A Nation-wide Mapping of Dry Soils for Plant Production - A case study from Denmark

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A Nation-wide Mapping of Dry Soils for Plant Production – A case study from Denmark

Henrik Breuning Madsen & Kristian Aagaard Holst

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For economical or environmental reasons the arable land in Denmark will probably decrease in size in the nearby future. Therefore some areas will change into marginal land, especially wetlands, undulating areas and areas with dry soils. A nation-wide mapping of those areas has been carried out, and this paper describes the methodology used for mapping dry soils for grass and barley production.

Keywords: *Marginal land, Root zone capacity.*

Henrik Breuning Madsen, lektor, dr.scient, Geographical Institute, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen K.

Kristian Aagaard Holst, Vid.ass., lic.agro, Ministry of Agriculture, Bureau of Land Data, Enghavevej 2, DK-7100 Vejle.

Being too poor for farming, some areas in Denmark have changed from agricultural land to forest or scrub during the last century (Jensen, 1976). These soils are called marginal land. Because of surplus production of agricultural products within the EEC and for environmental reasons the arable land in Denmark is expected to decrease significantly during the next decades. Hereby large areas will be marginal and change from intensively cultivated land to forests, grassland or more specific biotopes.

In order to elucidate what areas will become marginal land in the future, Jensen & Kock (1987) questioned farmers of their reasons for changing agricultural land to marginal land. The main reason was that the soil was too wet, too dry or too steep. In 1986 a nation-wide mapping of these soil types was carried out (Madsen & Holst, 1987), and this paper describes the methodology used for mapping dry soils, defined by the root zone capacity for barley and grass production.

METHODOLOGY

The method used for calculating and mapping the root zone capacity is as follows. First, approximately 36,000 soil profiles were constructed with information on texture and organic matter content at three depths: 0-30 cm, 30-60 cm and 60-120 cm. The available water content in the soil layers was calculated from regression equations combining the water content at field capacity and wilting point with texture and organic matter content. An effective root depth is defined for different crops in relation to soil type, and on the basis hereof the root zone capacity is calculated.

The calculations are exclusively based on computerized nation-wide soil maps combined with analytical databases containing point measurements. In the following, a short presentation of the databases used will be given, followed by a more detailed presentation of the different steps in the calculation of root zone capacity.

The soil database

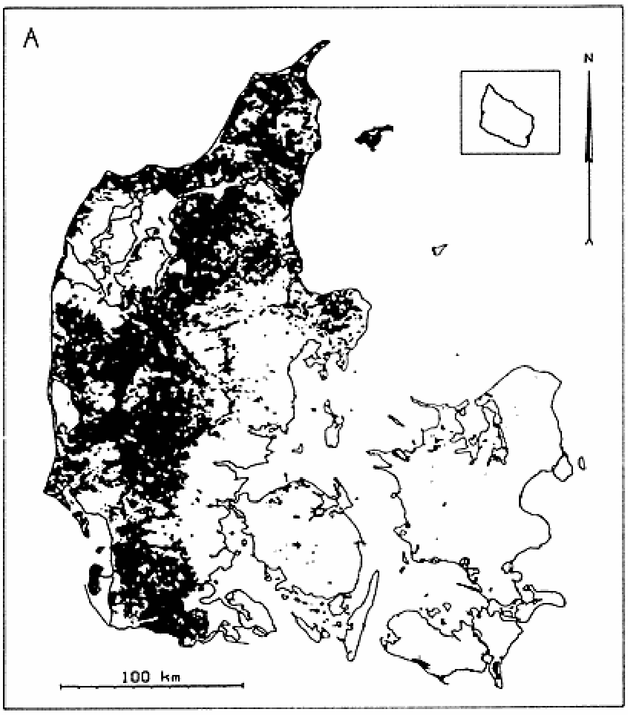
The soil database contains information from the Danish soil classification and from later investigations improving this classification. Furthermore, information from earlier mappings, e.g. wetlands, has been computerized. All information has been digitized with reference to the UTM coordinate system in order to provide facilities for production of computer-drawn soil maps at different scales and with different combinations of parameters.

The soil data can be divided into two main types, parameter data and line area data (Platou, 1984) of which the following have been selected for mapping the root zone capacity.

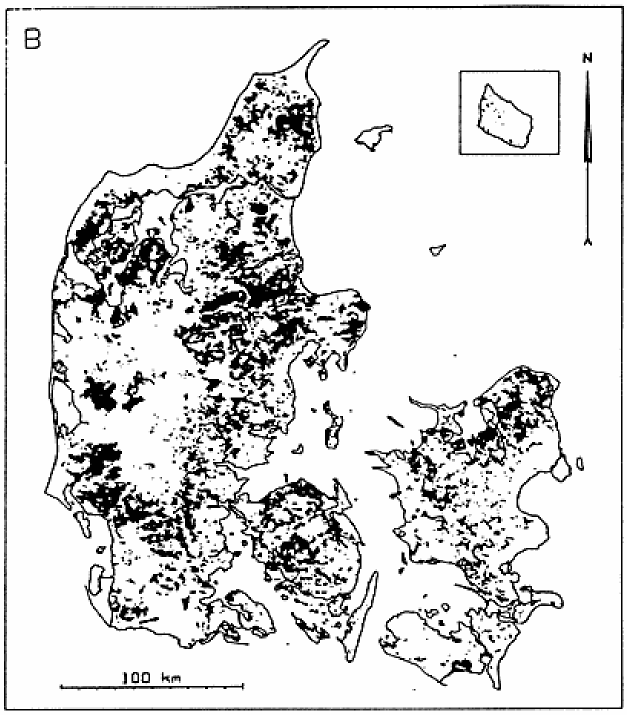
Parameter data

There are two major types of parametric data used for the mapping: information on texture and organic matter from the Danish soil classification and analytical data from pedological investigations.

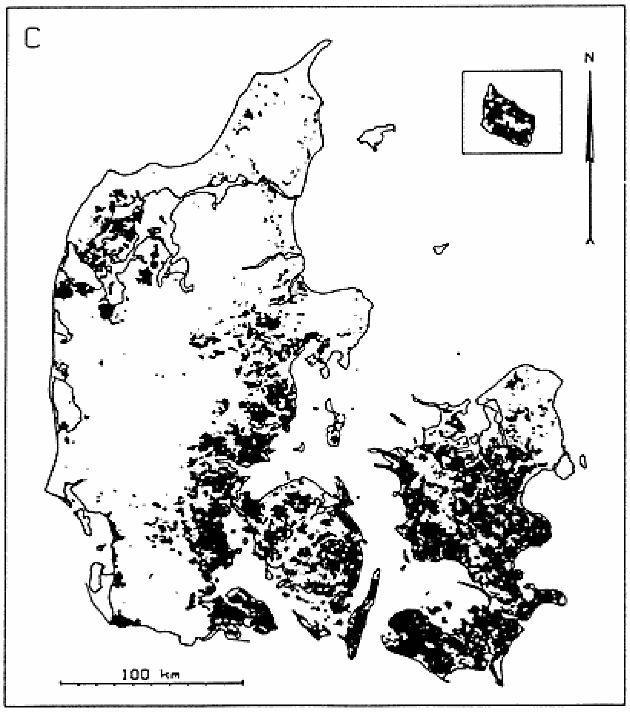
The primary data in the Danish soil classification are texture analyses. From approximately 36,000 sites soil samples were taken by local agronomists. At each site a sample was taken from a depth of 0-20 cm and at selected sites from a depth of 35-55 cm. Texture, organic matter content and calcium carbonate were determined in all samples. The following grain sizes (μm) were determined <2, 2-20, 20-63, 63-200 and 200-2000. The hydrometer method was used for determining the grain sizes <2 and 2-20, while sieving was used for the others. The organic matter content was determined on an IR-Leco apparatus and calcium carbonate content was determined by dilute acid titration (Mathiesen & Nørr, 1976). Since 1979 this database has been increased with several thousand



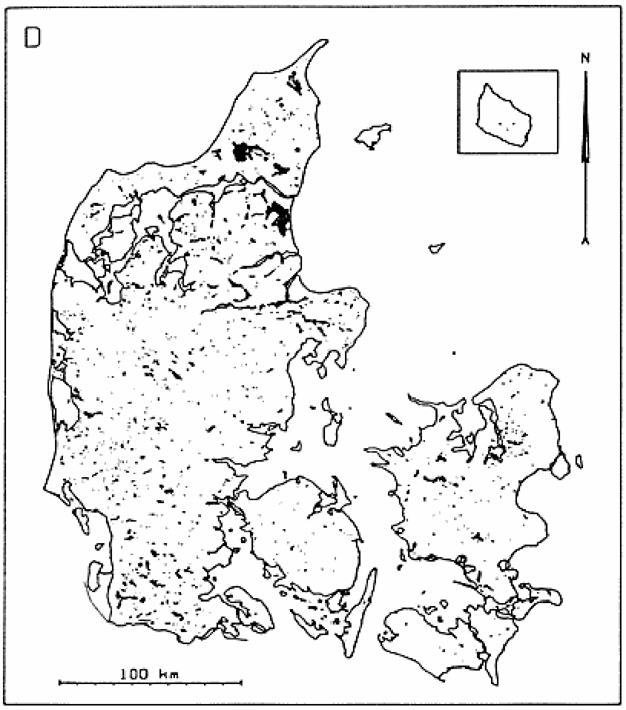
A = sandy topsoils (MCC 1,2);



B = loamy sandy topsoils (MCC 3);



C = loamy topsoils (MCC 4,5,6);



D = peaty topsoils (MCC 8).

Fig. 1. The location of different topsoils in Denmark.

analyses, e.g. from field experiments carried out on private farmland by local agronomists.

Pedological investigations have been carried out along the main gas pipeline system from the North Sea gas field across Denmark. More than 800 profiles have been excavated and described (Madsen & Jensen, 1985). On an average five to six samples were taken from each profile. In the laboratory, texture, organic matter content, calcium carbonate content and pH were determined on nearly all samples, and from selected profiles dithionite-citrate and pyrophosphate-soluble iron and aluminium, CEC, exchangeable bases, total N and P, mineralogy, soil water retention and root densities were measured.

Line area data

Four nation-wide line area databases with soil and climatic information have been used for mapping the root zone capacity. These are:

- soil boundaries from the Danish soil classification,
- boundaries between loamy and sandy subsoil,
- landscape boundaries drawn on topographic maps,
- boundaries between wetlands and non-wetlands

In 1975-84 soil maps covering Denmark were produced at 1:50,000. They were mainly based on texture analyses of the topsoil (0-20 cm) and, according to these, the agricultural land was divided into eight classes, Table 1. The soil maps also give information on the location of forest areas and urban zones (Mathiesen, 1980). Fig. 1 shows the location of sandy (MCC 1,2), loamy sandy (MCC 3), loamy (MCC 4,5,6) and peaty (MCC 7) topsoils in Denmark. In the western part of the country sandy soils dominate, while in the eastern part loamy soils dominate.

A map showing the location of loamy and sandy subsoil within non-marine landforms has been constructed based on a geological map at 1:500,000 (Bornebusch & Milthers, 1935) and on other geological maps at 1:100,000. Fig. 2 shows the location of sandy and loamy subsoils within the non-marine landforms in Denmark. The eastern part of the country has mainly loamy subsoil, while the western part has mainly sandy subsoil.

A landscape map has been produced at 1:100,000. It is based on topographic maps, earlier landscape maps (Schou, 1949; Smed, 1979) and geological surveys published at 1:100,000. The country is divided into nine different landforms: morainic areas from the Saale glaciation, morainic areas from the Weichsel glaciation, outwash plains, dune sand areas, old marine deposits (Yoldia), marsh areas, younger marine forelands including littorina, reclaimed areas, and rock. Some mixed areas were outlined where it was not possible to separate the landforms. Fig. 3 shows the location of the different landforms in Denmark.

A wetland map was outlined from the landscape map and from old topographic maps (1:20,000) showing the

Map Colour Code	SOIL TYPE	JB-nr.	Percentage by weight: Clay < 2 µm	Silt 2-20 µm	Fine Sand 20-200 µm	Total Sand 20-2000 µm	Humus 58.7% C
1	Coarse Sand	1	0-5	0-20	0-50	75-100	≤ 10
2	Fine Sand	2			50-100		
3	Clayey Sand	3	5-10	0-25	0-40	65-95	
		4			40-95		
4	Sandy Clay	5	10-15	0-30	0-40	55-90	
		6			40-90		
5	Clay	7	15-25	0-35		40-85	
6	Heavy Clay or Silt	8	25-45	0-45		10-75	
		9	45-100	0-50		0-55	
		10	0-50	20-100		0-80	
7	Organic Soils	11					> 10
8	Atypic Soils	12					

Table 1. Definition of soil types and map colour codes for the soil classification of Denmark.

extent of wetlands 60-80 years ago. From the landscape map, marsh areas, younger marine forelands including littorina, and areas below sea-level are considered as wetlands, while in the other six landforms all areas with wetland signature on the old topographic maps are considered as wetlands. These old maps were preferred for younger ones because of the recent decrease in wetlands due to drainage. Fig. 4 shows a nation-wide wetland map. The wetlands cover approximately 20 % of the total area.

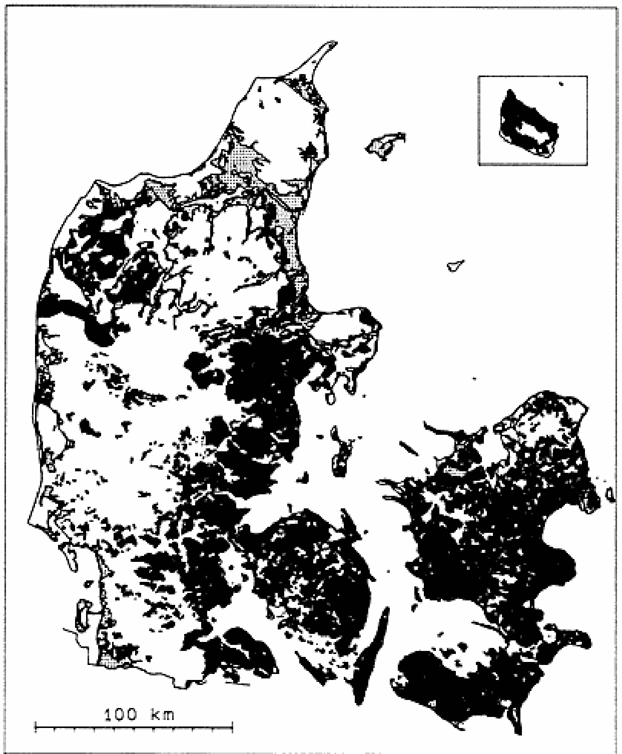


Fig. 2. The location of sandy and loamy subsoil in Denmark. Loamy areas are black, sandy areas are white, and wetlands are dotted.

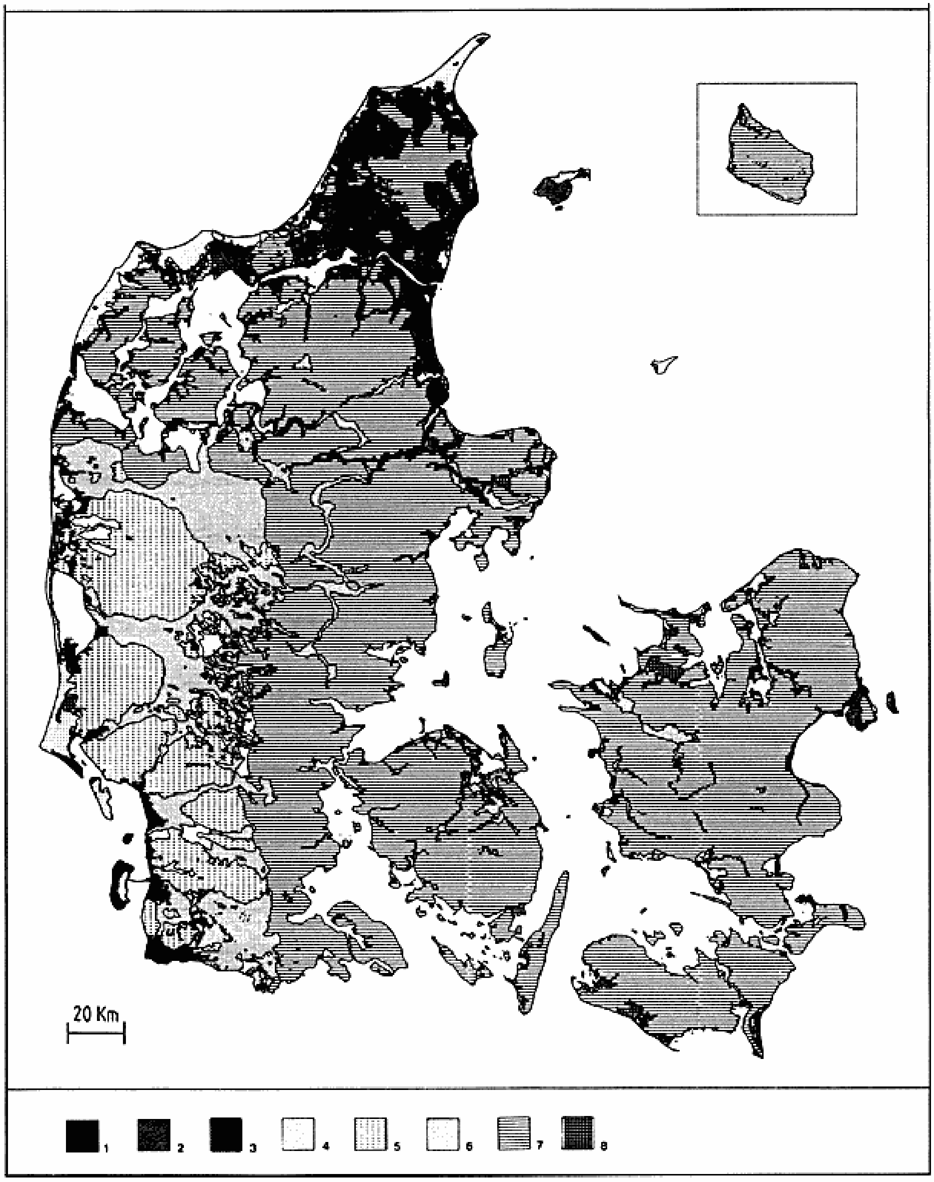


Fig. 3. Landscape map of Denmark. 1. Salt marsh, 2. Raised sea-floor, Littorina, and younger marine foreland, 3. Late glacial raised sea-floor, 4. Dune landscape, 5. Saale glaciation landcape, 6. Outwash plain, 7. Weichsel moraine landscape, 8. Reclaimed area. Mixed areas have no signature. High-lying granite and gneiss (Bornholm) appear as small black areas.

CALCULATION AND MAPPING ROOT ZONE CAPACITY

The root zone capacity (RZC) is defined as the amount of water in the soil profile which can be utilized by the plants before wilting due to lack of water supply. RZC is calculated by combining the available water content in the soil layers with information on root profiles from different crops. The RZC has not been determined in wetland areas because in these regions capillary rise of groundwater into the root zone is significant.

Construction of soil profiles

Approximately 36,000 soil profiles have been constructed with information on soil texture and organic matter. The profiles are located at the sampling sites from the Danish Soil Classification and they are based on analytical data from this classification and information from the subsoil map. The soil profiles are divided into three sections 0-30 cm, 30-60 cm and 60-120 cm, and within these sections the texture and organic matter content are considered as uniform. The assessment of texture and organic matter content in the sections is as follows:

- The texture and organic matter content in the soil sample 0-20 cm from the Danish soil classification determine the texture and organic matter content in the uppermost 30 cm of the profile.
- The texture and organic matter content in the soil sample 35-55 cm from the Danish soil classification determine the texture and organic matter content in the section 30-60 cm depth.

  If sampling has not been carried out at 35-55 cm depth, the texture from 0-30 cm is used with an organic matter content reduced to the average values for samples taken at 35-55 cm depth.

  These values are between 1.9 % and 1.4 % depending on map colour code (Madsen & Platou, 1983).
- In section 60-120 cm no texture analyses are available from the Danish soil classification. The assessment of texture and organic matter content is therefore based on the texture in section 30-60 cm and information on type of subsoil from the subsoil map.

  The organic matter content is in all samples arbitrarily set to 0.5 %. If the texture in section 30-60 cm has less than 10 % clay and the subsoil is sandy, the texture in 60-120 cm will be equal to 30-60 cm with a reduction in organic matter content to 0.5 %. If the subsoil is loamy the following mean MCC5 texture is used: 18.6 % clay, 15.1 % silt, 42.8 % fine sand, 23.0 % coarse sand, and 0.5 % organic matter.
- If the texture in section 30-60 cm has more than 10 % clay and the subsoil is loamy, the texture in 60-120 cm will be equal to that in 30-60 cm with a reduction in organic matter content to 0.5 %.

  If the subsoil is sandy the following mean MCC3 texture is used: 7.1 % clay, 8.5 % silt, 45.9 % fine sand, 38.0 % coarse sand, and 0.5 % organic matter.

Available water content in the different soil profiles

The available water content for plant production (AWC) is defined as the water content between field capacity (FC) and the permanent wilting point (PWP). For Danish soils this means a water content between pF2.0 and pF4.2 (Madsen, 1983). For a calculation of AWC by means of the data from the soil profiles it is necessary to establish a relationship between soil texture and soil water retention. Soil profile investigations have been carried out in Denmark showing this relationship (Hansen, 1976; Madsen & Platou, 1983).

In the actual study, AWC in the soil layers is calculated from the regression equations based on samples from profile investigations in southern Jutland (Madsen, 1986). The equation for pF2.0 is based on 285 samples and the equation for pF4.2 on 111 samples. Calciumcarbonate-containing samples, samples with bulk density below 1.0 g/cm^3, and samples with organic matter content above 10 % were excluded. The following classes have

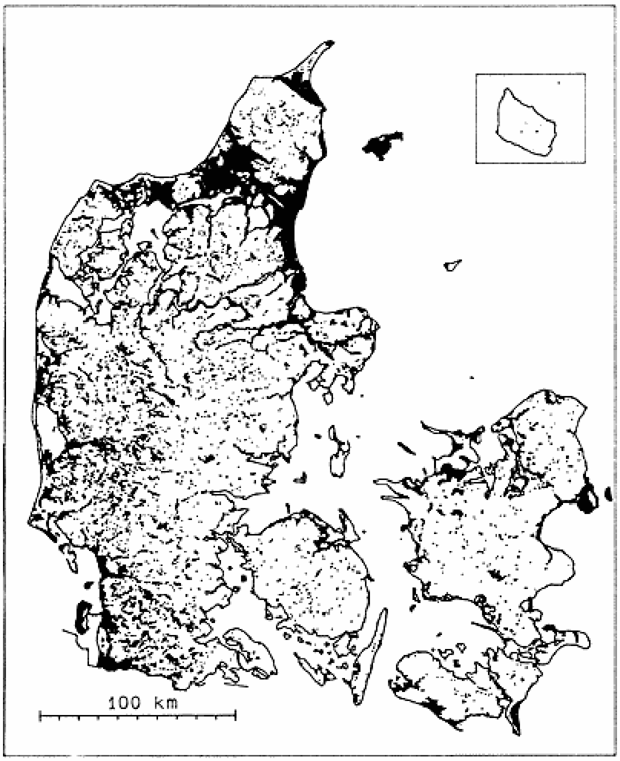


Fig. 4. Wetland map of Denmark.

been used in the regression analyses: clay 0-2 μ, silt 2-20 μ, fine sand 20-200 μ, coarse sand 200-2000 μ, and the mean values for the pF2.0-samples were clay 9.1 %, silt 5.7 %, fine sand 33.7 %, and organic matter 1.4 %.

$$\text{pF2.0 (vol\%)} = 2.34 \times \%\text{organic matter} + 0.70 \times \%\text{clay} + 0.47 \times \%\text{silt} + 0.18 \times \%\text{fine sand} + 3.68. \quad r = 0.914,\ s = 4.10 \qquad (1)$$

$$\text{pF4.2 (vol\%)} = 0.58 \times \%\text{organic matter} + 0.64 \times \%\text{clay} + 0.16 \times \%\text{silt} + 0.01 \times \%\text{fine sand} + 0.82. \quad r = 0.941,\ s = 1.81 \qquad (2)$$

Root depth

The effective root depth (ERD) is defined as the depth of soil in which AWC is equal to the amount of soil water utilized by the plants until wilting occurs due to lack of water. At this point the soil water potential will be about -15 bar in the upper profile part, because of a high root density there, while in the deeper sections of the profile, where the root density is low, only part of AWC has been utilized by the vegetation, and the soil water potential will be higher than -15 bar. Fig. 5 shows a decreasing utilization of soil water with decreasing root density, and ERD is equal to the soil depth where area a is equal to area b.

Based on investigations of Wiklert (1962), Vetter & Scharafat (1964), Bohm (1978), and Madsen (1979, 1983, and 1985) a mean ERD can be established for grass, spring-sown and winter-sown cereals, Table 2.

	Grass loamy	Grass sandy	Spring-sown cereals loamy	Spring-sown cereals sandy	Winter-sown cereals loamy	Winter-sown cereals sandy
MCC 1	50	50	50	50	50	50
MCC 2	60	55	80	60	90	60
MCC 3	60	55	90	60	100	60
MCC 4	60	60	90	80	110	100
MCC 5, 6, 8	60	60	90	80	110	100

Table 2. The mean effective root depth (ERD) in cm for different crops in relation to soil type (MCC) and loamy and sandy subsoil.

RESULTS

Based on the analytical data from the 36,000 soil profiles, the regression equations (1) and (2) and Table 2, the following mean root zone capacities for grass and barley in relation to soil types and landforms can be calculated, Table 3. The root zone capacity increases with increasing MCC-number, except for MCC 3. For a specific soil type, RZC is highest on the Yoldia landform and lowest on outwash plains and dune landforms. The subsoil strongly influenced the RZC for barley and for a specific soil type (MCC-number) the RZC is higher on loamy subsoil than on sandy. This is not the case for grass because the effective root depth for this crop does not exceed 60 cm. A classification of the RZC for barley and grass production in three categories will be as follows: Low RZC is less than 80 mm; medium RZC is between 80 mm and 110 mm for grass and between 80 mm and 140 mm for barley, and high RZC is above 110 mm for grass and 140 mm for barley. Dry soils for plant production are soils with low root zone capacity. These soils have a high irrigation need and in practice many of them are irrigated. Soils with a medium RZC are normally not irrigated.

Fig. 6 shows a root zone capacity map of Vejle county for barley production. Each point is a sampling site from the Danish soil classification with information on texture and organic matter content. In the eastern part of the county loamy Weichsel moraines dominate, while in the western part sandy outwash plains and dune landscapes dominate. Most of the eastern part of the county has a high root zone capacity, frequently above 170 mm but not above 200 mm. Dry soils are rare in that region. In the west, sandy soils cover great areas. The RZC is low, and especially in north-west dry soils dominate. The major part of the dry soils has a root zone capacity between 50 mm and 80 mm, but in between root zone capacities below 50 mm may be found. The greater white areas on Fig. 6 are urban zones or forests.

Landform:	Yoldia		Dune sand		Saale till		Outwash plains		Weichsel till	
Subsoil:	sand	loam	sand	loam	sand	loam	sand	loam	sand	loam
Barley:										
MCC 1	82	88	64	72	75	77	67	63	78	74
MCC 2	134	158	119	-	119	153	117	-	119	149
MCC 3	135	-	98	-	106	155	98	-	114	163
MCC 4	169	-	-	-	141	151	-	-	146	165
MCC 5	172	206	-	-	152	165	-	-	152	171
MCC 6	-	-	-	-	-	-	-	-	173	194
Grass:										
MCC 1	82	88	64	72	75	77	67	63	78	74
MCC 2	123	124	110	-	110	119	108	-	110	115
MCC 3	124	-	91	-	98	105	91	-	105	112
MCC 4	139	-	-	-	111	107	-	-	116	116
MCC 5	142	145	-	-	122	119	-	-	122	119
MCC 6	-	-	-	-	-	-	-	-	143	139

Table 3. The root zone capacity for barley and grass in relation to soil type and landform.

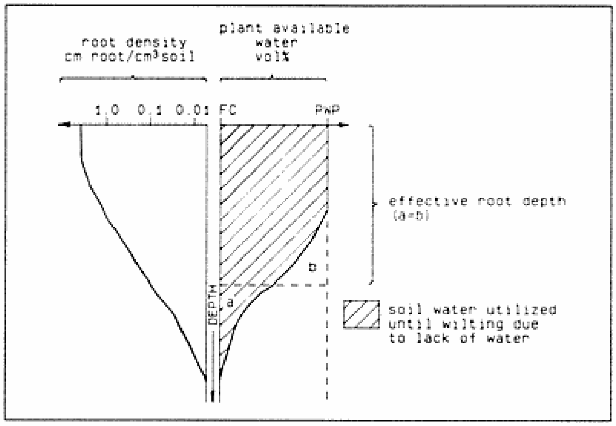


Fig. 5. Schematic drawing showing the root density, the effective root depth, and the amount of soil water utilized in the soil layers when wilting occurs.

Fig. 7 shows the location of dry soils for plant production on a nation scale. Most of them are situated in Jutland, where they cover approximately one third of the non-wetland area. Less than 1 % of the islands are dry soils. Table 4 shows the relationship between dry soils and landforms. Dry soils are especially situated in dune landforms and in outwash plains, where they cover more than three quarter of the area. In Saale glaciation landforms dry soils cover roughly half the area, and in the Weichsel glaciation landscape less than 10 %. Dry soils are not found on the Yoldia plateau.

Summary

A nation-wide mapping of root zone capacity for grass and barley production has been carried out. The mapping was based on computerized soil maps and analytical data. Approximately 36,000 soil profiles have been constructed with information on texture and organic matter content. The plant available water content in the different soil layers was calculated by regression equations combining the texture and organic matter content with the water content at pF2.0 and pF4.2. An effective root depth for different crops in relation to soil type has been defined, and the root zone capacity was calculated by combining the effective root depth with the available water content in the soil layers. The mapping shows that dry soils defined as soils with a root zone capacity below 80 mm for grass and barley production cover approximately one-third of the non-wetland area in Jutland and less than 1% on the islands. The dry soils are mainly situated in dune landforms, outwash plains, and Saale glaciation landscapes in mid- and west Jutland.

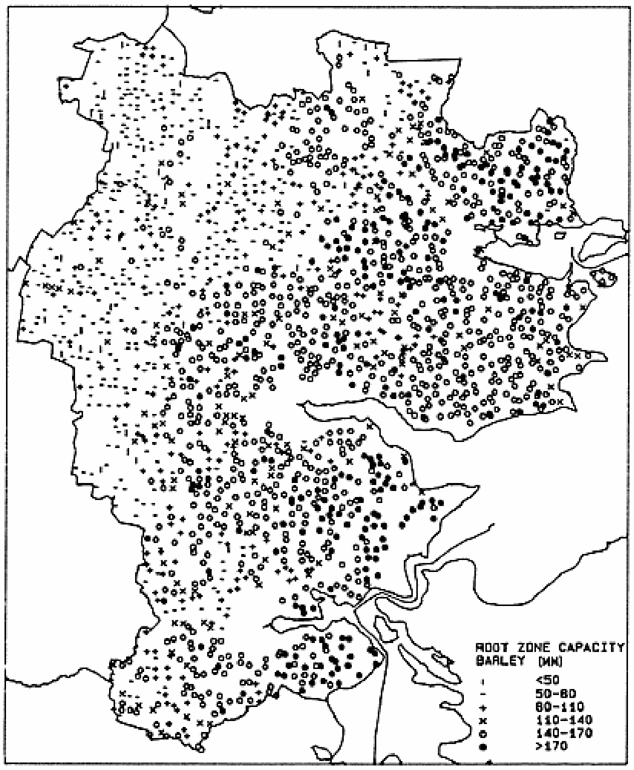


Fig. 6. A root zone capacity map for barley production. Vejle county.

Landscape	Area in km^2	% of non-wetland area
Yoldia	0	0
Dune	592	84
Saale glaciation	2065	55
Outwash plain	2335	77
Weichsel glaciation	1593	8

Table 4. Dry soils in relation to landform. Dry soils = soils with RZC below 80mm for grass and barley production.

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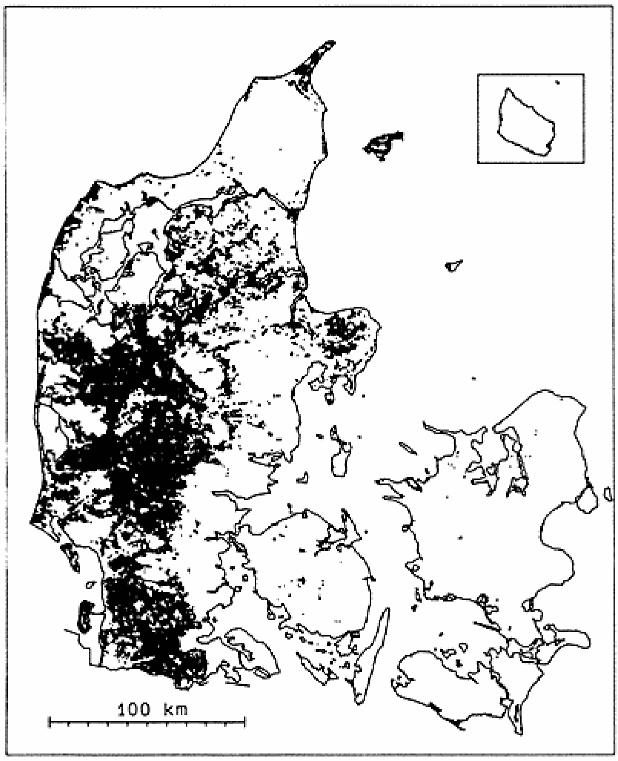

Fig. 7. A nation-wide map showing the location of dry soils. Dry soils = soils with a RZC below 80 mm for grass and barley production.

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Agricultural land-use in Denmark in the 1980s

Anette Reenberg

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The regional agricultural land-use pattern on community level is shown for selected Danish crops. It appears that even within the four years from 1981 Danish agriculture has experienced a substantial development towards a more intensive use of winter crops and crops rich in protein. This implies also some regional change in the relative importance of the major crops, where f.i. barley has lost its former total dominant position in Jutland.

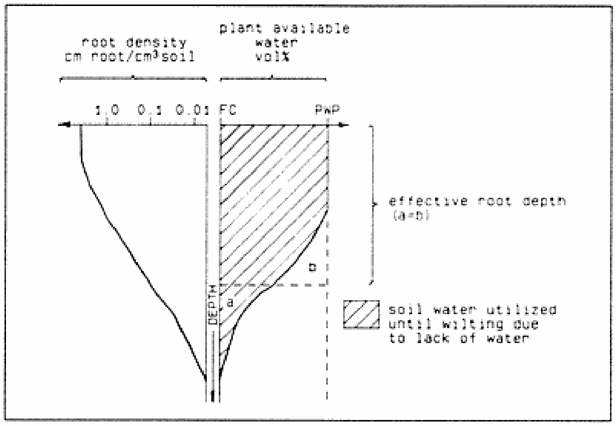
Keywords: *Denmark, Agriculture, Regional pattern, Land-use.*

Anette Reenberg, associate professor, Institute of Geography, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen K.

Since the mid 1950s Danish agriculture has gradually developed in the direction of specialization and decreasing diversity as described in detail in Jensen (1984). At the beginning of the 1980s the status was that of a highly mechanized agriculture with an outstanding specialization in production structure. The animal husbandry has been concentrated on fewer units with either cattle or pigs while the former dominance of mixed farming is dwindling. In plant production specialization is almost at its peak evaluated at a national level. Cereals, and especially spring barley, constitute a substantial part of the crop pattern as it appears from table 1. The largest percentage was reached in 1979, when spring barley covered 55 % of the total agricultural area in Denmark.

Main regional structures

However, national tendencies do not reveal some very important regional differences in the agricultural production structure. Most of the regional patterns in Danish agriculture can be related to the natural environment. Especially the marked difference between the young moraines in the eastern part of the country and the outwash plains in West-Jutland is mirrored in the production structure, but also other and more detailed characteristics of the natural environment have influenced the local production strategies (for a more comprehensive discussion of this matter see Jensen and Reenberg (1986) which gives a throughout presentation of the regional production pattern on municipality level for the years 1971 and 1981). The economic conditions in Danish agriculture are rather similar, however, for the different parts of the country, and therefore influence less the overall regional structure.



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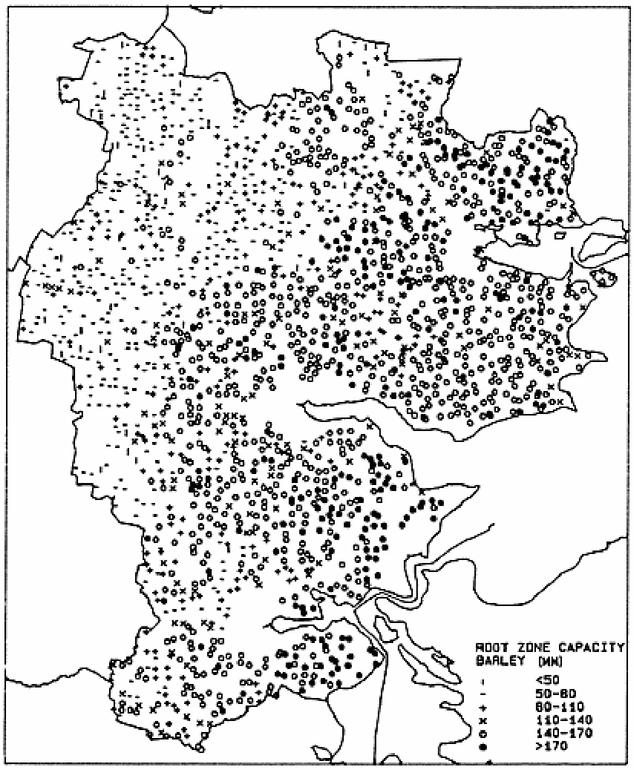

Fig. 6. A root zone capacity map for barley production. Vejle county.

Landscape	Area in km^2	% of non-wetland area
Yoldia	0	0
Dune	592	84
Saale glaciation	2065	55
Outwash plain	2335	77
Weichsel glaciation	1593	8

Table 4. Dry soils in relation to landform. Dry soils = soils with RZC below 80mm for grass and barley production.

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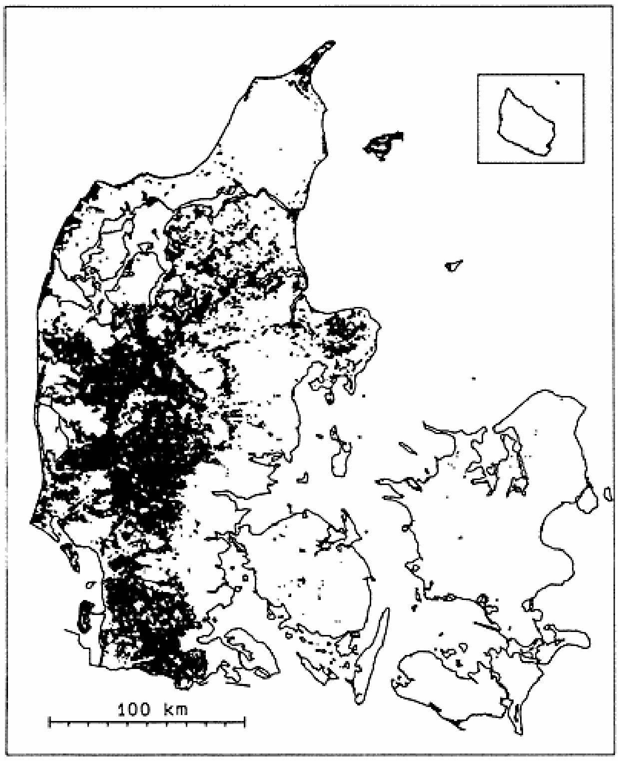

Fig. 7. A nation-wide map showing the location of dry soils. Dry soils = soils with a RZC below 80 mm for grass and barley production.

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Agricultural land-use in Denmark in the 1980s

Anette Reenberg

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The regional agricultural land-use pattern on community level is shown for selected Danish crops. It appears that even within the four years from 1981 Danish agriculture has experienced a substantial development towards a more intensive use of winter crops and crops rich in protein. This implies also some regional change in the relative importance of the major crops, where f.i. barley has lost its former total dominant position in Jutland.

Keywords: *Denmark, Agriculture, Regional pattern, Land-use.*

Anette Reenberg, associate professor, Institute of Geography, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen K.

Since the mid 1950s Danish agriculture has gradually developed in the direction of specialization and decreasing diversity as described in detail in Jensen (1984). At the beginning of the 1980s the status was that of a highly mechanized agriculture with an outstanding specialization in production structure. The animal husbandry has been concentrated on fewer units with either cattle or pigs while the former dominance of mixed farming is dwindling. In plant production specialization is almost at its peak evaluated at a national level. Cereals, and especially spring barley, constitute a substantial part of the crop pattern as it appears from table 1. The largest percentage was reached in 1979, when spring barley covered 55 % of the total agricultural area in Denmark.

Main regional structures

However, national tendencies do not reveal some very important regional differences in the agricultural production structure. Most of the regional patterns in Danish agriculture can be related to the natural environment. Especially the marked difference between the young moraines in the eastern part of the country and the outwash plains in West-Jutland is mirrored in the production structure, but also other and more detailed characteristics of the natural environment have influenced the local production strategies (for a more comprehensive discussion of this matter see Jensen and Reenberg (1986) which gives a throughout presentation of the regional production pattern on municipality level for the years 1971 and 1981). The economic conditions in Danish agriculture are rather similar, however, for the different parts of the country, and therefore influence less the overall regional structure.