The analysis of agricultural land use in Denmark 1950-1997 - some reflections on changes in data availability and methodology

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Abstract

The analysis of agricultural land use in Denmark has for decades been a central research theme at the Institute of Geography, University of Copenhagen. The definitions and availability of agricultural census data and other important sources of information have changed during the 20th century and have presented researchers in agricultural geography with different opportunities and constraints for analysis. Research themes and results have also been influenced by changes in research methodology and priorities. This article discusses how changes in availability and spatial scale of data have affected agricultural land use analysis, based on a review of studies published between 1950 and 1997. The last part of the article examines the potential for agricultural land use analysis at different scale levels using GIS software and new agricultural databases.

Keywords

Agricultural geography, agricultural census data, GIS, Denmark.

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Agriculture is still the dominant land use in Denmark, covering nearly two thirds of the area and therefore has a great impact on the rural landscape. Similar to the development in other European countries, the land use pattern of rural landscapes has changed dramatically over the past 50 years as a result of changing socio-economic conditions for agricultural production (Kampp 1963, Jensen & Reenberg 1986, Ilbery & Bowler 1998). The spatial diversity and change of agricultural land use has been the subject of numerous case studies and regional studies by researchers and Masters students at the Institute of Geography, University of Copenhagen, and many of the results have been reported in previous volumes of this journal. This review of articles published since 1950 makes it clear that research topics and results to a large extent have been influenced by data availability and the capability for data analysis. The possibility of emphasising different spatial scales has also had a major impact on the research themes examined in this period. The article is divided into three parts in order to analyse different aspects of the relationship between data availability and research themes. The first section categorizes the studies according to research themes and priorities during the period in question. Section two categorizes research according to spatial levels and discusses the advantages of research at different spatial levels. The last section describes the sources of information which are available for research in agricultural land use and the perspectives for research in the future using GIS software and administrative databases.

Types of research themes

Most of the studies which form the basis of this review fall under the heading of agricultural geography. In an attempt to classify these studies, a definition of agricultural geography by Ilbery (1985) is adopted. He suggests that research in this discipline can be divided into two broad categories of studies:

1. Research on the location and context of agricultural land use. These studies seek to recognize and analyse spatial variations in agriculture. The classification of agricultural systems according to the type, size and strategies of production is a central issue in these studies as well as mapping the extent and location of different agricultural systems.

2. Research on the diversity of agricultural land use. These studies seek to identify the driving socio-economic and bio-physical factors influencing agricultural land-use change, and illustrate the interaction between agricultural land use and the environment at various spatial levels.

In short, studies belonging to the first group are mostly concerned with the analysis of variation and spatial patterns of agricultural land use whereas studies in the second category focus on the processes of interaction and exchange between agricultural land use and the environment.

However, the studies examined in this article lead to suggest that the second category can be further divided into two sub-categories to allow a more exact characterization of the type of interaction between agricultural land use and the environment. This sub-division distinguishes between the following two groups:

2.a) Research on forces of change which condition and direct agricultural land use into certain development paths, e.g. socio-economic factors such as agricultural policies, legislation and market conditions, or bio-physical factors such as topography and pedological characteristics.

2.b) Research on the impact of agricultural land use on the surrounding environment. This branch of research includes investigation of the negative effects of agricultural land use, such as nutrient leaching to aquifers and increased wind erosion due to mono-cropping. Research on the impact of agricultural land use on rural landscape patterns also belongs to this category.

A flow-diagram showing the relationship between research themes covered by categories 1, 2a and 2b is presented in Figure 1.

Research at the Institute of Geography has dealt with themes belonging to all categories. However, changes in data availability and technology available for data analysis have had a strong influence on the objectives and results which were obtained at various points in time. Some studies contain results which at the same time describe the spatial variation in agricultural land use and analyse the spatial distribution according to the influence of driving factors. These studies cannot simply be categorized as belonging only to one category, but in order to create an overview, the studies are placed under the most relevant heading. It appears that the research themes investigated in the studies included in Table 1 have received similar attention with an equal number in the two main categories (category 1 and 2a/2b respectively).

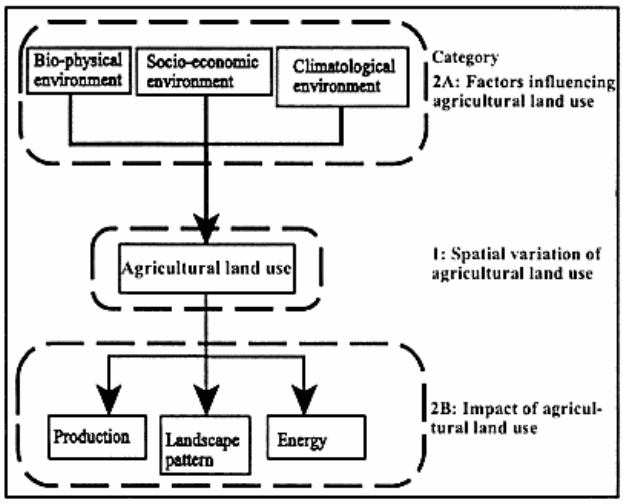

Figure 1: Flow diagram of research themes dealing with agricultural land use (after Duivenbooden (1995))

The spatial level addressed in different studies is not always restricted to just one level. For example, a description of regional patterns of farm sizes may form part of a classification on a national scale. Again, each study has been categorized to the most fitting category. It is evident from Table 1 that the studies examined in this review include all spatial levels.

Spatial diversity of agricultural land use

A large number of these studies examined the regional differences in Denmark through analysis of the spatial variation and distribution of agricultural land use. They focussed on various spatial levels to examine the differences in a regional or national perspective (Kampp 1959a) or to explain adaptations of agricultural land use to local conditions (Jensen & Jensen 1979). In the following, two examples illustrate studies undertaken at the national level. They have been selected because they include or summarize a large proportion of the studies included in the review.

Kampp investigated different aspects of agricultural land use in the period from 1900 to 1980. An example from his doctorate dissertation illustrates the basis of his work, in which the close relationship between the natural environment and agricultural land use was a central issue (Kampp 1959a). The point of departure was a dissatisfaction with a geographical division of Denmark primarily based on soil types proposed by Vahl (1942). Kampp agreed that soil parameters should be an important part of the classification of agricultural land use, but found that the current

Main research theme	*Spatial level*	*Research category*	*Reference*
Land use on the island of Mandø with emphasis on the history of settlement, landuse as well as plans for creation of small farms	*l*	*1*	*Jacobsen (1953)*
Land use on the island of Askø and reflections on geographical research problems in isolated communities	*l*	*1*	*Møller (1954)*
Cultivation problems in reclaimed area (former Søborg lake), in particular problems of flooding	*l*	*2a*	*Amstrup (1955)*
Land use and settlement development since 1688 based on land register records and historical maps	*l*	*2b*	*Hansen (1959)*
Agricultural land use and crop rotation systems in two different areas. Use of crop pattern indexes to classify land use systems	*l/n*	*1*	*Kampp (1959a)*
Classification of agricultural land use in Denmark based on crop yelds and land use patterns. Analysis of sub-division of agricultural holdings 1904-40	*r*	*1*	*Kampp (1959b)*
Relationship between settlement patterns and geomorphology in northern Jutland, examplified by 2 case studies	*r*	*1*	*Hansen (1960)*
Agricultural land use in the Waddensea marsh area. Description of historical settlement patterns and land ownership in different polder areas.	*l*	*1*	*Jacobsen (1960)*
Industrialisation of farming, changes in farming area and land distribution. Particular emphasis on state holdings and state tenant holdings.	*n*	*1*	*Kampp (1963)*
Meadow irrigation systems using Skjernå river as a case study	*r*	*1*	*Rasmussen (1964)*
Cultural landscape and rural settlement relationship in Northern Jutland	*r*	*1*	*Hansen (1964)*
Open-field agricultural system in a Danish village. The development in ownership and land use from 1682 is examined	*l*	*1*	*Kampp & Frandsen (1967)*
Land-use changes in coastal zone. A historical analysis shows gradual transition from farm and fishing village to primarily recreational land use	*l*	*2b*	*Thiesen (1974)*
Updating and simplification of agricultural divison of Denmark from 7 to 3 regions and discussion of recent changes in agricultural land use	*n*	*1*	*Kampp (1976)*
Atlas with 75 examples of cultural landscapes in Denmark, illustrated with historical and geomorphological maps and aerial photographs	*r*	*1*	*Jensen (1976a)*
Processes of land marginalisation in Jutland	*r*	*2b*	*Jensen (1976b)*
Agricultural development in central Jutland	*l*	*2b*	*Jensen & Jensen (1977)*
Processes of sub-division and amalgation of agricultural farms with emphasis on the period between 1940 and 1977	*n*	*1*	*Kampp (1979)*
Agricultural development in central Jutland	*l*	*2b*	*Jensen & Jensen (1979)*
Elaboration of soil survey system based on field work in central Jutland. Calculation of yield classes based on soil water availability	*l*	*2a*	*Madsen (1979)*
Regional variation in farm size	*n*	*1*	*Reenberg (1984)*
Development in farmtypes with emphasis on the period between 1950-1980	*n*	*1*	*Jensen (1984)*
Study of the potential of using satellite images to map agricultural land use	*l*	*1*	*Niels-Christiansen & Rasmussen (1984)*
Identification of abandoned and afforested agricultural areas in Jutland. Discussion of processes leading to marginalization of agricultural land	*r*	*2b*	*Jensen (1986)*
Atlas of agricultural land use in Denmark, regional variation, historical development. Discussion of driving factors of agricultural change	*n*	*1*	*Jensen & Reenberg (1986)*
Nation-wide mapping of surface topography with emphasis on the identification of areas with steep slopes	*n*	*2a*	*Breuning-Madsen et al. (1987)*
Description of spatial patterns of agricultural land use in the 1980s and recent changes in the agricultural sector	*n*	*1*	*Reenberg (1988)*
Identification of marginal land based on irrigation needs	*n*	*2a*	*Breuning-Madsen & Holst (1988)*
Identification of marginal land based on physical parameters: topography, soil texture and humidity condtions	*n*	*2a*	*Breuning-Madsen (1989)*
Analysis of potential acidity in Danish soil types in relation to land use	*r*	*2a*	*Madsen & Jensen (1991)*
Comparison of landscape dynamics and patterns in Portugal and Denmark	*r*	*2b*	*Pinto-Correia (1993)*

Table 1. *Overview of studies of agricultural land use published (mainly) in Geografisk Tidsskrift since 1950. Studies are classified according to spatial level investigated (l=local, r=regional, n=national) and research category (see section 2 for explanation of codes).*

information about soil data was too scarce and inadequate to reflect the complex relationship between soil parameters and agricultural potential. Instead, he suggested a classification based on crop production parameters which would be a better measure of the relationship. In his own words, he suggested to "*...let the crops do the soil analysis themselves...*" (1959: p. 16). In an effort to formulate a method which produced a more satisfying division, Kampp identified 7 agricultural regions in Denmark, based on a combination of two indices: a) the yield index of 7 common crops and b) the percentage of land cultivated with wheat and barley in each of the 1800 parishes. In this way he managed to separate the more fertile areas (primarily found in the eastern part of the country), from the less productive areas in the western part of the country in a more detailed manner than the previous classification based on soil values.

Kampp realized that this method was statistically a rather rough method, and that a more refined approach should take other factors into account. He suggested to relate yields at parish level to national yield levels and subsequently weight the results with this percentage to obtain a more representative figure. However, this would require an additional 13.000 calculations and was prohibitive taking the technology at the time into consideration. His work was based on the agricultural census data collected annually at parish level until 1970 and represents an impressive effort in data analysis with the means available at the time.

In summary, it could be said that Kampp and researchers before him were fortunate in having access to data collected on a very fine scale (yield figures for a large number of crops for all 1800 parishes). However, the potential for data analysis, integration with other sources of information as well as recalculation and updating of results was very limited due to the level of technology available.

Another landmark in the research undertaken at the Institute of Geography is represented by a number of research initiatives which form the basis of the "Atlas of agriculture" (Jensen & Reenberg 1986). Based mainly on data from the years 1971 and 1981, this atlas permits an assessment of the dramatic changes in agricultural land use since World War 2 and more recently the changes which occurred since Denmark became a member of the EU in 1973.

A few comments should be given concerning the research approach represented by the atlas. Until the 1950s, agricultural geography as a discipline was mainly concerned with the influence of the natural environment on agricultural land use. The decline of the importance of agriculture in the economy and the rejection of environmental determinism led to a decrease in the interest in agricultural geography after the 1950s. The 1980s marked a revival of the discipline in an international context, as a stronger emphasis on socio-economic factors of influence broadened the scope to link with economic, sociological and political sciences (Grigg 1994). This development is recognizable in the atlas, which describes the spatial distribution and variation of agricultural land use in Denmark in terms of crops, animal production, input factors (fertilizer, fuel, machinery, etc), but also contains chapters describing rural population movements, labour availability, energy consumption and the influence of market conditions on agricultural land use. The atlas combines the input of authors from various academic backgrounds and research interests and demonstrates the importance of multidisciplinary research in agricultural land use analysis.

The atlas also serves as an important reference for the change in statistical census data definitions. The data which forms the basis for the atlas is collected at the municipal level, which was the outcome of the administrative reform of Denmark in 1970. The reduction in the number of municipalities from 1200 to 275 meant that an analysis could no longer take place at such detailed level as mentioned in the first example. In fact, Kampp (1976) simplified his classification of agricultural regions in Denmark from 7 groups to 3 groups, because the reduction in data resolution after 1970 made it impossible to maintain a detailed division. In 1989 the publication of agricultural census data was changed again, this time from the municipal to county level. As a consequence, the lack of census data at a greater scale than county level has not permitted a similar exercise since 1989. This means that the effects of EU agricultural policy changes in 1992 on agricultural land use could not be documented at a detailed level using official statistical census data.

These two examples illustrate the spatial variation of agricultural land use at a national scale. They have shown how more detailed analyses of spatial patterns were possible when census data was available at the parish level and have illustrated the limitations due to the census unit being changed first to municipal and later to county level. They also illustrate the change in research priorities in agricultural geography during the past 50 years, away from

a mainly bio-physical focus to a more holistic view by incorporating socio-economic factors of explanation.

Driving forces of agricultural land-use change

The second group of studies have as their main objective the analysis of the dynamics of land-use changes. The focus for these studies lies on the interaction between agricultural land use and the parameters which influence and determine it. This relationship is complex, as many factors operating at different spatial and temporal scales interact to influence agricultural land use. As mentioned above, these studies can be divided into studies investigating the influence of the physical and socio-economic environment on agriculture (sub-group 2a in Table 1) or studies analysing the impact of agricultural land use on the environment (sub-group 2b in Table 1). The examples analysed in the following section represent studies from sub-group 2a.

The process of marginalization is selected as an example due to its central position in the agricultural policy discussion in the 1980s and the large volume of research it encouraged (Miljøministeriet 1986). Several studies offer interesting insight into the processes of marginalization, many of which were included in a special edition of this journal (Reenberg & Jensen 1989).

Marginalization can be defined as a process leading towards abandonment of agricultural land due to falling productivity and profitability levels (Jensen 1976b). During the mid-1980s it was predicted that as much as 15% of the agricultural area would be affected by marginalization as a result of falling grain prices (Jensen 1986) and would be afforested or revert to grass land. Results from a study in 1992 indicate that only a fraction of this area was affected, probably due to a combination of changing economic conditions and increased demand for arable land (Andersen et al. 1995). Although the concept was brought to public attention in the 1980s only, Jensen (1976b) demonstrated already earlier that the process of marginalization has been a common feature of Danish agricultural systems through time and certainly characterized the development during the last century. Recently, the process seems to be driven mostly by socio-economic forces whereas it was earlier mainly natural conditions which caused marginalization.

Jensen (1976b) analysed the processes in terms of areas where abandonment and afforestation had occurred on former agricultural land in central Jutland, based on a comparison of topographical maps from 1870 to 1965. On a regional level, Jensen showed that there was a correlation between geomorphology and afforestation patterns and that a large percentage of the afforestation had taken place in an area in Central Jutland. Other areas with a high degree of afforestation are located in the hilly areas of central Djursland and on sandy river banks along major streams in Jutland.

Madsen (1989) investigated the extent of potentially marginal land from the perspective of the physical environment. Areas characterized by poor agricultural potential were identified according to values of selected key soil parameters. This study concluded that wetland areas (high drainage need) constituted 10 % of the agricultural area, sandy areas (high irrigation needs) amounted to 20 % and areas on steep slopes (difficult cultivation) covered 1% of the agricultural area. These areas could be expected to be affected by marginalization, due to their low agricultural potential. The study used the information contained in a national soil database as well as topographical and geomorphological maps from different periods.

These studies dealing with the driving forces of agricultural change examplify the need for multidisciplinary approaches to the study of agricultural land use. Jensen (1976b) underlined the need to include historical information to explain processes of change whereas Madsen (1989) used bio-physical indicators as a point of departure.

Spatial scale

Agricultural land use can be examined at different levels in a spatial hierarchy in which some parameters are more influential than others at each level. This concept has been discussed in the works of Jones (1988), Fresco & Kroonenberg (1992) and Lefroy et al. (1993). As indicated in Table 1, the review of agricultural land use research in Denmark suggests that the spatial scale of research has involved all levels: local (farm, parish, municipality) (Møller 1954, Madsen 1979), regional (county) (Hansen 1960, Rasmussen 1964) and national level (Hansen 1964, Jensen & Reenberg 1986).

In the following section, the potentials and limitations of local level studies will be discussed. This spatial level has been chosen because it is a very suitable level to illustrate the complex interaction between agricultural land use and the socio-economic and bio-physical environment.

Local level investigations

Investigations at the level of the local landscape offer a good opportunity to integrate detailed information about agricultural practices and strategies at farm level with information about ecological conditions. In many studies, the area investigated corresponds to a parish, measuring between 1-10 km2 and with a farm population of 100-500 farms. The parish level offers the possibility of examining the diversity of development paths that farmers follow to respond to the varying socio-economic and bio-physical conditions over time. Research at this level represents the compromise between detailed case studies and investigations at a higher level.

Field work constitutes an important source of data for these studies and the only way to collect certain types of information. Most studies focussing on the local level use interviews with farmers as a source of information about land use decisions, farm production strategies and income sources, to supplement agricultural census data and information from topographical maps. These studies offer enriching examples of the complex interaction between agricultural land use and the physical and socio-economic environment. One interesting example is found in the work of Jensen & Jensen (1977). Here the historical development of agricultural land use until 1973 is examined for two parishes in central Jutland, each measuring approximately 35 km2.

The study concluded that the agricultural land use in the two parishes was undergoing a transition from traditional, mixed farming with crops, pigs and dairy production to specialized farming concentrating on one type of production. Young farmers who were investing in new buildings and machinery and specializing in one branch of agricultural production, partly stimulated by the recent EU-membership in 1973, were contrasted to a group of older farmers who were scaling down production while maintaining traditional, diverse agricultural production.

It was stressed earlier that the study of agricultural land use requires multidisciplinary research efforts. This point is illustrated by the diversity of studies undertaken at other research institutions in Denmark, which also base their work at the local level for investigations relating to different aspects of agricultural land use: farmers' landscape management strategies (Primdahl & Bramsnæs 1993), farmers' future farm development plans (Pinto-Correia et al. 1996, Sørensen 1996) and ecological consequences of agricultural land use (Agger & Brandt 1988).

Sources of information

The studies mentioned above have been based on a variety of data sources, including agricultural census data, property assessment values, cadastral information and soil data.

The use of historical maps and land register information often represents the only way to link spatial patterns of agricultural land use in the past with the present. Studies by Hansen (1959 & 1964), Jacobsen (1960) and Jensen & Jensen (1979) all offer examples of the integration of different historical data sources with empirical information on present agricultural land use. Table 2 specifies some of the data sources which have been available in the course of time as sources of information for the analysis of agricultural land use. A particular problem that arises is the change of definitions on map legends, which can render comparisons between maps from different periods difficult. Another general problem is constituted by the changes in parameters used in agricultural census which must be taken into account when analysing census data. For a more comprehensive treatment of census data and map compilations, see Jensen & Reenberg (1980 & 1986).

Agricultural census data is an important source of information for research on agricultural land use at all spatial levels. However, changes in definitions (base area of counties, minimum size of farms, type of production in farm categories) must be taken into consideration when using data from different periods. The most important changes that have occurred in relation to agricultural census data since 1965 are listed in Table 3 along with an indication of the impact on agricultural land use surveys. Recent changes which are relevant for the study of agricultural land use on a regional and national level include the reduction of the number of counties from 23 to 14 in 1970, which changes the base area of counties. Fortunately, many boundaries remained relatively constant, making it possible to compare agricultural census data before and after 1970. Changes in the lower size of recorded farm size in 1977 and again in 1983 also affected the number of farms included in the category of small farms. Turning to local level studies, it has already been mentioned that the absence of census data at the municipal level since 1989 puts serious constraints on the availability of statistical data for investigations at this level.

In short, it can be concluded that the use of agricultural census data from different periods must be done with care

Data source	Product	Type	Year	Scale	Content
Danmarks Statistik	*census data*	*statistical material*	*yearly since 1900*	*most years at county level*	*agricultural land use, livestock, yields, economic parameters*
Ministeriet for landbrug, fiskeri og fødevarer	*GLR/CHR*	*data base*	*since 1993*	*farm level*	*information about land use and land tenure on individual farms*
De Danske Landboforeninger	*Landøkonomisk oversigt*	*processed census data*	*various years*	*county*	*agricultural land use (yields, economy, distribution) in different regions*
Kort og Matrikelstyrelsen	*cadastral map*	*map*	*since 1844*	*1: 4.000*	*cadastral information, soil value, some topographical information*
Videnskabernes selskab	*Videnskabernes selskabs kort*	*map*	*1770-1800*	*1:20.000*	*map showing pre-enclosure land use, settlements*
Trap	*Danmark, various editions*	*local descriptions*	*1859-1970*	*parish*	*brief description of history, landscape, settlements and economic activities*
Kort og Matrikelstyrelsen	*aerial photos*	*aerial photos*	*various years*	*1:25.000*	*aerial photos recorded every 5 years*
Kort og Matrikelstyrelsen	*topographical maps*	*map*	*since 1870*	*1:20.000 to 1:1.000.000*	*topographical information in various scales and from various years*
Kort og Matrikelstyrelsen	*TOP10DK*	*digital map*	*1997*	*1:10.000*	*digital topographical map. Based on aerial photos and existing topographical maps*
Danmarks & Grønlands Geologiske Undersøgelse	*Danmarks jord-artsklassifikation*	*map*	*1977*	*1:25.000*	*quaternary geological map with information on soil parent material in 1 meters depth*
Danmarks Jordbrugsforskning	*JB-kort*	*map*	*1975*	*1:50.000*	*information on soiltype in 0-25 cm depth and geology*
Geografisk Forlag	*P. Smeds kort*	*map*	*1978*	*1:360.000*	*geomorphological map of Denmark*

***Table 2:** Important data sources for agricultural land use studies*

and that the most recent changes in the scale of published census data impairs its use in fine scale investigations.

Databases and agricultural land use analysis

The changes of Danish agricultural census data definitions during the 20th century have posed different constraints and possibilities for research on agricultural land use. Recent advances in data availability and processing technology have a great impact on the compilation of agricultural census data and provide new opportunities for agricultural land use analysis.

A new database has been compiled at the Ministry of Agriculture, Fisheries and Food since 1993, containing detailed information about agricultural production and land use on farm level The database is called "**G**enerelle **L**and-brugs**R**egister/**C**entrale **H**usdyrbrug **R**egister" (GLR/CHR) and contains information supplied by farmers applying for EU agricultural subsidies (Koushede 1996). Some of the key items contained in the database for each farm are:

- a geographic reference address for all fields
- area and crops for all fields
- total area cultivated for each crop
- location of all fields
- information about land tenure/rented land for each farm
- number of animals on the farm for each animal category

Year	Change	Effect
1965	*change of statistical unit from estate (ejendom) to holding (bedrift)*	*decrease in the number of farms*
1970	*reduction of the number of counties from 23 to 14*	*change in base area of counties*
1977	*greenhouse producers included in agricultural census*	*increase in the number of farms: an additional 4500 farms*
1977	*change in lower limit for small farms (includes certain farms measuring less than 0.5 ha)*	*increase in the number of farms: an additional 1300 farms*
1983	*change in lower limit for small farms (from 0.5 ha to 5 ha)*	*decrease in number of farms: an estimated 7800 farms disappear*
1989	*change from municipal to county level agricultural census*	*serious constraints for local level investigations*
1997	*use of GLR/CHR data base (see section 4.1 for details)*	*more detailed information with georeferencing possibility*
1999	*The first total count of farm population since 1989*	*improved data quality*

***Table 3:** Important changes affecting Danish agricultural census definitions since 1965*

The information in the GLR/CHR database can be linked to a digital map developed specifically for the administration of the EU agricultural subsidies (Digitale Markblok-Kort: DMK) through a reference to the address of the individual block of fields in which the fields cultivated by each farm are located. This georeferencing possibility increases the potential for using the data base information with other types of information, for example in connection with information on the location of Environmentally Sensitive Areas or other areas with planning priorities.

The information in the database has so far not been widely available, but it is likely that it will become more accessible in the future. Part of the information in the database has been used to produce the first agricultural census on municipal level since 1989 (Danmarks Statistik 1997).

GIS and agricultural land use analysis

The perspectives for land use analysis offered by computerized data bases are very promising. The use of GIS in combination with the GLR/CHR database offer a more efficient way of performing "traditional" analysis, such as representing statistical data on maps at different scale levels, but also opens up for a far more broad ranging type of data analysis than previously. Some of the possible applications of GIS analysis are summarized in the following points:

- integration of different types of spatial information (e.g. land tenure, soil type, hydrology, crop yield) with different spatial resolutions.
- instant calculation of geometric parameters (area, perimeter, distance).
- division of land cover classes into sub-classes to emphasise user-defined themes (e.g. the land cover class "forest" can be sub-divided into "deciduous" and "coniferous forest").
- easy updating, calculation and production of maps when new information becomes available.
- calculation of index values representing landscape pattern values related to habitat quality, environmental impact sensitivity, aesthetical character, accessibility (e.g. connectedness and connectivity of wooded areas).

For further description of possibilities offered by GIS technology in relation to agricultural land use studies, the following references are recommended: Kienast (1993), Stow (1993), Caspersen & Kristensen (forthcoming).

An example of the potential offered by the combination of databases and digital maps is shown in Figure 2. The map shows the percentage of farms measuring between 50 and 100 ha at municipality level in 1996. It is clear that farms of this size form a substantial proportion of all farms (between 10% and 20% in most municipalities). However, a concentration of large farms is found in Southern Jutland, in Ringkøbing County and in Storstrøms County, where 20% to 40% of all farms measure between 50 and 100 ha. The map was produced by linking information in the GLR/CHR database with a digital map of Denmark, using the municipal code as a linking parameter. This example illustrates the type of analysis which can be made using GIS technology and which open up to a range of applications.

Other advances are linked to the increasing availability and use of the Internet, which allows access to a multitude of information. Digital maps containing cadastral information and information about rural area administration (regional planning level) are available at different websites, giving increased access to thematic maps showing

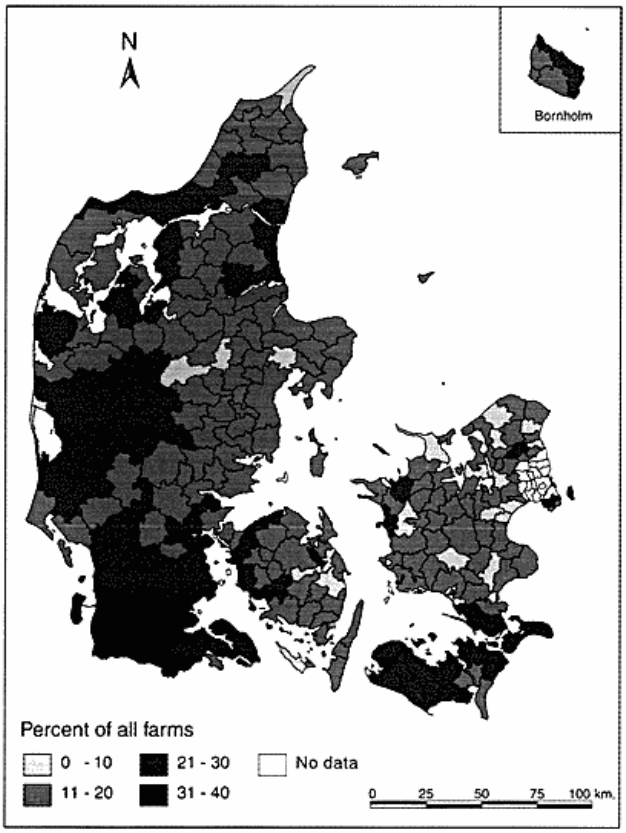

Figure 2: Distribution of farms between 50 and 100 ha in 1996.

land use, zonation and infrastructure at various scale levels (Nielsen 1998); (Ribe Amt 1998).

All in all, the advent of new databases which can be integrated with other sources of information in digital format opens up for a more dynamic analysis of agricultural land use than previously. Naturally, the advantages offered by the new technology can only be fully exploited as long as the data quality is satisfying.

Conclusion

The study of agricultural land use has a long history at the Institute of Geography, University of Copenhagen. The research themes covered have been diverse, ranging from studies that analyse the variation in spatial patterns to studies concerned with the factors influencing agricultural land use and the effects of land use on the environment. Research has taken place at all spatial levels, and local level investigations in particular offer good opportunities to study the adaptation of agricultural land use to local conditions while the regional and national level is well suited to show macro-scale variations and regional specialization of agricultural land use.

Agricultural census definitions have changed over the period investigated and put constraints on historical analysis involving data from different periods. The availability of census data on a local scale has been significantly reduced since 1989 and makes it difficult to study the response of farming systems to local conditions. Recent compilation of databases, however, is likely to improve data availability and enhance analysis at all spatial levels.

The promising applications for GIS in connection with research on agricultural land use will make it an increasingly useful tool. Most county administrations are now using GIS in the landscape management departments and the potential for combining information about agricultural land use with information on other land use priorities to improve rural landscape management needs to be investigated.

A final example puts the advances made by science over the period that has been covered in this article into perspective. In 1959, Kampp realized that a map of soil fertility on a more detailed scale than the parish division would require information apart from the agricultural census figures compiled at parish level, and would "*.....require the cooperation of all Danish farmers which is utopic....*"(1959a: p. 27). Nearly 40 years later, GIS technology now enables us to analyse, map and update information about agricultural land use and to integrate this information with other sources of information at scales ranging from the individual farm to the regional and national scale.

Reference

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land use, zonation and infrastructure at various scale levels (Nielsen 1998); (Ribe Amt 1998).

All in all, the advent of new databases which can be integrated with other sources of information in digital format opens up for a more dynamic analysis of agricultural land use than previously. Naturally, the advantages offered by the new technology can only be fully exploited as long as the data quality is satisfying.

Conclusion

The study of agricultural land use has a long history at the Institute of Geography, University of Copenhagen. The research themes covered have been diverse, ranging from studies that analyse the variation in spatial patterns to studies concerned with the factors influencing agricultural land use and the effects of land use on the environment. Research has taken place at all spatial levels, and local level investigations in particular offer good opportunities to study the adaptation of agricultural land use to local conditions while the regional and national level is well suited to show macro-scale variations and regional specialization of agricultural land use.

Agricultural census definitions have changed over the period investigated and put constraints on historical analysis involving data from different periods. The availability of census data on a local scale has been significantly reduced since 1989 and makes it difficult to study the response of farming systems to local conditions. Recent compilation of databases, however, is likely to improve data availability and enhance analysis at all spatial levels.

The promising applications for GIS in connection with research on agricultural land use will make it an increasingly useful tool. Most county administrations are now using GIS in the landscape management departments and the potential for combining information about agricultural land use with information on other land use priorities to improve rural landscape management needs to be investigated.

A final example puts the advances made by science over the period that has been covered in this article into perspective. In 1959, Kampp realized that a map of soil fertility on a more detailed scale than the parish division would require information apart from the agricultural census figures compiled at parish level, and would "*.....require the cooperation of all Danish farmers which is utopic....*"(1959a: p. 27). Nearly 40 years later, GIS technology now enables us to analyse, map and update information about agricultural land use and to integrate this information with other sources of information at scales ranging from the individual farm to the regional and national scale.

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