Farm size and landscape composition in relation to landscape changes in Denmark

Gregor Levin

Abstract

This paper explores relationships between farm size and landscape composition in terms of densities of uncultivated landscape elements and sizes of agricultural fields. The study is based on national agricultural registers for Denmark and on aerial photo interpretation of three study areas, representing different Danish landscape types. Results indicate significantly smaller fields and significantly higher densities of uncultivated landscape elements on small farms (<25 ha). At national level, current differences between small and large farms are to some extent caused by landscape changes between 1998 and 2004. Analyses of the study areas indicate that current differences between small and large farms mainly evolved between 1982 and 2002, while the influences of changes between 1954 and 1982 are limited. Relationships between farms size and landscape composition are independent of spatial variations in soil type and slope conditions. Consequently, attention must be paid to other parameters linked to farm size. In particular, the effects on landscape composition of part-time and hobby farming, as well as production type, must be considered.

Keywords

Landscape changes, farms size, part-time farming, hobby farming, landscape structure, field divides, hedgerows, small biotopes, field size, aerial photo interpretation.

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Several investigations point at a relationship between farm size and landscape composition (Belfrage et al., 2005; Frederiksen & Langer, 2005; Levin et al., 2006; Stoate et al., 2001; Walford, 2005). In general, farm size is negatively related to sizes of agricultural fields and positively related to densities of uncultivated landscape elements. However, how current relations between farm size and landscape composition are influenced by landscape changes is not well studied.

Based on earlier investigations it can be argued that in Denmark farms <25 hectares (ha) are usually dominated by parttime and hobby farming (Frederiksen & Langer 2005; Kristensen 1999; Præstholm, 2002). It has been shown that while on fulltime farms the major motivation for landscape management is maximisation of agricultural production, on smaller parttime 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). It can thus be hypothesised that due to differences in motivations for landscape management, landscape composition varies between small and large farms.

A different hypothesis is that current relations between farm size and landscape structure are the result of landscape changes that have taken place over the last 5 decades approximately. Especially after WWII, Danish and other European agricultural landscapes have undergone substantial changes. As a consequence of technological improvements and agricultural policies encouraging production maximisation, landscape composition was adjusted to modern large scale farming through the merging of fields, drainage of wetlands and removal of uncultivated landscape elements (Agger et al., 1986; Holmes et al., 1998; Huston, 2005; Kristensen, 1999). However, this development has not been uniformly distributed over space. It has been shown that spatial variations in landscape changes are often affected by variations in physical geographic conditions of soil type and slopes (Jensen & Reenberg, 1980; Kristensen, 1999; Levin & Reenberg, 2002). It can, therefore, be assumed that current variations in landscape composition between small and large farms are a conse-

quence of their location in the context of variations in physical geographical conditions and thus of spatial variations in landscape changes over the past decades.

The aim of this paper is to explore relationships between farm size and landscape composition in terms of sizes of agricultural fields and densities of uncultivated landscape elements. The central question is in what time period current variations in landscape composition between small and large farms have evolved. Furthermore, the influence of spatial variations in soil type and slope conditions on landscape changes, and consequently on differences in landscape composition between small and large farms, is investigated.

Data and methodology

For this investigation two scale levels, giving rise to two different methodological approaches, were applied. For the national level, data for farm and landscape parameters for the whole of Denmark excluding the island of Bornholm were used. Due to biophysical conditions, which are very different from Denmark in general, it was decided to exclude the Island of Bornholm from this study. For the local level, three study areas representing different Danish landscapes and embracing 112 farms were investigated.

Data collection for the national level

With regard to the national level, for each farm unit in Denmark (excluding Bornholm), information on farm size was derived on the basis of the national agricultural registers for 1998 and 2004 (Ministry of Food, Agriculture & Fisheries, 1998; Ministry of Food, Agriculture & Fisheries, 2004). Landscape patterns were analysed in terms of field sizes and in terms of uncultivated grassland. Field sizes were defined as the size of each individual field plot 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 Food, Agriculture & Fisheries, 2005). For 1998 and 2004, information on field sizes and quantities of uncultivated grassland was derived for field blocks (Danish Institute of Agricultural Sciences, 1998a; Danish Institute of Agricultural Sciences, 2004). In Denmark, all agricultural land is split up into ca. 330,000 field blocks, which are functional units for authorities' administration of agricultural subsidies. Field blocks are continuous areas of agricultural land and are demarcated with boundaries, which are relatively stable over space and time. One field block can cover several agricultural fields. On the basis of national agricultural registers, the percentage of each farm unit within a given field block can be determined. Subsequently, for 1998 and 2004, approximations

Table 1: *Characteristics of the local study areas.*

	Herning	Randers	Slangerup
size (km²)	42.3	41.7	31.9
Geomorphology	Outwash plain from last glaciation	River valley formed under last glaciation	Ground moraine and kettle holes formed under last glaciation
Soil conditions	Predominantly sandy soils with few peat soils along water courses	Peat soils in valley bottom, sandy soils on valley sides and clay soils on upland areas	Mosaic of sandy, peat and clay soils
Slope >5 degrees (%)	1.1%	14.5%	9.2%
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%
Mean farm size (ha)	50.1	47.2	30.5
Number farms <25 ha	17	11	24
Number farms >25 ha	19	24	17
Mean farm size (ha)	50.1	47.2	30.5
Dominant farm types	Large full-time farms focusing on dairy production and pig breeding. Few part time and hobby farms.	Large full-time farms focusing on dairy and grain production. Few part time and hobby farms.	Small part-time and hobby farms with mixed production. Few large farms producing grain, fruits and vegetables.

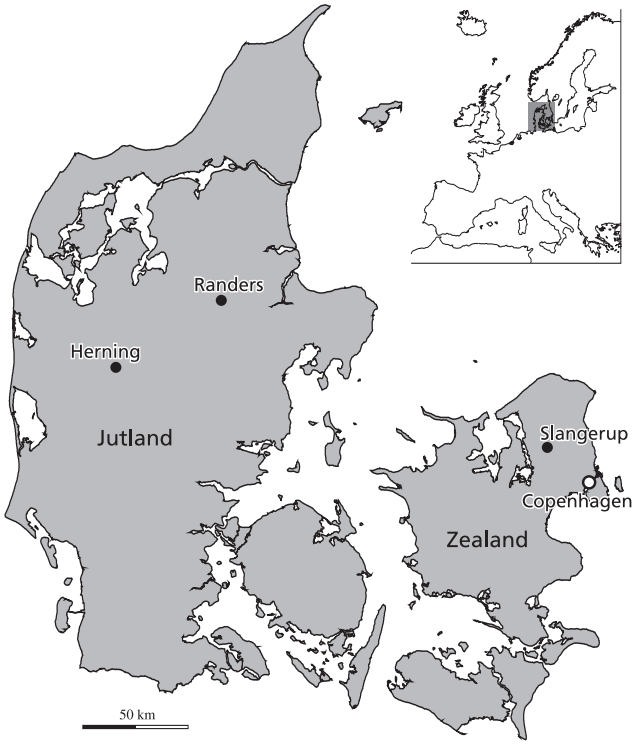

Figure 1: *Location of the study areas.*

of mean field sizes and of densities of uncultivated grass were calculated for each farm unit. Furthermore, changes in mean field size and in densities of uncultivated grass between 1998 and 2004 were calculated. By means of a spatial overlay between the field blocks, a national digital soil map (Danish Institute of Agricultural Sciences, 1998b) and a national digital terrain model (National Survey & Cadastre, 2004), for each farm unit, percentages of sand, clay and peat soils and percentages of land with slopes exceeding 5 degrees were estimated. The limit of 5 degrees was chosen as this, for Danish agriculture, generally represents the limit for the use of large machinery.

Data colle ction for the local level

In addition to national data, relationships between farm size and landscape patterns were investigated for three different study areas: two in Jutland (Herning and Randers) and one on Zealand (Slangerup) (Figure 1). The study areas, which are described in Table 1, were selected in order to represent different agricultural landscapes in terms of biophysical conditions and agricultural production, as well as in terms of their distance from major urban centres.

The three study areas include a total of 112 farms. Each farm unit was registered and demarcated using both maps of agricultural fields (Danish Plant Directory, 2002) and cadastre maps (National Survey & Cadastre, 2002). The demarcated farm areas embrace all owned land + rented land – land rented out. The selected 112 farms cover ca. 60% of the agricultural land within the study areas. The remaining agricultural land is managed by other farm units, which are not completely located within the study areas.

A land cover registration was carried out on the basis of visual interpretation of aerial photos from 1954 (National Survey & Cadastre, 1954), 1982 (National Survey & Cadastre, 1982) and 2002 (COWI, 2002). The registration embraces 18 land cover classes (Table 2). All landscape elements exceeding 20 m² were registered. The limit of 20 m² was chosen due to the resolution of the aerial photos (0.8 meters).

Although this was a census registration, focus was on uncultivated landscape elements. The landscape elements, which were chosen for this investigation are defined as follows:

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 patterns of cultivation.

Small biotopes are areas of uncultivated natural or

Table 2: *Land cover classes applied for interpretation of aerial photos.*

Line elements	Area elements
Road or path	Building / construction
Stream	Bare surface
Stream bank / lake shore with bare cover	Lake / pond
Stream bank / lake shore with vegetation cover	Forest / woodlot / shrub
Wet ditch	Forest plantation
Hedgerow	Uncultivated grass
Road verge with vegetation cover	Uncultivated grass with trees / shrubs
Field divide	Land in rotation
	Orchard / nursery
	Continuous urban area

seminatural land cover with an upper size limit of 2 ha. 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 ha is that small landscape elements are often patches located within cultivated farmland and thus are more exposed to the effects of agricultural practices than larger landscape elements. In this investigation, small biotopes comprise small ponds and lakes and small patches covered with trees, shrubs and/or herbs. Uncultivated grassland and uncultivated line elements, which Agger et al. (1986) included in the definition of small biotopes, are in this investigation treated individually as uncultivated grass, hedgerows and field divides.

Hedgerows are line elements covered with tree and/or shrub vegetation. Line elements are defined as elements with a length of at least 10 meters, a width of 1-10 meters and a length – width ratio of at least 5:1. The minimum width was chosen because the resolution of aerial photos hinders the registration of widths under 1 meter. The width of hedgerows is measured as the crown cover.

Field divides are line elements covered by grass and/or herb vegetation but no trees or shrubs. Field divides <1 meter in width were not invented as landscape elements but were registered as the demarcation of transitions between agricultural fields.

Uncultivated grasslands are areas covered by grass or herb vegetation without signs of recent cultivation and ploughing. Compared to cultivated land or grass in rotation, areas of uncultivated grass usually appear heterogeneous in spatial texture and colour.

Around the farm size of 25 ha, there exists a general threshold in the relationship between farm size and field size, and between farm size and densities of the selected landscape elements (Figure 2). Therefore, for all analyses, farms were divided into farms <25 ha and farms >25 ha.

The three study areas were split up into a grid with a cell size of 100 x 100 meters. This resolution was chosen because it is fine enough not to embrace variations in landscape composition, soil types, slopes and the location of farm units. A finer resolution would have resulted in a very large number of grids, which would have been difficult to handle with the use of GIS and statistics. By means of a spatial overlay with land cover maps, mean field sizes and densities of the applied landscape elements for each cell were calculated. Changes in mean field sizes and densities of landscape elements were calculated for the period 1954 to 1982, and 1982 to 2002. Furthermore, with the map of farm units, the respective farm unit for each cell was registered. Finally, for each cell, by means of a spatial overlay with soil maps and a terrain model, the dominant soil type and the proportion of land with slopes <5 degrees were calculated.

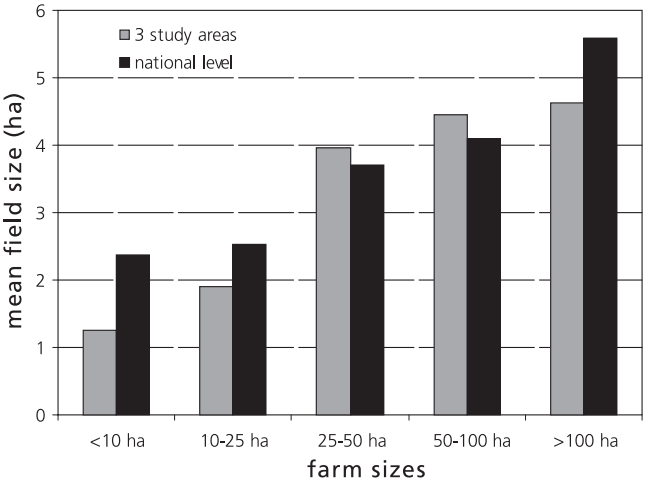

Figure 2: *Relationships between farm size and field size in Denmark (excl. Bornholm) in 2004 and in the three study areas in 2002.*

For both the national and the study area analysis, it is important to stress that the applied farm units, and thus farm sizes, represent the present situation, i.e. 2002 at local level and 2004 at national level. Analyses of landscape change in relation to farm size, therefore, explore the changes which took place in areas that, at present, are managed by small and large farms respectively. Information on whether these areas were managed by the same farms in earlier years was not available and is not included. Consequently, although it would be relevant, this study is not able to directly link farm specific parameters to landscape changes.

Statistical analysis

Relationships between farm size and landscape patterns 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 the investigated landscape elements, as well as changes in field sizes and in densities of the landscape elements. Independent variables were small farms (<25 ha) and large farms (>25 ha), soil type and proportion of land with slopes >5 degrees.

	N	Mean field size in 2004 (ha)	Density uncultivated grass in 2004 (% of farm unit)
farms < 25 ha	20861	2.63	9.27%
farms > 25 ha	25945	4.31	6.16%
significance of difference*		***	***

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

Table 3: *Differences in mean field size and in density of uncultivated grass between large and small farms in Denmark in 2004 (excl. Bornholm), (Ministry of Food Agriculture & Fiskeries, 2004; Danish Institute oa Agricultural Sciences, 2004).*

Results

Relationships between farm size, field size and landscape elements

National level

For the national level, differences in field sizes and in the density of uncultivated grassland between small and large farms are summarised in Table 3. There exists a strong positive relation between large farms and mean field size and a strong negative relation between large farms and densities of uncultivated grass. Although calculations show that farm sizes in general are smaller in eastern Denmark, differences in landscape composition between small and large farms are independent of this regional variation in farm sizes.

Local level

At local level, clear and significant relations between farm size and landscape composition were found (Table 4). Corresponding with the national sample, mean field sizes are significantly smaller on small farms. Densities of small biotopes, hedgerows and field divides are significantly higher on small farms. No significant difference in density of uncultivated grass between small farms and large farms was found.

The influence of landscape changes

Changes in field sizes and densities of landscape elements

For the three at local level, landscape changes are summarised for the periods 1954 to 1982 and 1982 to 2002. From 1954 to 1982 all study areas were characterised by substantial increases in field sizes and decreasing densities of small biotopes, field divides and uncultivated grass (Table 5). During the same period, densities of hedgerows increased, particularly in Herning.

The period 1982 to 2002 shows different directions of landscape change. While Herning and Randers are characterised by a continued but weaker increase in field size and a continued but weaker decrease in densities of field divides and small biotopes, opposite changes of decreasing field sizes and increasing densities of small biotopes and field divides characterise Slangerup.

Landscape changes in relation to physical geographical conditions of soil type and slope

Figure 3 illustrates landscape changes in the three study areas from 1954 to 1982 and from 1982 to 2002 in relation to soil types and slopes. In all study areas, the proportion of uncultivated grass on peat soils decreased gradually from 1954 to 2002 (Figure 3(A)). Furthermore, from 1954 to 2002, uncultivated grassland on slopes exceeding 5 degrees almost disappeared (Figure 3(B)). Particularly from 1954 to 1982, the area of small biotopes located on peat soils decreased (Figure 3(C)), while the area of small biotopes on slopes >5 degrees was stable or even in-

Table 4: *Differences in mean field size and in densities of landscape elements between large and small farms in the three study areas in 2002. (Aerial photo interpretation, field maps 2002, cadastre maps 2002)*

	Mean field size (ha)	Density of hedgerows (% of area)	Density of field divides (% of area)	Density of small biotopes (% of area)	Density of uncultivated grass (% of area)
farms < 25 ha	1.80	2.29%	0.69%	8.35%	13.99%
farms > 25 ha	3.38	1.36%	0.50%	4.69%	14.77%
significance of difference*	***	**	**	**	ns

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

				change per year	
Mean field size (ha)	1954	1982	2002	1954 - 1982	1982 - 2002
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	1982 - 2002
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	1982 - 2002
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	1982 - 2002
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	1982 - 2002
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%

Table 5: *Landscape changes from 1954-1982 and from 1982-2002 in the three study areas. (Aerial photo interpretation).*

creased (Figure 3(D)). Both increases in field sizes and decreases in field divides were significantly higher on clay and sand soils than on peat soils (Figure 3(E+F)). Throughout the investigated periods, the largest proportion of cultivated land was found on sand and peat soils. Conse-quently, the influence of agricultural development on landscape patterns, characterised by increasing field sizes and decreasing densities of field divides, was most pronounced on sand and peat soils. Finally, throughout the investigated period, increases in hedgerows in Herning and Randers were most pronounced on sand soils (Figure 3(G)).

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

A central aim of this study is to explore how present differences in landscape composition between small and large farms are related to landscape changes. Therefore, for the present location of each farm unit, i.e. the area which at present is managed by the specific farm, landscape changes were investigated. At the national level, changes in field sizes and density of uncultivated grass from 1998 to 2004 were investigated for farm units in 2004. At local level, changes in field sizes and densities of hedgerows, field divides, small biotopes and uncultivated grass were investigated for farm units in 2002.

At national level, mean field sizes remained almost stable in areas managed by small farms in 2004, while areas managed by large farms were characterised by a significant increase in mean field sizes (Table 6). Already in 1998, field sizes were significantly higher in areas managed by large farms. But, due to a more significant change in areas managed by large farms, this difference became significantly greater in 2004.

National data also point at differences in the development of uncultivated grass between 1998 and 2004 (Table 6). Areas managed by small farms in 2004 were characterised by significantly larger increases than in areas managed by large farms. Present differences in densities of uncultivated grass between small and large farms have thus been strengthened.

Generally, both increases in mean field sizes and in densities of uncultivated grass were larger in western Denmark. However, differences between areas managed by small farms and areas managed by large farms in 2004 are independent of this regional factor.

Analyses of landscape changes at national level are limited to the six years between 1998 and 2004, which is a rather limited time horizon. Furthermore, national data only allow for investigations of field sizes and unculti-

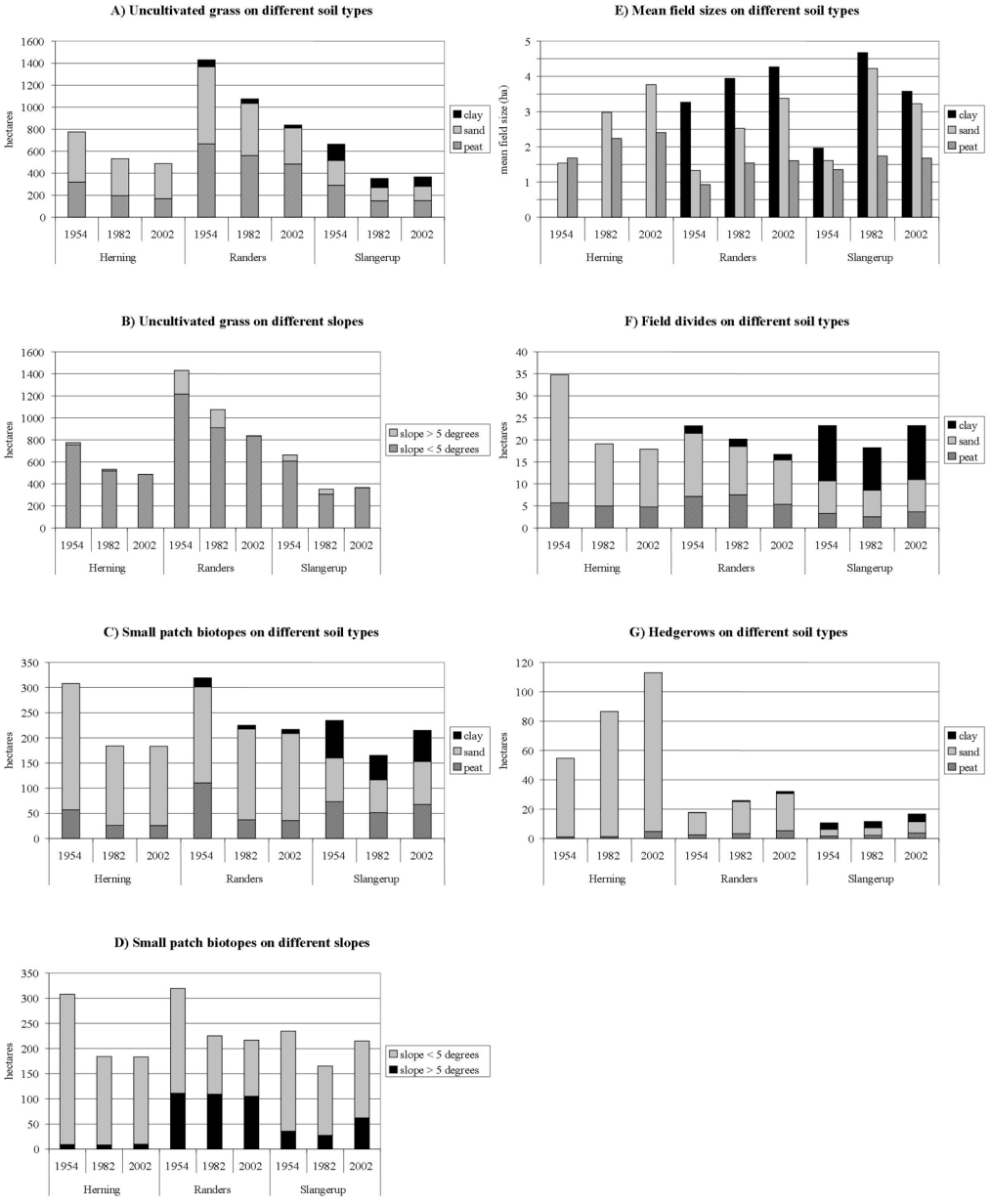

Figure 3: *Relationships between landscape composition and physical geographical conditions of soil types and slope in the three study areas in 1954, 1982 and 2002.*

Table 6: *Landscape changes 1954-1982 and 1982-2002 in relation to farm sizes in 2002 in the three study areas. (Aerial photo interpretation, field maps 2002, cadastre maps 2002)*

Mean field size (ha)							
	1954	1982	change per year 1954-1982	direction of change 1954-1982	2002	change per year 1982-2002	direction of change 1982-2002
<25 ha	0.98	1.79	0.14	increase	1.82	0.01	stable
>25 ha	1.36	2.73	0.23	strong increase	3.40	0.11	increase
significance of difference*	**	**	***		***	***	
Density of uncultivated grass (% of area)							
	1954	1982	change per year 1954-1982		2002	change per year 1982-2002	
<25 ha	22.42%	18.23%	-0.70%	decrease	14.96%	-0.55%	decrease
>25 ha	25.98%	18.19%	-1.30%	strong decrease	14.42%	-0.63%	decrease
significance of difference*	**	ns	**		ns	ns	
Density of hedgerows (% of area)							
	1954	1982	change per year 1954-1982		2002	change per year 1982-2002	
<25 ha	0.80%	1.26%	0.08%	increase	2.28%	0.17%	increase
>25 ha	0.76%	1.14%	0.06%	increase	1.40%	0.04%	stable
significance of difference*	ns	ns	ns		***	***	
Density of field divides (% of area)							
	1954	1982	change per year 1954-1982		2002	change per year 1982-2002	
<25 ha	0.72%	0.52%	-0.03%	decrease	0.70%	0.03%	increase
>25 ha	0.70%	0.48%	-0.04%	decrease	0.50%	0.00%	stable
significance of difference*	ns	ns	ns		***	***	
Density of small biotopes (% of area)							
	1954	1982	change per year 1954-1982		2002	change per year 1982-2002	
<25 ha	0.74%	0.62%	-0.02%	decrease	0.84%	0.04%	increase
>25 ha	0.74%	0.44%	-0.05%	decrease	0.47%	0.01%	stable
significance of difference*	ns	***	***		***	***	

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

vated grasslands. Therefore, for the local level, present differences in landscape composition between small and large farms were investigated in relation to landscape changes over the last 50 years.

In general, analyses at local level indicate that present differences in landscape composition between small and large farms mainly evolved in the period from 1982 to 2002 (Table 7). Landscape changes from 1954 to 1982 were, as described earlier, considerable, but did not vary strongly between areas managed by, respectively, small and large farms in 2002.

From 1954 to 1982 mean field sizes increased consid-

Mean field size (ha)	1954	1982	change per year 1998-2004	direction of change 1998-2004
<25 ha	3.4	3.5	0.02	stable
>25 ha	4.8	5.4	0.10	increase
significance of difference*	***	***	***	

Density of uncultivated grass (% of area)	1954	1982	change per year 1998-2004	direction of change 1998-2004
<25 ha	5.20%	6.94%	0.29%	strong increase
>25 ha	4.91%	5.61%	0.12%	moderate increase
significance of difference*	***	***	***	

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

Table 7: *Changes in mean field sizes and in density of uncultivated grass 1998-2004 in relation to farm sizes in 2004 in Denmark (excl. Bornholm).*
(National agricultural register 1998 and 2004, map of field blocks 1998 and 2004).

erably. However, while from 1982-2002 increases in mean field sizes continued in areas managed by large farms in 2002, for 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 large degree, a result of differences in changes over the past 20 years. In all areas, densities of small biotopes decreased considerably until 1982. After 1982, areas which were managed by small farms in 2002 are characterised by significantly larger increases in densities of small biotopes. A similar tendency can be observed for field divides. Until 1982, densities of field divides decreased in all areas. However, the period from 1982 to 2002 is characterised by significantly stronger increases in areas managed by small farms compared to areas managed by large farms in 2002. Throughout both investigated time periods, hedgerow densities increased strongly. Between 1982 and 2002 densities of hedgerows increased at a significantly higher rate in areas which were managed by small farms in 2002, compared to areas managed by large farms. Finally, from 1954 to 1982 and from 1982 to 2002, densities of natural grass generally decreased both in areas managed by small farms in 2002 and areas managed by large farms.

Table 8: *Differences in soil types and slopes between small and large farms in 2004 in Denmark (excl. Bornholm).*
(Source: National agricultural register 2004, map of field blocks 2004, soil map, digital terrain model)

		slopes > 5 degrees (% of farm unit)	clay soils (% of farm unit)	sand soils (% of farm unit)	peat soils (% of farm unit)
Whole Denmark	farms < 25 ha	0.4%	33.5%	61.8%	4.2%
	farms > 25ha	0.3%	32.1%	62.2%	5.1%
	significance of difference*	***	ns	ns	***
East Denmark **	farms < 25 ha	0.5%	49.8%	42.3%	2.9%
	farms > 25 ha	0.4%	49.2%	44.2%	3.5%
	significance of difference*	***	ns	ns	***
West Denmark ***	farms < 25 ha	0.3%	12.6%	77.2%	4.8%
	farms > 25 ha	0.2%	11.8%	76.6%	6.3%
	significance of difference*	***	ns	ns	***

* *significance levels: p<0,05=**, p<0,001=***, ns= not significant*
** *East Denmark: County of Frederiksborg, County of Fyn, County of København, County of Roskilde, County of Storstrøm, County of Vejle, County of Vestsjælland, County of Århus.*
****West Denmark: County of Nordjylland, County of Ribe, County of Ringkøbing, County of Sønderjylland, County of Viborg.*

Table 9: *Differences in soil types and slopes between small and large farms in 2002 in the three study areas. (Source: Aerial photo interpretation, field maps 2002, cadastre maps 2002, soil map, digital terrain model)*

		slopes > 5 degrees (% of farm unit)	clay soils (% of farm unit)	sand soils (% of farm unit)	peat soils (% of farm unit)
Herning	farms < 25 ha	0.0%	-	86.3%	13.6%
	farms > 25 ha	1.8%	-	84.7%	15.1%
	significance of difference*	**	-	ns	ns
Randers	farms < 25 ha	10.9%	6.2%	70.7%	21.4%
	farms > 25 ha	12.9%	3.3%	71.2%	25.1%
	significance of difference*	ns	ns	ns	ns
Slangerup	farms < 25 ha	10.0%	31.1%	45.8%	20.8%
	farms > 25 ha	8.7%	40.5%	34.2%	24.3%
	significance of difference*	ns	**	***	Ns

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

Relations between farm size and landscape composition in relation to variations in soil type and slope

As has been shown for the local level, landscape composition and landscape changes are related to soil type and slope conditions. Therefore, variations in these conditions, and their influence on present differences in landscape composition between small and large farms were investigated.

At the national level, small farms are characterised by significantly higher percentages of slopes exceeding 5 degrees and significantly smaller percentages of peat soils (Table 8). Considerable regional variations in both soil

farm size	slopes > 5 degrees (% of farm unit)	Mean field size in 2004 (ha)	Change in mean field size 1998-2004 (ha)
all farms	0	3.63	0.05
all farms	0-0,25	3.37	0.03
all farms	0,25-0,5	3.15	0.02
all farms	>0,5	2.82	-0.01
significance of difference*		***	***
farms < 25 ha	0	2.65	-0.07
farms > 25 ha	0	3.96	0.11
significance of difference*		***	***
farms < 25 ha	0-0,25	2.50	-0.15
farms > 25 ha	0-0,25	4.01	0.11
significance of difference*		***	***
farms < 25 ha	0,25-0,5	2.47	-0.09
farms > 25 ha	0,25-0,5	3.60	0.09
significance of difference*		***	***
farms < 25 ha	>0,5	2.49	-0.03
farms > 25 ha	>0,5	3.23	0.00
significance of difference*		***	***

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

Table 10: *Changes in mean field sizes 1998-2004 in relation to farm sizes and slopes in Denmark (excl. Bornholm).*

(Source: National agricultural register 1998 and 2004, map of field blocks 1998 and 2004, digital terrain model)

and slope conditions exist. Generally, percentages of slopes exceeding 5 degrees and of clay soils are highest in the counties of East Denmark while percentages of peat and sandy soils are highest in the counties of West Denmark. Yet, dividing this analysis between East and West Denmark shows that differences between small and large farms are independent of regional differences in soil types and slopes. In comparison, analyses at study area level point to only a few significant differences between areas managed by small farms and areas managed by large farms (Table 9).

At national level, mean field sizes are smaller on farms with a high percentage of slopes exceeding 5 degrees. While in the period from 1998 to 2004 mean field sizes generally increased, high percentages of slopes are related to a relative stability in mean field sizes (Table 10). Yet, in 2004 small farms with a high percentage of slopes >5 degrees do have significantly smaller mean field sizes compared to large farms with a high percentage of slopes >5 degrees. Furthermore, from 1998 to 2004, areas managed by large farms in 2004 and with a low percentage of slopes >5 degrees are characterised by significantly stronger increases in field sizes compared to small farms with a low percentage of slopes >5 degrees. Consequently, differences in field sizes and changes in field sizes between small and large farms are independent of variations in slope conditions.

Between 1998 and 2004, increases in uncultivated grass are significantly related to peat soils (Table 11). However, irrespective of percentages of peat soils, small farms are characterised by higher densities of uncultivated grass and larger increases in densities of uncultivated grass. Consequently, the relationship between densities of uncultivated grass and small farm sizes is independent of variations in percentages of peat soils.

For the local level, several relationships between landscape changes and soil types and slope conditions have been described. Yet, only few significant differences in

farm size	Peat soil (% of farm unit)	Density of uncultivated grass (% of farm unit)	Change in density of uncultivated grass (% of farm unit)
all farms	0	4.96%	0.12%
all farms	0-12.5	6.78%	0.20%
all farms	12.5-25	10.35%	0.21%
all farms	25-50	13.06%	0.36%
all farms	>50	14.07%	0.67%
significance of difference*		***	***
farms < 25 ha	0	6.09%	0.15%
farms > 25 ha	0	3.91%	-0.09%
significance of difference*		***	***
farms < 25 ha	0-12.5	11.93%	0.24%
farms > 25 ha	0-12.5	6.02%	0.12%
significance of difference*		***	***
farms < 25 ha	12.5-25	13.92%	0.42%
farms > 25 ha	12.5-25	9.04%	0.26%
significance of difference*		***	***
farms < 25 ha	25-50	18.15%	0.45%
farms > 25 ha	25-50	10.41%	0.34%
significance of difference*		***	***
farms < 25 ha	>50	17.73%	0.59%
farms > 25 ha	>50	10.71%	0.46%
significance of difference*		***	***

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

Table 11: *Changes in density of uncultivated grass 1998-2004 in relation to farm sizes and densities of peat soils in Denmark (excl. Bornholm). (National agricultural register 1998 and 2004, map of field blocks 1998 and 2004, soil map)*

	Sheep and goats (animal units / ha)	Meat cattle (animal units / ha)	Subsidies for environmentally friendly management (% of farm unit)
farms < 25 ha	0.0067	0.09	2.82%
farms < 25 ha	0.0011	0.03	0.86%
significance of difference*	***	***	***

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

Table 12: *Difference between small and large farms in density of grazing animals and in subsidies for environmentally friendly management in Denmark (excl. Bornholm). (National agricultural register 2004).*

soil types and slope conditions exist between large and small farms, and these differences are not capable of explaining present differences in landscape patterns between small and large farms.

Discussion

Present relationships between farms size and landscape composition

Analyses at both national and local level point at significantly smaller mean field sizes on farms <25 ha. Furthermore, at local level, densities of hedgerows, field divides and small biotopes are significantly higher on farms <25 ha. While national data point at significantly higher densities of uncultivated grass on farms <25 ha, this dif-ference was not found at local level. This inconsistency between the national and local level can be caused by the rather small sample of only 112 farms at local level not being representative for the national level in terms of densities of uncultivated grass. Another possible explanation is that at local level, uncultivated grass is registered by means of interpretation of aerial photos, while for the national level, data for uncultivated grass are derived from agricultural registers, which are based on farmers' applications for EU-subsidies. Earlier investigations (Levin, 2006) indicate the possibility that quantities of uncultivated grass are generally overestimated in these registers.

Landscape changes

At local level, landscape changes from 1954 to 1982 were characterised by increasing field sizes and decreasing densities of field divides, small biotopes and uncultivated grassland. These landscape changes correspond with changes described for other Danish and European landscapes during this period (Agger et al., 1986; Barr & Gillespie, 2000; Brandt, 1998; Burel & Baudry, 1990; Deckers et al., 2005; Hietala-Koivu, 2002; Holmes et al., 1998; Huston, 2005; Ihse 1995; Kristensen, 1999). The period from the early 1950s to the early 1980s was in general characterized by an increasing significance of large scale production, technological improvements and subsequent adjustments of landscape composition to modern large scale farming by means of the merging of fields, drainage of wetlands and removal of constraining landscape elements such as field divides and small biotopes. Decreasing densities of uncultivated grass can be explained by 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 can be explained by schemes for hedgerow planting for protection against wind erosion in this area (Fritzbøger, 1998).

From 1982 to 2002, Herning and Randers were characterised by a continued increase in field size and a continued but weaker decrease in densities of field divides and small biotopes. However, compared to the period from 1954 to 1982, these changes were less pronounced, and Slangerup was even characterised by opposite changes with decreasing field sizes and increasing densities of field divides and small biotopes. These different characteristics in landscape change between the two periods can partly be explained by changes in agricultural policy, as well as the introduction of the environmental discourse in the mid 1980s. Particularly since the early 1990s, focus on the conservation and restoration of farmland nature has increased (Skov- og Naturstyrelsen 1992). Furthermore, since the mid-1980s, agriculture increasingly showed signs of a shift of focus from production maximisation to values like environmental quality and recreation (Kristensen 1999; Ilbery & Bowler, 1998). Because Slangerup is located close to Copenhagen with a large urban population, the influence of recreational, scenic and environmental interests in this area is significant and, at least to some degree, explains decreasing field sizes and increasing densities of field divides and small biotopes.

Within both investigated periods, landscape changes

were significantly related to physical geographical properties. Technological improvement, followed by the drainage and cultivation of humid soils and the decreasing significance of extensive grazing, weakened the formerly strong connection between uncultivated grasslands and peat soils. Also, due to the decline of extensive grazing, uncultivated grasslands on slopes >5 degrees were largely abandoned and changed into woodlands or shrub. The decline of small biotopes on peat soils from 1954 to 1982 can be subscribed to the removal of ponds, which originally were closely related to humid soils. Throughout both investigated periods, the largest proportion of cultivated land was found on sand and clay soils. Consequently, the rearrangement of landscape composition to large scale agriculture, characterised by increasing field sizes and decreasing densities of field divides, is most pronounced on sand and clay soils. Finally, as schemes for hedgerow planting focused on the protection from wind erosion, in both periods increases in densities of hedgerows were most pronounced on sand soils. In summary, the last 5 decades were characterised by a development in which technological improvements resulted in a gradual decline of agriculture's dependence on physical geographical conditions.

The evolvement of present relationships between farm size and landscape composition

Present relations between farm size and landscape composition, in terms of mean field sizes and in densities of the investigated landscape elements, are significantly influenced by variations in past landscape changes. At national level, 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 from 1998 to 2004. Investigations at study area level reveal that present differences between small and large farms have mainly evolved between 1982 and 2002. Present differences are partly the consequence of different directions of change, and partly the consequence of a stability in space and time in relation to a change (Table 6 and Table 7).

Relations between farm size and landscape composition evolved independently of variations in soil type and slope conditions. Consequently, relations between landscape composition and farm size must be the consequence of other, farm specific parameters related to farm size. Although the investigation of such parameters was beyond the scope of this study, some assumptions can be made.

On the basis of a number of existing studies (Frederiksen and Langer, 2004; Kristensen, 1999; Præstholm, 2002) it can be assumed that in Denmark farm sizes of <25 ha are generally too small to provide an acceptable household income and will therefore often be characterised by parttime or hobby farming. Furthermore, it has been argued that parttime and hobby farms are different from fulltime farms with respect to the driving forces for agricultural and thus landscape practices (Busck, 2002; Frederiksen and Langer, 2004; Tress, 1999). A part time farmer is defined here as a farmer whose chief source of income is not farming, but who still carries on a farming business. A hobby farmer is defined as a farmer whose chief source of income is not farming and who carries on some farming activities, but without reasonable expectation of profit. On fulltime farms, maximisation of agricultural production dominates farmers' decision making (Walford, 2005). On parttime and hobby farms, where the main household income is derived from other, usually off-farm activities, maximisation of agricultural production is less important. Maximisation of agricultural production will often lead to a rationalisation of agricultural land use in terms of the merging of fields. It can therefore be assumed that the stability in mean field sizes on farms of <25 ha is a consequence of a lesser focus on production maximisation.

However, this does not explain the significantly larger increases in densities of small biotopes, hedgerows and field divides on small farms. A possible explanation is that the awareness of the environmental functions of these uncultivated landscape elements has a profound effect on the landscape management of small hobby and parttime farms. 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 <25 ha (Table 12). It can be argued, that this difference is caused by a greater awareness of environmental functions on small farms.

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

A reasonable explanation for higher densities of uncul-

tivated grass on small farms is to be found in the differences in agricultural production. Uncultivated grassland is usually grazed by sheep and goats and by cattle for meat production. At national level, numbers per hectare of meat cattle and of sheep and goats are significantly higher on farms <25 ha (Table 12). It is, therefore, reasonable to argue that higher densities and larger increases of uncultivated grass on farms <25 ha are the consequence of larger densities of sheep, goats and meat cattle.

Conclusion

The aim of this paper was to investigate relationships between farm size and landscape composition, and how such differences are related to landscape changes and to variations in physical geographical conditions. Both at national and at local level, small farms are characterised by significantly smaller field sizes and significantly higher densities of different uncultivated landscape elements. Analyses indicate that these differences primarily evolved during recent years (the last 20 years at local level, and the last 6 years at national level). Differences are partly the result of different directions of landscape change, partly of stability in space and time in relation to a change. Although landscape changes are significantly related to soil types and slope conditions, and are characterised by a declining dependence of agricultural land use on physical geographical conditions, differences in landscape composition between small and large farms evolved independently of variations in soil types and slopes.

Investigating the influence of other farm parameters was beyond the scope of this study. However, on the basis of existing investigations it is reasonable to assume that production maximisation and subsequent harmful effects on landscape composition are less important on farms <25 ha. Furthermore, assuming comparable household incomes, the amount of money per unit area available for landscape management is higher on small farms. Finally, higher densities of grazing animals favour higher densities of uncultivated grass on farms <25 ha.

It is argued that small farm sizes contain a potential for increased sustainability of the management of Danish agricultural landscapes. Realising the methodological limitations of this study, it is recommended that future investigations place an increased focus on the characteristics of small farm sizes and their influence on landscape changes.

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