concepts provide opportunities to incorporate the critical issues, which were discussed earlier in this chapter. These involve the recognition of multiple, often interrelated factors influencing agriculture – landscape interactions, the necessity of paying attention to spatial and temporal scales and hierarchies between scales and the importance of recognizing the spatial character of landscapes and landscape changes.

These issues lead to the following suggestions, which are important to the design of a practicable methodology:

- Data should reflect information for variety of parameters influencing agricultural land use and thus its impact on the landscape. Applied methodologies should enable the examination of interrelations between different parameters.

- To approach an evaluation of landscape composition, data on landscape elements should be quantifiable.

- To enable the analysis of interrelations between the landscape's physical character and influencing parameters, a spatial reference for both landscape and other data should be attempted. Furthermore, applied methods for analysis should enable the extrapolation between different spatial scales.

- In order to elucidate agriculture's impact on the landscape over time, data for different points in time (years) should be used.

The following chapter aims at integrating these suggestions into the design of an appropriate methodology for this study.

4 Methodology

In this chapter, the applied methods for this study are presented and discussed. To recall the aim of the study, the central key questions are repeated here:

- Does landscape composition differ between organic and conventional farms?
- Is the conversion to organic farming followed by trends in changes in landscape composition, which differ from changes on conventional farms?
- How are differences in landscape composition and changes in landscape composition between organic and conventional farms influenced by other biophysical, socio-economical and production parameters, characterising the two farm types?

In order to answer, or at least approach answers to these questions, two different methodologies were applied. The first method is based on an analysis of Danish national agricultural registers. The second method is applied for three case areas and is based on landscape data derived from the interpretation of aerial photos.

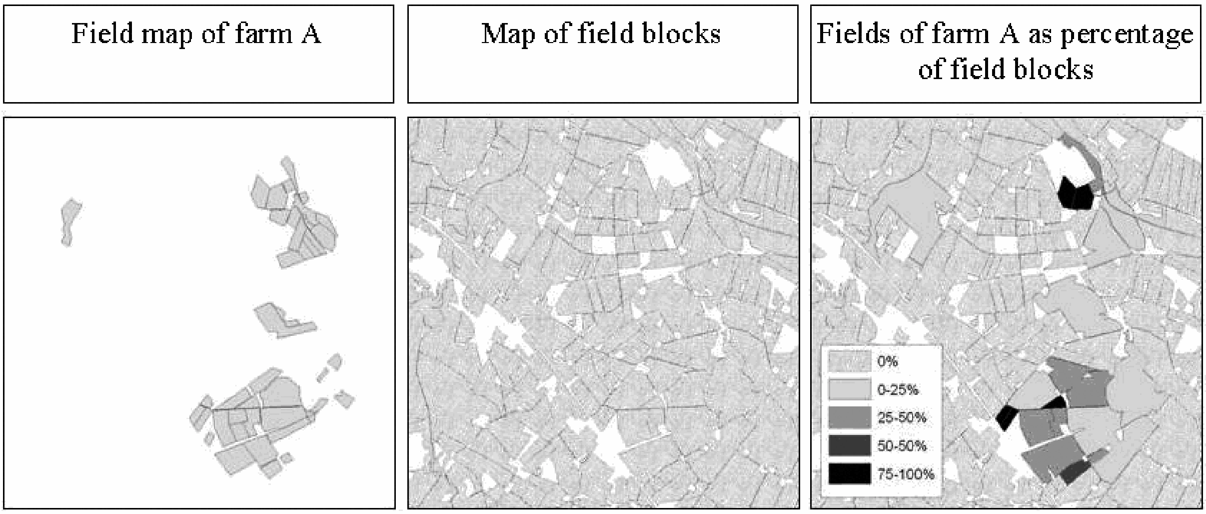
Both approaches have strengths and limitations. The analysis at case area scale is characterised by a very detailed spatial and classification resolution. Also its temporal resolution is high, including 4 points in time, stretching over almost 50 years. However, care is needed when attempting to generalize findings from the case area to the national scale. In contrast, findings at national scale apply for the whole country. Data from national agricultural registers are, however, less detailed and do only contain landscape information on field sizes and diversity of agricultural land uses. Furthermore, the time scale of the national analysis is limited to the period from 1998 to 2004. In spite of their respective strengths and limitations, the two methodological approaches complement each other and thus aim at a more comprehensive examination of relationships between agriculture, particularly organic agriculture, and the landscape. The different data sources used in the two methods are listed in Table 1.

Table 1: Applied data sources

Aerial photos		**Resolution /scale**	**Source**
	Colour ortophoto 2002	0.4 meters	COWI (2002)
	Colour ortophoto 1995	0.8 meters	COWI (1995)
	B&W aerial photo 1982	0.8 meters	National Survey and Cadastre (1982)
	B&W aerial photo 1954	0.8 meters	National Survey and Cadastre (1954)
Map data			
	Topographic map 2001	1:25,000	National Survey and Cadastre (2001a)
	Soil map	1:50,000	Danish Institute of Agricultural Sciences (1998a)
	Digital terrain model	1:10,000	National Survey and Cadastre (2001)
	Field block map 1998	1:10,000	Danish Institute of Agricultural Sciences (1998b)
	Field block map 2001	1:10,000	Danish Institute of Agricultural Sciences (2001)
	Field block map 2004	1:10:000	Danish Institute of Agricultural Sciences (2004)
	Cadastre map 2001	1:4,000	National Survey and Cadastre (2001b)
	Field maps 2001	0.8 meters	Danish Plant Directorate (2001a)
Other data			
	Agricultural register 1998		Ministry of Food Agriculture and Fisheries (1998)
	Agricultural register 2001		Ministry of Food Agriculture and Fisheries (2001)
	Agricultural register 2004		Ministry of Food Agriculture and Fisheries (2004)

4.1 The investigation of national agricultural registers

In Denmark information on agricultural land use and on animal husbandry is registered on a yearly basis and has been accessible to the public since 1998. Land use data are based on farmers' application for EU-subsidies and thus embrace data for the type of land use and area of every field plot included in the farmer's application. Data for animal husbandry are based on a yearly registration of all animals. Both land use and animal data can be directly linked to the single farm unit. Furthermore, for each field plot in the registers a spatial reference exists to a specific field block. Field blocks are administrative units, which are relatively stable in space and time. As one field block can contain several field plots it is, however, not possible to determine the exact location of the field within the field block. Still, using land use data at field scale in combination with the field block map enables a reasonable approximation of the spatial location of the agricultural land managed by each farm unit. The spatial relation between field plots and field blocks is illustrated in Figure 8.


Field map of farm A

Map of field blocks

Fields of farm A as percentage of field blocks

Figure 8: The relation between field plots and field blocks

4.1.1 Data handling

The practical handling of the data derived from agricultural registers is outlined in Figure 9. For every farm unit, land use registers provide information on:

- Farm size (the sum of the area of fields managed by the farm)
- Mean field size (the average size of all fields managed by the farm)
- Diversity of land use (using Shannon's diversity index[4])
- Organic/conventional production and year of conversion (for each field plot, registers contain information for the year of conversion to organic farming)

On the basis of land use and animal registers it is possible to group farms into different production types. In this study the chosen production types are cattle, pig/chicken and mixed/stockless farms. The grouping was based on a calculation of the economic significance of the respective agricultural products[5].

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[4] For a more detailed description of the calculation of Shannon's Index for land use diversity, see paper 1.

[5] The farm types are defined as follows: cattle: >=50% of agricultural income from dairy/meat cattle production; pig/chicken: >=50% of agricultural income from pig/chicken/egg production; mixed/stockless farms: neither dairy/meat cattle nor pig/chicken production provide >=50% of the agricultural income.

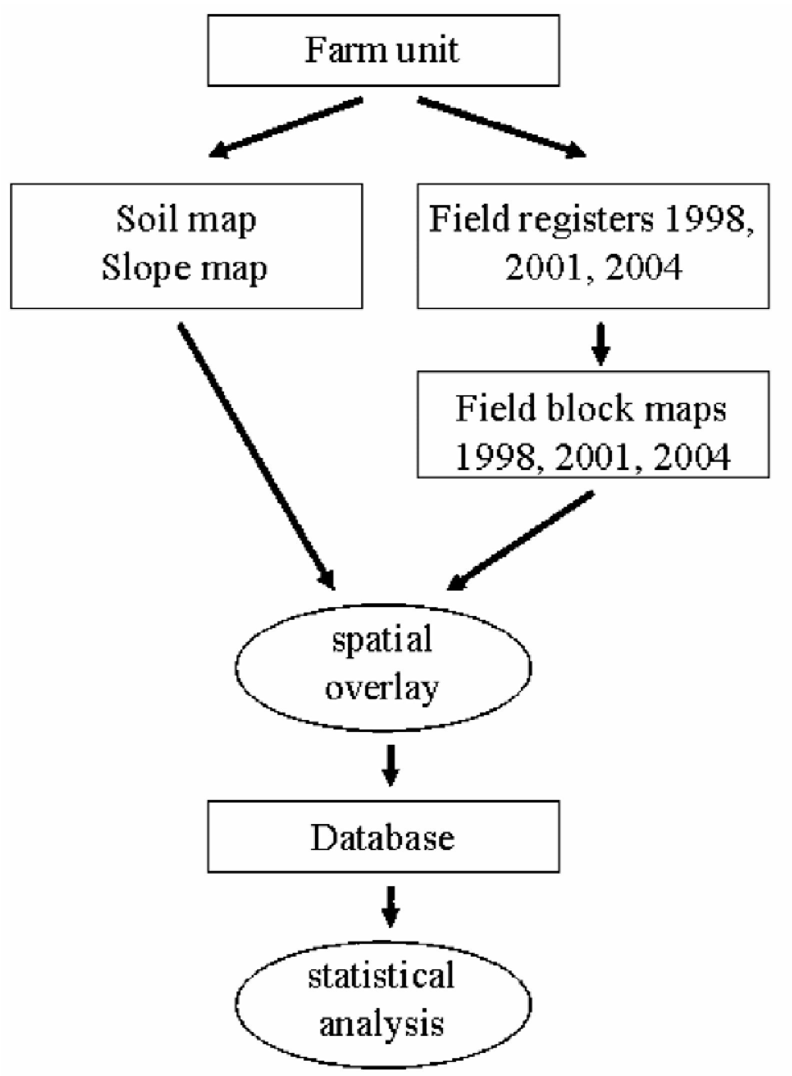

Figure 9: Analyses of national data

Finally, elaborating the spatial reference between field plots and field blocks, for each farm unit, the approximate location of the farm area was derived. By means of a spatial overlay with a soil and a slope map[6], for each farm unit approximations of soil and slope conditions were calculated.

In the first step of the national analysis, relations between farm and landscape parameters were tested on the basis of registers from 2001. This analysis included 3,339 organic and 46,264 conventional farms. The analysis thus embraces all registered farms in Denmark in 2001, though excluding the island of Bornholm[7].

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[6] Applied soils are sandy soils, clay soils and peat soils; the slope map is based on a digital terrain model and was divided into areas with slope under 5 degrees and areas with slopes equal to or exceeding 5 degrees.

[7] Due to biophysical conditions, which are very different from Denmark in general, it was chosen to exclude the Island of Bornholm from this analysis.

4.1.2 Analyses of changes

Changes in landscape parameters were investigated on the basis of registers from 1998 and 2004. Changes in farm sizes, mean field sizes and diversity of lands use were calculated for 38,506 farms, which could be traced in both registers. About ¼ of all farms in 2004 could not be traced in the 1998 registers. This is due to changes in ownership, the merging of farm units and due to the establishment of new farms, all implicating a change in the farm ID, which was used to define the farm units.

In order to test relationships between time of conversion to organic farming and landscape changes the farms were grouped into: organic farms converted before 1998 (N=825); organic farms converted between 1998 and 2003 (N=1,248); and farms, which in 2004 were managed conventionally (N=36,433). As one organic farm unit can contain different field plots with different years of conversion to organic farming, the average time of conversion weighted by the size of each field was used as the year of conversion of the farm. For the group of farms converted from 1998 to 2003, the 1998 agricultural register represents the situation prior to conversion, while the 2004 register represents the situation subsequent to conversion to organic farming. Farms, which have been converted back from organic to conventional, were classified as conventional.

4.1.3 Strengths and limitations of using agricultural registers

The obvious strength of using national agricultural registers is that they enable general conclusions for agriculture – landscape relations in Denmark. However, landscape data are restricted to information on field sizes and land use diversity. Furthermore, the investigation of changes only covers 6 years, which is a relatively narrow time scale for the analysis of landscape changes. It is also important to stress that land use data only contain information for land, for which farmers have applied for EU-subsidies. Corresponding with Nyholm Poulsen et al. (2002) analyses at case area scale point at the fact that roughly 7% of the agricultural land is not included in the registers. The land, which is not included in the registers, is primarily composed of uncultivated natural and seminatural land cover, which is of limited importance to the production system but of large significance to landscape composition. However, in the national analysis, landscape composition is investigated in terms of sizes of field plots of land in rotation and diversity of agricultural land use. As land not included in the registers is primarily composed of land outside rotation this lack of about 7% is acceptable. Finally, while data on land use can be directly related to the specific farm unit, spatial references for farm units and consequently data of soil and slope conditions at farm scale are approximations. In spite of these limitations, national agricultural registers provide very valuable data sources, and analyses of these data are fruitfully applied in all three papers included in this thesis.

4.2 The investigation at case area scale

In order to overcome or at least attempt to overcome some of the inadequacies of the analysis of national agricultural registers, a case area analysis was carried out. The aim of this analysis was to attain a more detailed picture of agriculture – landscape relations, with particular focus on the role of organic farming, than it is possible on the basis of national registers. For three different case areas, this analysis uses aerial photo interpretation for a detailed registration of landscape features and changes in these. In combination with other data sources, these data aim at a more profound understanding of the impact of agriculture on and the role of organic farming for landscape composition.

4.2.1 Selection and demarcation of case areas and farm units

The following requirements were set up for the selection and spatial demarcation of the three case areas:

- The areas should represent different typical Danish agricultural landscape types in terms of biophysical conditions and socio-cultural character.
- The demarcation of the areas should be carried out in such a way that the case areas contain the full biophysical and socio-cultural variation, which characterises the respective landscape types. Furthermore, the splitting up of landscape features should be avoided.
- The case areas should be characterised by a high density of organic farms.
- The case areas should cover the total area managed by the selected farms.

In order to represent different Danish agricultural landscape types, it was decided to select one area in western Jutland, one in the eastern part of Jutland and one on the island of Zealand in the periphery of Copenhagen.

Selection of farms

A point map of all organic farms for 2001 was created using address coordinates derived from the 2001 agricultural registers. On the basis of this map, areas with a high density of organic farms were pointed out. Topographical maps, soil maps and maps of geomorphology were used to broadly demarcate the areas in order to contain the characteristic biophysical and socio-cultural variation of the landscapes.

Using field block maps in combination with land use registers; the approximate location and extent of the selected farms were added to the map. In addition all conventional farms, which were completely located within the areas, were selected for analysis. For some farms it was, however, not possible to include all managed land. This is primarily due to fallow land located at a large distance (often in a different part of the country). Therefore, up to 3% of the farm unit located outside the case areas was accepted.

In total 40 organic and 72 conventional farms, covering about half of the agricultural land in the areas, were selected. The other half of the agricultural land was managed by farms that had part of their land located outside the study areas. The final map of farm units is shown in Appendix 4.

Demarcation of the case areas

In order to avoid splitting up landscape features, for the detailed spatial demarcation of the case areas, linear features like streams, transportation lines and hedgerows, derived from topographical maps, were used as boundaries for the case areas. Gaps of maximal 25 metres were, however, accepted. The selected case areas are Herning in western Jutland, Randers in eastern Jutland and Slangerup, located north-east of Copenhagen. The areas cover respectively 42.3; 41.7 and 31.9 km². A more detailed description of the case areas is included in Papers 1 and 2.

Demarcation of farm units

The process of demarcation of farm units for this study is illustrated in Figure 10. For this study, the land belonging to one farm unit is defined as the land, which is under the management of this farm unit. In Denmark about 1/3 of all agricultural land is rented out between different farm units. An adequate spatial demarcation must consequently include both rented and owned land. In practice the spatial demarcation of a farm unit was for this study defined as owned land + rented land – land rented out.

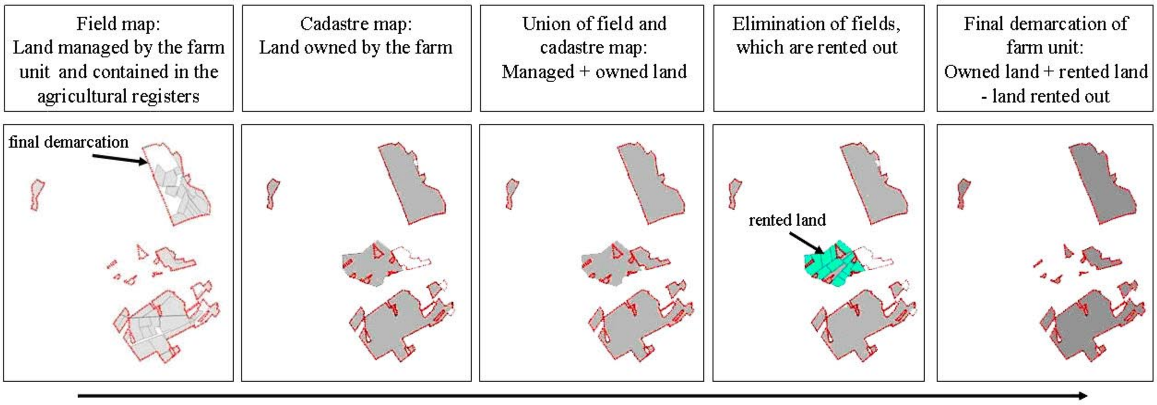

Figure 10: The process of demarcation of farm units

As mentioned, the land use data from agricultural registers only contain field plots for which farmers have applied for EU-subsidies. Furthermore, an exact spatial demarcation of the fields is not possible on the basis of the registers. Therefore, for the case area analysis, the spatial demarcation of farm units was based on field and cadastre maps.

As part of the administration of EU-subsidies, on a paper print of an aerial photo, each farmer or land user is bound to manually demarcate all field plots, for which he applies for EU-subsidies. These field maps are accessible to the public. For this study, fields for all selected farms were digitized on the basis of field maps from 2001. Field maps embrace land managed by a farmer and thus contain both owned and rented land. The registers do, however, not contain information on whether a field plot is owned or rented.

In order to include the parts of the farm unit that are not contained in the agricultural registers and therefore in the field maps, the national cadastre map for 2001 was used. Agricultural registers contain a reference between the farm unit and the respective properties owned by the single farmer or land owner. For each of the selected farms, the combination of the digitized field maps with the cadastre map thus enabled the demarcation of both managed and owned land. Yet, as owned land can be rented out to other farms all owned land is not necessarily managed by the farmer who owns the land. Therefore, field maps for farms managing rented land within the selected farms were used to exclude land, which was rented out. The resulting map of farm units thus reflects all land, which in 2001 was under the management of the 112 selected farms.

4.2.2 Interpretation of aerial photos

For the case area analysis data on landscape composition were derived from a registration of landscape features on the basis of a visual interpretation of aerial photos. Although very time consuming, the use of aerial photos in landscape analyses has several advantages compared to other data sources. As aerial photos are a "raw" data source, which has not been interpreted previously, the use of aerial photos allows for the design of a classification scheme, which is suitable to the study purpose. Furthermore, aerial photos do generally have a high spatial resolution, which enables the registration of very small landscape features. Finally, choosing aerial photos from different dates, allows for a selection of a temporal scale and resolution, which is suitable to the study purpose.

A large number of studies, which have used aerial photo interpretation in landscape analyses and in investigations of landscape change exists (Hietala-Koivu 2002, Ihse 1995, Kienast 1993, Levin & Reenberg 2002). Aerial photo interpretation is also a central tool in several landscape monitoring programmes. In addition to surveys in the field, aerial photos are used in the Norwegian monitoring of agricultural landscapes 3Q (Engan 2004), the Swedish landscape monitoring programme NILS (Allard et al., 2003) and in the Danish monitoring of small biotopes (Agger et al. 1986).

The choice of classification, which is used for aerial photo interpretation in this study, was primarily based on the relevance of the classification to the study purpose, which is the analysis of landscape composition and changes in landscape composition. However, the practical applicability of the classification is of course crucial. Several classes may be relevant but not possible to register on the basis of the applied aerial photos.

In practice, the development of the final classification was an iterative process. On the basis of the study purpose and of a review of existing classification schemes, particularly those of the Danish, Swedish and Norwegian landscape monitoring programmes, a list of desirable classes was elaborated. The registration of these classes was tested for a set of aerial photos for 2002. Several classes were difficult to determine. E.g. dividing between cultivated land and grass in rotation was very difficult. The two classes were therefore merged into one class, defined as land in rotation. On the other hand, it was relatively easy to distinguish between forest plantations and other forested land. Consequently, a specific class for forest plantation was created.

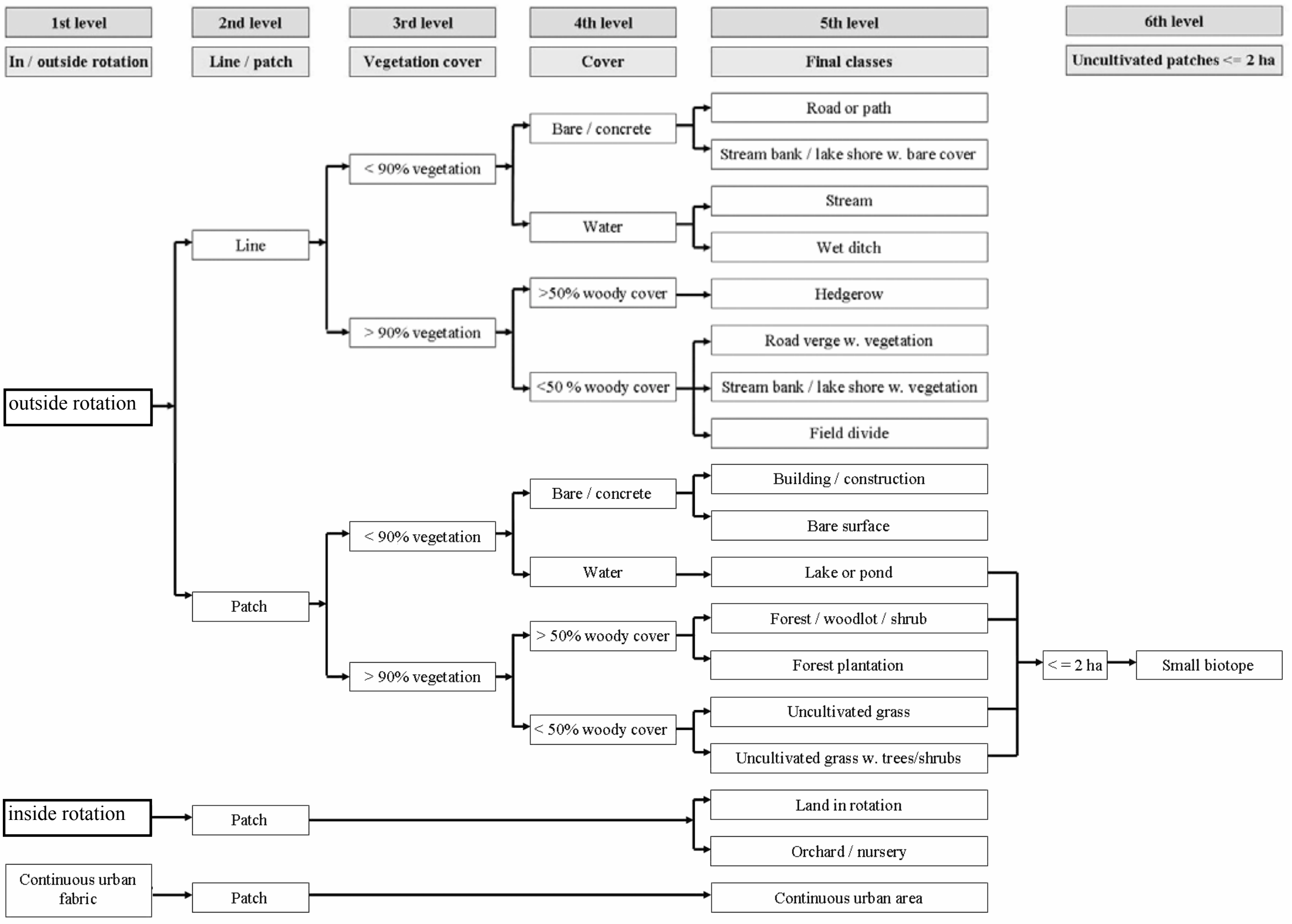

Figure 11: The classification key for interpretation of aerial photos

The final classification contains 18 land cover classes. The classification key is shown in Figure 11. The classification procedure contains four different levels. At the first level, all land is grouped into land in rotation and land outside rotation. At the second level, landscape elements are divided into line or patch elements. At the third level, the physical land cover is identified and at the fourth level the final class is defined.

The classification key

The spatial resolution of the classification is 20m². Elements smaller than 20m² are subscribed to the class next to them. If an element smaller than 20m² is located between two different classes, this element is split up between the two classes.

1st level: in rotation / not in rotation

At the first level of classification, all landscape elements are classified into elements, which are part of the agricultural rotation and elements, which are not. Elements in rotation are normally ploughed with a frequency of at least 5 years. Exceptions are orchards and nurseries, which are ploughed with a much lower frequency, but which are still part of a rotation cycle and are subject to a relatively intensive agricultural use. In addition, areas, characterised by a continuous urban fabric, containing buildings, constructions, infrastructure, gardens and other urban facilities are defined at this stage of classification.

2nd level: Line or patch

At the second level of classification, all elements are divided into line or patch elements.

Line elements are defined as:

- At least 20 meters long
- 1-10 metres wide
- At least 5 times longer than wide

The width of line elements is registered as the average width of a segment of at least 20 metres. Different line elements are attributed different widths, when the change in width exceeds 2 metres. For hedgerows, the width is registered as the average width of crown cover. For all other line elements the width is registered as the average width at the ground level.

Bits of line elements shorter than 20 metres are classified as line elements, if they are located in continuation of another line element.

In the case of roads and streams, widths exceeding 10 metres are accepted.

All elements of at least 20 m^2, but which do not fulfil requirements for lines are classified as patches. For patch elements dominated be tree or shrub vegetation, crown cover is used for demarcation. All other elements are demarcated at ground level.

3rd level: Vegetation cover

At the third level all elements are divided into areas covered by vegetation and areas not covered by vegetation. Vegetation cover is defined as >90% crop-, grass-, herb-, shrub-, and/or tree-vegetation. For shrubs and trees, vegetation cover is registered as crown cover. In the case of recently planted hedgerows and recently ploughed or sown fields vegetation cover <90% is accepted.

4th level: Cover

At the fourth level of classification elements are further divided into different cover types. Elements with vegetation cover are divided into classes with >50% woody cover and elements with <50% woody cover. The percentage of woody cover is defined by the extent of crown cover. However, in the case of recently planted forest plantations and hedgerows, woody vegetation cover <50% is accepted. Elements with no vegetation cover (<10% vegetation cover), are further divided into bare / concrete cover and water surfaces.

5th level: Final classes

At the fifth level of classification 18 final land cover/land use classes are defined. The definitions are based on a combination of evaluations of structure and cover at levels 1-4 and on more detailed interpretations of land cover, the internal spatial structures of the land cover and the elements' location in relation to each other. While levels 1-4 are mainly concerned with the interpretations of the physical cover and structure, definitions at level five also integrate the interpretation of the elements' functions.

Road or path:
Line element with bare or concrete cover used for transportation. In the case of paths, grassy vegetation cover is accepted. Road verges with bare cover are registered as part of the road or path. Other road verges are treated as own classes like road verge with vegetation or hedgerow.

Stream bank / lake shore with bare cover:
Line element located at the border of ponds, lakes or streams and with a vegetation cover of less than 90%.

Stream:
Not straight line element with water surface. Streams only contain the water surface. Areas along rivers are treated as own classes.

Wet ditch:
Straight line element with water surface. Ditches without water surface are often not visible or classified as field divides.

Hedgerow:
Line element with more than 50% woody vegetation (crown cover). Gaps <20 meters, covered by non-woody vegetation (grass or shrubs) are accepted. In the case of recently planted hedgerows <90% vegetation cover and <50% woody vegetation cover (crown cover) is accepted.

Road verge with vegetation:
Line along roads or paths covered by >90% vegetation but less than 50% woody vegetation cover. Lines along roads or paths with more than 50% vegetation cover are registered as hedgerows.

Stream bank / lake shore with bare cover:
Line element located at the border of ponds, lakes or streams and with a vegetation cover exceeding 90% but less than 50% woody vegetation cover. Lines at the border of ponds, lakes or streams with more than 50% vegetation cover are registered as hedgerows.

Field divide:
Line element with less than 50% woody vegetation (crown cover). Gaps <20 meters length, covered by woody vegetation are accepted. Many field divides have a width less than 1 meter. These are registered in terms of boundaries between different plots of agricultural land but are, however, not included in the calculation of densities of field divides.

Building or construction:
Any kind of building or construction.

Bare surface:
Any area, which has a bare or concrete surface and which is located in connection to buildings and other constructions and to roads or with clear signs of gravel exploitation. Bare surfaces on agricultural fields and without clear signs of gravel exploitation are classified as part of the agricultural land.

Lake or pond:
Any patch element, which is covered by water. Areas with rush-vegetation in connection to ponds or lakes are classified as part of the water

surface. Other areas located along lakes and ponds are not part of this class, but are assigned to one of the other classes in the classification key.

Forest, woodlot and shrub:
Patch element characterised by >50% woody vegetation (crown cover) with no clear geometrical vegetation patterns.

Forest plantation:
Patch elements with >50% woody vegetation (crown cover), which in contrast to forest, woodlots and shrub are characterised by trees being positioned in clear lines. In the case of recently planted plantations <90% vegetation cover and <50% woody vegetation cover (crown cover) is accepted.

Uncultivated grass:
Areas covered by grass and with less than 25% woody vegetation (crown cover). There are no signs of recent cultivation (no tractor tracks) and the areas appear heterogeneous in spatial texture and colour. The applied classification key does not contain a particular class for fallow land. Fallow land will thus form part of uncultivated grass or of uncultivated grass with trees and shrubs.

Uncultivated grass with trees and shrubs:
Areas covered by grass and 25-50% dispersed woody vegetation (crown cover). The dispersed patches of woody vegetation cover must not exceed 20m^2. Otherwise these would be classified as patches of forest/ shrub. As for natural grass, there are no signs of recent cultivation (no tractor tracks) and the areas appear heterogeneous in spatial texture and colour.

Land in rotation:
Areas with clear signs of cultivation like tracks from ploughing or from tractor use. This class contains both cropped areas and areas with grass in rotation. In the case of recently ploughed or sown fields, vegetation cover <90% is accepted.

All land in rotation was demarcated as individual field plots. The size or area of these field plots was registered and resulting field sizes were applied as parameters in several analyses. Plots of land in rotation were demarcated by transitions to other landscape elements or to other plots of cultivated land.

Orchard or nursery:
Area with solitary trees located in a geometrical pattern and with equal distances between each other. Tree cover is 10-20% (crown cover).

Continuous urban area:
Areas, characterised by a continuous urban fabric, containing buildings, constructions, infrastructure, gardens and other urban facilities.

6th level: Uncultivated patches smaller than two hectares

Small biotopes:
The small biotope class is a compound of different classes. The class is defined as patches of uncultivated natural or semi natural land cover with an upper size limit of two hectares. The size definition for small bio-

topes corresponds with Agger et al. (1986) who developed the term in the early 1980s. The argument for a size limit of two hectares is that small landscape elements often are patches located within the cultivated farmland and thus are more exposed to effects from agricultural practices than larger landscape elements. In this investigation small biotopes comprise small woodlots, small ponds and lakes and small patches covered by natural grass, shrubs and/or herbs. Uncultivated line elements, which by Agger et al. (1986) are included in the definition of small biotopes, are, in this investigation treated individually as hedgerows and field divides.

4.2.3 Selection of aerial photos and image processing

For the registration of landscape features, aerial photos for 2002, 1995, 1982 and 1954 were selected. The 1982, 1995 and 2002 photos were chosen in order to cover the last two decades, where most conversion to organic farming in Denmark has taken place. Additionally, the 1954 photos were chosen in order to relate landscape composition and changes in landscape composition over the last 2 decades to landscape changes over the last approx. 50 years. 50 years is a convenient time scale as the early 1950s represent a period just before a noticeable structural rationalisation of Danish agriculture and Danish agricultural landscapes began.

The photos for 2002 and 1995 are colour ortophotos, with a resolution of respectively 0.4 and 0.8 meters. The orthophotos are available as digital and spatially referenced images. The 1982 and 1954 images are only available as black and white paper prints. These were scanned at a resolution of 1200 dpi. Subsequently, the scanned images were geometrically rectified and spatially referenced, using ArcView 9 software. Second order models were applied for the spatial rectification. Using the central part of the scanned images, rectification accuracies did not exceed one meter. Furthermore, the spatial resolution of the scanned images is 0.8 meters.

The mapping procedure

The procedure for the mapping or digitising of landscape elements is illustrated in Figure 12. All digitisation and image processing was performed with ArcView 9 software. At the first step of the mapping, all line elements were registered as line features. Each feature was assigned to a class and given a width. In the second step, each line element was buffered, using half of the width as buffer distance. In the third step, all buffers were united into one theme. Areas, where two or more buffers cross, were assigned to the class, which is placed at the highest level in the hierarchy shown in Table 2. During the buffering procedure multiple small remaining patches were generated (e.g. where a hedgerow "dangles" over a road). Such patches were eliminated. Finally, in the last step, the blank areas between the line elements were digitised and subscribed to the specific classes. The elaborated maps of land cover for 2002 are shown in appendix 1.

Table 2: Hierarchy of line elements applied for land cover registration

Hierarchical level	Land cover class
1	Roads and paths
2	Streams
3	Ditches
4	Hedgerows
5	Field divide
6	Stream bank / lake shore w. vegetation cover
7	Stream bank / lake shore w. bare cover
8	Road verge w. vegetation

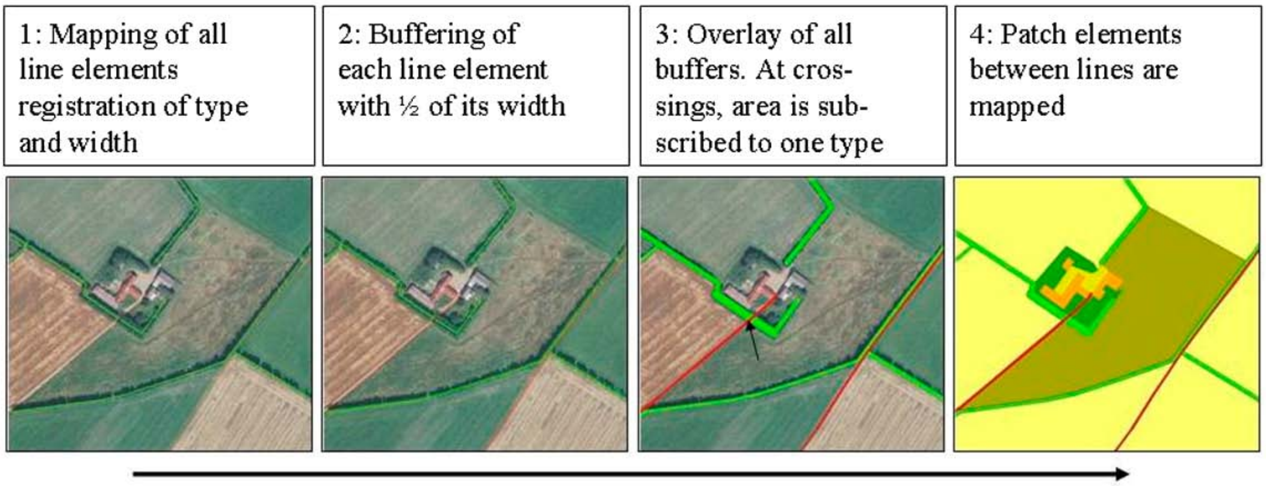

Figure 12: The process of landscape mapping on basis of aerial photos

Detection of landscape changes

Landscape changes were analysed on the basis of visual interpretation of the aerial photos from 1954, 1982, 1995 and 2002. The land use classification from 2002 was compared to the 1995 photo and where land cover or the spatial boundary of land cover classes were different, the classification was modified resulting in a new land cover map for 1995. This procedure was then continued backwards to 1982 and finally 1954. Applying this method, considerable errors due to spatial slivers in later spatial overlays of the images was avoided.

Subsequently, all final land cover maps were united into one map. Within this map it was possible to point out the land cover class for each location for each specific year. I.e. it is possible to describe the (life) history for every mapped element, which has existed at one of the registered years. Consequently, changes in land cover occurring between the four selected years could be registered for each element or location. A possible (life) history for a certain element or location could be: '54: hedge, 82': in rotation, 95': in rotation, 02': woodland.

Accuracy of the aerial photo interpretation

Since the registration of landscape features was exclusively based on a visual interpretation of the aerial photos and no control in terms of registration in the field was carried out, it is difficult to estimate the accuracy of the elaborated land cover maps. However, two attempts to evaluate to accuracy of the data were made.

In the first attempt two different persons used the classification key to register land cover for 2002 within three test sites. This test aimed at pointing at land cover classes that are difficult to determine through visual interpretation. The second attempt used data on land use from the 2001 agricultural registers and compared these to the land cover registered on the basis of the 2002 aerial photos. This test aimed at pointing out accuracies in the registration of agricultural land uses.

Comparing two persons' classification

This test was applied for three test sites covering 25 hectares each. The test sites were distributed over the three case areas of the study and were selected to cover as many of the 18 classes as possible. Forest plantations, orchards / nursery, stream banks / lake shores with bare cover as well as continuous urban areas were not contained in the test sites. Figure 13 shows the total area of the different classes classified by respectively person 1 and person 2. The figure points at a relatively high concordance between the two classifications, indicating a general validity and practicability of the classification key. However, for uncultivated grass, uncultivated grass with trees and shrubs and for land in rotation concordances are somewhat lower. Figure 14 shows the spatial coherence between the two classifications. Also here, coherences of uncultivated grass, uncultivated grass with dispersed trees and shrubs and of land in rotation, are relatively low. The figures indicate the difficulty in distinguishing between these different classes of agricultural land use. One reason is probably that all aerial photos were taken in late May and early June. At this time of the year cultivated land will often be covered by young crops, which are characterised by a colour and structure that makes them difficult to distinguish from uncultivated grass. However, the largest overlaps exist between uncultivated grass and uncultivated grass with dispersed trees and bushes. This is almost certainly due to difficulties in determining the coverage of dispersed woody vegetation.

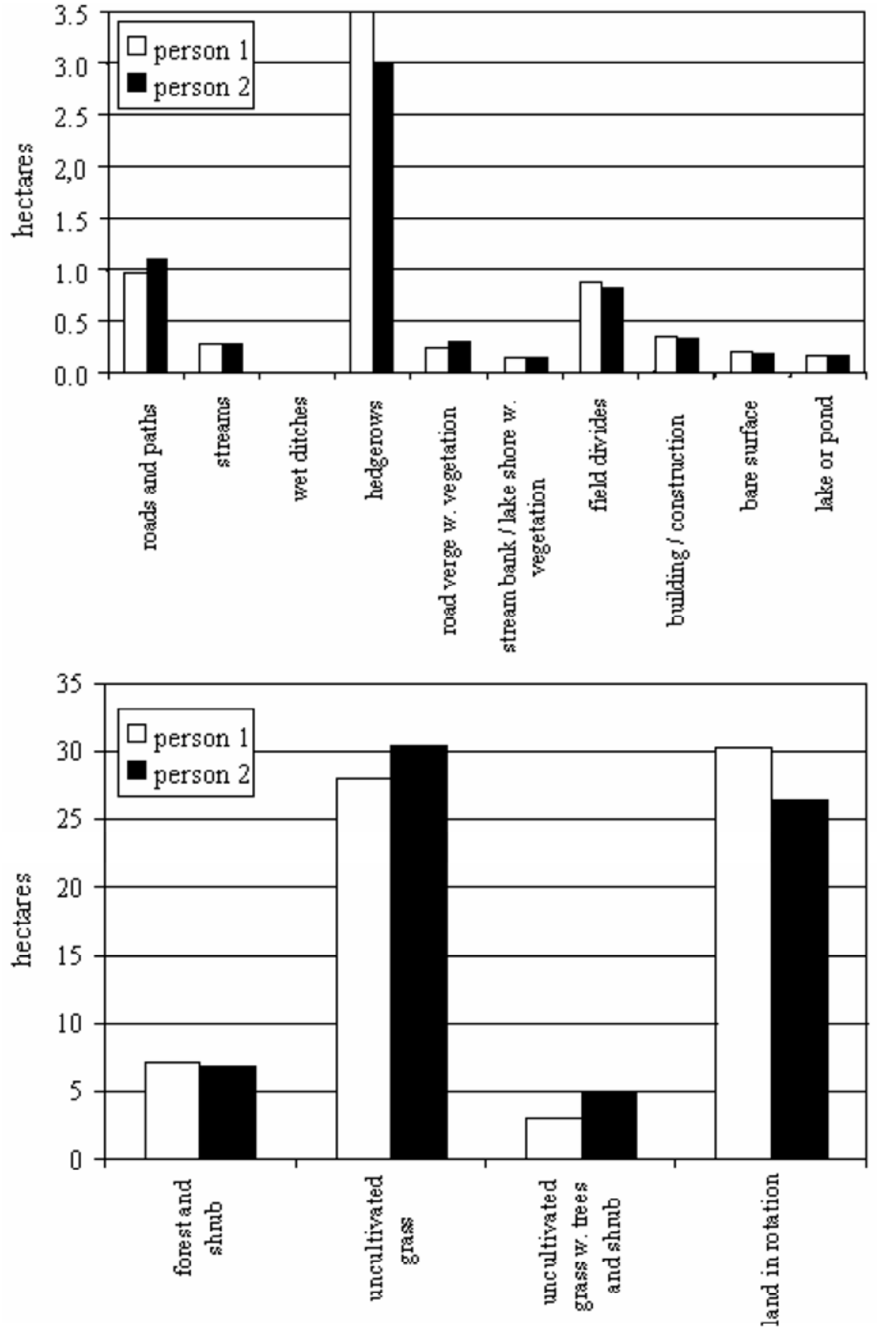

Figure 13: Total area of different land cover classes classified by two different persons
Source: mapping of 3 test sites covering 25 ha each

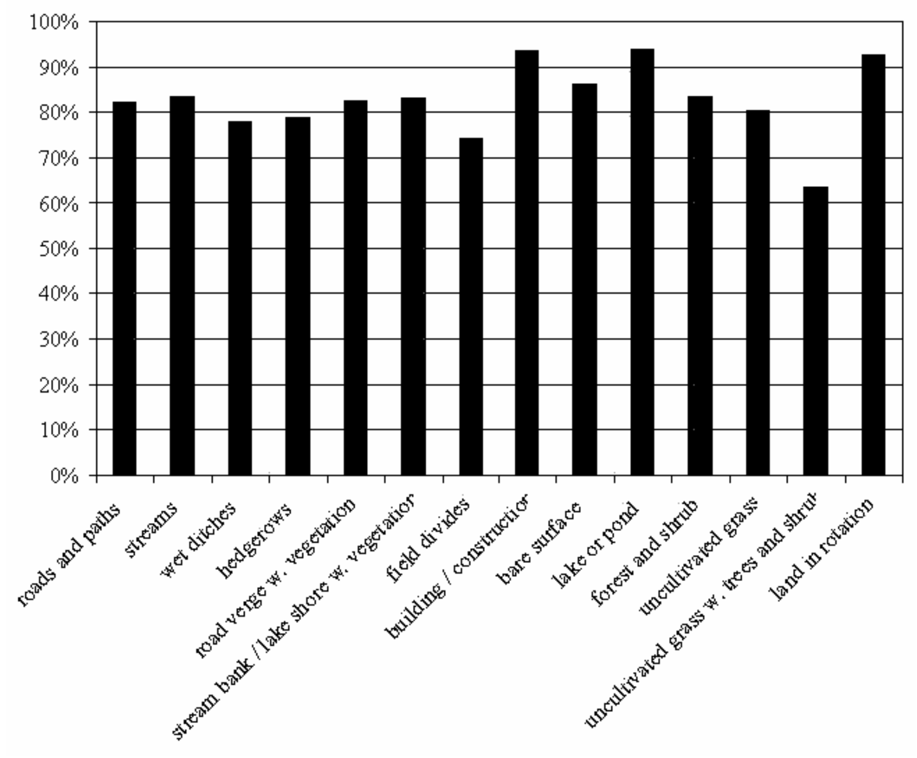

Figure 14: Spatial coherence between land cover classifications of two different persons
Source: mapping of 3 test sites covering 25 ha each

All other patch classes have spatial accuracies exceeding 90%, which is very reasonable for a visual interpretation. In terms of the total classified area, line classes have a relatively high accuracy (Figure 13). However, the spatial accuracy of line elements is only around 80%. A detailed investigation of the overlay between the two classifications indicates that the low accuracy is not a result of difficulties in the classification, but is rather influenced by the digitization process. In the digitization process all line elements are first registered as line features and then buffered with half of their width. If person 1 positions e.g. a field divide of one metre width only 30 cm besides the positioning of person 2, this result in an overlap of only 70%. Taking into account the resolution of the aerial photos of 0.4 – 0.8 meters, such spatial deviation is unavoidable. As a large part of line elements are located next to land in rotation, this spatial inaccuracy in the registration of line elements does also to some degree explain the spatial accuracy of only 82% of land in rotation. As long as the classification accuracy, i.e. the sum of area of the single classes, exceeds 90% and the registration of land cover and land cover changes is carried out as described above, such spatial deviation is, however, acceptable.

In summary, for most classes this test points at generally high correspondences between the classifications of two different persons. Consequently, the classification key forms an applicable tool for this study. However, correspondences for uncultivated grass, uncultivated grass with trees and shrubs and to some extent also of land in rotation, are rather low. Analyses and findings later in this study should pay attention to this.

Comparison with field data

In the other attempt to estimate the accuracy of land cover data, information on land use from the agricultural registers from 2001 was compared to the registration on the basis of the aerial photos from 2002. Field maps were digitized in relation to the demarcation of farm units and the elaborated field map covers about half of the case areas' total area. For each field, the register contains information on the agricultural land use as reported by the farmer. In total the registers contain 122 different classes. In order to make these comparable to the classification applied in the interpretation of aerial photos; the 122 classes were grouped into the following four main classes: Cultivated land, grass in rotation, uncultivated grass and fallow land. As the field data primarily contain information of agricultural land use[8] the comparison focuses on the classes: Land in rotation, uncultivated grass and uncultivated grass with trees and shrubs.

The results from this analysis must be interpreted in relation to two main sources of inaccuracy in the field data. First, the applied field maps contain a very detailed registration of field plots. However, since this registration is done manually by the individual farmer or land user, the accuracy varies between different farms and registration errors are not avoidable. Furthermore, data for land use are based on information reported by the farmer. Although no estimates of the accuracy of this information are not available, errors or false information are probably not avoidable. Finally, while field data refer to 2001, the aerial photos are from 2002 and between the two years, land use might have changed.

In spite of this insecurity for data quality, field data is a reasonable data source to compare with the aerial photo interpretation. Figure 15 shows the result from an overlay between the field data and the registration based on aerial photos. For land in rotation the concordance to field data is very high. Of land in rotation ¾ is classified as cultivated land in the registers, and 18% is classified as grass in rotation, which is reasonable, as no division between cultivated land and grass in rotation was made in the aerial photo interpretation. Respectively 3% and 4% are in the registers classified as natural grassland and fallow land. Part of this discrepancy between the data may be a result of the different reference years or due to insecurity of the quality of field data.

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[8] The registers also contain some information on forestry

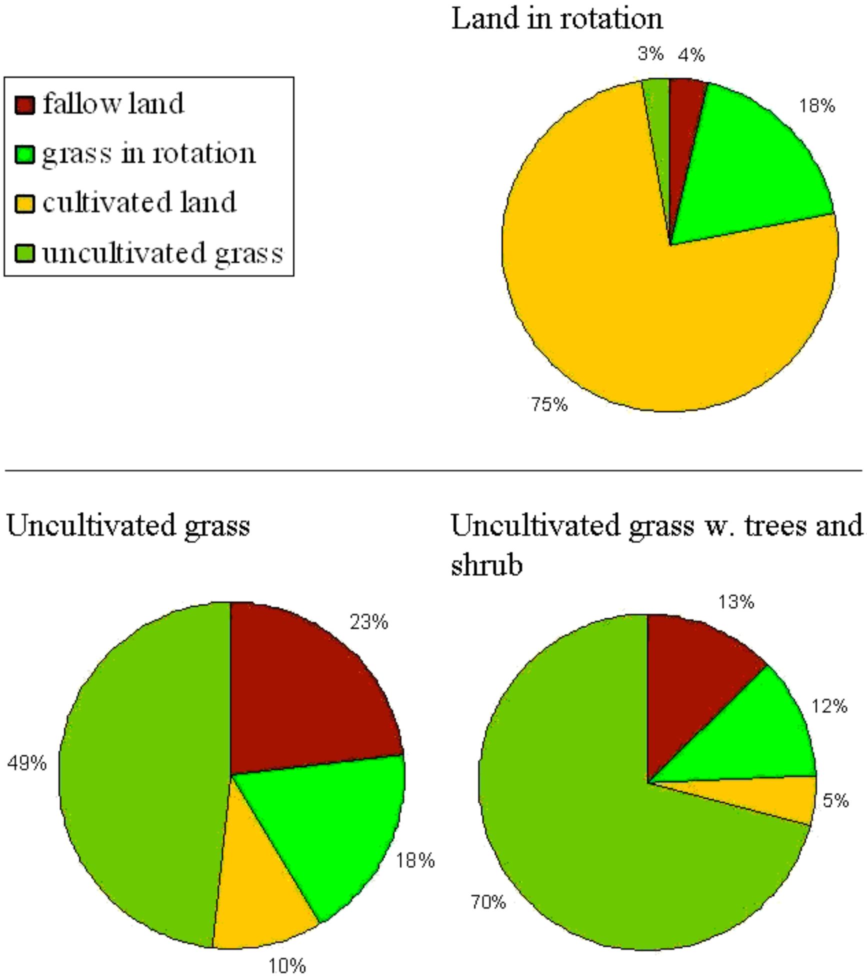

Figure 15: Comparison of land cover classification on basis of aerial photos with field data from agricultural registers

Source: Aerial photo interpretation for 2002, agricultural registers 2001 and field maps 2001

About half of the uncultivated grass is also recorded as uncultivated grass in the field registers. Almost one quarter is recorded as fallow land. No specific class for fallow land was identified in the aerial photo registration. Fallow land would thus most likely be registered as natural grass or natural grass with dispersed trees and bushes. Respectively 10% and 18% of natural grass was recorded as cultivated land and as grass in rotation in the registers. This conforms to the findings from the first test, which points at difficulties in distinguishing between different kinds of agricultural land use – especially in terms of grass. However, another likely source of inaccuracy is that farmers might report uncultivated grass as other kinds of land use. The reason is that land management on areas of uncultivated grass is legally bound to several restrictions. E.g. there are restrictions for ploughing of land, once it has been reported as uncultivated grass. In order not to restrict from future options to change land use, farmers may choose to report areas of uncultivated land as grass in rotation or cropped land.

70% of uncultivated grass with dispersed trees and shrubs is in the registers recorded as uncultivated grass. As the registers do not comprise a certain group for uncultivated grass with trees and shrubs, this high overlap is reasonable. Probably due to the same reason as for uncultivated grass, 13% of the uncultivated grass with dispersed trees and shrubs is in the registers recorded as fallow land. Finally, respectively 12% and 5% of the class are in the registers recorded as grass in rotation and cultivated land. While this discrepancy might partly be due to false reporting by the farmer, it does again point at difficulties in distinguishing between different kinds of agricultural land use, especially in terms of grass.

Summary of tests of accuracy

In summary the two tests of accuracy of the land use registration on the basis of aerial photos indicate that most classes have reasonably high classification and spatial accuracies. However, for classes of agricultural land use, especially when distinguishing between grass in rotation, uncultivated grass and uncultivated grass with trees and shrubs, classifications are less precise. Consequently, analyses and findings later in the study should pay attention to this lack in accuracy.

4.2.4 Relating landscape data to farm units

The method for the case area analysis is outlined in Figure 16. By means of a spatial overlay between the map of farm units and the aerial photo land cover registrations, densities of the different land cover classes and mean field sizes were calculated for each of the 112 farm units. Spatially relating landscape data to farm units necessitated some decisions on how to assign a given landscape element to a certain farm unit. In principle, landscape elements located within two farm units were split up between the two units. Unless being clearly located within one farm units, in the case of line elements like hedgerows and field divides, located at the border between two farms these elements were also equally split up between the two farm units. As described earlier, the demarcation of farm units was based on field and cadastre maps. These data are, however, not always absolutely precise. Consequently, the demarcation of farm units needed to be spatially adjusted to the land cover maps in order to avoid errors in later spatial overlays.

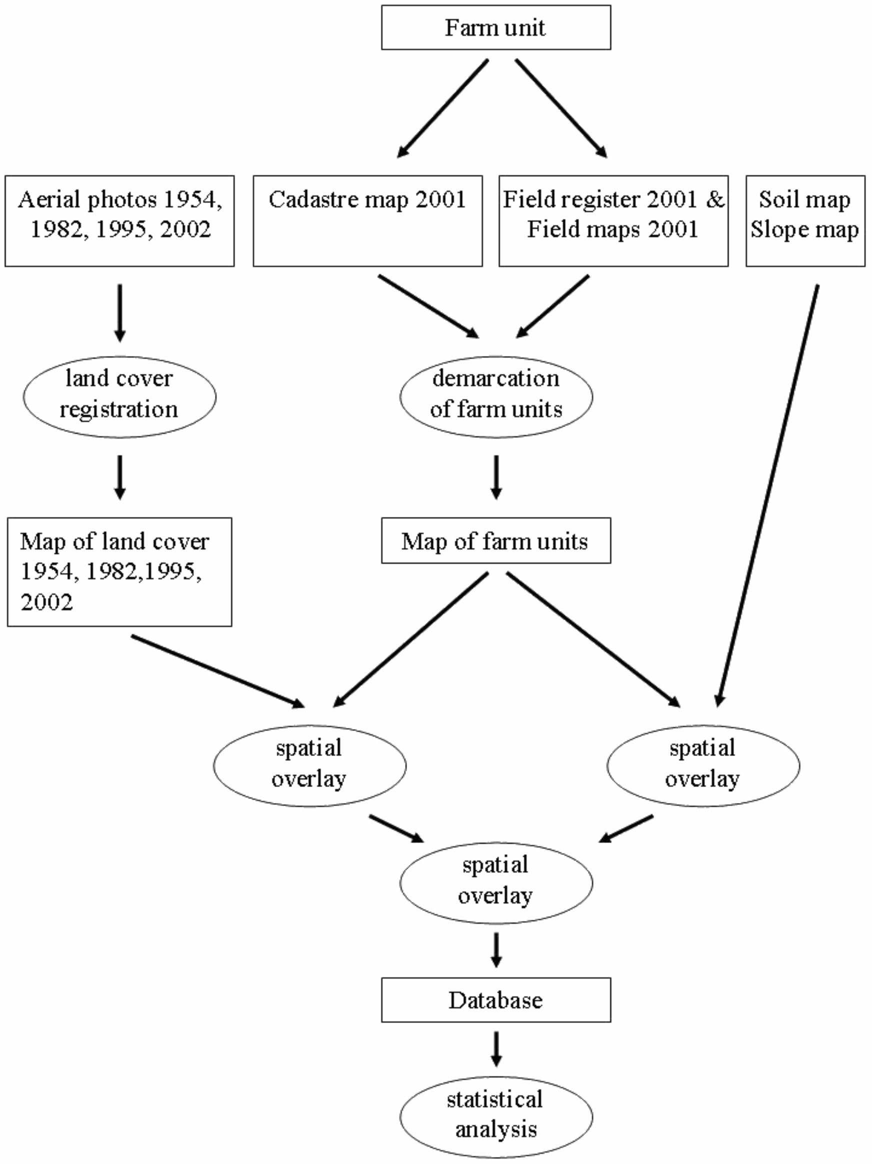

Figure 16: Data analysis at case area scale

In addition, maps for slope and for soil properties were overlaid with the map of farm units and densities of sand, clay and peat soils as well as of land with slopes exceeding five degrees were calculated for each farm unit. Soil and slope maps of the case areas are shown in Appendix 2 and 3. On the basis of field and animal registers, the farms were grouped into different production types. This grouping, which was based on a calculation of the economic significance of different agricultural products, has been described earlier in this chapter.

For the analysis of landscape changes it is important to note that the demarcation of farm units refers to 2001. Data on the location of farm units in 1995, 1982 or even 1954 were not available. Therefore, the analysis of landscape changes following conversion to organic farming was elaborated at field scale. For each organically managed field plot, the registers contain information on the year of conversion to organic farming. Therefore, at field scale it was possible to investigate landscape changes in relation to the date of conversion to organic farming and hence to compare these to general landscape changes in the case areas. This analysis of landscape changes following conversion to organic farming is described in more detail in Paper 1.

4.3 Statistical analyses

Relationships between farm properties and landscape composition were investigated with an analysis of variance using the Anova general linear model procedure (SAS Institute Inc. 2004). The strength of this method is that it allows the analysis of both continuous and categorical data as explanatory variables. Furthermore, the method gives the opportunity to cross explanatory variables in order to test interactions between these and their relation to landscape parameters.

Dependent and independent variables, which were applied in this study, are listed in Table 3. To ensure variance homogeneity logit transformation was performed for all density data. As relationships between farm size and densities of the investigated landscape elements and between farm size and mean field sizes are characterised by an S-shaped curve, the logarithm of farm size was used in the analyses.

Table 3: Dependent and independent variables applied in statistical analyses

	Description	**Unit**	**Source**
National analysis			
Landscape parameters (dependent variables)			
Number of land uses	Number of land uses* per farm	Count	Agricultural registers 1998, 2001, 2004
Land use diversity	Shannon diversity for land uses per farm	0-infinite	Agricultural registers 1998, 2001, 2004
Mean field size	Mean area of all cultivated field plots per farm	Hectares	Agricultural registers 1998, 2001, 2004
Farm parameters (independent variables)			
Organic / conventional farming	Organic or conventional farming in 2001	Discrete	Agricultural register 2001
Time of conversion to organic farming	Conversion before 1998; from 1998-2003; conventional	Discrete	Agricultural register 2001
Farm size	Land managed by one farm unit and reported in agricultural registers	Hectares	Agricultural registers 1998, 2001, 2004
Case area analysis			
Landscape parameters (dependent variables)			
Density of small biotopes	Uncultivated patch elements < 20 hectares	Area as % of farm	Aerial photos 1982, 1995, 2004
Density of hedgerows	Line elements covered by scrubs or trees	Area as % of farm	Aerial photos 1982, 1995, 2004
Density of field divides	Line elements covered by grass or herbs	Area as % of farm	Aerial photos 1982, 1995, 2004
Mean field size	Mean area of all cultivated field plots per farm	Hectares	Aerial photos 1982, 1995, 2004
Farm parameters (independent variables)			
Organic / conventional farming	Organic or conventional farming in 2001	Discrete	Agricultural register 2001
Time of conversion to organic farming	Conversion before 1995; conversion after 1995	Discrete	Agricultural register 2001
Farm size	Total area managed one farm unit	Hectares	Cadastre map 2001, field map 2001, aerial photos 2001
Percentage peat soil		Area as % of farm	National soil map
Percentage slopes > 5%		Area as % of farm	Digital terrain mode
Production type	Cattle; pig/chicken; mixed/stockless**	Discrete	Agricultural register 2001
Case area	Herning; Randers, Slangerup	Discrete	

* Applied crops are: spring cereals, autumn cereals, other spring crop, other autumn crop, whole crops, row crops, leguminous plants, fallow, grass in rotation, grass outside rotation.

** Production types were calculated on basis of the economic significance of respective agricultural products.

5 Papers

5.1 Paper 1:

Relationships between Danish organic farming and landscape composition

By Gregor Levin

The paper has been submitted to the Journal: Agriculture, Ecosystems & Environment.

The paper has been through the first review and the editor has supposed it for publication after changes.

Abstract

A general expectation exists that organic farming benefits composition of agricultural landscapes and consequently conditions for wild species. This article presents an investigation of relationships between organic farming and landscape composition in Denmark. Landscape composition is analysed in terms of densities of uncultivated landscape elements, in terms of field sizes and in terms of number and diversity of land uses. Two analytical approaches are applied. The first is based on an investigation of national agricultural registers. The second approach uses aerial photo interpretation for an analysis of 72 conventional and 40 organic farms within three case areas. The national analysis points to a significantly higher number of land uses, a higher land use diversity and smaller field sizes on organic farms. In general scale enlargement in agriculture with increasing farm sizes, decreasing land use diversity and increasing field sizes characterises the period from 1998 – 2004 and applies to both organic and conventional farms. But conversion to organic farming weakens or even reverses this trend. The case area analysis shows no significant direct relationships between organic farming and landscape composition. However, taking into account differences between organic and conventional farms with respect to farm size, soil types and topography and relations between these parameters and landscape composition, within two of the case areas significant differences in landscape composition between organic and conventional farms were elucidated. Changes in landscape composition following conversion to organic farming point in different directions. From 1982 to 1995 farms converted to organic farming are dominated by small farm sizes, and areas converted to organic farming are characterised by decreasing field sizes and increasing densities of field divides. Between 1995 and 2002 converted farms are dominated by large dairy producers, and areas converted to organic farming are characterised by increasing field sizes and decreasing densities of field divides. Results at case area scale point to differences in landscape composition and changes in landscape composition between organic and conventional farming being significantly influenced by differences in terms of other parameters, particularly farms size, soil conditions and topography, which themselves are related to the location of organic and conventional farms within the landscape. Furthermore, it is argued that other, both productive and non-productive landscape functions should be considered for an appropriate interpretation of differences in landscape composition between organic and conventional farming.

Key words
landscape composition, organic farming, landscape change, farm properties

Introduction and background

Throughout history socio-economic, cultural and political changes together with technological improvements affected land use options and led to alterations of landscape composition. Consequently, alterations in agricultural practices related to the conversion from conventional to organic farming imply a potential effect on landscape composition.

In Europe organic farming has a history of more than 75 years. Following a rising awareness of the negative environmental effects of conventional farming, from the late 1980s, in most EU-member states subsidies for organic farming led to a considerable growth of the organic farming sector (Yussefi and Willer, 2003). Thus, at present organic farming constitutes an important actor in many European countries, not least Denmark where, according to national agricultural registers, in 2004 over 6% of all arable land was farmed organically. In the societal and political sphere a general expectation exists that organic farming benefits nature content in rural landscapes. Due to its holistic system approach it is seen as a tool to counteract the accelerated negative impact on Danish and other European landscapes that followed intensification and industrialisation of agriculture.

Among others, the Wilhjelm Committee, which was set up to elaborate a basis for a national action plan for biological diversity and nature protection, points at organic farming as an instrument for more efficient protection of natural and semi-natural elements in Danish landscapes (Wilhjelmudvalget, 2001). Furthermore, for EU countries, the proportion of land under organic farming has recently been suggested as a response indicator for relations between agriculture and the landscape (EEA, 2005). Yet, though principles for organic farming include the maintenance and protection of plant and wildlife habitats (IFOAM, 2002) in most countries, standards and rules for organic farming do not specifically concern these uncultivated parts of the farms. While a beneficial effect of organic farming on the flora and fauna within the cultivated land and in edge biotopes is relatively well documented (Aude et al., 2003; Benton et al., 2003; Stolze et al., 2000; Tybirk et al., 2003), knowledge on relations between organic farming and landscape composition is rather limited.

Potential relations between organic farming and landscape composition, however, exist and reasons are in principle twofold. First, qua its definition and ensuing standards and regulations, organic farming induces changes in agricultural practices that have a potential effect on landscape composition. Due to a ban on chemicals organic farming is forced to maintain nutrient balances through crop rotation, possibly leading to a larger land use diversity and consequently to more and smaller fields with longer field margins, which are potential habitats and corridors for wild flora and fauna (Frederiksen, 2001; van Elsen, 2000).

Second, recent research indicates that land use practices and thus their effect on the landscape composition have to be seen within a broader framework, embracing socio-economic, cultural parameters and physical parameters (Brandt et al., 1999; Ellis et al., 1999; Kristensen et al., 2001; Primdahl, 1999). Several Danish case studies point to other aspects than agricultural production, e.g. soil conditions, topography but also aesthetic and environmental functions as important factors for farmers' landscape management (Busck, 2002; Kristensen, 2003; Kristensen, 2001; Madsen, 2001). Research on socio-economic, cultural and physical differences between organic and conventional farming is scarce, but if such differences exist, they may possibly imply differences in landscape composition.

In conclusion, agricultural practices as well as physical properties, socio-economic conditions and cultural background directly or indirectly influence the way farmers manage the landscape on their farms. If these properties differ between organic and conventional farms, they imply potential differences in landscape composition between the two groups.

Review of existing studies

Several studies have addressed the relation between the landscape and organic farming. Larsen and Clausen (1995) investigated densities of small biotopes on 30 organic farms located within two larger case areas on Zealand and compared them to data on small biotopes[9] in 13 other case areas in eastern Denmark. Results pointed at markedly higher densities of small biotopes and smaller field sizes on organic farms.

Tress (1999) investigated extent and management of natural and semi-natural landscape elements for 137 organic and 330 conventional farms in two Danish counties[10]. Results pointed at a generally higher proportion of uncultivated land and higher densities of linear biotopes on organic farms, while densities of area biotopes were higher on conventional farms. However, variations in densities of landscape elements were generally more distinct in relation to other variables, like e.g. agricultural production, farmer type[11], farm sizes and particularly the regional location.

Ackermann (2003) investigated content of natural and semi-natural landscape elements for 17 organic and all 11 conventional farms in a case area in southern Jutland. An analysis of landscape dynamics from 1990 to 1999 indicated that spatial variations in densities of uncultivated land were related to local variations in biophysical conditions rather than organic vs. conventional farming.

Lindkqvist (2002) focused on differences in landscape composition for 27 organic and 27 conventional farms in Sweden. The results indicated a slightly positive, but not statistically significant relation between densities of uncultivated landscape elements and organic farming. Differences

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[9] Here the term small biotope embraces small uncultivated landscape elements, e.g. woodlots, ponds, hedgerows, field boundaries (Agger, Brandt et al. 1986).

[10] The analysis was carried out for the counties of Vestsjælland in eastern Denmark and Ribe in western Denmark in order to represent two regions with very different biophysical conditions for agriculture.

[11] Tress (1999) distinguishes between full time, part time and hobby farmers.

in landscape composition were most pronounced between regional landscape types.

For 24 organic and 24 conventional farms a British study found few significant impacts of organic farming on landscape composition (ENTEC, 1995). These impacts were, however, related to differences in production types between organic and conventional farming rather than organic farming as such.

As part of the EU Concerted Action "The landscape and nature production capacity of organic/sustainable types of agriculture."(van Mansveld and van der Lubbe 1999), amounts of natural and semi-natural landscape elements were evaluated for organic and conventional farms in the Netherlands, Germany & Sweden (van Mansvelt et al., 1998); Tuscany (Rossi and Nota, 2000); Ireland (MacNaeidhe and Culleton, 2000); Crete (Stobbelaar et al., 2000); Andalusia, Netherlands, Portugal and Crete (Kuiper, 2000); Netherlands (Hendriks et al., 2000) and Norway (Clemetsen and van Laar, 2000). All investigations were based on field observations and pointed almost exclusively to organic farms having considerably larger densities of natural and semi-natural landscape elements than their conventional counterparts.

Issues of sampling and scale

Results and findings from the different studies on relations between organic farming and the landscape need to be seen in the context of applied methodologies. Approaches differ widely as do sampling methods and sample sizes, applied temporal and spatial scales and types of parameters incorporated in the investigations.

Small samples bias results, particularly when farms are selected rather subjectively as it is the case in the European Concerted Action (2-8 farms per region). In comparison Tress (1999), using a randomly stratified sampling method with a relatively large number of farms, found a rather weak relationship between organic farming and quantities of natural and semi-natural landscape elements.

The review also points to the importance of incorporating information on biophysical conditions in both farm sampling and in data analyses. E.g. selecting the farms for the investigation within 3 principal landscape types Lindkqvist (2002) was able to relate landscape features on the investigated farms to the biophysical conditions of the principal landscape types.

Also the importance of including different farm specific parameters in terms of variations in agricultural production and socio-economic conditions must be stressed. In summary, those investigations paying attention to biophysical and socio-economic conditions as well as farm sizes and types of agricultural production indicated that landscape composition was strongly related to these parameters rather than to organic vs. conventional production. Still, only few of the here reviewed studies investigated interactions between different farm specific parameters in relation to the landscape. It is thus difficult to conclude, whether relationships between organic farming and the landscape in fact were influenced by other farm specific properties.

Most of the presented studies were limited to an up-to-the-minute account. This lack of temporal dimension hindered findings on whether conversion to organic farming was followed by distinct trends in landscape dynamics. Those investigations applying a wider time horizon showed only modest (Tress, 1999) or no clear effect (Ackermann, 2003; ENTEC, 1995) of conversion to organic farming on landscape composition.

Without empirical evidence and adequate discussions of methodological limitations several of the presented investigations suggested that organic farming positively affected the landscape and that organic farmers provide net benefits to the landscape largely because of their awareness of the environment in general (ENTEC, 1995; Larsen and Clausen, 1995; van Mansvelt et al., 1998). Furthermore, without discussing the obvious limitations related to specific methodological designs, others, e.g. Mander et al. (1999) and Stolze et al. (2000) referred to these findings as confirming positive relations between organic farming and landscape composition.

The main aim of this paper is to investigate differences in landscape composition between organic and conventional farms. Landscape composition is analysed in terms of densities of different uncultivated landscape elements, in terms of field sizes and in terms of numbers and diversity of land uses. Two central questions are put forward. First, do differences in landscape composition between organic and conventional farms exist? Second, is the conversion to organic farming followed by changes in landscape composition? Furthermore, the influence of other farm specific parameters, e.g. biophysical conditions and farm size and interactions between these and organic/conventional farming are to be investigated to grasp more of the complexity of relations between organic farming and landscape composition.

Data and methods

This investigation imposes several requirements to data and methods. Landscape data must be suitable for quantification. For investigation of landscape changes data must exist for at least two points in time. In order to relate landscape data to the farm level a spatial reference for location and delimitation of farms is important. Finally, information on farm specific parameters is needed. For this paper two methodological approaches are applied. In the first method data for farm and landscape parameters for the whole country exclusive the island of Bornholm[12] are used. In the second method three case areas, embracing 40 organic and 72 conventional farms are investigated. Table 1 summarizes the parameters applied in the two analyses.

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[12] Due to biophysical conditions, which are very different from Denmark in general, it was chosen to exclude the Island of Bornholm from this analysis.

Table 1: Dependent and independent parameters applied in the analyses

	Description	**unit**	**source**
National analysis			
Landscape parameters (dependent variables)			
Number of land uses	Number of land uses* per farm	Count	Agricultural registers 1998, 2001, 2004
Land use diversity	Shannon diversity for land uses per farm	0-infinite	Agricultural registers 1998, 2001, 2004
Mean field size	Mean area of all cultivated field plots per farm	Hectares	Agricultural registers 1998, 2001, 2004
Farm parameters (independent variables)			
Organic / conventional farming	Organic or conventional farming in 2001	Discrete	Agricultural register 2001
Time of conversion to organic farming	Conversion before 1998; from 1998-2003; conventional	Discrete	Agricultural register 2001
Farm size	Land managed by one farm unit and reported in agricultural registers	Hectares	Agricultural registers 1998, 2001, 2004
Case area analysis			
Landscape parameters (dependent variables)			
Density of small biotopes	Uncultivated patch elements < 20 hectares	Area as % of farm	Aerial photos 1982, 1995, 2004
Density of hedgerows	Line elements covered by scrubs or trees	Area as % of farm	Aerial photos 1982, 1995, 2004
Density of field divides	Line elements covered by grass or herbs	Area as % of farm	Aerial photos 1982, 1995, 2004
Mean field size	Mean area of all cultivated field plots per farm	Hectares	Aerial photos 1982, 1995, 2004
Farm parameters (independent variables)			
Organic / conventional farming	Organic or conventional farming in 2001	Discrete	Agricultural register 2001
Time of conversion to organic farming	Conversion before 1995; conversion after 1995	Discrete	Agricultural register 2001
Farm size	Total area managed one farm unit	Hectares	Cadastre map 2001, field map 2001, aerial photos 2001
Percentage peat soil		Area as % of farm	National soil map
Percentage slopes > 5%		Area as % of farm	Digital terrain mode
Production type	Cattle; pig/chicken; mixed/stockless**	Discrete	Agricultural register 2001
Case area	Herning; Randers, Slangerup	Discrete	

* Applied crops are: spring cereals, autumn cereals, other spring crop, other autumn crop, whole crops, row crops, leguminous plants, fallow, grass in rotation, grass outside rotation.

** Production types were calculated on basis of the economic significance of respective agricultural products.

The national analysis

For the national investigation information on organic/conventional production, year of conversion, farm size, field size and for number and diversity of land uses was derived for each farm unit in Denmark on the basis of the national agricultural registers from 1998, 2001 and 2004. Land uses were classified into categories, which represent different types and stages of vegetation and thus deliver different functions for farmland species[13]. Diversity of land use was derived using Shannon's index for diversity[14]. Relations to landscape composition in 2001 were tested for 3,339 organic and 46,264 conventional farms (covering all registered farms in Denmark, exclusive the island of Bornholm). Furthermore, for the period from 1998 to 2004 changes in farm sizes, field sizes and numbers as well as diversity of land uses were calculated for 38,506 farms, which could be traced in both registers. In order to test relationships between time of conversion to organic farming and landscape changes the farms were grouped into: organic farms converted before 1998 (N=825); organic farms converted between 1998 and 2003 (N=1,248); and farms, which in 2004 were managed conventionally (N=36,433). For the group of farms converted from 1998 to 2003, the 1998 agricultural register represents the situation prior to conversion, while the 2004 register represents the situation subsequent to conversion to organic farming. Farms, which have been converted back from organic to conventional, were classified as conventional.

The case area analysis

For the investigation at case area level, three case areas with a high density of organic farms were selected. Another criterion for the selection was the representation of different agricultural landscapes in terms of biophysical conditions, in terms of agricultural production and in terms of their cultural history. The location of the case areas is shown in Figure 1.

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[13] Applied land uses are: spring cereals, autumn cereals, other spring crop, other autumn crop, whole crops, row crops, leguminous plants, fallow, grass in rotation, grass outside rotation

[14] Shannon's index was calculated as follows: $Sh = -\sum_{i=1}^{n} (P_i * \ln P_i)$, where P_i = the proportion of the farm occupied by land use i. Shannon equals 0 if only one land use occupies the whole farm unit and land use diversity is thus very low. Shannon increases with an increasing number of land uses and with an increasing equal distribution of these land uses across the farm unit. A high Shannon index thus indicates high land use diversity.

Figure 1: Location of the case areas

Case area description

The Herning area is located in the western part of Jutland. Its natural conditions are characterised by an outwash plain with sandy soils deposited under the last glaciation and only few steep slopes (Table 2). Peat soils are mainly located along water courses. The area is dominated by large fulltime farms focusing on dairy production and pig breeding. In 2001 organically farmed land occupied about 18% of all agricultural land in Herning and most of it was converted after 1995. Due to sandy soils and problems with sand drift, the area has been subject to several schemes for hedge planting, particularly since World War II and today it is characterised by a very high density of hedgerows.

Table 2: Description of the three case areas

	Herning	**Randers**	**Slangerup**
Size (km²)	42,3	41,7	31,9
Number organic farms	12	12	16
Number conventional farms	24	23	25
Sand (%)	90,1%	76,2%	44,3%
Clay (%)	0,0%	5,3%	38,6%
Peat (%)	9,7%	18,1%	16,5%
Slope >5% (%)	1,1%	14,5%	9,2%
Mean farm size (ha)	50,1	47,2	30,5
Mean field size (ha)	2,6	2,3	2,1
Small biotopes (%)	5,6%	5,2%	6,7%
Hedgerows (%)	2,7%	0,8%	0,5%
Field divides (%)	0,4%	0,5%	0,5%

Sources: Agricultural register 2001, digital terrain model, soil map, aerial photo interpretation for 2002

Randers, in the eastern part of Jutland is located along a river valley formed under the last glaciation. The valley bottom is dominated by peat soils. The valley sides are characterised by steep slopes and sandy soils, while the uplands are dominated by young moraines with a high content of clay. Like Herning, the area is dominated by fulltime farmers. Agriculture focuses on dairy and grain production and in 2001 about 17% of all agricultural land was farmed organically and was mainly converted after 1995. Randers is characterised by a high density of permanent grassland, which is linked to difficult conditions for cultivation on the humid peat soils in the valley bottom and on the steep valley slopes. Over the last approx. 50 years, dry natural grasslands on the valley slopes have been largely abandoned and have developed into shrub or forest.

Finally, Slangerup is located on the island of Zealand, about 30 km from the centre of Copenhagen. The topography is dominated by a moraine deposited during the last glaciation interspersed with kettle holes and is characterised by a mixture of clay and sand soils with hollows dominated by peat soils. In 2001 about 10% of all agricultural land was farmed organically and over ¾ of the organic land was converted before 1995. Agriculture is dominated by a few large fulltime farms, mainly producing grain, fruits and vegetables and many smaller part-time and hobby farms. Although hobby and part-time farms also exist in Herning and Randers, they dominate in Slangerup. This is also reflected in a smaller mean farm size and the major explanation is the area's proximity to Copenhagen. The area is bordered by commuter towns and the easy accessibility from Copenhagen can be seen as a motivation for "town people" to settle in the area and run a small farm, with a main income coming from outside agriculture. In terms of landscape composition, Slangerup is characterised by slightly higher densities of small biotopes than Herning and Randers, while densities of hedgerows are smaller, which is typical for eastern Denmark.

Parameters at case area scale

The case area analysis included all 40 organic and 72 conventional farms, which in 2001 were completely located within one of the three case areas. Each farm unit was registered and demarcated using both field maps and cadastre maps for 2001. The registered farm areas thus embrace all land managed by the single farm units including both owned and rented land and excluding land rented out to another farm. Information on production type and organic/conventional farming was derived from the national agricultural register for 2001. A total land cover registration was carried out for all case areas on the basis of aerial photos from 1982, 1995 and 2002. The dates for the photos were chosen to give detailed information on land cover changes over the last two decades and especially for the second half of the 1990s, where the major part of conversion to organic farming in Denmark took place. Land cover registration was carried out on the basis of visual interpretation of the aerial photos. The registration embraces 18 land cover classes. All landscape elements exceeding 20m^2 were registered. Although it is a census registration, focus was on natural and uncultivated landscape elements. The landscape elements, which were used to illustrate landscape composition at case area scale, are defined as follows:

1) For this investigation Small biotopes are defined as patches of uncultivated natural or semi natural land cover with an upper size limit of

2 hectares. The size definition for small biotopes corresponds with Agger et al. (1986) who developed the term in the early 1980s. The argument for a size limit of two hectares is that small landscape elements often are patches located within the cultivated farmland and thus are more exposed to effects from agricultural practices than larger landscape elements. In this investigation small biotopes comprise small woodlots, small ponds and lakes and small patches covered by shrubs and/or herbs, while permanent grassland is not included. Furthermore, uncultivated line elements, which by Agger et al. (1986) are included in the definition of small biotopes, are in this investigation treated individually as hedgerows and field divides.

For this investigation line elements are defined as elements with a length of at least 20 meters, a width of 1-10 meters[15] and a length – width ratio of at least 5:1.

2) Hedgerows are line elements covered by tree and/or shrub vegetation. The width of hedgerows is measured as the width of crown cover.

3) Field divides are also line elements, but in contrast to hedgerows covered by grass and/or herb vegetation. Field divides with a width under 1 meter are not included here, but were, however, registered as lines or boundaries between agricultural fields.

4) Finally, field size is the area of an individual plot of cultivated land. Plots of cultivated land are demarcated by transitions to other landscape elements or to other plots of cultivated land.

By means of a spatial overlay between the demarcation of farm units for 2001 and the land cover registration for 2002, densities of landscape elements and mean field sizes were calculated for each farm unit. Furthermore, on the basis of overlays with maps of slope and soil properties, for each farm unit percentages of different soil types and percentages of slopes exceeding 5 degrees were calculated.

Changes in landscape composition were investigated by means of an overlay between land cover maps for 1982, 1995 and 2002. As information on the location of farm units in 1995 and 1982 is not available, the analysis of landscape changes in relation to conversion to organic farming was not elaborated at farm scale. However, for all organically farmed fields, the agricultural register for 2001 contains information on the year of conversion. In combination with field maps the case areas were divided into land converted to organic farming before 1995, land converted between 1995 and 2001 and conventionally managed land. Subsequently, the case areas were split up into squares of 100 by 100 meters, and for each square, information on the time of conversion to organic farming, soil type, topography, and on changes in field size and in densities of landscape elements was registered. For the two investigated time periods, changes in landscape composition on land converted to organic farming during the respective period were compared to changes on other agricultural land.

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[15] The minimum width was chosen because the resolution of aerial photos hinders the registration of widths under 1 meter.

Statistical analyses

Relationships between farm properties and landscape composition were investigated with an analysis of variance using the Anova general linear model procedure (SAS Institute Inc., 2004). Dependent and independent variables are listed in Table 1. To ensure variance homogeneity, logit transformation was performed for all density data. As relationships between farm size and densities of the investigated landscape elements and between farm size and mean field sizes are characterised by an S-shaped curve, the logarithm of farm size was used in the analyses. Furthermore, by crossing explanatory variables, interactions between these variables and their relation to landscape composition and to landscape changes were tested.

Results

The national analysis

Relationships between organic farming and landscape composition

Results from the national analysis show that in 2001 mean field sizes were significantly smaller on organic farms than on conventional farms. Meanwhile, both number of land uses and land use diversity (Shannon index for diversity of land uses) were higher on organic farms (Table 3). Furthermore, mean field sizes and land use diversity were significantly larger on farms with large numbers of land uses.

Table 3: Relations between organic / conventional farming and landscape composition in Denmark (excl. Bornholm) in 2001

		Mean values		
	N	Number of land uses per farm	Land use diversity (Shannon)	Mean field size (ha)
Conventional	46.364	3,02	0,81	3,59
Organic	3.339	3,52	0,92	2,83
significance levels		***	***	***

Significance levels: p<0.05=**, p<0.001=***

Source: Agricultural register 2001

Mean field sizes, number of land uses and land use diversity also had a strong and positive relation to farm size. The difference between conventional and organic farming in terms of number of land uses, land use diversity and mean field sizes could thus in fact be related to differences in farm size between organic and conventional farms. However, testing relationships within different categories of farm size still shows that mean field sizes were significantly smaller on organic farms (Figure 2), while the number of land uses and land use diversity were significantly larger on organic farms. Consequently, the relation between organic farming and these three parameters was independent of the influence of farm size on the same parameters. In order to examine if these differences are in fact influenced by organic farming practices, changes in mean field size, in number of land uses, land use diversity and in farm size between 1998 and 2004 were examined and analysed in relation to the date of conversion.

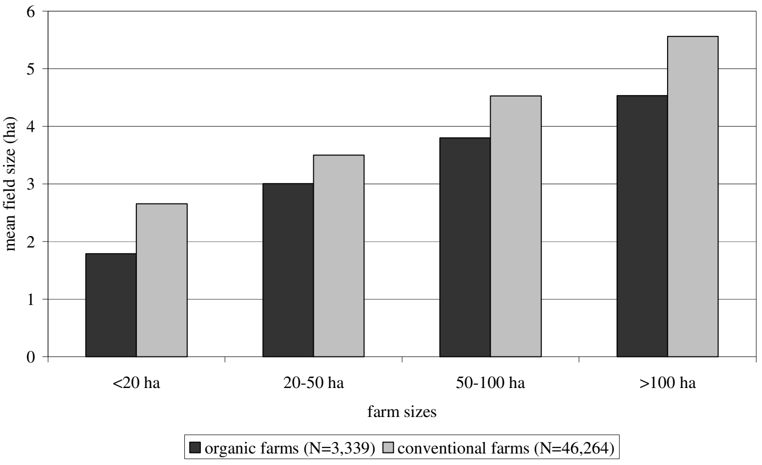

Figure 2: Mean field sizes on organic and conventional farms over different farm size categories in Denmark (excl. Bornholm) in 2001.

Source: Agricultural register 2001

Landscape changes following the conversion to organic farming

The results in Table 4 point to a relationship between the conversion to organic farming and change in mean field sizes, in number of land uses and in land use diversity. Mean field sizes decreased significantly on organic farms, particularly on those converted between 1998 and 2003, while there was an increase in mean field sizes on conventional farms. The number of land uses and land use diversity decreased on all farms but decreases were more significant on conventional farms. These results indicate an obvious effect of conversion to organic farming on landscape composition. Yet, changes in all three parameters were also significantly correlated with change in farm size. Furthermore, while from 1998 – 2004 mean farm size increased within all groups, farms converted before 1998 and particularly farms converted between 1998 and 2003 increased by a significantly higher rate than conventional farms. The relationships between date of conversion and landscape changes could thus be influenced by this difference in farm size change. However, when testing relati-onships for different categories of farm size change, results point to conversion to organic farming significantly influencing changes in the three parameters, independently of changes in farm size. For farms converted to organic agriculture, mean field size only increased on farms, which increased by more than 10% in size and even within this category increase in mean field size was less than for conventional farms (Figure 3). Correspondingly, mean field size only decreased on conventional farms where farm sizes decreased by more than 10%. Data on change in the number of land uses and in land use diversity follow the same tendency. Within all categories of farm size change, decreases in both parameters were most pronounced on the conventional farms. The relation between conversion to organic farming and changes in number of land uses, land use diversity and in field sizes was thus independent of the effect of farm size change on the same parameters. A positive influence of land use diversity on farmland species is well documented (Krauss et al., 2003; Nagendra, 2002; Norderhaug et al., 2000; Pino et al., 2000; Weibull, A.C., 2003). Consequently, an increasing land use diversity following conversion to organic farming does benefit conditions for farmland species.

Table 4: Landscape changes on organic and conventional farms in Denmark (excl. Bornholm)

		Mean values			
		N	1998	2004	change
Mean field size (ha)					
	Conventional	36.433	3,9	4,0	0,13
	Converted 1998-2003	1.248	3,6	3,4	-0,21
	Converted before 1998	825	3,1	3,0	-0,09
Number of land uses					
	Conventional	36.433	3,95	3,15	-0,79
	Converted 1998-2003	1.248	4,17	4,04	-0,13
	Converted before 1998	825	4,35	4,11	-0,24
Land use diversity (Shannon index of lanc uses)					
	Conventional	36.433	1,02	0,83	-0,19
	Converted 1998-2003	1.248	1,07	1,05	-0,02
	Converted before 1998	825	1,12	1,07	-0,06

Sources: Agricultural registers 1998 and 2004 from 1998 – 2004

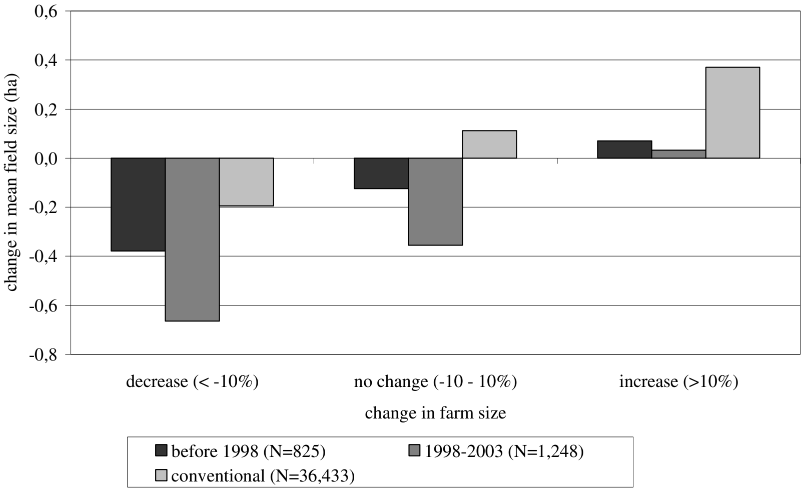

Figure 3: Change in mean field sizes on organic and conventional farms over different farm size categories in Denmark (excl. Bornholm) from 1998 - 2004.

Sources: Agricultural registers 1998 and 2004

In conclusion, results at national scale support the hypothesis that due to a ban on chemicals, organic farming is forced to maintain nutrient balances through crop rotation, resulting in larger numbers of land uses, higher land use diversity and subsequently more and smaller fields. In spite of a general scale increase in agriculture between 1998 and 2004, conversion to organic farming is clearly followed by increases in number and diversity of land uses and decreases in mean field sizes.

The case area analysis

Relationships between organic farming and landscape composition

For the 40 organic and 72 conventional farms, which were investigated at case area level, Table 5 summarises the results of an analysis of variance of relations between farm specific properties and landscape composition in 2002. Significant relations to organic farming were only found for density of small biotopes. However, the analysis unveiled several relations to other parameters. All density measures were significantly positively related to farm size, while mean field size was significantly negatively related to farm size. Physical conditions were significantly related to several landscape parameters. While density of hedgerows was significantly smaller on farms with a high percentage of peat soil, mean density of small biotopes was significantly higher on farms with a high percentage of peat soils. Mean density of small biotopes was also significantly related to a high percentage of slopes exceeding 5 degrees. While case area was only related to density of hedgerows, which was significantly higher in the Herning area, no significant relations to farm type did exist.

Table 5: Relationships between farm parameters and landscape composition for 116 farms in 2002

	Small biotopes	**Hedgerows**	**Field divides**	**Mean field size**
	(% of farm)	*(% of farm)*	*(% of farm)*	*(ha)*
Organic / conventional	**	ns	ns	ns
Farm size (lg)	***	***	**	***
Peat soil, % of farm	**	**	ns	ns
Slope >5%, % of farm	**	**	ns	ns
*Production type**	ns	ns	ns	ns
Case area	ns	***	ns	ns

* Cattle; pig/chicken; mixed/stockless.

Significance levels: $p<0.05$=**, $p<0.001$=***.

Sources: Aerial photo interpretation for 2002, national soil map, digital terrain models

The influence of other farm specific parameters

In the next step, relationships between conventional/organic farming and farm specific parameters were tested (Table 6). Organic/conventional farming as a single parameter was not significantly related to any of the other farm specific parameters. However, when analysing the influence of interactions between conventional/organic farming and the case area several clear relations were unveiled. Farm sizes were significantly smaller among organic farms in Slangerup and a weak but significant relationship between organic farms in Herning and percentage of peat soil did exist (Figure 4). Finally, in Slangerup organic farms had significantly higher percentages of slopes exceeding 5 degrees than conventional farms (Figure 5). These relationships between farm specific parameters and organic farming within the single case areas possibly influence relations between organic farming and landscape parameters. Therefore relationships between landscape parameters and interactions between conventional/organic farming and farm specific parameters were analysed. Table 7 summarizes results, which in the following will be treated for each of the five landscape parameters.

Table 6: Relationships between interactions between organic/conventional farming and case area and landscape composition for 116 farms in 2002.

Farm parameters	Farm size, (lg)	Peat soil, (% of farm)	Slope >5%, (% of farm)
Organic / conventional	ns	ns	ns
Organic / conventional * case area	**	**	***

Significance levels: p<0.05=**, p<0.001=***.

Sources: Aerial photo interpretation for 2002, national soil map, digital terrain model.

Table 7: Relationships between interactions between organic/conventional farming and farm specific parameters and landscape composition for 116 farms in 2002

Farm parameters	Small biotopes, (% of farm)	Hedge-rows, (% of farm)	Field divides, (% of farm)	Mean field size, (ha)
Organic / conventional * case area	**	ns	***	**
Organic / conventional * case area * farm size (lg)	**	ns	***	***
Organic / conventional * case area * % peat	**	ns	***	ns
Organic / conventional * case area * slope >5%	**	ns	ns	ns
Significance levels: p<0.05=**, p<0.001=***.				

Sources: Aerial photo interpretation for 2002, national soil map, digital terrain model.

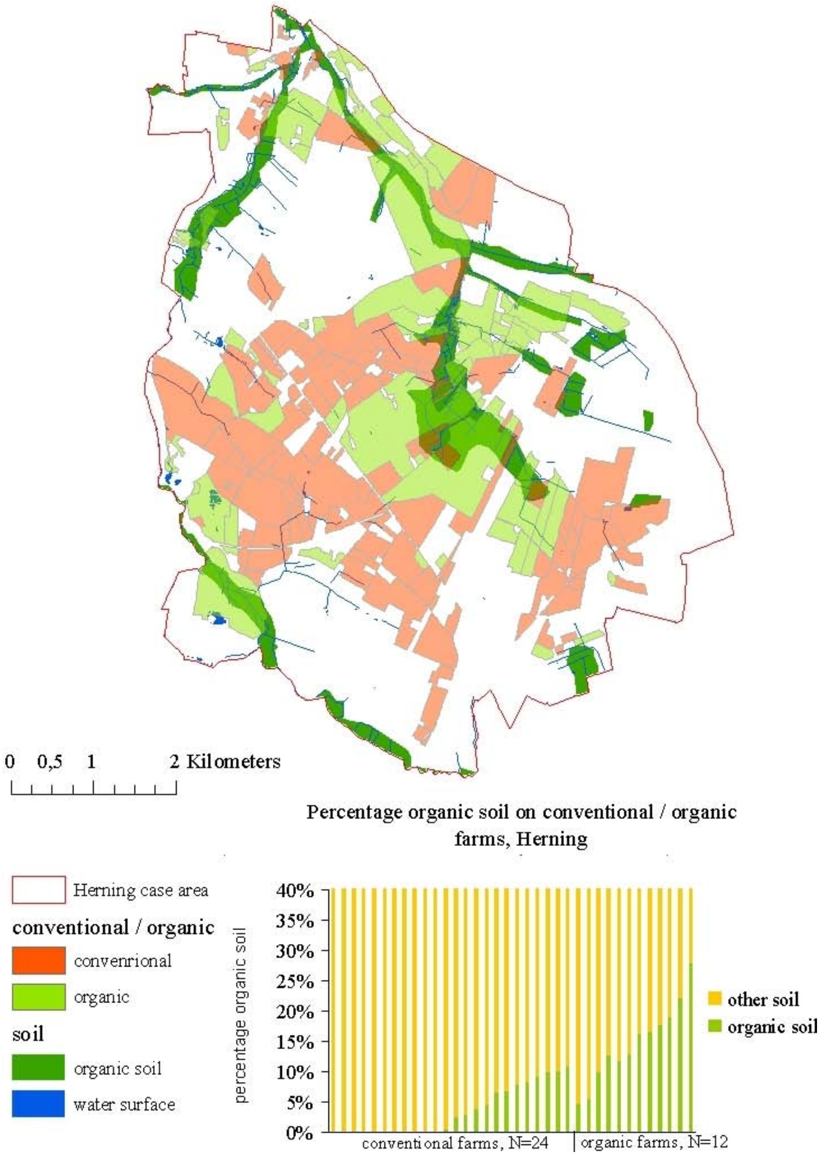

Figure 4: Relationships between organic farming and peat soils in Herning.

Sources: Aerial photo interpretation for 2002, national map of soil types, field and cadastre maps for 2001 and agricultural register 2001.

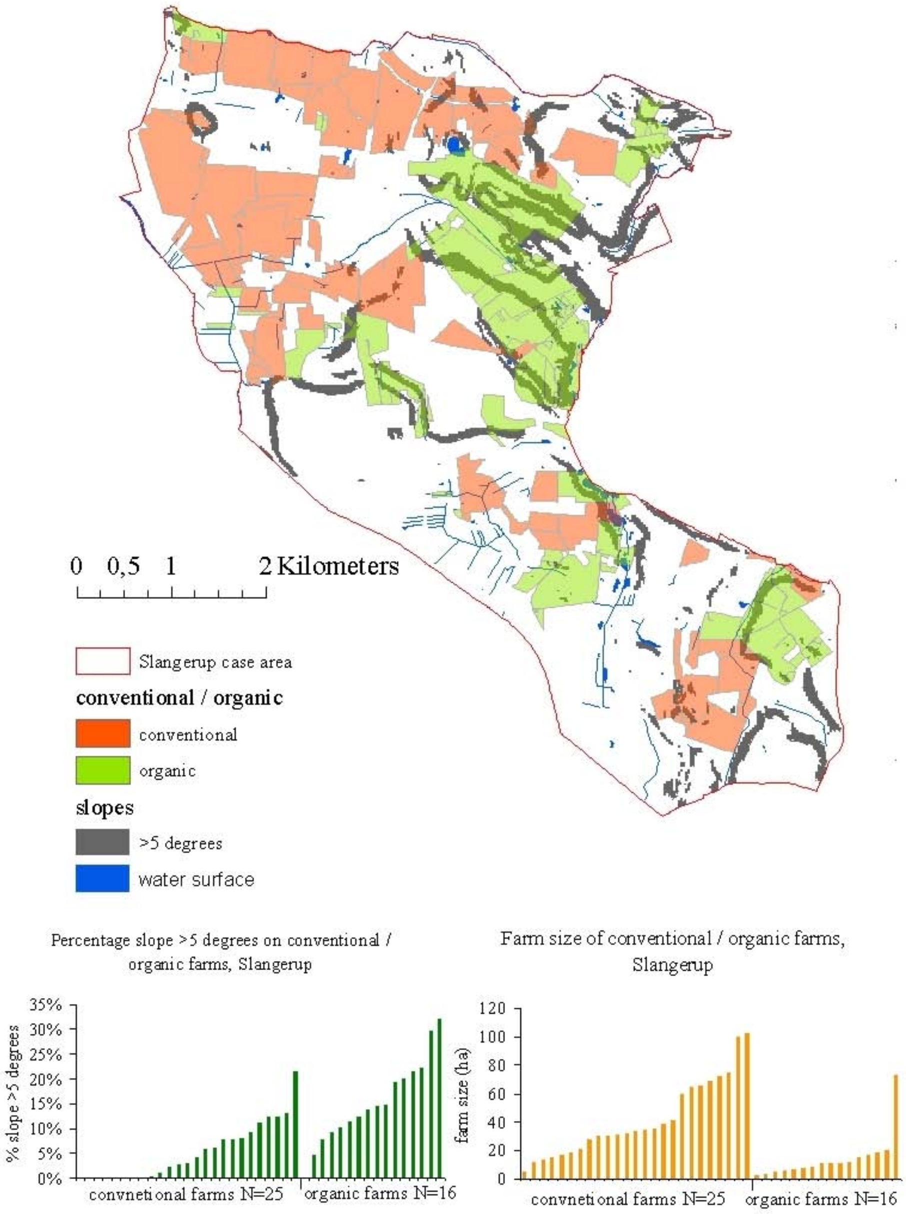

Figure 5: Relationships between organic farming and slope conditions in Slangerup. Sources: Aerial photo interpretation for 2002, national digital terrain model, field and cadastre maps for 2001 and agricultural register 2001.

Densities of small biotopes showed a positive relation to organic farms in Herning and Slangerup. Differences were related to high percentages of peat soil on organic farms in Herning and to high percentages of slopes exceeding 5 degrees in Slangerup. In addition there was also a significant and strong positive relationship between density of small biotopes and small organic farms in Slangerup.

Mean densities of hedgerows were significantly higher on small organic farms. However, testing for interactions with other farm parameters revealed no further trends.

Mean density of field divides was significantly positively related to organic farms in Slangerup. Testing for interactions with other farm parameters revealed significantly higher densities of field divides on small organic farms in Slangerup. Furthermore, there was a strong and significant relationship between density of field divides and organic farms with a high percentage of peat soil in Herning.

Finally, mean field sizes were significantly smaller on small organic farms. Testing for interactions with other farm specific parameters revealed a strong and significant relation to small organic farms in Slangerup.

At case area scale these results point towards the conclusion that the location of organic farms with respect to soil and topography, is an important explanation for relationships between organic farming and landscape composition. In Slangerup, organic farms are small and primarily located in areas with steep slopes resulting in high densities of small biotopes, in field divides and in small field sizes. Here, small biotopes are primarily composed of small woodlots and patches of shrub, which are related to steep slopes. In Herning, high proportions of peat soil on organic farms result in high densities of field divides and of small biotopes. Furthermore, in Herning small biotopes are mainly composed of ponds, which are highly related to peat soils. In contrast, in Randers, organic farms did not differ from conventional farms in terms of landscape composition or in terms of farm sizes, soil properties or topography.

Landscape changes following the conversion to organic farming

Table 8 summarises landscape changes from 1982 to 1995 and from 1995 to 2002 in all three case areas. During both periods, densities of small biotopes increased in Slangerup, while Herning and Randers were characterised by decreasing densities of small biotopes. Densities of hedgerows increased in all three areas. Increases were largest in Herning, which is related to high proportions of sand soils and consequently planting of hedgerows as shelter against wind erosion in this area.

Table 8: Landscape changes in the three case areas from 1982 – 2002

Density of small biotopes (% of farm)		**1982**	**1995**	**1982-1995 year-1**	**2002**	**1995-2002 year-1**
	All areas	4,96%	5,14%	0,01%	5,31%	0,02%
	Herning	4,35%	4,35%	0,00%	4,34%	0,00%
	Randers	5,40%	5,32%	-0,01%	5,19%	-0,02%
	Slangerup	5,18%	5,97%	0,06%	6,74%	0,11%
Density of hedgerows (% of farm)						
	All areas	1,07%	1,31%	0,02%	1,39%	0,01%
	Herning	2,05%	2,53%	0,04%	2,67%	0,02%
	Randers	0,62%	0,73%	0,01%	0,77%	0,01%
	Slangerup	0,36%	0,47%	0,01%	0,52%	0,01%
Density of field divides (% of farm)						
	All areas	0,50%	0,51%	0,00%	0,58%	0,01%
	Herning	0,45%	0,43%	0,00%	0,42%	0,00%
	Randers	0,48%	0,46%	0,00%	0,40%	-0,01%
	Slangerup	0,57%	0,69%	0,01%	0,73%	0,01%
Mean field size (ha)						
	All areas	2,99	3,35	2,80%	3,36	0,08%
	Herning	2,94	3,49	4,23%	3,7	3,00%
	Randers	2,53	3,25	5,54%	3,28	0,43%
	Slangerup	3,87	3,31	-4,31%	3,04	-3,86%

Source: Aerial photo interpretation for 1982. 1995 and 2002

During both periods, Slangerup was characterised by increasing densities of field divides and decreasing mean field sizes. In contrast, both Herning and Randers were characterised by opposite trends with increasing mean field sizes and decreasing densities of field divides.

Table 9 summarizes results from an analysis of variance (Anova linear modelling) of relationships between conversion to organic farming and landscape changes. As information on the year of conversion was available for all organically managed land, but the demarcation of farm units in 1995 and 1982 was not possible, landscape changes on land converted before 1995 and on land converted from 1995 to 2001 were compared to changes on other agricultural land. The analysis was elaborated for squares of 100 by 100 meters. In 2001 about 16% of all agricultural land was farmed organically. Of this land about 20% was converted before 1995. The largest proportion of land converted before 1995 is found in Slangerup, where it accounts for 65% of all organic land, while in both Herning and Randers about 90% of all organically managed land was converted between 1995 and 2001.

Table 9: Relationships between farm parameters and landscape changes 1982 – 2002

	Changes 1982 - 1995 year -1			
	Small biotopes	**Hedgerows**	**Field divides**	**Field size**
	(% of farm)	**(% of farm)**	**(% of farm)**	**(ha)**
Converted to organic farming before 1995	ns	***	ns	***
Converted to organic farming before 1995 * case area	***	***	***	***
	Changes 1995 - 2002 year -1			
	Small biotopes	Hedgerows	Field divides	Field size
	(% of farm)	(% of farm)	(% of farm)	(ha)
Converted to organic farming from 1995 - 2001	ns	ns	***	***
Converted to organic farming from 1995 - 2001 * case area	ns	***	***	***

Significance levels: p<0.05=**, p<0.001=***.

Source: Aerial photo interpretation for 1982. 1995 and 2002 and calculations of landscape changes and farm parameters for squares of 100 by 100 meters

In the period from 1982 to 1995, land converted to organic farming before 1995 was significantly related to decreasing field sizes and increasing densities of field divides. As land converted before 1995 is primarily located in Slangerup, these results are highly related to characteristics of landscape changes in this area. However, also within the Slangerup area land converted to organic farming is characterised by significantly higher rates of decreases in field sizes and increases of densities of field divides than conventionally managed land.

In the period from 1995 to 2002 relations between conversion to organic farming and landscape change were very different from the previous period. Land converted between 1995 and 2001 was significantly related to increasing field sizes and decreasing densities of field divides. Land converted in this period is primarily located in Herning and in Randers. Changes in landscape composition on land converted between 1995 and 2001 are thus highly related to the general landscape changes in these two areas. However, within the Herning area, land converted between 1995 and 2001 is characterised by higher degrees of decreases in field divides and of increases in field sizes than other agricultural land, while no significant relations between landscape changes and conversion to organic farming were found within the Randers or Slangerup areas.

While areas converted before 1995 are characterised by a subsequent decrease in field size and an increasing density of field divides, the opposite trend is true for areas converted after 1995. Consequently, these results only correspond to a limited degree with findings at national scale. The differences in the relation between conversion to organic farming and subsequent landscape changes are obviously related to their location. As land converted before 1995 is primarily located in Slangerup, changes in landscape composition correspond highly to general changes in this area. Still, a significant difference between areas converted before 1995 and other agricultural land exists. A possible explanation is that conversion to organic farming is followed by changes in agricultural practices and consequently changes in field structure. However, since agriculture in Slangerup in general is characterised by small part-time and hobby farmers, which also applies for organic farms in this area, other explanations embracing non-productive functions of the landscape should be considered.

As land converted after 1995 is primarily located in Herning and Randers changes in landscape composition correspond to general changes in these areas, which from 1995 to 2002 are characterised by increasing field sizes and decreasing densities of field boundaries. This contradicts with effects of conversion to organic farming at national scale. A possible explanation is that about 3/4 of all organic farms in Herning and Randers mainly focus on dairy production and that the conversion of dairy farms does not lead to reductions in field sizes as it is the case when converting other production types.

Discussion and conclusion

Effects of organic cultivation practices on landscape composition

The main aim of this paper is to elucidate the relationships between organic farming and landscape composition in Denmark. Both the national and the case area approach point to several relations, but their character and the underlying reasons differ substantially. National data for 2001 show strong and significant relations between organic farming and landscape composition in terms of larger numbers of land uses, a higher land use diversity and smaller mean field sizes. In general, data for the period from 1998 to 2004 show a scale enlargement in agriculture. However, compared to conventional farms, during the same period conversion to organic farming is related to decreasing field sizes and significantly smaller decreases in number and diversity of land uses. On the basis of these results it is reasonable to conclude that conversion to organic farming is related to changes in cultivation practices, resulting in increasing numbers of land uses, increasing land use diversity and subsequently decreasing field sizes. It is relatively well known that high land use diversity benefits farmland species due to the coexistence of different land uses or land uses of different kinds and stages of vegetation, which deliver different functions like breeding, feeding and shelter (Krauss et al., 2003; Nagendra, 2002; Norderhaug et al., 2000; Pino et al., 2000). High land use diversity also implies high spatial diversity, where distances between different land uses are smaller compared to a situation with a low diversity.

This beneficial effect of diversity of agricultural land use mainly applies to plant and animal species, which live on the agricultural land. Higher land use diversity and smaller field sizes on organic farms do thus not elucidate the relation between organic farming and landscape composition in terms of densities of uncultivated landscape elements, which is a central focus in this paper. Smaller field sizes imply a longer circumference in relation to the area of the field and longer circumferences imply higher densities of field boundaries and field divides. Whether field boundaries and field divides provide habitat and corridor functions, depends on their width, and this information is not contained in agricultural registers. However, land cover data on case area scale for 2002 show strong and significantly negative relationships between field sizes and density of field divides (with a width exceeding 1 meter). Furthermore, strong and significantly negative relationships exist between field size and density of small biotopes and of hedgerows. For the periods from 1982 to 1995 and from 1995 to 2002, case area data also point to a significant and strong negative relationship between changes in field sizes and change in density of field divides. A negative relationship between change in field size and change in density of small biotopes and in density of hedgerows also exists but is much weaker and less significant. Presuming that these relations are valid at national scale too, it can be argued that decreasing field sizes following conversion to organic farming imply increasing densities of particularly field divides and to a lesser degree also of hedgerows and of small biotopes.

Effects of other farm specific properties

At case area scale, only density of small biotopes is significantly positively related to organic farming. However, several significant relations exist between landscape composition, farm size, soil properties and topography on the investigated farms. Furthermore, in terms of these farm-specific properties, in Slangerup and in Herning organic farms differ significantly from conventional farms, implying differences in landscape composition between organic and conventional farms. Small farm sizes result in higher densities of small biotopes, higher densities of field divides and smaller mean field sizes on organic farms in Slangerup. Furthermore, high densities of small biotopes are also related to high percentages of steep slopes on organic farms in Slangerup. In Herning, organic farms are characterised by high percentages of peat soils, resulting in higher densities of small biotopes on organic farms in this area. In Randers, organic and conventional farms do not differ significantly from each other in terms of farm sizes, soil properties and topography and/or in terms of landscape composition. Consequently, the differences in landscape composition between organic and conventional farms, which were observed in Herning and in Slangerup are a result of differences in the location between the two farm types.

In the period from 1982 to 1995 and from 1995 to 2002, landscape changes following conversion to organic farming point into different directions. While areas converted before 1995 are characterised by subsequent decreases in field sizes and increasing densities of field divides the opposite trend is observed for areas converted after 1995. This difference in landscape changes following conversion to organic farming is obviously related to differences in the location between land converted before 1995 and land converted after 1995. Land converted before 1995 is primarily located in Slangerup, and changes in landscape composition correspond highly to general changes in this area. Still, a significant difference between areas converted before 1995 and other agricultural land exists. Corresponding to the results at national scale, a feasible explanation is that conversion to organic farming is followed by changes in agricultural practices and consequently changes in field structure. However, agriculture in Slangerup is characterised by small part-time and hobby farmers, which also applies for organic farms in this area. Therefore other explanations, embracing non-productive functions of agriculture and of the landscape should be considered.

Land converted after 1995 is primarily located in Herning and Randers and changes in landscape composition correspond to general changes in these areas, which from 1995 to 2002 are characterised by increasing field sizes and decreasing densities of field boundaries. This contradicts with effects of conversion to organic farming at national scale. A feasible explanation is that about 3/4 of all organic farms in Herning and Randers mainly focus on dairy production; differences between dairy and other agricultural production should be considered. Finally, even though clear trends in changes in landscape composition following conversion to organic farming were elucidated, these changes can only to a very limited degree explain differences in landscape composition between organic and conventional farms in 2002. Thus, present differences in landscape composition between the two groups must be a result of spatial patterns of landscape change further back in time. Investigating such patterns of landscape change would, however, necessitate a wider time horizon than applied in this study.

Explaining relations between organic farming and landscape composition

So far, the presented results from both the national and the case area study are only based on statistical analyses of relationships between organic farming and other farm specific properties and landscape composition as well as changes in landscape composition. A more detailed understanding of the causes for these relationships necessitates an interpretation of results and findings. Due to the lack of qualitative information on the investigated farms, in this study such interpretations are based on knowledge about Danish organic farming and Danish agriculture in general. Reasons for the significant effect of organic farming on landscape composition in terms of number of land uses, land use diversity and field sizes as well as on changes in these, which are found at national scale, are obviously linked to differences in cultivation practices between organic and conventional farms. In spite of the fact that Danish organic farms generally resemble conventional farms in terms of scale enlargement with concentration of production on larger farms (Langer et al., 2005), the ban on chemicals possibly forces organic farms to maintain nutrient balances through crop rotation. As a consequence, compared to conventional farms, organic farms need to have a larger number of land uses resulting in higher land use diversity and smaller field sizes. This tendency is also supported by the changes in these parameters following conversion to organic farming.

In contrast, at case area level it is difficult to explain relationships between organic farming and landscape composition by means of differences in cultivation practices. Relationships between organic farming and landscape composition are to be explained by differences within other properties, particularly farm sizes, soil properties and topography. Organic farms in Slangerup are characterised by small farm sizes. In spite of the lack of information on farmer types, it is reasonable to assume that these small organic farms in general are characterised by part-time and hobby farming, where the income from agricultural production is less important than it is the case on large and production-oriented full-time farms. Assuming a general relation between farm size and landscape composition, it can be concluded that the overrepresentation of Danish organic farms within small farm sizes (<20 ha) indirectly results in differences in landscape composition between organic and conventional farms. Furthermore, small organic farms are particularly located in regions close to the major urban centres of Aarhus and Copenhagen, which are characterised by an increasing importance of part-time and hobby farming.

In addition to farm size, in Herning higher percentages of peat soils and in Slangerup higher percentages of steep slopes among organic farms result in higher densities of small biotopes. A possible explanation is that organic farms predominantly are located in regions, which generally are characterised by steeper slopes and more peat soil. The largest number of organic farms and the highest percentages of organically farmed land are found in counties in the western part of Jutland, which also are characterised by higher percentages of peat soils compared to the national average. However, this regional location only explains part of this relation as organic farms, also within these counties are characterised by higher percentages of peat soil than conventional farms. Organic farms are not particularly located in regions characterised by steep slopes. Within all Danish counties (excl. Bornholm) organic farms are characterised by higher percentages of steep slopes. However, national data also revealed a significant relationship between small farm sizes and high proportions of steep slopes and it is feasible to conclude that in a local context small farms generally are located on more marginal land, which is often characterised by steep slopes.

At case area scale changes in landscape composition following conversion to organic farming are highly related to the respective location of land converted before 1995 and converted after 1995. About ¾ of all organically farmed land, which was converted before 1995, is located in Slangerup, and organic farms in this area are primarily characterised by small part-time and hobby farmers. It could be presumed that environmental and aesthetic landscape functions rather than maximisation of agricultural production rule landscape management on these farms, thus explaining conversion to organic farming being followed by decreasing field sizes and increasing densities of field divides. No national data on time of conversion in relation to part-time or hobby farming are available. Furthermore, national data show no significant differences in farm sizes between organic farms converted before and organic farms converted after 1995. The assumed relation between conversion to organic farming before 1995 and part-time and hobby farming can thus not be generalised to the national scale.

Land converted after 1995 is primarily located in Herning and Randers. Both organic and conventional farms in these areas are dominated by dairy farms. It is reasonable to suppose, that the need to maintain nutrient balances through crop rotation does not apply to dairy farms, which generally are characterised by high proportions of grassland. Consequently, as Langer (1997) argues, conversion of dairy farms does not lead to reductions in field sizes as it is the case when converting other production types. The overrepresentation of dairy farming among organic farms converted after 1995 does however, only apply to the investigated case areas, while no such relation exists at national scale. A feasible explanation for significantly larger increases of field sizes and larger decreases in field divides on organically farmed land converted after 1995 is the age of farmers managing this land. E.g. Ackermann (2003) points to younger farmers being more production oriented and thus rearranging field structures in order to reach higher production efficiency. However, concluding whether such explanation applies for this investigation would require information on farmers' age.

Future perspectives for organic farming in a landscape perspective

The principles for organic farming, as stated by the International Federation for Organic Farming Movement (IFOAM, 2002), include the maintenance and protection of plant and wildlife habitats. Also in Denmark there exists a general expectation that organic farming benefits nature content in rural landscapes (FØJO, 2000; Strukturdirektoratet, 1999; Wilhjelmudvalget, 2001). However, landscape aspects are not imbedded in standards and rules for organic farming in Denmark. Furthermore, among others Clausen and Larsen (1997), ENTEC (1998) and van Mansvelt et al. (1998) suggest that organic farmers provide net benefits to the landscape largely because of their awareness of the environment in general. The results and finding from this paper do not confirm this suggestion. Higher land use diversity and smaller field sizes on organic farms are related to the necessity to have a larger number of different land uses on organic farming. At case area scale, differences in densities of small biotopes, hedgerows and field divides and differences in mean field sizes between organic and conventional farms are related to differences between the two groups in terms of farm sizes, soil properties and topography, rather than organic farming as a single factor. Differences in farm sizes are obviously related to part-time and hobby farming. Furthermore, differences in soil properties and topography are related to the location of organic farms in a local context. The case area investigation also points to farm type characteristics, rather than the change to organic practices as the main explanation for changes in landscape composition following conversion to organic farming. Of course these data only apply to changes, which can be seen on the aerial photos. There may be differences between organic and conventional farms in terms of maintenance of uncultivated land cover, e.g. the cleaning of a pond, or in terms of landscape management, e.g. the careful management of grasslands. But such activities are beyond the scope of this investigation.

After a period of substantial growth in purchase of agricultural products and an increasing significance of Danish organic farming, particularly in the second half of the 1990s, the organic sector is now stagnating and several organic farms have even been converted back to conventional farming (Kaltoft and Risgaard, 2004). Furthermore, as environmental standards are becoming stricter for conventional farming too, the justification for organic farming as being environmentally more beneficial has become a subject of debate. In 2001, a legal requirement for at least five percent of uncultivated natural land cover on Danish organic farms has been suggested by the Danish organic farmers' movement (Harttung, 2001). However, this requirement was refused by farmers because its practicability would vary highly between farms and would particularly depend on soil and topographical conditions on the individual farm. A more fruitful attempt has been the introduction of farm specific nature plans (Holbeck et al., 2002). Nature plans are elaborated in cooperation between the farmer, agricultural advisers and local authorities and concern preservation, management and establishment of natural and semi natural landscape elements. The first pilot projects have been successful but are, until now, only voluntarily. A legal requirement to prepare and carry out nature plans on all organic farms would possibly benefit landscape composition on organic farms. But its practicability depends on possibility for financial support and is thus linked to future agricultural policy.

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5.2 Paper 2:

Relationships between farm size and landscape composition in the light of changes in Danish agricultural landscapes

By Gregor Levin

The paper has been submitted to the Danish Journal of Geography.

The paper has been throgh the first review and the editor has supposed it for publication after changes.

Abstract

Based on agricultural registers for all of Denmark and on aerial photo interpretation for three case areas, differences in landscape composition between large (>25 ha) and small farms (<25 ha) and influences of landscape changes were analysed. Both national and case area analyses showed significantly smaller field sizes and higher densities of different uncultivated landscape elements on small farms. At national scale, present differences between small and large farms were to some extent caused by landscape changes between 1998 and 2004. Case area analyses indicated that present differences between small and large farms mainly evolved between 1982 and 2002, while relations to changes between 1954 and 1982 were limited. Influences of landscape change were either due to stability in some locations compared to change in other locations or due to different directions of change. Furthermore, differences in landscape composition and in landscape change between large and small farms were largely independent of differences within soil conditions and topography. As Danish farms <25 hectares are predominantly part-time and hobby farmers, in addition to the harmful influence of large scale farming, an increased awareness of the potential influence of small part-time and hobby farming is recommended.

Key words

Landscape changes, landscape composition, farms size

Introduction

For Danish and other intensively cultivated landscapes several investigations point at a relationship between farm sizes and landscape composition (Belfrage et al., 2005, Frederiksen and Langer, 2005; Levin, in prep.; Levin et al., 2006; Stoate et al., 2001; Walford, 2005). In general, small farms are characterised by higher densities of different uncultivated landscape elements and by smaller sizes of agricultural fields. However, causes for these significant differences in landscape composition are not well explored. It is argued that in Denmark, small farms are dominated by part-time and hobby farming. It has been shown that while on full-time farms the major incentive for landscape management is optimisation of agricultural production, on smaller part-time and hobby farms aesthetic and environmental functions often dominate farmers' decision making in landscape management (Busck, 2002; Kristensen et al., 2004; Kristensen, 1999; Kristensen et al., 2001; Præstholm, 2002). Correspondingly, several investigations point at differences between full-time and part-time or hobby farms in terms of the quantity of landscape activities as the establishment or maintenance of uncultivated landscape elements (Frederiksen and Langer, 2004; Tress, 1999). However, the time scale of these studies is limited to the past 10 years. How current differences in landscape composition between small and large farms are related to landscape dynamics over a longer time horizon has, at least in a Danish context, not yet been studied.

The influence of former landscape changes on differences in landscape composition between small and large farms could be manifold. Current differences could have existed for a long time. However, in the light of considerable changes in Danish agricultural landscapes since the early 1950s, this possibility is rather unlikely. Alternatively, it can be assumed that landscape changes were less pronounced in areas, where small farms are located today. Consequently, present differences in landscape composition would be a result of spatially unequal patterns of landscape changes and current landscape composition on small farms would be remnants of former landscape composition. Finally, it could be assumed that landscape changes were characterised by different directions of change, where e.g. densities of uncultivated landscape elements increased in some locations, while they decreased in other locations. As will be shown later in this paper causes for differences in landscape composition between large and small farms are manifold and depend on the types of landscape elements.

It is relatively well documented that changes in Danish and other intensively cultivated landscapes differed over time (Agger et al., 1986; Holmes et al., 1998; Huston, 2005; Kristensen, 1999). The period from the early 1950s to the early 1980s was in general characterised by technological improvements and subsequent adjustments of landscape composition to modern large scale farming by means of merging of fields, drainage of wetlands and removal of uncultivated landscape elements. While scale enlargement in agriculture continued after the 1980s, other trends in landscape change emerged. E.g. financial support for setting aside agricultural land resulted in a decline of cultivated land and increasing densities of fallow land. Furthermore, since the late 1980s and particularly during the 1990s, the growing awareness of the harmful environmental effect of agriculture led to stricter environmental regulations, including the protection of uncultivated landscape elements and the introduction of support for environmental schemes in agriculture. In the light of these different directions of and drivers for landscape changes during the past 5 decades, it is relevant to investigate how present differences in landscape composition between large and small farms are related to the period from the early 1950s to the early 1980s and to the subsequent period up until the present.

Data and methods

The focus of this paper is thus to understand present differences in landscape composition between small and large farms in the light of past landscape changes. For this investigation two different methodological approaches were applied. For the first approach data for farm and landscape parameters for the whole country exclusive the island of Bornholm were used. In the second approach three case areas, embracing 112 farms were investigated.

The national approach

For the national investigation, for each farm unit in Denmark (exclusive Bornholm) information on farm size was derived on the basis of the national agricultural register for 2004. Landscape composition were analysed in terms of field sizes and in terms of uncultivated grassland. Field sizes were defined as the size of each individual field plots as reported by the farmer. Also, uncultivated grassland is reported by farmers and is defined as areas of grass or clover, which have not been cultivated for at least five years (Ministry of Agriculture, 2005). For 1998 and 2004 information on field sizes and quantities of uncultivated grassland was derived for field blocks. In Denmark, all agricultural land is split up into about 330.000 field blocks. Field blocks are functional units for authorities' administration of agricultural subsidies. On the basis of agricultural registers the percentage of each farm unit within a given field block can be determined. Subsequently, for 1998 and 2004, approximations of mean field sizes and of densities of uncultivated grass were calculated for each farm unit. Furthermore, changes in field sizes and in densities of uncultivated grass between 1998 and 2004 were calculated. By means of a spatial overlay between the field blocks, a national soil map and a terrain model, for each farm unit percentages of sand, clay and peat soils and percentages of land with slopes exceeding 5 degrees were estimated.

Data from national registers only embrace land, for which farmers have applied for EU-subsidies. Corresponding with other analyses (Nyholm Poulsen et al., 2002) calculations at case area scale indicate that approx. 7% of all agricultural land is not reported in the agricultural registers. This land is thus not included in the national analysis.

On the basis of these data, for all Danish farms (exclusive Bornholm) mean field sizes and densities of uncultivated grass as well as changes in these between 1998 and 2004 were analysed in relation to farm sizes in 2004. Furthermore, the influence of soil and slope conditions on differences between small and large farms was investigated.

The case area approach

In addition to the national analysis relationships between farm size and landscape composition were investigated for three different case areas. The case areas were selected in order to represent different agricultural landscapes in terms of biophysical conditions, of agricultural production and in terms of their cultural history. The location of the case areas is shown in Figure 1.

Figure 1: Location of the case areas

Case area description

The Herning area is located in the western part of Jutland. Its natural conditions are characterised by an outwash plain with sandy soils deposited under the last glaciation and only few steep slopes (Table 1). Peat soils are mainly located along water courses. The area is dominated by large full-time farms focusing on dairy production and pig breeding. Due to sandy soils and problems with sand drift, the area has been subject to several schemes for hedgerow planting, particularly since World War II. Today the area is therefore characterised by a very high density of hedgerows.

Table 1: Description of the three case areas

	Herning	Randers	Slangerup
Size (km²)	42,3	41,7	31,9
Number farms <25 ha	17	11	24
Number farms >25 ha	19	24	17
Sand (%)	90,1%	76,2%	44,3%
Clay (%)	0,0%	5,3%	38,6%
Peat (%)	9,7%	18,1%	16,5%
Slope >5% (%)	1,1%	14,5%	9,2%
Mean farm size (ha)	50,1	47,2	30,5
Mean field size (ha)	2,6	2,3	2,1
Small biotopes (%)	5,6%	5,2%	6,7%
Hedgerows (%)	2,7%	0,8%	0,5%
Ffield divides (%)	0,4%	0,5%	0,5%

Sources: Agricultural register 2001, digital terrain model, soil map, aerial photo interpretation for 2002

Randers, in the eastern part of Jutland, is located along a river valley formed under the last glaciation. The valley bottom is dominated by peat soils. The valley sides are characterised by steep slopes and sandy soils, while the uplands are dominated by young moraines with a high content of clay. Like Herning, the area is dominated by full-time farmers and agriculture focuses on dairy and grain production. Randers is characterised by a high density of permanent grassland, which is linked to difficult conditions for cultivation on the humid peat soils in the valley bottom and on the steep valley slopes. Over the last approx. 50 years, dry natural grasslands on the valley slopes have been largely abandoned and have developed into shrub or forest.

Finally, Slangerup is located on the island of Zealand, about 30 km from the centre of Copenhagen. The topography is dominated by a ground moraine deposited during the last glaciation interspersed with kettle holes and is characterised by a mixture of clay and sand soils with hollows dominated by peat soils. Agriculture is dominated by a few large full-time farms, mainly producing grain, fruits and vegetables and many smaller part-time and hobby farms. Although hobby and part-time farms also exist in Herning and Randers, they dominate in Slangerup. This is also reflected in a smaller mean farm size and the major explanation is the area's proximity to Copenhagen. The area is bordered by commuter towns and the easy accessibility from Copenhagen can be seen as a motivation for "town people" to settle in the area and run a small farm, with their main income coming from outside agriculture. In terms of landscape composition, Slangerup is characterised by slightly higher densities of small biotopes than Herning and Randers, while densities of hedgerows are smaller, which is typical for eastern Denmark.

The case area analysis included 112 farms, which in 2001 were completely located within one of the three case areas. However, 3% of the area of the selected farms is fallow land located at a long distance from the farm. This land was not included in the analyses. Each farm unit was registered and demarcated using both field maps and property maps for 2001. Thus, in contrast to the national analysis, at case area scale the registered farm areas embrace all land managed by the single farm units including both owned and rented land. A total land cover registration was carried out for all case areas on the basis of visual interpretation of aerial photos from 1954, 1982 and 2002. The registration embraces 18 land cover classes. All landscape elements exceeding 20m^2 were registered. Although it is a census registration, focus was on natural and uncultivated landscape elements. The landscape elements, which were chosen for the investigation of landscape composition, are described below.

Investigated landscape elements

1) Field size is the area of an individual plot of cultivated land. Plots of cultivated land are demarcated by transitions to other landscape elements or to adjacent plots of cultivated land with different crops or clearly different composition of cultivation.

2) For this investigation Small biotopes are defined as patches of uncultivated natural or semi natural land cover with an upper size limit of 2 hectares. The size definition for small biotopes corresponds with Agger et al. (1986) who developed the term in the early 1980s. The argument for a size limit of two hectares is that small landscape ele-

ments often are patches located within the cultivated farmland and thus are more exposed to effects from agricultural practices than larger landscape elements. In this investigation small biotopes comprise small ponds and lakes and small patches covered by trees, shrubs and/or herbs. Uncultivated grassland and uncultivated line elements, which by Agger et al. (1986) are included in the definition of small biotopes, are in this investigation treated individually as uncultivated grass, hedgerows and field divides.

3) Hedgerows are here defined as line elements covered by tree and/or shrub vegetation. For this investigation line elements are defined as elements with a length of at least 20 meters, a width of 1-10 meters[16] and a length – width ratio of at least 5:1.

The width of hedgerows is measured as the width at crown cover.

4) Field divides are also line elements, but in contrast to hedgerows covered by grass and/or herb vegetation. Field divides with a width under 1 meter are not included here, but were, however, registered as lines to demarcate transitions between different plots of agricultural land. The width of field divides is measured at ground level.

5) Uncultivated grass is here defined as patches covered by grass or herb vegetation without signs of recent cultivation, e.g. no tractor tracks. Compared to cultivated land or grass in rotation, areas of uncultivated grass usually appear heterogeneous in spatial texture and colour.

The three case areas were split up into a grid with a cell size of 100 by 100 meters. By means of a spatial overlay with land cover maps, for each cell mean field sizes and densities of the applied landscape elements were calculated. Changes in mean field sizes and in densities of landscape elements were calculated for the period from 1954 to 1982 and from 1982 to 2002. Furthermore, with the map of farm units for 2001, for each cell, the respective farm unit was registered. Finally, by means of a spatial overlay with soil maps and a terrain model, for each cell, the dominant soil type and the proportion of land with slopes exceeding 5 degrees were calculated.

On the basis of this database, relationships between landscape composition and farm sizes in 2002 were analysed. Furthermore, differences in landscape composition between small and large farms in 2002 were analysed in relation to changes in landscape composition between 1954 and 1982 and between 1982 and 2002. Finally, landscape changes during the two investigated periods were analysed in relation to soil and slope conditions.

For both the national and the case area analysis it is important to stress that farm units and thus applied farm sizes refer to the present situation, i.e. 2001 at case area scale and 2004 at national scale. Analyses of landscape change in relation to farm size thus describe what changes occurred in areas, which today are managed by respectively small and

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[16] The minimum width was chosen because the resolution of aerial photos hinders the registration of widths under 1 meter.

large farms. Information on whether these areas were managed by the same farms in earlier years was not included.

Statistical analysis

Relationships between farm size and landscape composition were investigated with an analysis of variance using the Anova general linear model procedure (SAS Institute Inc., 2004). Dependent variables were mean field sizes and densities of landscape elements as well as changes in these and independent variables were farm size, soil type and proportion of land with slopes exceeding 5 degrees. Furthermore, as a general threshold was found in the relationship between landscape composition and farm size around the farm size of 25 hectares, for statistical analyses all farms were divided into farms less than 25 hectares and farms larger than 25 hectares. In the remaining part of this paper, small farms refer to farms less than 25 hectares and large farms refer to farms larger than 25 hectares.

Results

Relationships between farm size and landscape composition

Tables 2 and 3 summarise differences in landscape composition between farms less than 25 hectares and farms larger than 25 hectares. At national scale, a strong and significant positive relation exists between large farms and mean field size and a strong negative relation between large farms and densities of uncultivated grass. Although farm sizes in general are smaller in eastern Denmark, elaborating this analysis within the 13 Danish counties reveals that the clear differences in landscape composition between small and large farms are independent of regional variations in farm sizes.

Table 2: Differences in the landscape between small and large farms in Denmark in 2004

	N	**Mean field size in 2004 (hectares)**	**Density of uncultivated grass in 2004 (% of farm)**
Farms < 25 hectares	20.861	2,63	9,27%
Farms > 25 hectares	25.945	4,31	6,16%
Significance of difference		***	***

*Significance levels: p<0,05=**, p<0,001=***, ns= not significant

Sources: national agricultural register 2004 and map of field blocks 2004

Table 3 Differences in the landscape between small and large farms in 3 case areas in 2004

	Mean field size	**Density of hedgerows**	**Density of field divides**	**Density of small biotopes**	**Density of woodlots**	**Density of uncultivated grass**
	(hectares)	(% of area)	(% of area)	(% of area)	(% of area)	(% of area)
farms < 25 hectares	1,80	2,29%	0,69%	8,35%	8,91%	13,99%
farms > 25 hectares	3,38	1,36%	0,50%	4,69%	6,21%	14,77%
significance of difference*	***	**	**	**	ns	ns

*significance levels: p<0,05=**, p<0,001=***, ns= not significant

Source: Aerial photo interpretation for 2002, field and cadastre maps 2001; based on calculations for squares of 100 by 100 meters

Also at case area scale, clear and significant relations between farm size and landscape composition were found. Corresponding with the national sample, mean field sizes are significantly smaller on small farms. Densities of small biotopes, hedgerows and of field divides are significantly higher on small farms. No significant difference in density of uncultivated grass between small farms and large farms was found. Differences between the three case areas exist. In general, differences between small and large farms are less pronounced, but still significant in the Herning area. As small and large farms are relatively evenly distributed over the case areas (Table 1) differences between case areas are independent of differences in farm sizes between the case areas.

The influence of landscape changes

General landscape changes

For the three case areas, Table 4 summarises landscape changes between 1954 and 1982 and between 1982 and 2002. In the period until 1982 all case areas are characterised by substantial increases in field sizes and decreasing densities of small biotopes, of field divides and of uncultivated grass. These changes confirm with the general development in Danish agricultural landscapes (Brandt, 1994; Holmes et al., 1998) and other agricultural landscapes of Western Europe (Bouma et al., 1998; Hietala-Koivu, 2002; Ihse, 1995; Stoate et al., 2001). Technological development together with an increasing significance of large scale production was followed by merging of fields and the removal of constraining small uncultivated landscape elements such as field divides, ponds and patches of uncultivated land. Meanwhile, the decrease in densities of uncultivated grass can be subscribed to drainage and subsequent cultivation of peat soils and to a general decrease in dependency on grassland for grazing. During the same period densities of hedgerows increased particularly in Herning, which is due to schemes for hedgerow planting for protection against wind erosion in this area.

Table 4: Landscape changes in the three case areas from 1954 – 1982 and 1982 – 2002

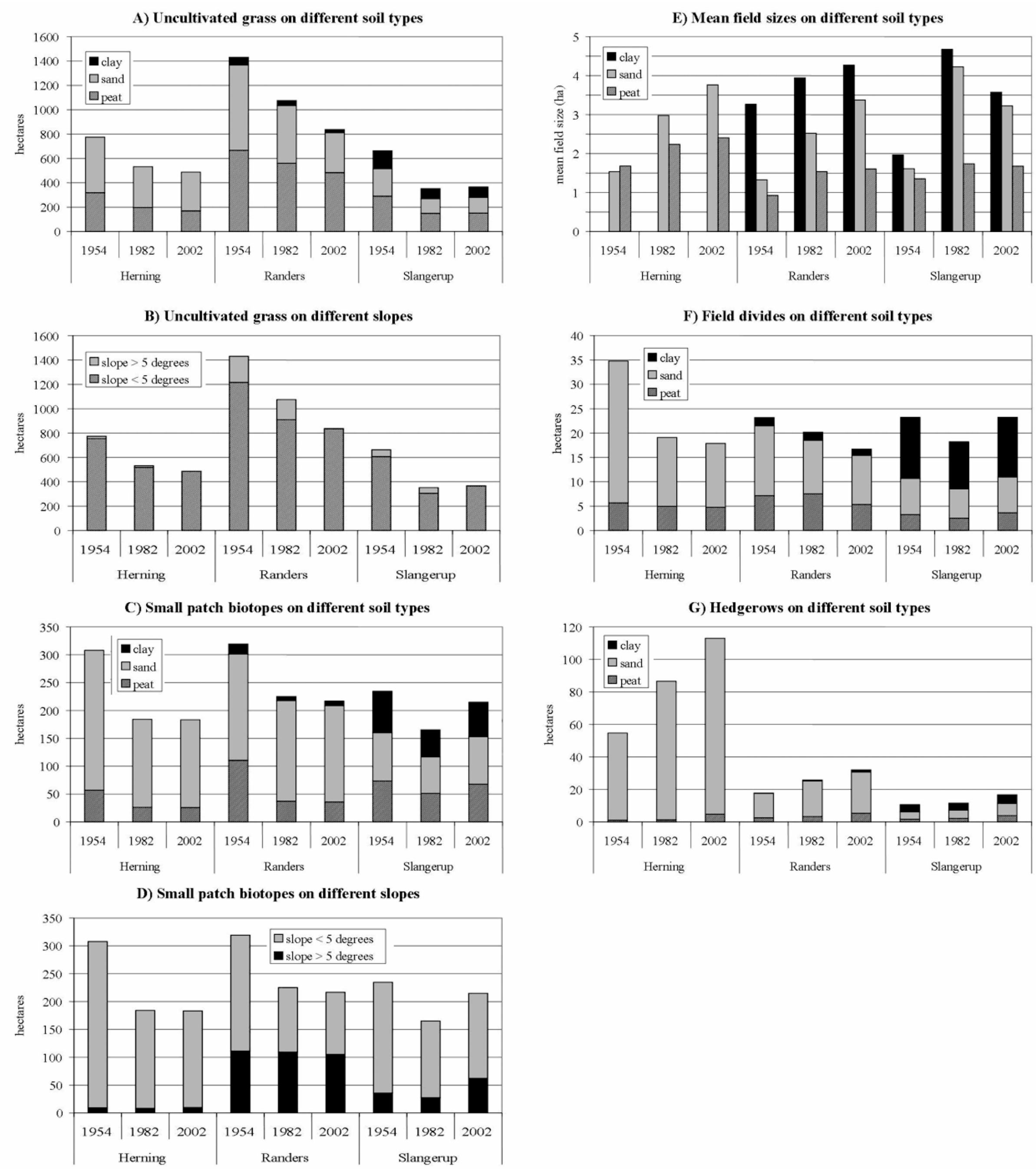
Mean field size (hectares)	**1954**	**1982**	**2002**	**1954-1982 year-1**	**1982-2002 year-1**
All areas	1,53	2,99	3,36	0,052	0,019
Herning	1,54	2,94	3,70	0,050	0,038
Randers	1,37	2,53	3,28	0,041	0,038
Slangerup	1,73	3,87	3,04	0,077	-0,042
Density of hedgerows (% of area)	**1954**	**1982**	**2002**	**1954-1982 year-1**	**1982-2002 year-1**
All areas	0,72%	1,07%	1,39%	0,013%	0,016%
Herning	1,30%	2,05%	2,67%	0,027%	0,031%
Randers	0,43%	0,62%	0,77%	0,007%	0,007%
Slangerup	0,33%	0,36%	0,52%	0,001%	0,008%
Density of field divides (% of area)	**1954**	**1982**	**2002**	**1954-1982 year-1**	**1982-2002 year-1**
All areas	0,74%	0,50%	0,58%	-0,009%	0,004%
Herning	0,82%	0,45%	0,42%	-0,013%	-0,001%
Randers	0,56%	0,48%	0,40%	-0,003%	-0,004%
Slangerup	0,88%	0,57%	0,73%	-0,011%	0,008%
Density of small biotopes (% of area)	**1954**	**1982**	**2002**	**1954-1982 year-1**	**1982-2002 year-1**
All areas	7,43%	4,96%	5,31%	-0,088%	0,017%
Herning	7,28%	4,35%	4,34%	-0,105%	-0,001%
Randers	7,65%	5,40%	5,19%	-0,081%	-0,010%
Slangerup	7,35%	5,18%	6,74%	-0,078%	0,078%
Density of uncultivated grass (% of area)	**1954**	**1982**	**2002**	**1954-1982 year-1**	**1982-2002 year-1**
All areas	24,92%	17,21%	14,64%	-0,275%	-0,128%
Herning	18,37%	12,61%	11,54%	-0,206%	-0,053%
Randers	34,51%	25,90%	20,15%	-0,308%	-0,288%
Slangerup	21,04%	11,94%	11,55%	-0,325%	-0,020%
Density of woodlots (% of area)	**1954**	**1982**	**2002**	**1954-1982 year-1**	**1982-2002 year-1**
All areas	4,76%	8,38%	10,86%	0,129%	0,124%
Herning	6,49%	9,12%	11,53%	0,094%	0,120%
Randers	3,99%	7,30%	10,78%	0,118%	0,174%
Slangerup	3,47%	8,80%	10,08%	0,190%	0,064%

Source: Aerial photo interpretation for 1954, 1982 and 2002

The period after 1982 shows different directions of landscape change. While Herning and Randers are characterised by a continued increase in field size and a continued decrease in densities of small biotopes and of field divides, opposite changes characterise Slangerup. Here, a decrease in field sizes and an increase in both small biotopes and in field divides is observed. This indicates a continuing harmful influence of agricultural development on landscape composition in Herning and Randers, while this influence is reversed in Slangerup.

Landscape changes in relations to soil and slope conditions

Figure 2 points at different tendencies in landscape changes in relations to soil and slope properties. Changes within natural grassland indicate a development, where the connection between natural conditions and agricultural land use did not disappear but was gradually weakened (Figure 2A and B). In all three case areas, the proportion of uncultivated grass on peat soils decreased gradually from 1954 to 2002. This tendency is partly caused by drainage and subsequent cultivation of peat soils, partly by the abandonment of extensive grazing and subsequent change into shrub or three cover. Furthermore, between 1954 and 2002 uncultivated grassland on slopes exceeding 5 degrees almost disappeared, which was due to the abandonment of extensive grazing and subsequent change into shrub or three cover. Change into shrub or three cover can be caused by natural succession but is often the result of land owners' planting of forest.


A) Uncultivated grass on different soil types

B) Uncultivated grass on different slopes

C) Small patch biotopes on different soil types

D) Small patch biotopes on different slopes

E) Mean field sizes on different soil types

F) Field divides on different soil types

G) Hedgerows on different soil types

Figure 2: Relationships between the landscape and soil and slope conditions in 1954, 1982 and 2001

Source: Aerial photo interpretation for 1954, 1982 and 2002, national soil map, national slope map

Figure 2C shows that particularly until 1982, the area of small biotopes located on peat soils decreased. This decrease was due to the removal of ponds, which originally were closely related to peat soils. On the other hand, while until 1982 the area of small biotopes decreased in all case areas, this decrease mainly applies to land with slopes less than 5 degrees (Figure 2D), while the area of small biotopes on slopes exceeding 5 degrees remained unchanged or even increased throughout the investigated period. This relative stability and increase of small biotopes on steep slopes is probably explained by poor conditions for the use of large scale machinery and thus abandonment and subsequent succession into shrub and woody vegetation in these areas.

Both increases in field sizes and decreases in field divides are significantly higher on clay and sand soils than on peat soils (Figure 3E and F). Throughout the investigated period the largest proportion of cultivated land is found on sand and clay soils. Consequently, the influence of agricultural development on landscape composition, characterised by increasing field sizes and decreasing densities of field divides, is most pronounced on these soil types. Finally, throughout the investigated period, increases of hedgerows in Herning and Randers are most pronounced on sand soils (Figure 3G), which is probably due to schemes for hedgerow planting mainly focusing on sand soils, which are most affected by wind erosion.

Differences in landscape composition between large and small farms in relation to landscape changes

In order to elucidate differences in landscape composition between small and large farms in the light of past landscape changes, at both national and case area scale, changes in landscape composition were analysed in relation to the present location of small and large farms.

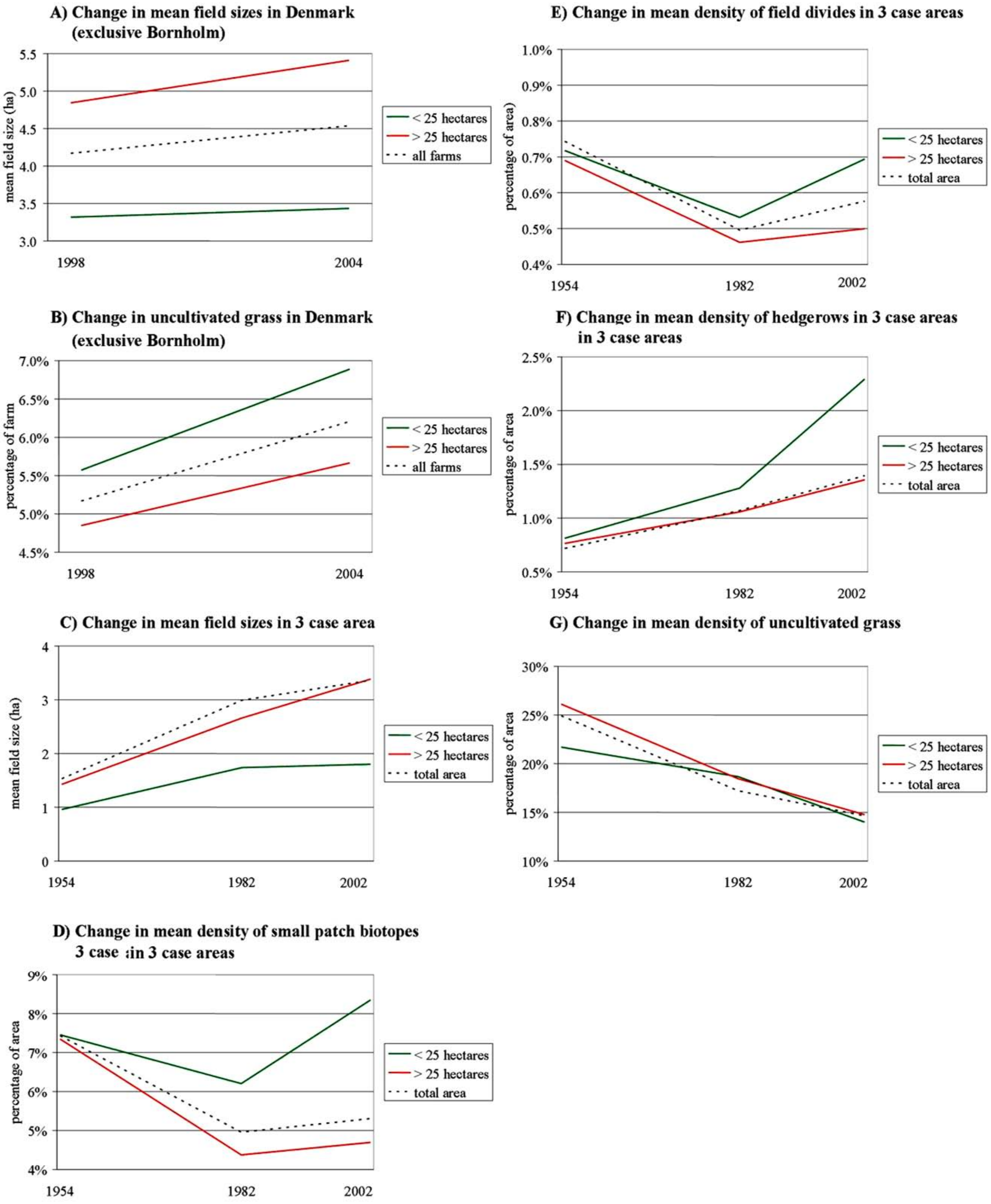


Figure 3: Landscape development on small farms (<25 ha) and large farms (>25 ha).

Source: Agricultural registers 1998 and 2004, field block maps 1998 and 2004, aerial photo interpretation 1954, 1982, 2002, national soil map, national slope map

The national scale

National data show an increase in mean field size of almost 10% between 1998 and 2004 (Figure 3A). While in areas, which in 2004 were managed by small farms mean field sizes remained almost stable, areas managed by large farms are characterised by a significant increase in mean field sizes. Already in 1998 field sizes were significantly higher in areas, which in 2004 were managed by large farms. But, due to a relative stability compared to a significant increase, in 2004 the difference in mean field sizes between small and large farms was considerably stronger.

National data also point at differences in the development of uncultivated grass (Figure 3B). Between 1998 and 2004, densities of uncultivated grass increased by about 20%. Areas, which in 2004 were managed by small farms are characterised by significantly larger increases in densities than areas managed by large farms. During the period from 1998 to 2004, present differences in densities of uncultivated grass between small and large farms have thus been strengthened.

Although regional variations in changes of mean field sizes and in changes of densities of uncultivated grass exist, differences between areas managed by small and areas managed by large farms are independent of the regional location. In conclusion, national data indicate that present differences in landscape composition in terms of mean field sizes and in terms of uncultivated grass are influenced by variations in change of these landscape elements between 1998 and 2004. However, six years represent a rather small time horizon. Thus, in the following, present differences in landscape composition between small and large farms are investigated in relation to landscape composition over the past 50 years.

The case area scale

In general, analyses at case area scale indicate that present differences in landscape composition between small and large farms mainly evolved in the period from 1982 to 2002, while the effect of changes from 1954 to 1982 is less significant. Figure 3C shows that in the period from 1954 to 1982 mean field sizes increased considerably in all areas. However, while between 1982 and 2002 increases in mean field sizes continued in areas, which in 2002 were managed by large farms, in areas managed by small farms mean field sizes remained stable. The significant difference in mean field sizes between small and large farms in 2002 is thus to a considerable degree a result of differences in changes over the past 20 years.

In all areas, densities of small biotopes decreased considerably until 1982 (Figure 3D). After 1982, areas, which in 2002 were managed by small farms are characterised by significantly larger increases in densities of small biotopes than areas managed by large farms.

A similar tendency can be observed for field divides (Figure 3E). While until 1982, densities of field divides decreased in all areas, the period from 1982 to 2002 is characterised by significant increases in areas managed by small farms compared to areas managed by large farms.

Throughout both investigated time-periods hedgerow densities increased considerably (Figure 3F). Between 1982 and 2002 densities of hedgerows increased at a significantly higher rate in areas, which in 2002 were managed by small farms compared to areas managed by large farms.

Finally, from 1954 to 1982 and from 1982 to 2002 densities of natural grass generally decreased in all areas (Figure 3G). Compared to national data, no significant differences exist between areas, which in 2002 were managed by small farms and areas managed by large farms.

In conclusion, the case area analysis indicates that present differences in landscape composition between small and large farms have mainly evolved during the period from 1982 to 2002. While differences in landscape composition between areas, which in 2002 were managed by respectively small and large farms, to some degree already existed in 1954 and in 1982, due to spatial variations in landscape changes these differences became significantly stronger in 1982 and particularly in 2002.

The influence of soil and slope conditions

As landscape composition and changes in landscape composition are related to soil conditions and topography, variations in these conditions, and their influence on present differences in landscape composition between small and large farms were investigated. Table 5 points to significantly higher percentages of slopes exceeding 5 degrees and significantly smaller percentages of peat soils on small farms. Considerable regional variations in both soil and slope conditions exist. Yet, elaborating this analysis for the 13 different Danish counties shows that differences between small and large farms are independent of regional differences.

Table 5: Relationships between small and large farms and soil and slope conditions

		percentage slopes > 5 degrees	**percentage clay soils**	**percentage sand soils**	**percentage peat soils**
National	Farms < 25 hectares	0,4%	33,5%	61,8%	4,2%
	Farms > 25 hectares	0,3%	32,1%	62,2%	5,1%
	Significance of difference	***	ns	ns	***
Case areas					
Herning	Farms < 25 hectares	0,0%	-	86,3%	13,6%
	Farms > 25 hectares	1,8%	-	84,7%	15,1%
	Significance of difference	**	-	ns	ns
Randers	Farms < 25 hectares	10,9%	6,2%	70,7%	21,4%
	Farms > 25 hectares	12,9%	3,3%	71,2%	25,1%
	Significance of difference	ns	ns	ns	ns
Slangerup	Farms < 25 hectares	10,0%	31,1%	45,8%	20,8%
	Farms > 25 hectares	8,7%	40,5%	34,2%	24,3%
	Significance of difference	ns	**	***	ns

*significance levels: p<0,05=**, p<0,001=***, ns= not significant

Sources: National agricultural register 2004, national map of hedgerows 2001 and map of field blocks 2001 and 2004

In comparison, analyses at case area scale point at only a few significant differences in soil and slope conditions between areas managed by small and areas managed by large farms. In Slangerup, small farms are characterised by significantly higher percentages of sand soils and correspondingly lower percentages of clay soils. Furthermore, in Herning a significant but weak relation between large farms and percentages of slopes exceeding 5 degrees exists.

Both at national and at case area scale, these results indicate few but rather limited effects of variations in soil and slope conditions on differences in landscape composition between small and large farms. At national scale, mean field sizes are smaller on farms with a high percentage of slopes exceeding 5 degrees. Furthermore, while in the period from 1998 to 2004, mean field sizes generally increased, a high percentage of slopes is related to a relative stability in mean field sizes. Thus, at national scale, higher percentages of slopes do to some degree explain differences in change in mean field sizes between large and small farms. Still, these differences are not large enough to explain the whole difference in mean field sizes between small and large farms.

Between 1998 and 2004, increases in uncultivated grass are significantly related to peat soils. However, small farms have significantly smaller percentages of peat soil. Higher densities and larger increases in densities of peat soils on small farms are thus independent of variations in soil conditions.

Furthermore, at case area scale, several relationships between changes in landscape composition and soil and slope conditions exist. Yet, the few significant differences in soil and slope conditions between large and small farms do not explain present differences in landscape composition between small and large farms.

In conclusion, both at national and at case area scale, these results indicate the present differences in landscape composition between small and large farms being largely independent of variations in soil conditions and topography.

Discussion and conclusion

This investigation elucidates significant differences in landscape composition between small and large farms. Both at national and at case area scale, mean field sizes are significantly smaller on farms less than 25 ha. Furthermore, investigations at case area scale show significantly higher densities of small patch biotopes, of hedgerows and of field divides on farms less than 25 ha. While national data point to significantly higher densities of uncultivated grass on small farms, this difference was not found at case area scale.

Results also indicate that present differences in landscape composition between small and large farms are significantly influenced by variations in past landscape changes. At national scale, present differences in mean field sizes and in densities of uncultivated grass are not entirely, but to a significant degree the result of different trends in changes during the period from 1998 to 2004. Investigations at case area scale reveal that present differences between small and large farms have mainly evolved due to different trends in landscape change between 1982 and 2002. The influence of changes between 1954 and 1982 was less significant.

In general changes in landscape composition at both national and case area scale are significantly related to soil and slope conditions. However, the influence of differences in these conditions on differences in landscape composition between small and large farms was very limited. Furthermore, national analyses reveal that differences in landscape composition between small and large farms are largely independent of regional variations. Consequently, differences in landscape composition between small and large farms must have evolved independently of both local and regional differences in landscape composition, in landscape change and in soil and slope conditions. Thus, causal explanations for differences in landscape composition and in landscape changes between small and large farms must therefore be found within other farm specific characteristics.

The significance of part time and hobby farming

In present Danish agriculture, farm sizes less than 25 hectares are generally too small to provide an acceptable household income. Consequently, although the applied data in this study do not include information about farm type, it is reasonable to assume that farms less then 25 hectares are generally characterised by part-time or hobby farming. Several investigations point at part-time and hobby farms being different from full-time farms with respect to driving forces for agricultural and thus landscape practices (Busck, 2002; Frederiksen and Langer, 2004; Tress, 1999). On full-time farms, optimisation of the agricultural production dominates farmers' decision-making (Walford, 2005). On part-time and hobby farms, where the main household income is derived from other, usually off-farm activities, optimisation of the agricultural production is of less importance.

Optimisation of agricultural production will often lead to rationalisation of agricultural land use and thus to rearrangement of landscape composition in order to meet requirements for the use of modern large scale machinery. Such rearrangement of landscape composition is characterised by the merging of field plots and subsequent increases in field sizes. While general increases in field sizes are seen at both national and at case area scale, areas managed by small farms are characterised by a relative stability in field sizes. It is thus reasonable to assume that due to less focus on production optimisation, structural change in agriculture and its effect on changes in field sizes has been less significant in areas managed by small farms.

However, this does not explain the significantly larger increases in densities of small patch biotopes, of hedgerows and of field divides and small farms. A possible explanation is that the awareness of the environmental functions of these uncultivated landscape elements has a profound effect on landscape management on small hobby and part-time farms. Consequently, small farms are more active in terms of establishment of small biotopes, hedgerows and field divides.

Economic causes form another explanation for higher rates of such landscape activities on small farms. Assuming that part-time and hobby farmers generally have comparable household incomes and use a comparable proportion of this income for hedgerow planting and establishment of small biotopes, the amount of money per farm area, available for these activities would be considerably higher on small farms. Thus, higher rates in establishment of uncultivated landscape elements on small farms might be caused by a comparably larger economic margin for such activities.

Finally, a reasonable explanation for significantly higher densities of uncultivated grass, which were observed for small farms at national scale, are to be found in differences in the agricultural production between small and large farms. Uncultivated grassland is usually grazed by sheep and goats and by cattle for meat production. National data for 2004 show that both numbers per hectare of meat cattle and of sheep and goats are significantly higher on farms less than 25 hectares (Table 6). Furthermore, this difference is independent of regional variations. Breeding of sheep and goats and of meat cattle does fit better to small scale production on part-time and hobby farms than to large scale full-time farms. Consequently, higher densities and larger increases of uncultivated grass can be explained by larger densities of sheep, goats and meat cattle on farms less than 25 hectares.

Table 6: Relationships between small and large farms and densities of grazing animals and percentage of area receiving subsidies for environmentally friendly management

	Sheep and goats	**Meat cattle**	**Subsidies for environmentally friendly management**
	(animal units/ha)	(animal units/ha)	(% of farm area)
Farms < 25 hectares	0,0067	0,09	2,82%
Farms > 25 hectares	0,0011	0,03	0,86%
Significance of difference*	***	***	***

*significance levels: p<0,05=**, p<0,001=***, ns= not significant

Sources: National agricultural register 2004 and map of field blocks 2004

In addition, corresponding with an investigation from Switzerland (Mann, 2005), national data also show that the proportion of the farm area, for which farmers in 2004 received subsidies for environmentally friendly production, was significantly larger on farms less than 25 hectares. It could be argued, that this difference is caused by a larger awareness of environmental functions on small farms. However, as these environmental schemes mainly apply to uncultivated grasslands, a more reasonable explanation is the larger density of uncultivated grass on small farms.

Future perspectives

Structural development, with increasing farm size and concentration of the land on fewer and larger farms has taken place in Danish agriculture during several decades. From 1960 until 2000 mean farm size has more than tripled (Hansen, 2000). During recent years, this development thus continued at an even accelerated rate. From 1998 to 2004, the average farm size in Denmark increased from 44 to 57 ha, while the total number of farms decreased from over 60,000 to about 47,000. In the same period mean field size for the whole country increased by about 8% from 3.7 to

4.0 ha. Furthermore, scenarios for agricultural development estimate that until 2010 the numbers of farms will decrease to 38,500 while mean farm size will increase to 65 ha (Landboforeningerne, 2002). Scenarios also estimate that the number of farms will decrease both among full-time and part-time farms. However, the relative proportion of part-time farms will increase from 59% in 2000 to 64% of all farms in 2010.

On the basis of the results from this paper, these estimations point at two different trends in the structural development of Danish agriculture and its influence on changes in agricultural landscapes. A continued scale enlargement with increasing farm sizes and consequently a continued adjustment of landscape composition to a rationalisation of agricultural production has a potentially harmful effect on landscape composition. Such harmful influences of the structural development on landscape composition are most effectively met by means of stricter standards for nature protection and by means of financial subsidies for environmental schemes for management and establishment of valuable landscape elements.

Alongside a continued awareness of the harmful effects of scale enlargement, the results from this investigation call for an increased focus on the obvious beneficial effects of small farms, which are often related to part-time and hobby farming. These farm types differ from larger full-time farms in terms of a lesser focus on optimisation of agricultural production, differences in production types and, possibly, a larger influence of environmental considerations in landscape management. These differences are reflected in landscape composition in terms of a lesser influence of scale enlargement and thus a relative stability in field size structure and in more significant increases in densities of uncultivated landscape elements. Consequently, small part-time and hobby farms form a potential instrument for a more sustainable management of Danish agricultural landscapes.

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5.3 Paper 3:

Structural development in Danish agriculture and its implications for farmland nature

By Gregor Levin, Vibeke Langer and Pia Frederiksen

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Abstract

During the last decades, development of Danish agriculture was characterised by concentration of land on fewer and larger farms and consequently increasing farm sizes. On basis of three case studies supplemented by national data we explore relationships between farm size change and farmland nature in terms of field sizes and hedgerow densities. Data point to a significant relationship between farm enlargement and increases in mean field sizes. Furthermore, mean field size is negatively related to densities of hedgerows. For the coming decades, scenarios for Danish agriculture point to a continued increase in farm sizes. We argue for an increased focus on the effects of a continued scale enlargement on farmland nature in terms of changes in field size structure. In order to reduce harmful influences of scale enlargement, we suggest that in relation to changes in field structure, agricultural policies should focus on restrictions on removal of old hedgerows and on subsidies for planting of new hedgerows.

Keywords

Structural development in agriculture, farm size, farmland nature, field size, field size structure, hedgerow density

Background

In Denmark, from 1960 until 2000 mean farm size has more than tripled (Hansen 2001). Scenarios of the agricultural development estimate that the number of farms will decrease by 52 % from 79,300 in 1990 to 38,500 in 2010 (Landboforeningerne 2002). Scenarios also estimate that the number of farms in all size categories up to 100 ha will decrease, while number of farms larger than 100 ha will increase, leading to a dramatic concentration of farmland on fewer farms.

During the last century, farmland nature has suffered as a consequence of the structural development, due to homogenisation of the cultivated area, adjusting it to new technology (Ministry of Environment and Energy 1995). However, in the mid-1980s the environmental discourse was introduced in agricultural policy and particularly since the early 1990ies, focus on the conservation and restoration of farmland nature increased. However, it remains an important question, whether the continued scale enlargement in agriculture still implies continued homogenisation and impoverishment of the farmland nature.

Over the last 50 years new technology necessitated the enlargement of agricultural fields through the merging of field plots, resulting in increasing field sizes (Benton et al. 2003). In both Denmark (Clausen and Larsen 1997) and England (Barr et al. 1993, Westmacott and Worthington 1997), during the last 50 years mean field sizes increased considerably and negative impacts on farmland nature and on hedgerow densities have been documented (Smith et al. 2005, Benton et al. 2003, Robinson and Sutherland 2002).

Hedgerows have been planted in Denmark with public subsidies since 1880 (Fritzbøger 2002). The Nature protection Agency however estimates a 40% decrease in dikes and hedgerows during the last 100 years (Prip 1995). Decreases in hedgerow densities have also been documented for other intensively farmed landscapes in Western Europe (Deckers et al. 2005; Barr and Gillespie, 2000; Haines-Young et al., 2003; Burel and Baudry, 1990). Hedgerows in field divides are sensitive to the merging of fields and it can be hypothesised that merging of fields does influence hedgerow density.

Due to the varying functions of hedgerows, the development has not been continuous in time and space. In addition to agricultural production also other factors like e.g. farmers' age (Ackerman 2003) or aesthetic and environmental functions (Kristensen 2003, Busck 2002, Kristensen 2001) are important for hedgerow dynamics. Moreover during the last century subsidy schemes for hedgerow planting have particularly focused on protection against soil erosion in western Denmark, where sandy soils dominate (Fritzbøger 2002).

In this paper we focus on scale enlargement in agriculture as driver for field size- and hedgerow dynamics. Combining results from different Danish studies we discuss the effect of a continued scale enlargement on field size- and hedgerow development. Our aim is to draw up a picture of future landscape development for use in policy making on nature conservation in the general farmland outside protected areas.

Data and methods

The paper draws on partial results from 3 case studies and a national analysis. Focus is on the period from 1995 to 2004, and the main analytical variables used are farm size, field size (the area covered by a single plot of agricultural land use) and density of hedgerows (measured as m/ha).

The first study is based on quantitative interviews with app. 10% (N=340) of Danish organic farmers, exploring land use and field- and farm size in 2001 and landscape activities from 1996 to 2001 (Frederiksen and Langer 2005). The second study analyses landscape changes on 72 conventional and 40 organic farms in the period 1995 to 2004 using aerial photos (Levin in prep.). Hedgerow and field size development were followed, while changes in farm size were not investigated. This study has also been used to confirm that hedgerow data for organic farms are representative for Danish farms in general. The third study analyses changes in field and farm sizes from 1997 to 2002 on 234 organic farms, which converted to organic farming in 1997 and were still organic in 2004 (Langer et al. 2005). The 3 studies are supplemented by national data on changes in field- and farm sizes from 1998 to 2004. Furthermore, national data on hedgerow density in 2001 were derived from a national map of hedgerows. Finally, as data on hedgerow change are only available from study 2, we explore field size as an indicator of hedgerow density through this study.

For studies 1, 3 and national data, field sizes are derived from agricultural registers and reflect field units, for which farmers have applied for EU subsidies. Here, fields are administrative units, which however also constitute units of agricultural land use. For study 2, field sizes were registered on basis of aerial photos. Fields registered on aerial photos highly conform to fields recorded in agricultural registers. In this paper we estimate mean field size as the mean size of all fields within one farm unit.

Relationships between hedgerow density, farm size and field size in 2001/2002 are analysed on basis of studies 1, 2 and national data. How these variables change over time, is explored for the period from 1995 to 2004 in three steps. 1) On basis of study 1 we first establish the relationship between farm size, field size and hedgerow density in 2001 for a sample of farms, which are distributed over all major Danish landscape types and have a similar distribution over farm types as at national scale. 2) Based on study 2, we analyse the link between development in field size and in hedgerow densities. 3) Based on study 3 and national data, we explore the link between development in farm size and field size. Finally, based on study 1, we analyse how hedgerow activities are related to farm size.

Results

From 1998 to 2004, the average farm size in Denmark increased from 44 to 57 ha, while the total number of farms decreased from over 60,000 to about 47,000. In the same period mean field size for the whole country increased from 3.7 to 4.0 ha. As large fields (>8 ha) increased by number, and the total agricultural area has been decreasing, change in mean field size must be linked to the merging of fields.

Relationship between hedgerow density, farm size and field size.

Data collected in study 1 show a hedgerow density of 59m/ha in 2001 and a weak but significant negative relationship between density of hedgerows and farm size (r^2= 0.12 for log of farm size). There is also a weak, but significant negative relationship between hedgerow density and mean field size (r^2= 0.07). Analysing the relationship between mean field size and farm size in 2001 shows a clear and significant negative relationship (r^2= 0.39 for log of farm size).

In study 2 the mean density of hedgerows was 39m/ha and a weak but significant negative relationship is found between hedgerow density and farm size (r^2= 0.08 for log of farm size) and between hedgerow density and mean field size (r^2= 0.04). Also a strong and positive relationship between farm and mean field sizes was found (r^2= 0.38 for log of farm size).

National registry data for 2001, including all 53,750 Danish farms, show a significant positive relation between farm size and mean field size (r^2= 0.22 for log of farm size)(Figure 1) and significant negative relations between farm size and hedgerow density (r^2= 0.03 for log of farm size) and between mean field size and hedgerow density (r^2= 0.03).

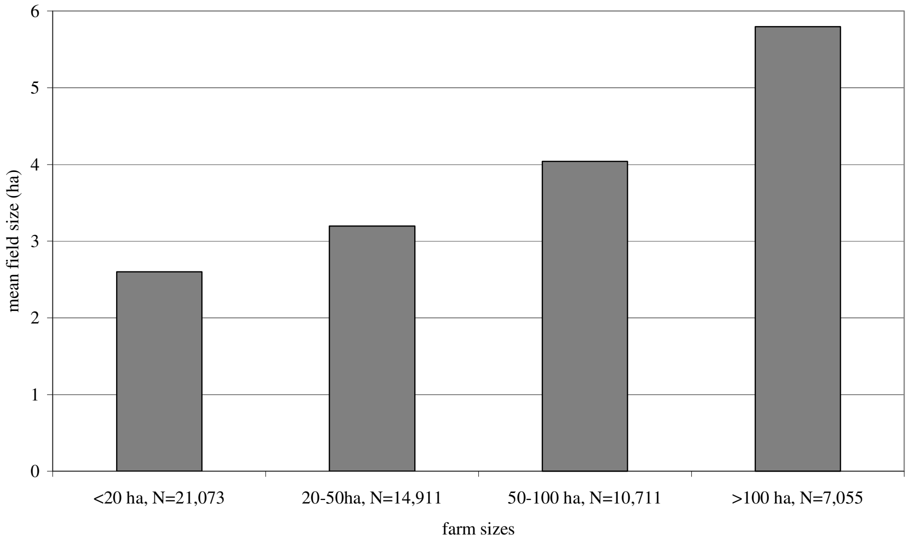

Figure 1: Mean field size over farm size, Denmark 2001
Sources: Agricultural register 2001

Changes in hedgerow density, field size and farm size

On the 112 farms in study 2, mean field sizes increased at average from 2,2 ha in 1995 to 3.2 ha in 2002, while hedgerow density increased on average by 12%. 25% of all farms removed hedgerows and 50% planted new hedgerows. While no relationship between change in mean field size and total change in hedgerow density was found in this study, a clear positive relationship between change in mean field size and both density of removed and density of planted hedgerows was found, indicating that farms with larger fields are most active in adjusting their field structure.

Among the 234 farms in study 3 significant increases in mean field size (>20%) were seen on 20% of all farms, and on 35-50% of the farms with considerable or major growth in farm size. There is a significant relationship between change in farm size and change in mean field size from 1997 to 2004, indicating that enlargement in farm area is linked to field enlargement. National data on farm size and field size development from 1998 to 2004 support this: on the 40.385 farms, which could be traced in both the 1998 and 2004 agricultural register there is a strong and significant relationship between change in farm area and change in mean field size (r^2= 0.32) (Figure 2).

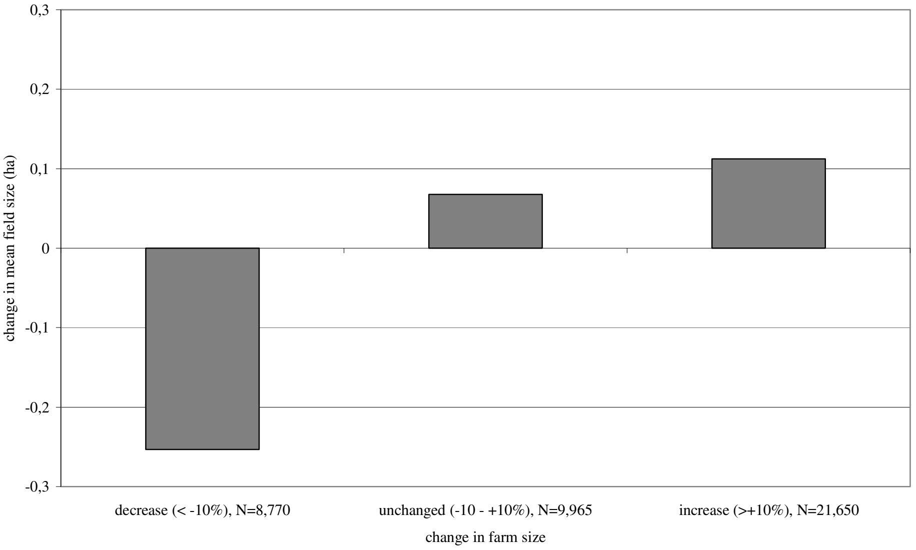

Figure 2: Change in mean field size over change in farm size, Denmark 1998 – 2004
Sources: Agricultural registers 1998 and 2004

Planting and removal of hedgerows on different farm sizes

From 1996 to 2002 11% of the 340 farmers in study 2 removed hedgerows, but very few of these did not establish hedgerows during the same period. 37% of the farms established hedgerows. On small farms (<20 ha) the net increase in hedgerow length was app. 10 m pr ha of farmed area, while for the other 3 farm size groups net increases were only 2-3 m/ha. Thus, although there is a higher planting activity on large farms (Figure 3), the resulting densities are higher on the area managed by small farms.

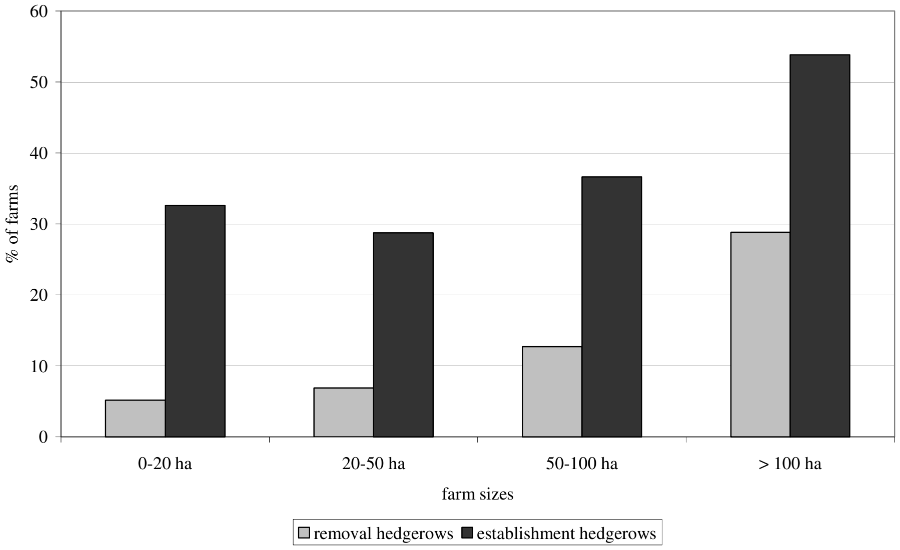

Figure 3: Farm hedgerow activities 1996 – 2002
Source: Questionnaires with 340 organic farms in Denmark

Discussion

Our data show that during the last decade increasing proportions of large farms were accompanied by increasing mean field sizes. Enlargement of farms and fields does not necessarily lead to a decrease in over-all hedgerow density but very large farms seem to be most active in both establishment and removal, which could be due to a rationalisation of farm layout. While hedgerow densities increased among all farm sizes, small farms show the relatively highest increases. As farm enlargement is widely expected to continue in the next decade, this development will probably lead to a continued merging and thus enlargement of fields. This may affect farmland nature by removal and replacement of old hedgerows, as hedgerow removal and establishment is extensive on large farms. Small farms seem to have higher hedgerow densities in general and density of plantings is relatively high. Consequently, worries of farmland nature in relation to hedgerows should be primarily directed towards large farms and the possible removal of old and valuable hedgerows, and policies of advice on farm nature supplemented by continued subsidies for planting new hedgerows and protection of existing hedgerows would appear to be beneficial. However, other landscape elements such as field divides and remnant biotopes cannot be expected to follow the same development. Particularly densities of field divides can be expected to be largely affected by the scale enlargement within agriculture.

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6 Discussion, conclusion and perspectives

In this chapter the main findings of the thesis are discussed. The chapter is divided into four sections. The first section outlines the empirical results from the 3 papers. In the second section the applied methodology is discussed in terms of its strengths and limitations for an appropriate understanding of agriculture – landscape relations. The third section discusses conclusions and perspectives, which can be drawn on basis of the study. As organic farming is the central issue of this study focus is put on the past and future role of organic farming in relation to landscape composition and structure. Finally, the last section outlines perspectives for future research on organic farming – landscape relations.

6.1 Summary of empirical results

Organic farming and the landscape

Paper 1 aimed at analysing relationships between organic farming and the landscape. National analyses pointed to clear effects of the conversion to organic farming on the landscape in terms of changes in field sizes and changes in diversity of agricultural land uses. Analyses at case area scale pointed to differences in landscape composition and changes in landscape composition being significantly influenced by other farm specific properties like farms size, soil conditions and topography. To some extent, at the scale of the single case areas, organic and conventional farms differed from each other with respect to these parameters. As a consequence, these differences indirectly resulted in differences in landscape composition between organic and conventional farms. However, these relations only characterised the situation at the case of the single case areas and can therefore hardly be generalised to a broader regional or national scale.

In conclusion, these results indicated that organic farming has to be seen as a particular kind of agricultural production system. Cultivation and rotation practices on organic farms are different from conventional farms, and therefore affect landscape composition in terms of field sizes and land use diversity. The empirical results do, however, not support the assumption that organic farming as a farm type is related to a clear engagement in landscape management, which results in beneficial effects on landscape composition and structure.

The relationship between farm size and the landscape

Paper 2 elaborated on an investigation of relations between farm size and landscape composition as well as changes in landscape composition from 1954 to 1982 and from 1982 to 2002. Farm size was significantly related to several landscape parameters. Mean field sizes were significantly smaller on small farms (< 25 ha) compared to large farms. Meanwhile, densities of several uncultivated landscape elements were significantly higher on small farms. Analyses of landscape change indicated that these differences between small and large farm sizes were mainly a result of landscape changes over the last 20 years and were not an inheritance of landscape changes, which took place between the early 1950s until the early 1980s.

Recent structural changes in Danish agriculture and its implication on farmland nature

On basis of different data sources paper 3 explored recent relationships between farm size change and farmland nature in terms of field sizes and hedgerow densities. Data pointed to a significant relationship between farm enlargement and increases in mean field sizes. Furthermore, small mean field sizes were positively related to densities of hedgerows. For the coming decades, scenarios for Danish agriculture point to a continued increase in farm sizes. Therefore, the paper argued for an increased focus on the effects of a continued scale enlargement on farmland nature in terms of changes in field size structure and hedgerow densities.

6.2 Strengths and limitations of the applied methodologies

In the light of the empirical results outlined above, the methodologies, which were applied in this study, proved to be practicable and convenient tools for investigating relationships between agriculture and landscape composition and structure. However, applying exclusively quantitative methods also implicated limitations, particularly with regard to analysis of causal relationships. The following section aims at outlining strengths and limitations of the applied methodologies.

The importance of the spatial link

As argued earlier in this thesis, everything, whether representing socioeconomical, biophysical or other aspects, has a spatial dimension. It is the spatial dimension which links the different aspect together. In this study, farm units and to some extent field units were used as the spatial link between farm specific and landscape parameters. Through this spatial link relationships between farm characteristics and the spatial composition of the landscape could be investigated.

The need for multiple information

Agriculture – landscape relations are highly complex and involve a variety of different, often interrelated parameters. A comprehensive investigation of agriculture – landscape relations consequently requires a variety of information derived from different data sources. In this study, deriving information on landscape parameters and on farm specific properties from different data sources and linking these together through a spatial reference provided an appropriate data base for quantitative analyses of agriculture – landscape relations, not least with focus on the role of organic farming. Using a variety of data also enabled the identification of interrelationships between different parameters and at least to some extent permitted the recognition of the complexity of agriculture – landscape relations.

The strength of quantitative methods

Quantitative data together with statistical methods enabled the quantitative evaluation of the significance of relationships between farm properties and the landscape. Quantitative data and statistics are important in terms of actually documenting and quantifying relationships. In the light of only few existing studies of organic farming – landscape relations, the quantification of relationships between organic farming and the landscape as well as between conversion to organic farming and landscape changes was central to this study.

The specific strength of using national agricultural registers is that these data apply to the whole of Denmark (although the island of Bornholm was excluded). The findings from these data can thus be used to indicate general trends. Data at case area scale only apply to 112 farm units. However, compared to the national scale, the case area scale provides much more detailed information on landscape composition and structure and on changes in these. Furthermore, while the time scale in the national analysis was limited to 6 years, in the case area analysis, the time scale of 50 years enabled the link between the composition of the present landscape and landscape changes, which occurred between the early 1950s to the 1980s.

Complementing each other, the two methodologies provided a valuable base for an interpretation of the development of Danish agricultural landscapes and the role of organic farming. In spite of these obvious strengths, the use of quantitative methods also implied a number of limitations, particularly in terms of opportunities to explain causal relationships.

The limits of land cover registration

It is important to be aware of that the data derived from the interpretation of aerial photos only comprises what in fact can be seen on an aerial photo. First of all this means that what can be registered must have a spatial / physical character, which can be seen on a photo. Of course this depends highly on the quality and resolution of the used aerial photos. In spite of the relatively high spatial resolution of the used aerial photos (0.4 – 0.8 metres) there are specific characteristics of landscape elements, which are difficult to or even impossible to determine on basis of these photos. E.g. estimations of the accuracy of the land cover interpretation pointed to difficulties in distinguishing between different kinds of grass vegetation. Furthermore, coniferous and deciduous vegetation imply different habitat quality of e.g. hedgerows. However, on basis of the aerial photos it was not possible to distinguish these two vegetation types. Furthermore, several kinds of nature management, like the cleaning up of a pond or the environmentally friendly management of uncultivated grass could not be seen on an aerial photo. Such information would require interviews or questionnaire surveys. However, as these types of nature management were not the central focus here, the lack of such information does therefore not directly weaken the findings in this study.

The limit for causal explanations

Figure 17 is a repetition of the conceptual framework of this study. The figure, which is described in more detail in chapter 3, has been extended to comprise the actual parameters, which were included in the analyses of this study. Here, the figure is used for a discussion what conclusions are legitimate and reasonable to draw on basis of the applied methods and data.

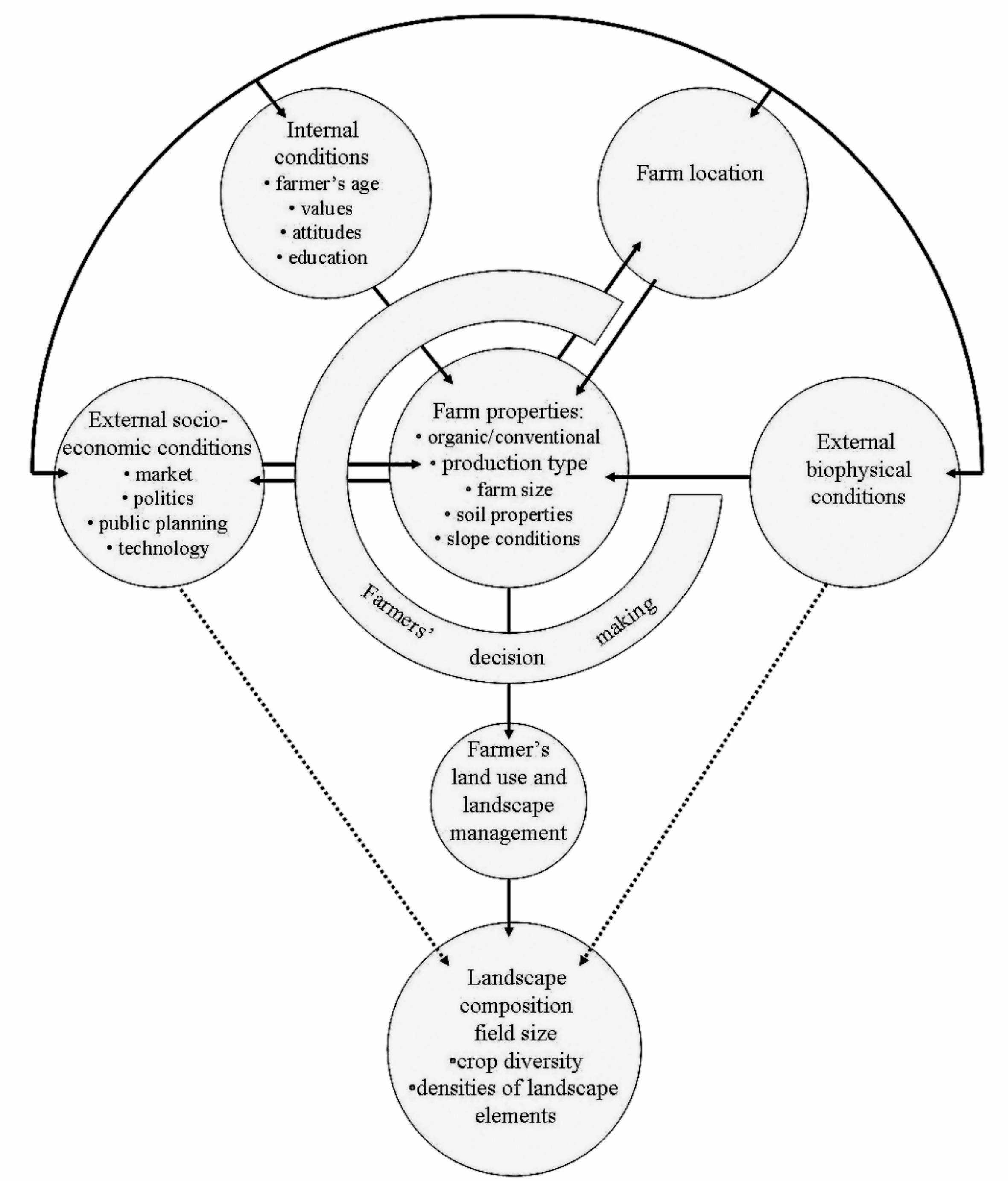

Figure 17: A conceptual framework for agriculture – landscape relations

In the conceptual framework for this study it was hypothesised that the physical appearance of agricultural landscapes in terms of spatial composition mainly is a result of farmers' land use and consequently their landscape management. Furthermore, it is assumed that the land use within a specific farm unit is related to farm specific properties in terms of the socio-economic, production and biophysical conditions characterising the farm unit. Finally, these farm specific properties are influenced by a number of both internal and external conditions, which themselves are interrelated.

Beyond the recognition of these relationships, the conceptual framework also assumes that farm properties and internal and external conditions as well as the farm properties and farmers' land use and landscape management are in principle linked together through the single farmers' decision making. In the figure, farmers' decision making is illustrated by the ring, which surrounds the farm properties and is crossed by the links to internal and external conditions on the one hand and to farmers' land use and landscape management on the other hand. This means that farmers' land use management is the result of his or her decision making within the frame given by the properties characterising the farm unit. Correspondingly, farm properties are the result of farmers' decision making within the framework of external and internal conditions.

In spite of this conceptual framework, the analyses applied within this study were limited to investigations of statistical relationships between these farm properties and parameters for landscape composition and structure (both are in the figure highlighted with italic letters). This has two main implications for the findings, which can be drawn from this study. First, the role of internal conditions characterising the single farmer and external conditions like market forces and agricultural policies were discussed as part of the background for the study but were not treated specifically in the analyses. Second, farmers' decision making as the central linkage between farm properties and external and internal conditions on the one hand and as linkage to farmers' land use management on the other hand has been discussed as conceptual framework but has not been specifically addressed through the applied methodologies.

Consequently, the applied methodologies as such allow for analyses of statistical relationships between farm conditions and landscape parameters. However, drawing causal explanations would in principle necessitate other, more qualitative approaches, like interviews with farmers. E.g. on basis of the analysis of national agricultural registers it can be concluded that the conversion to organic farming has a significant effect on changes in field sizes and in diversity of agricultural land uses. However, concluding that this relation is a result of the ban on chemicals on organic farms and thus a need for different rotation patterns implying a higher diversity of land uses and hence smaller field sizes would in principle necessitate interviews with farmers. As qualitative methods were not applied, the interpretation of the results from statistical analyses is based on hypotheses and assumptions about causal relationships. These assumptions are based on a general knowledge about Danish agriculture and on findings from other research. Being aware of the limitations of applied quantitative methods for causal explanations, the conclusions and perspectives, which are discussed in the next section, should, however, be reasonable.

6.3 The role of organic farming in the landscape

Relationships between organic farming and the landscape have particularly been investigated in paper 1. Papers 2 and 3 did not specifically address organic farming. However, organic farming, its relations to the landscapes and its effects on landscape change is the central issue of this thesis. Therefore the next section aims at discussing the findings of all three papers with focus on the role of organic farming in past and future development of agricultural landscapes. While findings and conclusions from the three papers to some degree are repeated, it is intended to broaden the discussion and to sketch out future perspectives of the role of organic farming. However, before going into a broader discussion, the next section aims at arguing for the relevance of this study.

The relevance of this study

Paper 1 contains a review of existing research on organic farming – landscape relationships. In this review several investigations were criticized to draw conclusions, which often are not justifiable on the basis of the applied data and methodologies. Inadequate sampling, small samples, inadequate recognition of multiple parameters and limited spatial and temporal scales were outlined as critical issues. On the basis of this review it was attempted to design a methodology, which incorporated these issues and thus was able to give a better understanding of the role of organic farming than was possible on the basis of the existing research.

Consequently, the question arises whether three years of study comprising a large amount of data and rather complex analyses are justifiable. It is thus relevant to examine whether results and findings from this study are able to confirm or disprove findings from other studies.

Among others, van Elsen (1997) argues that the conversion to organic farming implies the necessity to maintain nutrient balances through crop rotation, resulting in a larger diversity of crops. Analyses of national agricultural registers very clearly support this hypothesis. However, the hypothesis, that organic farmers are more active in the establishment of small uncultivated landscape elements as habitats for natural predators could not be supported on the basis of the current study.

Several authors suggest that as a result organic farmers' larger awareness of the environment, organic farming benefits agricultural landscapes, including densities of uncultivated natural land cover (ENTEC 1995, Larsen & Clausen 1995, Mander et al. 1999, Stolze et al. 2000, van Mansvelt et al. 1998). Farmers' environmental considerations were not specifically addressed in this study. However, in terms of densities of uncultivated landscape elements, the results and findings from this study do not support the suggestion that organic farming benefits agricultural landscapes. Consequently, although organic farmers might differ from conventional farmers with respect to their environmental considerations, the results and findings of this study do not support the hypothesis that such difference leads to differences in landscape management which induce higher densities of uncultivated landscape elements on organic farms.

As discussed earlier, the current study is limited in terms of the ability to explain casual relationships between organic farming and the landscape. But it must be concluded that on the basis of the applied methodologies the study contributes with new and important findings on organic farming – landscape relationships.

The impact of organic farming on the landscape

The empirical results from paper 1 indicated that the conversion to organic farming significantly influences landscape composition and structure. Compared to a general increase in field sizes and decreasing diversity of agricultural land uses, in the period between 1998 and 2004, conversion to organic farming was followed by significant increases in land use diversity and decreasing mean field sizes.

These results support following hypothesis. Rules and standards for organic farming include a general ban on chemicals including the application of chemical fertilizers. Consequently, organic farmers have to maintain nutrient balances in the soil through a crop rotation with a larger variety of crops. As a consequence, compared to conventional farms, organic farms are generally characterised by a higher diversity of agricultural land uses. As an increase in land use diversity necessitates a larger number of fields within the same farm unit, mean field sizes decrease. In conclusion, higher land use diversity and smaller field sizes are a consequence of organic farming practices, which themselves are induced by rules for organic farming.

Results at case area scale indicated that organic and conventional farms differed from each other with respect to soil properties, slope conditions and farm sizes. These parameters are themselves related to landscape composition and structure in terms of densities of different uncultivated landscape elements and in terms of mean field sizes. Differences in the landscape between organic and conventional farms are thus a consequence of differences in these parameters between organic and conventional farms. Also at national scale organic farms are characterised by higher percentages of peat soils and higher percentages of land with steep slopes. Assuming that the relation between soil and slope conditions and landscape composition, which were elucidated at case area scale are also valid at national scale, differences in soil and slope conditions between organic and conventional farms might result in differences in the landscape between the two farm types at national scale.

Furthermore at national scale, organic farms are slightly overrepresented among small farms. In 2004 about ½ of all organic farms were smaller than 25 ha, compared to 44% of all conventional farms. Assuming that the relation between farm size and landscape composition in terms of densities of uncultivated landscape elements also applies at national scale, the overrepresentation of organic farms among small farm sizes would indirectly result in higher densities of these landscape elements on organic farms. However, results in paper 2 also point to that present relations between densities of uncultivated landscape elements and farm sizes are a consequence of landscape changes which took place between 1982 and 2002. However, corresponding with the national scale, the majority of the investigated organic farms was converted in the second half of the 1990s. Furthermore, results point at only minor changes between 1995 and 2002. Together, these findings thus indicate that in general high densities of uncultivated landscape elements in 2002 are not the consequence of conversion to organic farming.

The benefits of organic farming as a production technique

With respect to organic farming as a farm or production type affecting the landscape, the two findings are very different. Changes in diversity of agricultural land uses and in field sizes can be assumed to be a direct consequence of organic farming practices and therefore of rules for organic farming. It is, however, unlikely that differences between organic and conventional farms with respect to farms sizes, soil properties and slope conditions and thus relations to landscape composition are direct consequence of standards and rules for organic farming. Furthermore, the question why organic farms differ from conventional farms with respect to these properties has not been addressed as part of this study.

These findings are highly relevant to the societal and political expectations to organic farming. As outlined in the background for this study both at the Danish and at the international level a positive effect of organic farming on agricultural landscapes is expected. As illustrated in Figure 18, organic farming as a specific kind of agricultural production technique has several positive effects on the environment. As rules and standards for organic farming embrace a general ban on chemicals, on organically farmed land no chemical fertilizers, herbicides or pesticides are applied. The ban on chemical herbicides and pesticides has a beneficial effect on the richness and diversity of farmland species and protects from groundwater contamination. In addition, the findings from this study extend the beneficial effects of organic farming to embrace benefits of organic farming on landscape composition and structure in terms of larger land use diversity and smaller field sizes, which consequently improve conditions for farmland species.

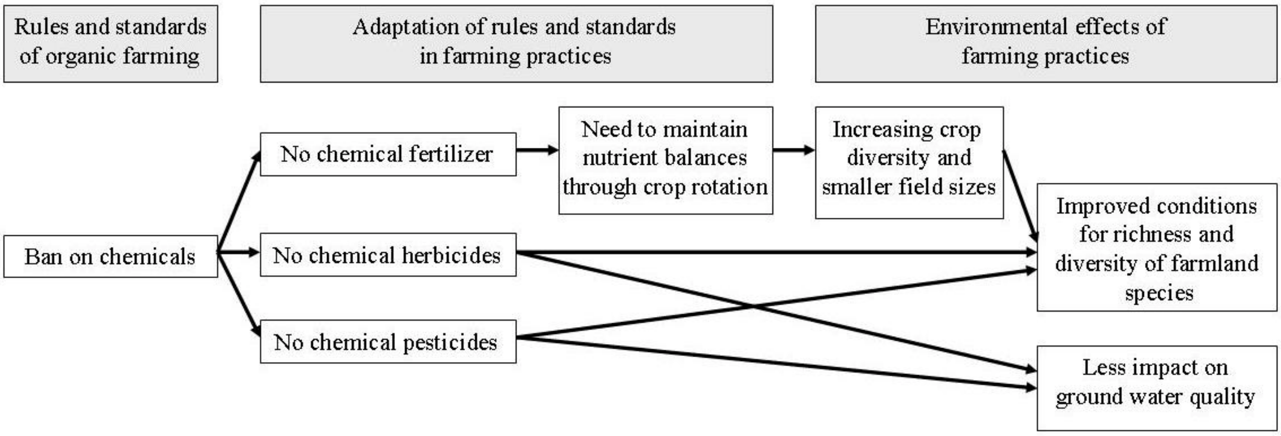

Figure 18: The environmental effects of organic farming in Denmark

In contrast, the findings of this study can not support the expectation of organic farming being characterised by a larger activity in terms of establishment of uncultivated landscape elements. Furthermore, the study points to higher densities of different uncultivated landscape elements on organic farms being an indirect consequence of other farm specific parameters, particularly farm size, and not of organic farming for itself.

Future perspectives for organic farming

As presented in paper 3, the recent structural development in Danish agriculture is characterised by a continued scale enlargement with a decreasing number of farms, increasing farm sizes and as a consequence increasing field sizes. Furthermore, future scenarios predict a continued scale enlargement. Recent increases in farm sizes apply for both conventional and organic farms. Agricultural registers show that from 1998 to 2004 organic farms increased at average by 32%. This increase is even considerably higher than for conventional farms (19%). Thus in general, scale enlargement in agriculture applies to both organic and conventional farms. However, analyses also pointed to organic farming weakening or even reversing trends of decreasing land use diversity and increasing field sizes. Although no estimates for future development of organic farm sizes exist, it is likely that future scale enlargement also will apply for organic farms. Presupposing that the beneficial effect of organic farming on land use diversity and field sizes also continues in the future, organic farming as a production technique would be able to weaken at least parts of the negative consequences of agricultural scale enlargement. However, in terms of stability of uncultivated landscape elements, it is not likely that organic compared to conventional farming will have a beneficial influence.

Integrating establishment of uncultivated landscape elements and higher stability of uncultivated landscape elements into organic farming would require an extension of existing rules and standards. As natural conditions and thus opportunities to establish uncultivated landscape elements highly varies between farms, a fixed standard for a certain percentage of uncultivated landscape elements on organic farms would be difficult to carry out. As mentioned earlier, a proposal for such a standard has already been rejected by the Danish organic farmers' movement. A different approach, which has proofed successful in several pilot projects, is the establishment and application of individual nature plans. By incorporating different, both environmental and production interests, nature plans can be a powerful tool to improve among other things the spatial composition of agricultural landscapes. However, the success of nature plans as well as of other schemes for landscape management highly depends on the willingness of farmers to apply such plans and on the societal and political willingness to financially support such schemes.

6.4 Perspectives for future research

This final section outlines perspectives for future research on organic farming – landscape relations. On the basis of the methodologies applied in this study as well as obtained results and findings, it is intended to give recommendations for the design of future studies. Hopefully, the recommendations will contribute to a better understanding of relationships between agriculture and agricultural landscapes in general and of the role of organic farming in particular.

Integrating additional information

The analyses for this study were based on farm specific information comprising the organic / conventional farming, production type, farm size and soil and slope conditions and as well as information on landscape composition comprising field sizes, land use diversity and densities of different landscape elements. Other parameters, providing more detailed information on farm characteristics, were discussed in the conceptual framework of the study, but were not included in the analyses. Information on part-time, hobby- or full-time farming as well as information on off-farm incomes would be highly relevant. Such data are not available from statistics or registers and would thus necessitate a questionnaire survey. A questionnaire survey would also provide the opportunity to derive information on types of landscape management, which can not be detected on basis of agricultural registers or on basis of aerial photos. Deriving additional farm specific data through a questionnaire survey would thus be a relevant task for future research on organic farming – landscape relations.

The need for qualitative approaches

As this study was based exclusively on quantitative data and statistical analyses, the opportunity to explain causal relationships was limited. Understanding how land use decisions and their effect on the landscape are related to farm properties and hence to external and internal parameters necessitates interviews with the farmers or land users, who actually make these land use decisions. It should, however, be intended to integrate qualitative and quantitative approaches. Constructing a spatial link between the farmer and the farm unit would provide an opportunity for such integration and thus enhance the explanatory power of investigations of organic farming – landscape relations.

Extending the spatial an temporal scale

Results from the case area investigation only apply to 112 farms within three case areas covering approx. 110 km². Although it was attempted to select case areas, which represent typical Danish landscape types, the data only represent a small section of Danish farms and of the Danish landscape. Even though aerial photo interpretation is very time consuming, extending the case area investigation to cover a larger part of the Danish landscape would make results and findings more general. Making use of data from other existing landscape registrations should be considered as a way to overcome the time consuming generation of aerial photo interpretation.

The majority of organic farms have been converted within the past 10 years. Particularly with respect to the establishment of uncultivated landscape elements, 10 years is a rather short time scale. In the light of this limited time scale; it would be relevant to follow this study up within the next 5 - 10 years. As a considerable conversion from organic back to conventional farming has taken place within recent years, following up the study in the future, would also provide an opportunity to investigate if this conversion to conventional farming if followed by landscape changes, reversing the beneficial effects of organic farming on land use diversity and field sizes, which were elucidated in this study.

The international perspective

Analyses, results and finding in this study only apply for Denmark. In terms of standards and rules and in terms of farm specific characteristics, organic farms and thus their relation to the landscape might be very different in other countries. To achieve a broader understanding of organic farming in terms of its relations to agricultural landscapes as well as its opportunities for landscape management, studies on organic farming – landscape relations within other countries are needed.

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Maps

Danish Institute of Agricultural Sciences (DIAS) 1998a: Map of field blocks 1998

Danish Institute of Agricultural Sciences (DIAS) 2001: Map of field blocks 2001

Danish Institute of Agricultural Sciences (DIAS) 2004: Map of field blocks 2004

Danish Institute of Agricultural Sciences (DIAS) 1998b: Basisdatakort (top-soil map) 1:50,000

Danish Plant Directorate 2001: Field maps 2001

National Survey and Cadastre (KMS) 2000a: Topographic map of Denmark 1:25,000

National Survey and Cadastre (KMS) 2001b: Cadastre map of Denmark 1:4,000

National Survey and Cadastre (KMS) 2000: Digital terrain model Denmark

Databases and Statistics

Ministry of Food Agriculture and Fisheries 1998: Agricultural registers 1998

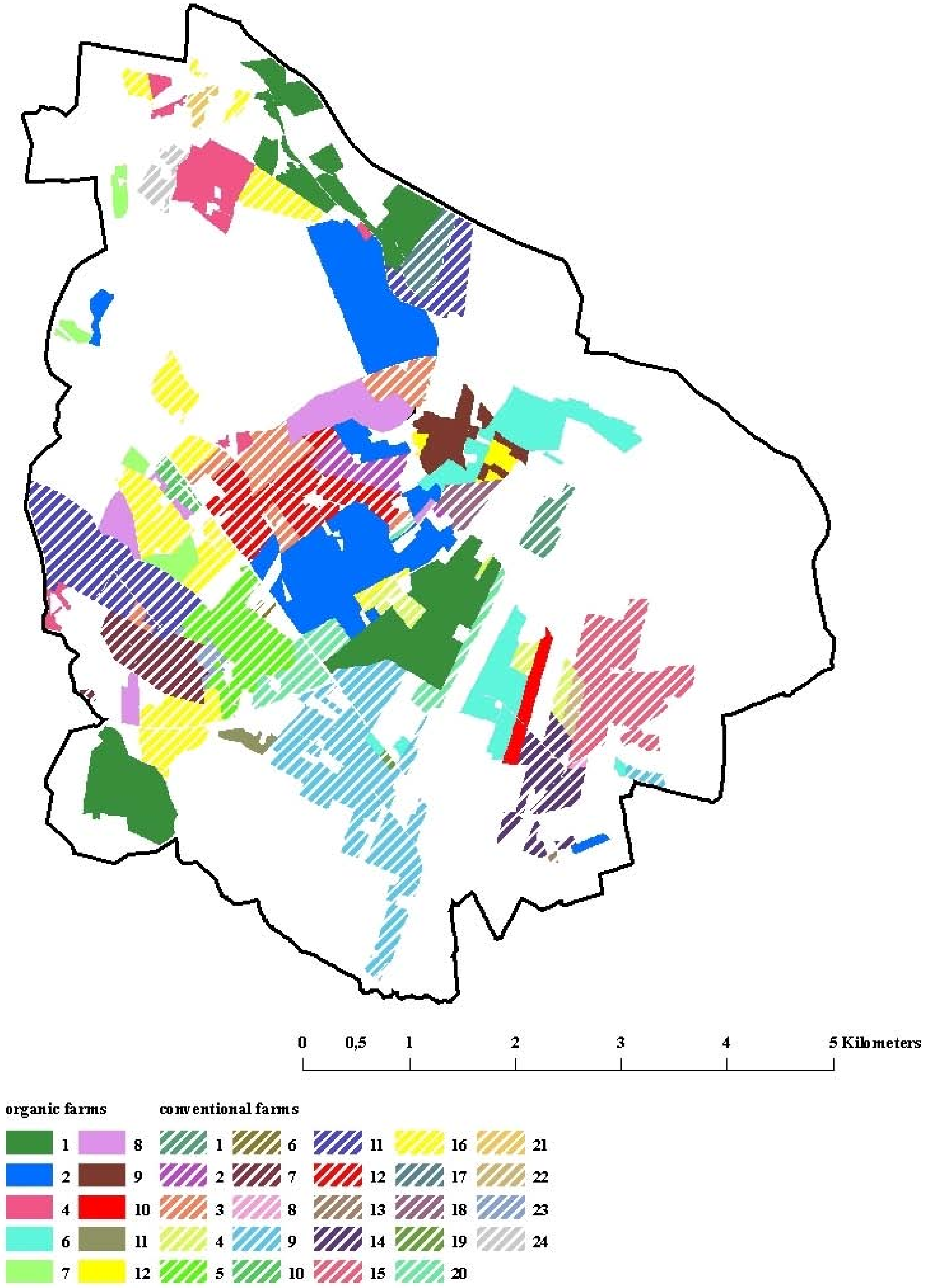
Ministry of Food Agriculture and Fisheries 2001: Agricultural registers 2001

Ministry of Food Agriculture and Fisheries 2004: Agricultural registers 2004

Statistics Denmark 2006: Agricultural statistics 1982-2004

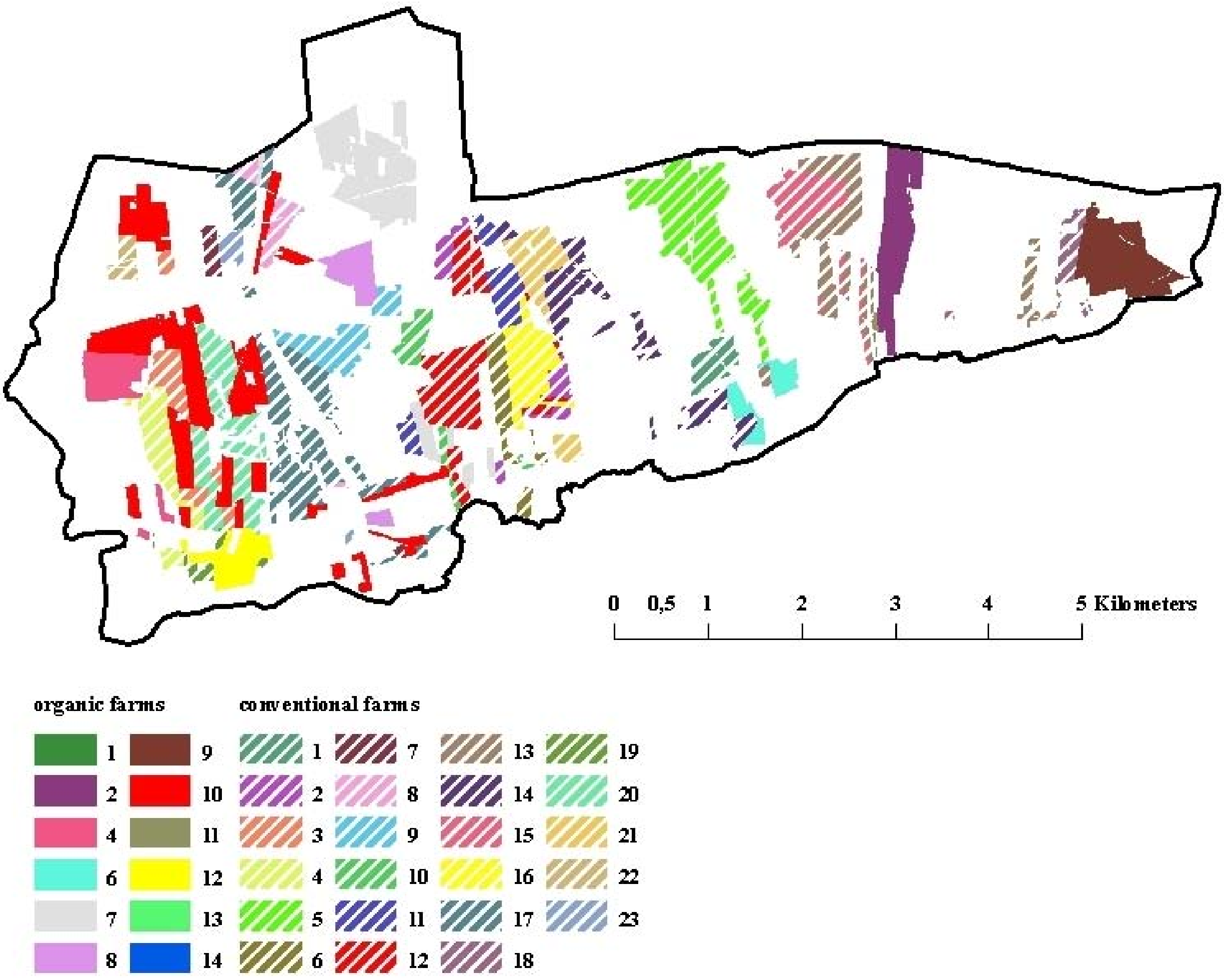
7 Appendixes

Appendix 7.1: Map of the 116 investigated farm units



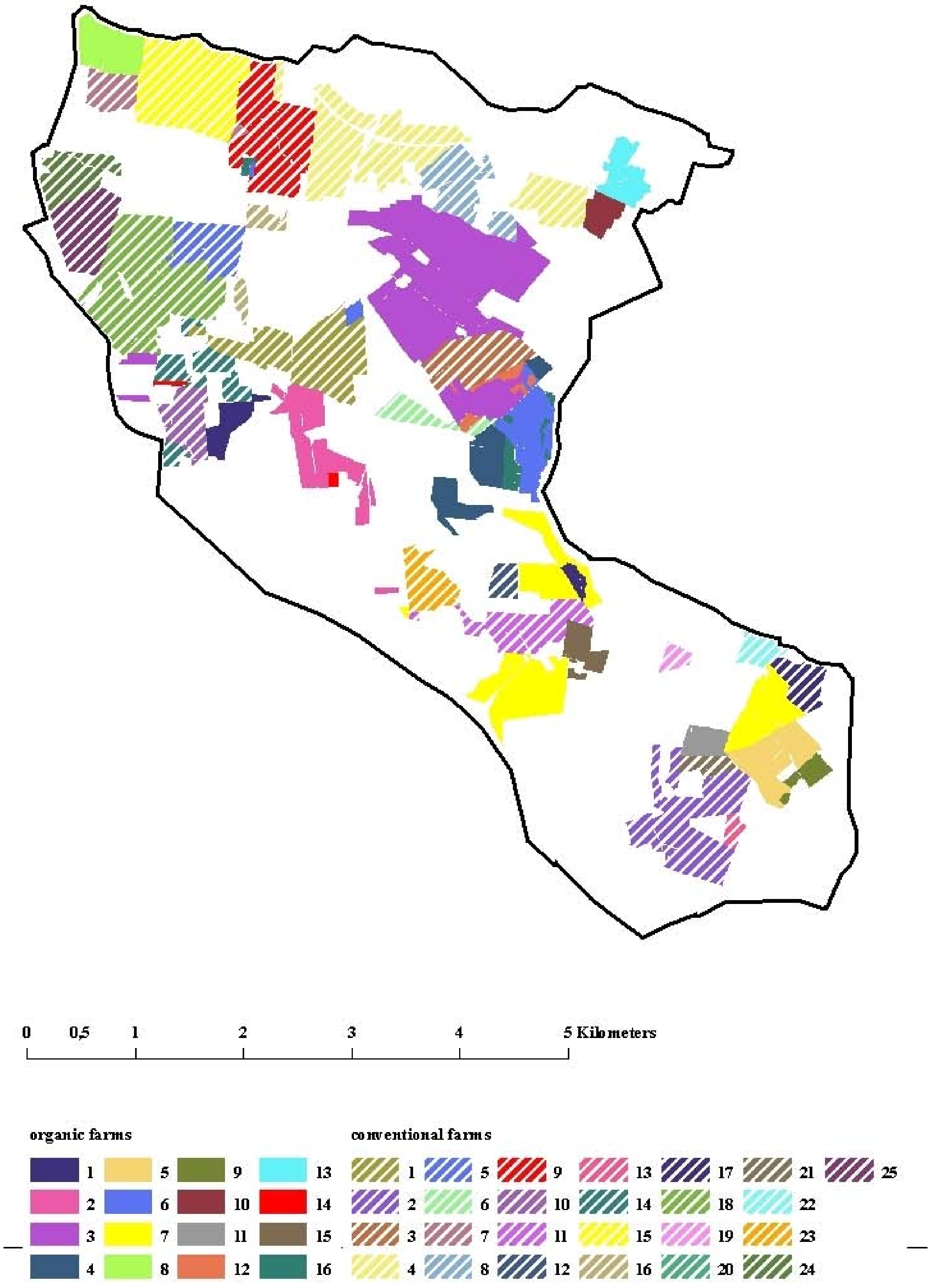
Appendix 1.1: Investigated farm units in Herning

Source: Field maps 2001, cadastral maps 2001, agricultural register 2001



Appendix 1.2: Investigated farm units in Randers

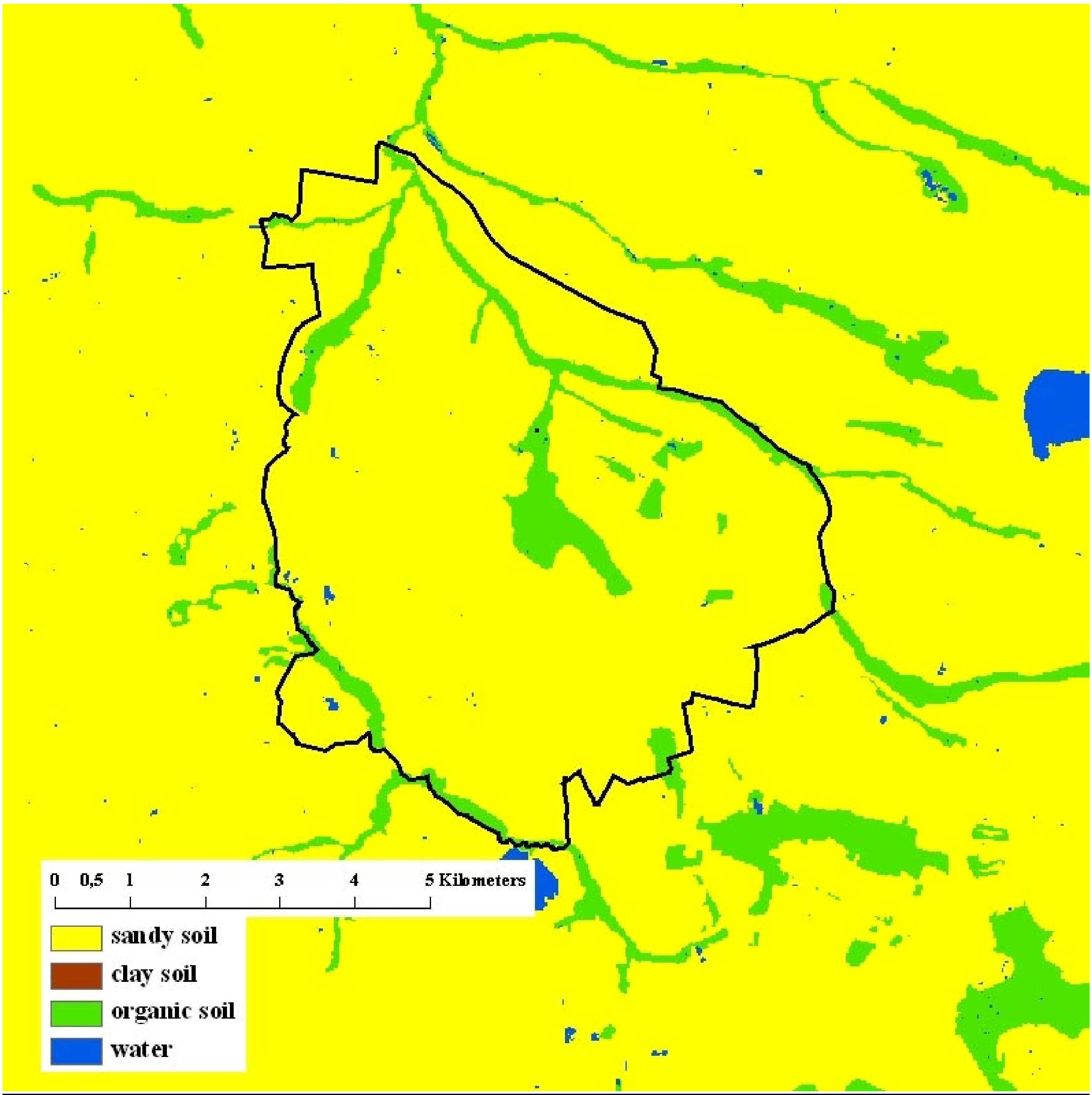
Source: Field maps 2001, cadastral maps 2001, agricultural register 2001



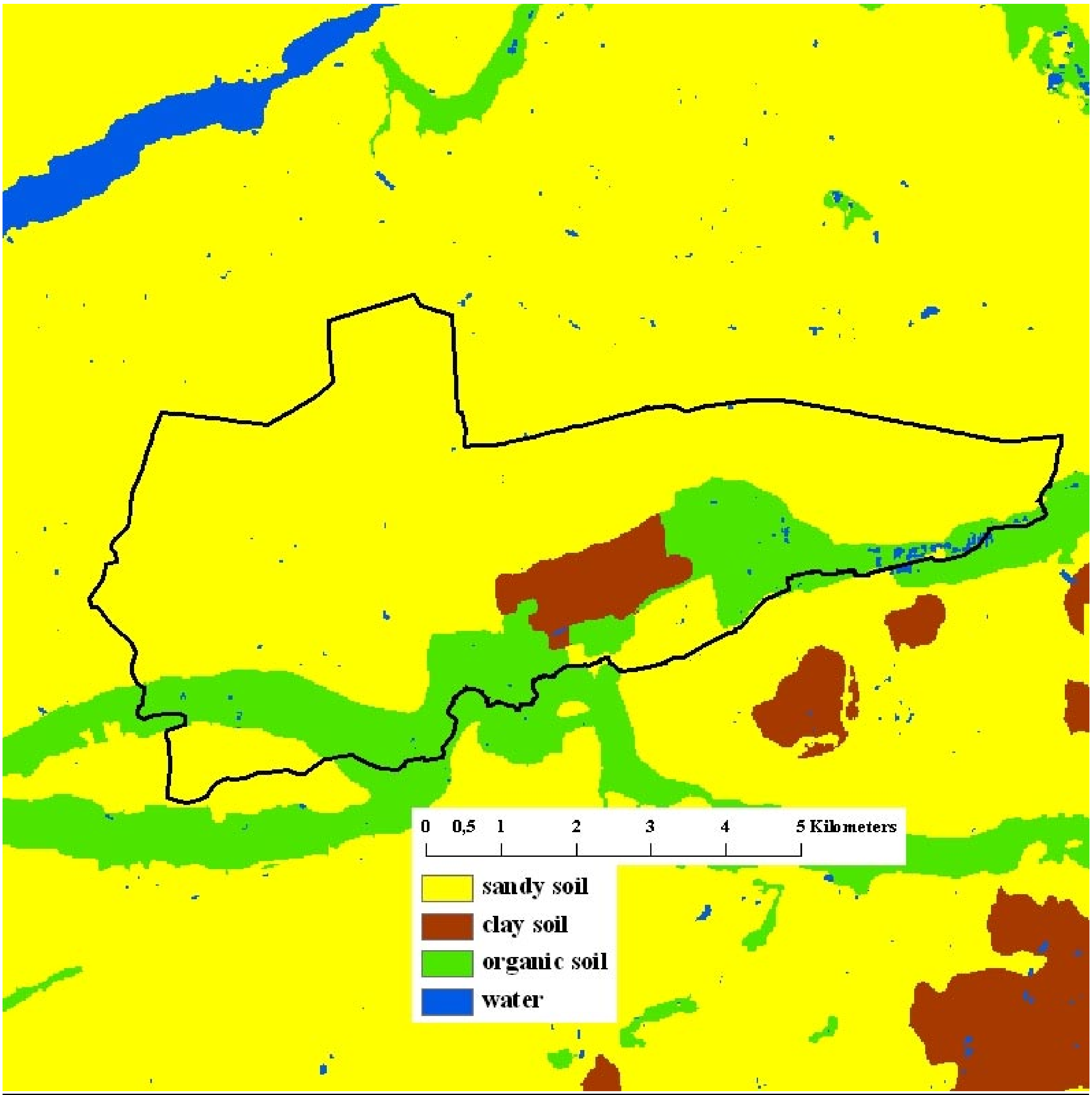
Appendix 1.3: Investigated farm units in Slangerup

Source: Field maps 2001, cadastral maps 2001, agricultural register 2001

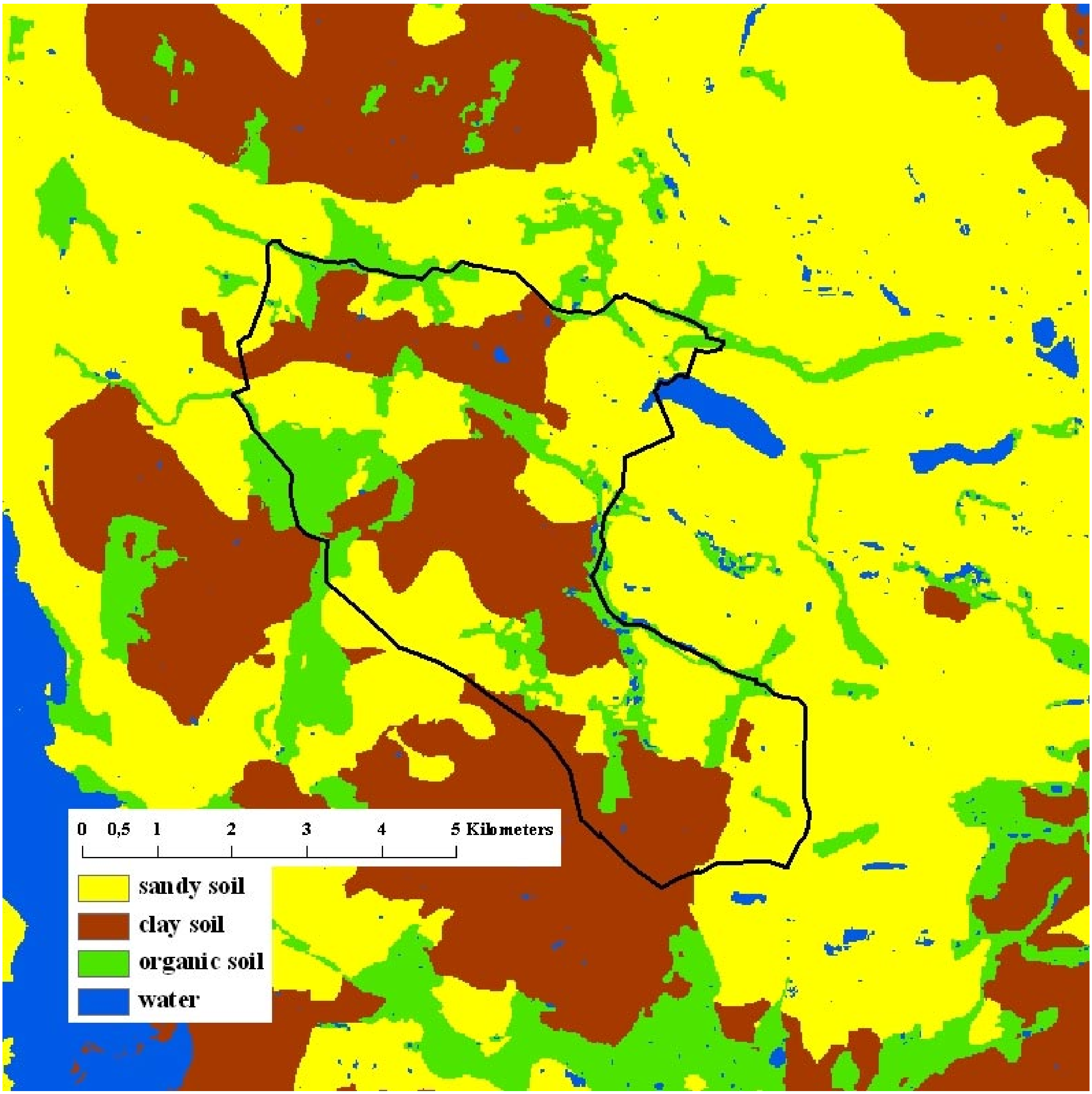
Appendix 7.2: Soil conditions in the three case areas



Appendix 2.1: Soil conditions in Herning
Source: National soil map (DIAS 1998b)

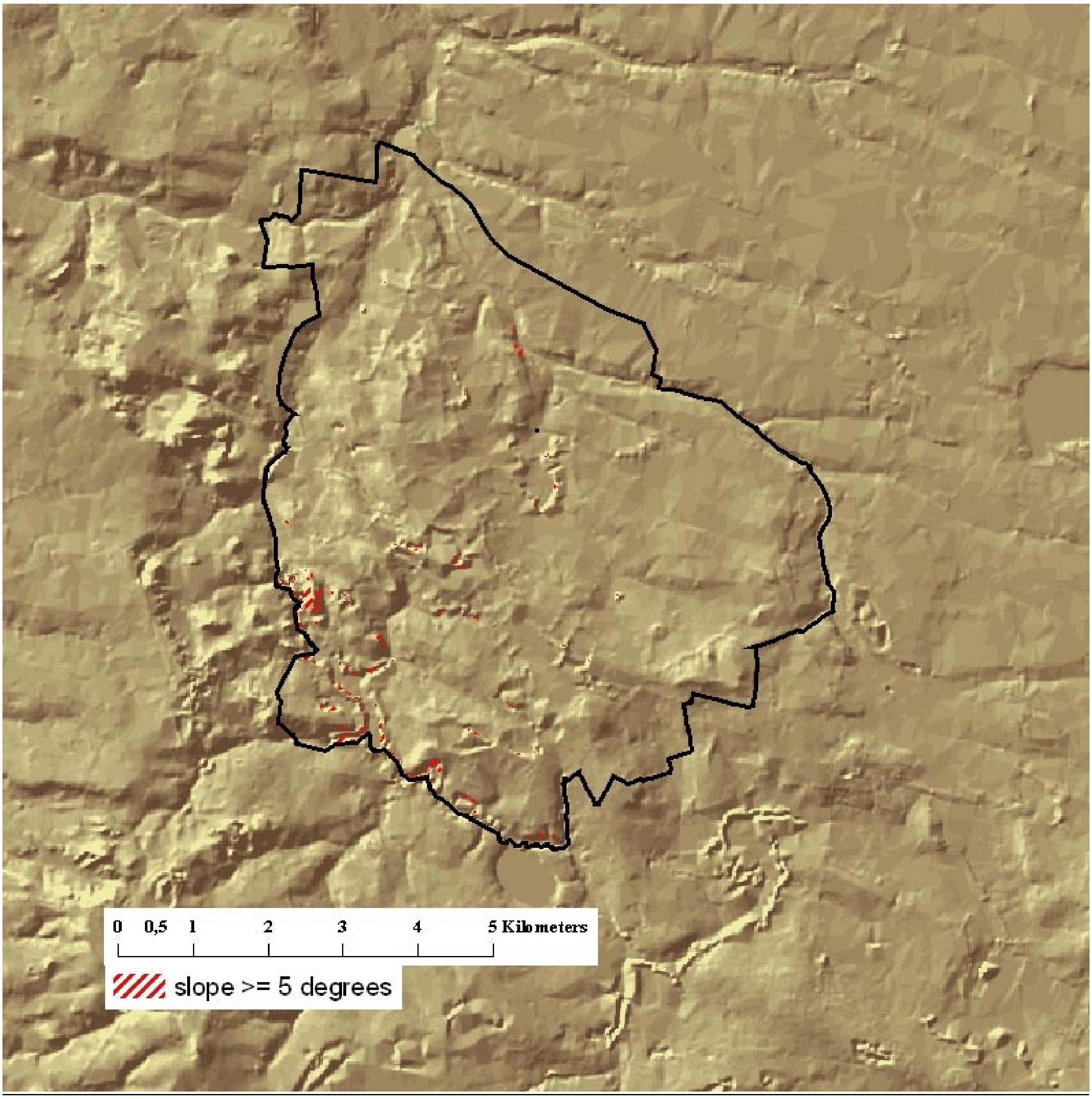


Appendix 2.2: Soil conditions in Randers
Source: National soil map (DIAS 1998b)



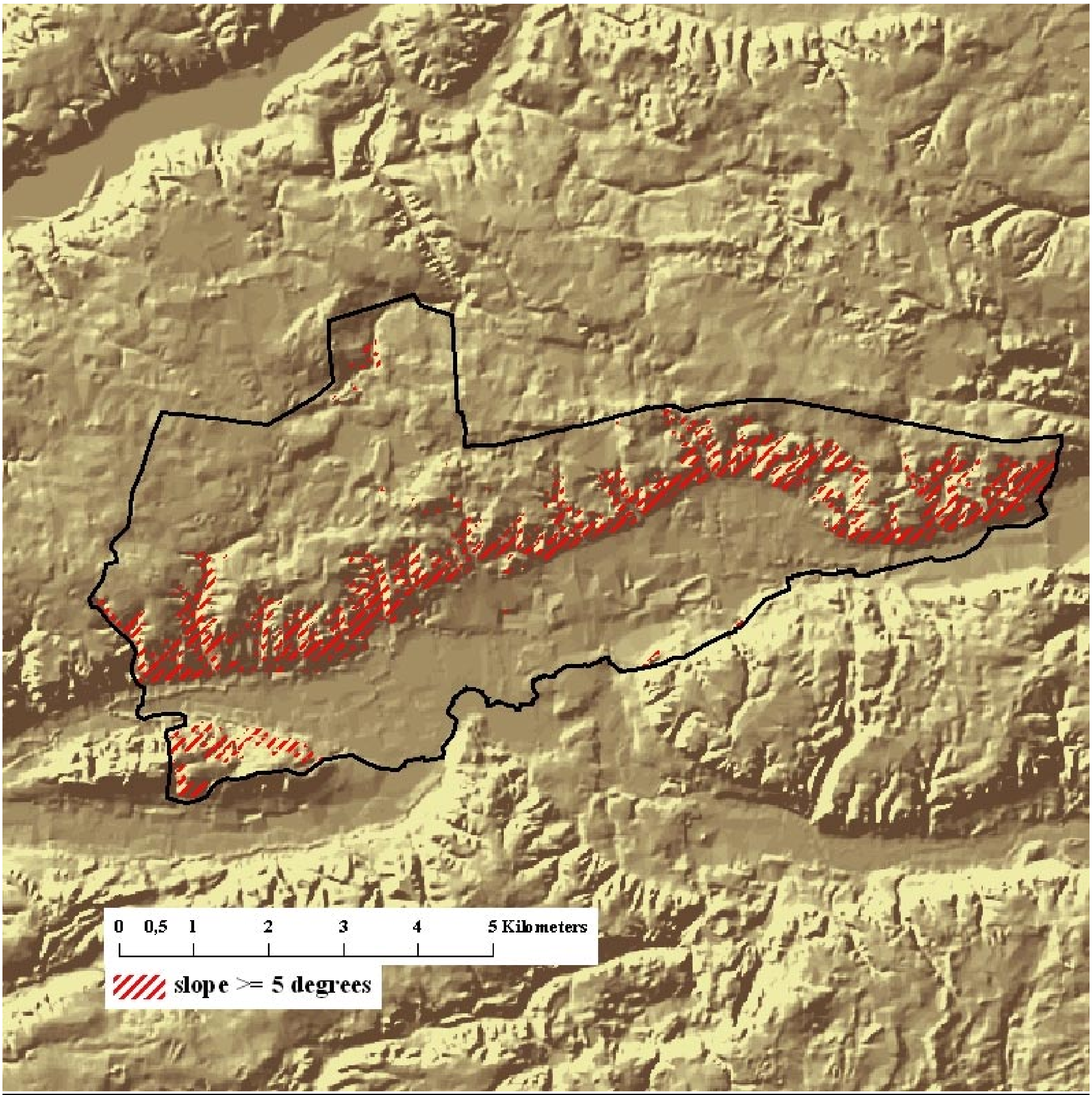
Appendix 2.3: Soil conditions in Slangerup
Source: National soil map (DIAS 1998b)

Appendix 7.3: Topographic conditions in the three case areas

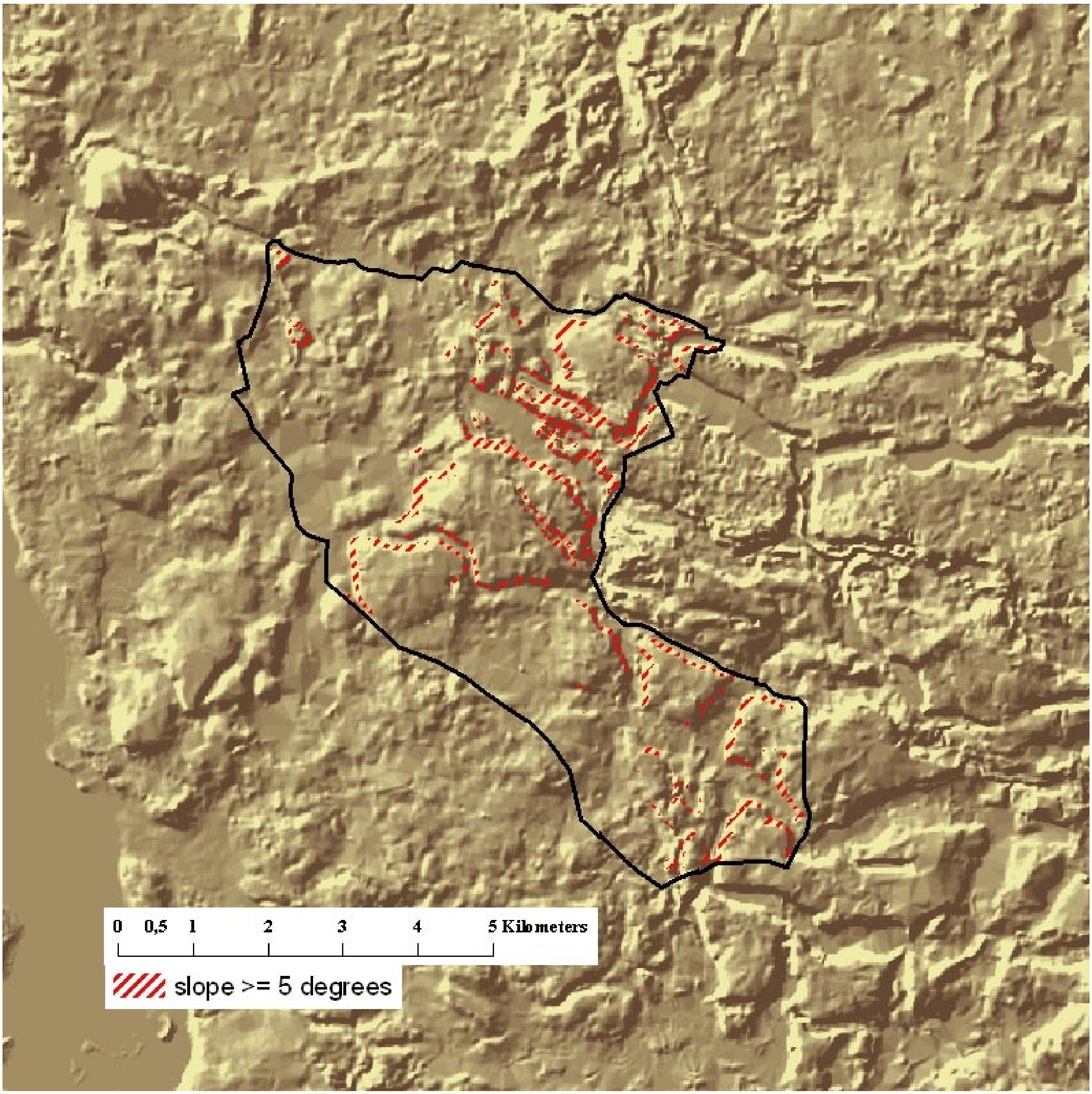


Appendix 3.1: Topographic conditions in Herning

Source: Digital terrain model of Denmark (KMS 2000)



Appendix 3.2: Topographic conditions in Randers
Source: Digital terrain model of Denmark (KMS 2000)



Appendix 3.3: Topographic conditions in Slangerup
Source: Digital terrain model of Denmark (KMS 2000)

Appendix 7.4: Land cover map of the three case areas based on aerial photo interpretation from 2002

The maps are appended as separate prints

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DMU Danmarks Miljøundersøgelser

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