# POPULATION AND RESOURCES IN TWO TYPES OF RURAL LANDSCAPE
## Denmark 1860, 1900, and 1960

*HENNING MØRCH*

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*An investigation on the basis of simple, linear regression of the relationship between size of population and physical resources in two types of landscape - moraine and outwash plain - Denmark 1860-1960.*

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This paper is limited to concern with the relationship between population and physical resources in two types of Danish landscape. In an earlier paper (Mørch 1975) the subject was more generally considered and more detailed information of sources of data, variables, model etc. presented.

The investigation comprises a sector across the peninsula of Jutland divided into two subregions, EAST and WEST (fig. 1). The subdivision follows roughly the main stationary line of the latest glacial period (Schou, 1949).

EAST consists of moraine landscapes from the last glaciation (Würm) with comparatively fertile soils which have been almost fully cultivated during the whole period of investigation.

WEST has outwash plains from the last glaciation and moraine from the former glaciation (Riss). This region has rather poor soils; before the middle of the 19th century a great part of it lay as heathlands which were reclaimed during the period of investigation (Jensen & Jensen 1979).

These two subregions represent two main types of Danish landscapes, and also reflect two main types of land use systems, as well as of rural population growth in Denmark (cf. Illeris 1965).

The period of investigation runs from 1860 - at the very beginning of the period of reclamation - up to 1960 when the reclamation was almost completed.

The sources of data are the official statistics which encompass agricultural and population censuses for Denmark even prior to 1860. The basic areas were parishes and municipalities. As the subject was rural population and resorces, urban areas with more than 10,000 inhabitants and their suburbs have been omitted. Minor towns have been regarded as, at least indirectly, to be dependent on the real rural population and production.


Fig. 1. Location of the study area in Jutland, Denmark. The hatched zone indicates the main stationary line of the last glaciation, and this was used to divide the study area into the two subregions - E (EAST) and W (WEST) mentioned in the text.
*Fig. 1. Placeringen af undersøgelsesområdet. Med skravering er vist hovedopholdslinjen fra sidste istid, som blev anvendt til opdelingen i de to delområder.*

## VARIABLES

The following six variables have been applied; as some of the abbreviations may seem unlogical, the Danish terms are stated in brackets:

- P total population
- A total area
- L rotational area (landbrugsareal i omdrift)
- S total agricultural area (samlet landbrugsareal)
- H soil fertility (hartkorn)
- V value of agricultural area

*P - total population.* An open population as the Danish rural population, including the populations in the period investigated here, is dependent upon local agricultural resources, system of utilization, and on other possibilities such as manu-

facturing, commercial relations with other regions, commuting etc. as well as upon a local service sector. For this study the population is defined as »the total population« for several reasons: in general, the population, including the local service sector, was in such areas largely dependent on the agricultural production. The commuting over longer distances was still in 1960 at its very beginning. Finally, it would be difficult to establish consistent data covering the whole period on a purely agricultural population.

The resources are difficult to measure, and it has been chosen to use only five types of areal measures, though a given area - all depending on system of utilization - might cover a resource of different size and quality.

*A - total area.* This variable might be problematic, but in any case it sets an upper limit for the agricultural resources.

*L - rotation area, or crop land.* This indicated the most intensively exploited resources and often the most important.

*S - total agricultural area.* This indicates the whole area within the farming system including fallow areas, permanent pastures etc., areas which in a specific year are mainly extensively utilized, but which may be of great importance in a certain region's farming system, or at certain times.

All A-, L-, and S-values are stated in hectares.

The area variables have been supplemented with estimates of soil quality, and of land values as these might differ much.

*H - soil fertility.* This variable is stated in »tønder hartkorn«, an ancient Danish standard of assessment indicating estimated productivity on the basis of soil quality and -structure. In all essentials, this assessment was established in the mid-19th century, i.e. at a time when the farming systems differed much from present-day's; it can therefore only be considered a very rough estimate of soil fertility, especially for areas which have since then been reclaimed, for example heathland.

*V - value of total agricultural area.* This assessment might be a more realistic estimate of fertility or productivity as it is intended to be in accordance with a reasonable sales price, which will of course again be influenced by a.o. distance from major towns. Therefore in 1900 and 1960 the official assessments of land - by and large corresponding to sales value in 1000 Danish kroner - were applied. For 1860, however, taxation values assessed in 1000 »Rigsdaler« (the monetary standard of that time) had to be used.

In respect of population per unit of the last two variables (H and V), this will thus not be a population density in the conventional sense of the term but, as used here, all measures should be regarded as relative values more than precise measures.

## THE METHOD

The relation between population and resources

$$P = f(R)$$

may be expressed generally as:

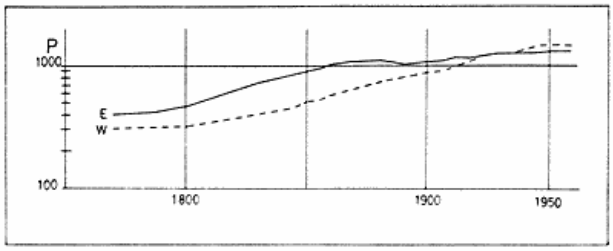


Fig. 2. Population growth 1769-1960 in the two subregions E (EAST) and W (WEST). The curves show the mean population of the two regions' parishes. There have been censuses for the whole period, since 1840 every 5th or 10th year, since 1901 every 5th. The ordinate P (population) with logaritmic scale.

*Fig. 2. Befolkningsudviklingen i de to delområder. Kurverne viser gennemsnitlig folkemængde i sogne.*

$$P = a R^b \quad (1)$$

from which it appears that the population density (D) is:

$$D = a R^{(b-1)} \quad (2)$$

In the present study the observations show a skew distribution, more minor populations and areas than bigger ones and a logarithmic transformation has therefore been used similar to other investigations of population-land relationships. By transforming to logarithmic values, the illogicality is avoided that population and area formally may turn out as negative values.

After transforming the equations (1) and (2) we get:

$$\log P = \log a + b \log R \quad (3)$$

$$\log D = \log a + (b-1) \log R \quad (4)$$

Model (3) was used for a regression and correlation analysis of the relationship between population and resources.

While relation (1) is exponential, relation (3) postulates a linear relationship. In (3) the constant b is the gradient of the regression line. From (3) and (4) it appears that the parameter *a* is the level of population density if log R = 0 (e.g. R = 1.0) on the precondition that *b* is not significantly different from 1.0. If these conditions are fulfilled, log *a* can be regarded as the population density, or carrying capacity, per resource unit (here area) at a given time even if the population is in a period of growth. To a certain carrying capacity a certain straight line with a gradient of 1.0 (45°) will correspond. If *b* is significantly different from 1.0, the relations are more complex.

## GROSS PATTERNS OF THE VARIABLES

In connection with the regression analysis, the means of the variables for the parishes in the two subregions were found. They give a picture of some general dimensions and trends. As the analysis gave the arithmic means of the observations transformed to logarithms, the antilog of these means therefore corresponds to the geometric means. The population densities, D = P/R, were calculated from these antilog values. The means and densities are shown in table 1; as can be seen, great differences exist between the two subregions.

P, the population, has during the whole 100-year period

| | 1860 | | | 1900 | | | 1960 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}$ | anti-log | D | $\bar{X}$ | anti-log | D | $\bar{X}$ | anti-log | D |
| EAST | | | | | | | | | |
| P | 3,0283 | 1068 | - | 3,0487 | 1119 | - | 3.0931 | 1239 | - |
| A | 3,3769 | 2382 | 0,45 | 3,3781 | 2389 | 0,47 | 3,3834 | 2417 | 0,51 |
| L | 2,9804 | 956 | 1,12 | 3,0208 | 1049 | 1,07 | 2,2323 | 1707 | 0,73 |
| S | 3,2892 | 1946 | 0,55 | 3,3146 | 2064 | 0,54 | 3,2894 | 1947 | 0,64 |
| H | 2,4819 | 303 | 3,52 | 2,4871 | 307 | 3,64 | 2,4633 | 291 | 4,26 |
| V | 3,2056 | 1605 | 0,67 | 3,3483 | 2230 | 0,50 | 3,6720 | 4698 | 0,26 |
| WEST | | | | | | | | | |
| P | 2,8461 | 702 | - | 2,9995 | 999 | - | 3,1952 | 1568 | - |
| A | 3,7416 | 5515 | 0,13 | 3,7416 | 5538 | 0,18 | 3,7541 | 5677 | 0,28 |
| L | 2,8568 | 719 | 0,98 | 3,0852 | 1216 | 0,82 | 3,5098 | 3234 | 0,48 |
| S | 3,3483 | 2205 | 0,32 | 3,5159 | 3280 | 0,30 | 3,5837 | 3834 | 0,41 |
| H | 2,2179 | 165 | 4,25 | 2,2191 | 166 | 6,02 | 2,1705 | 148 | 10,59 |
| V | 3,0197 | 1047 | 0,67 | 3,0990 | 1256 | 0,80 | 3,5527 | 3570 | 0,44 |

Table 1. Means of the six variables. Log = means of transformed variables, antilog corresponds to geometric means. The population density D = P/R is calculated from the antilog values.

Tabel 1. Gennemsnit for de seks variable. Log = gennemsnit af de transformerede værdier, antilog svarer derfor til geometrisk gennemsnit. Befolkningstæthed D = P/R er beregnet ud fra antilog-værdierne.

| | 1860 | 1900 | 1960 |
|---|---|---|---|
| EAST | | | |
| S/A | 0,82 | 0,86 | 0,81 |
| L/S | 0,49 | 0,51 | 0,87 |
| L/A | 0,40 | 0,44 | 0,71 |
| WEST | | | |
| S/A | 0,40 | 0,59 | 0,68 |
| L/S | 0,33 | 0,37 | 0,85 |
| L/A | 0,13 | 0,22 | 0,57 |

Table 2. The ratio between the total area (A), the total agricultural area (S), and the rotation area (L). Based on the antilog values in table 3.

Tabel 2. Forholdstal mellem det samlede areal (A), det samlede landbrugsareal (S) og omdriftsareal (L). Beregnet på grundlag af antilog-værdierne i tabel 3.

grown by exactly one fifth in EAST, but more than doubled in WEST.

A, the total area, is almost constant; the minor changes are due to administrative, inter-communal regulations.

S, the total agricultural area, has been almost constant in EAST, while it has grown by nearly 60% in WEST.

L, the rotation area has also grown in EAST, by ¾, but has more than quadroubled in WEST.

H, the soil fertility, shows for both regions a minor »fall« due to revisions of this very rough estimate.

V, the economic value, has of course grown, at least numerically, f.e. on account of the inflation; and, a comparison between the 1860-value and the two others is not possible at all.

The population density shows that, in general, EAST is more densely populated than WEST, especially for the total area, and the stagnation of population in EAST is in contrast to the growth in WEST. The fact that number of inhabitants per unit of soil fertility (H) and value (V) is higher in WEST than in EAST might have appeared from two contradicting interpretations: 1) that WEST is relatively overpopulated or, 2) that the (H)-and (V)-values for WEST are underestimated.

The different trends observed for the regions, especially as regards the two types of agricultural area, reflect the different systems of land utilization and their evolution. This appears especially from the ratios between total area and 1) total agricultural area, 2) rotation area, and 3) share of total agricultural area in rotation, as will appear from table 2.

The total agricultural area (S) constitutes a constant fraction of the total area (A) in EAST, whereas it grows from 40% to roughly 70% in WEST. The fraction in rotation area (L) was more or less doubled in EAST; for WEST (L) reached the same level although it started at a much lower one.

The growth of population in the two regions appears from fig. 2. The curves show the mean population of the parishes and municipalities in the two regions, and they demonstrate two typical types of rural population growth in Denmark. In EAST (as in eastern Denmark) the population expansion took place until the middle of the 19th century, when a stagnation set in more or less. In WEST (as in the rest of western Jutland) the expansion began later and took place at a slower rate, but continued then until the middle of this century.

These two types of population growth are reflecting the mentioned, different exploitation of agricultural resources.

## THE REGRESSION AND CORRELATION ANALYSIS

The results of the regression and correlation analysis appear from table 3.

In EAST, the coefficient of correlation (r) seems in general to be lower over time and lowest for P = f(H). For WEST, the conditions seem to be more complex. But for both regions the correlation is significant at 99% level, apart from P = f(H) in 1960, which is significant at 95% level. The coefficient of determination ($r^2$) varies from 0.87 and down to 0.09.

For EAST it can be seen that, with some exceptions, the coefficient of regression (b) is close to 1.0. This indicates, as mentioned, that the parameter *a* can be taken as an approximation of a certain population density or carrying capacity for the unit in which the resources are measured, cf. the antilog a-values; this so with reservation of limits of variation. In this respect the model - as one could expect - is not fitting just as well as was found for the more isolated populations of the minor Danish islands (Mørch, 1975). The b-values that have to be rejected, those differing significantly from 1.0, appear clearly from the table. This was tested by a t-test.

| log P = | a | + | b | log R | r | n | anti-log a |
|---|---|---|---|---|---|---|---|
| EAST | | | | | | | |
| 1860 | | | | | | | |
| log P = | -0,0319 | + | 0,9062 | log A | 0,9002 | 63 | |
| | -0,0098 | + | 1,0194 | log L | 0,9327 | 63 | 0,978 |
| | -0,0963 | + | 0,9500 | log S | 0,9023 | 63 | 0,801 |
| | 0,8828 | + | 0,8741 | log H | 0,8828 | 63 | |
| | 0,6672 | + | 0,7366 | log V | 0,8632 | 63 | |
| 1900 | -0,2409 | + | 0,9738 | log A | 0,8638 | 63 | 0,171 |
| | 0,1428 | + | 0,9620 | log L | 0,8566 | 63 | 1,389 |
| | -0,1936 | + | 0,9782 | log S | 0,8543 | 63 | 0,640 |
| | 0,8151 | + | 0,8981 | log H | 0,8152 | 63 | 6,533 |
| | -0,6693 | + | 1,1206 | log V | 0,8748 | 48 | |
| 1960 | -0,5444 | + | 1.0751 | log A | 0,7755 | 63 | 0,285 |
| | -0,2422 | + | 1,0319 | log L | 0,7323 | 63 | 0,573 |
| | -0,4028 | + | 1,0628 | log S | 0,7361 | 63 | 0,396 |
| | 0,9400 | + | 0,8740 | log H | 0,6513 | 63 | 8,710 |
| | -0,6111 | + | 1,0088 | log V | 0,7094 | 63 | 0,245 |
| WEST | | | | | | | |
| 1860 | 1,1001 | + | 0,4666 | log A | 0,4481 | 64 | |
| | 0,3850 | + | 0,8615 | log L | 0,8160 | 64 | |
| | -0,1895 | + | 0,9066 | log S | 0,7747 | 64 | 0,646 |
| | 1,1492 | + | 0,7651 | log H | 0,7573 | 64 | |
| | 1,0117 | + | 0,6075 | log V | 0,6531 | 64 | |
| 1900 | 0,8096 | + | 0,5681 | log A | 0,5681 | 64 | |
| | 0,7805 | + | 0,7192 | log L | 0,6943 | 64 | |
| | 0,0920 | + | 0,8270 | log S | 0,7265 | 64 | |
| | 1,6186 | + | 0,6222 | log H | 0,6143 | 64 | |
| | 0,0919 | + | 0,9430 | log V | 0,8619 | 41 | 1,236 |
| 1960 | -0,2404 | + | 0,9152 | log A | 0,7551 | 62 | 0,575 |
| | 0,7977 | + | 1,0259 | log L | 0,7977 | 62 | 0,393 |
| | -0,8625 | + | 1,1323 | log S | 0,8253 | 62 | 0,137 |
| | 2,4136 | + | 0,3550 | log H | (0,3069) | 62 | |
| | 0,3037 | + | 0,8107 | log V | 0,6390 | 62 | |

Table 3. Analysis of regression and correlation of population and resources for the two subregions. P: population, A: total area, L: rotation area, S: total agricultural area, H: soil fertility, V: land value. Underlining of b-values indicates that b is significantly different from 1.0 as follows: ..... at the 0.05 level, and _____ at the 0.01 level.

Tabel 3. Regressions- og korrelationsanalyse af befolkning og ressourcer i de to delområder. P: befolkning, A: samlet areal, L: omdriftsareal, S: samlet landbrugsareal, H: hartkorn, V: vurdering af landbrugsjord. Understregning af b-værdier angiver, at b er signifikant forskellig fra 1.0 således: ..... på 0.05 og _____ på 0.01 niveau.

The regression for WEST points at more complicated relations between population and area. But the model seems to fit fairly well for 1960.

## CONCLUSION

Generally, the correlation between population and resources was high. In the respect that it pointed at a certain carrying capacity per unit of resource (although the system cannot be characterized as a subsistenc system), the regression model was fitting quite well for the subregion EAST for all three years investigated, but for WEST it fitted only for the year 1960. This and other differences observed between the two regions originate in different systems of land use. During the whole period of investigation EAST has been more or less fully cultivated, and here the areal measures represent a reasonable estimate of the resources. The agricultural systems of WEST and EAST gradually approached each other so, by 1960, the areal measures should represent a fair estimate of resources. For 1860 and 1900 both population and farming system depended largely on the given physical resources: meadow - cultivated field - heathland for sheepgrazing, and these utilizations interplayed in a refined way (Jensen & Jensen, 1979); but how the resources were distributed, these rough areal data did not reveal.


### RESUME

Med anvendelse af simpel regressions- og korrelationsanalyse behandler artiklen sammenhængen mellem folkemængde og landbrugsressourcer i to danske landskabstyper. Sammenhængen er belyst på grundlag af modellen log P= a + b log R, hvor P = befolkning, R - ressourcer, a er en konstant som giver (logaritmen til) en bestemt befolkningstæthed eller bæreevne - forudsat, at konstanten *b* ikke afviger signifikant fra 1.0; i så fald er forholdene mere komplekse. Undersøgelsen er foretaget for 1850, 1900 og 1960. Materialet stammer fra den officielle statistik med sognekommuner som basisarealer. Som P er anvendt samlet folketal. Som R er anvendt 5 arealmål: A samlet areal, L omdriftsareal, S samlet landbrugsareal, H tønder hartkorn, og V vurdering af landbrugsareal. Undersøgelsen er foretaget for en sektor tværs over Jylland og opdelt i to delregioner: ØST, som består af moræne fra sidste istid og med forholdsvis frugtbar jord. VEST, som består af moræne fra næstsidste istid (bakkeøer) og hedesletter fra sidste, har betydelig ringere jord. Landbrugsmæssigt har ØST stort set været fuldt udnyttet gennem hele undersøgelsesperioden, medens VEST først for alvor blev lagt under plov i løbet af perioden (hedeopdyrkningen).

Korrelationen mellem befolkning og ressourcer var generelt signifikant høj. Regressionsmodellen synes at passe for alle 3 tidspunkter for ØST, men kun for 1960 for VEST. Denne forskel, og andre som blev observeret mellem de to delområder, må ses på baggrund af forskel i udnyttelsessystem. For ØST repræsenterer de anvendte mål for ressourcer rimelige skøn over de fysiske landbrugsressourcer. For VEST repræsenterer de grove arealmål derimod først i 1960, da udnyttelsessystemet havde nærmet sig ØSTs, anvendelige skøn over ressourcerne. Oprindeligt var udnyttelsessystem og befolkning nok så afhængige af fysiske ressourcer. Men her var systemet baseret på en komplex anvendelse af eng, ager og hede, og fordelingen af disse 3 ressourcetyper afspejles ikke i sognenes grove arealtal.



### ACKNOWLEDGMENTS

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| | 1,1492 | + | 0,7651 | log H | 0,7573 | 64 | |
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Table 3. Analysis of regression and correlation of population and resources for the two subregions. P: population, A: total area, L: rotation area, S: total agricultural area, H: soil fertility, V: land value. Underlining of b-values indicates that b is significantly different from 1.0 as follows: ..... at the 0.05 level, and _____ at the 0.01 level.

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Generally, the correlation between population and resources was high. In the respect that it pointed at a certain carrying capacity per unit of resource (although the system cannot be characterized as a subsistenc system), the regression model was fitting quite well for the subregion EAST for all three years investigated, but for WEST it fitted only for the year 1960. This and other differences observed between the two regions originate in different systems of land use. During the whole period of investigation EAST has been more or less fully cultivated, and here the areal measures represent a reasonable estimate of the resources. The agricultural systems of WEST and EAST gradually approached each other so, by 1960, the areal measures should represent a fair estimate of resources. For 1860 and 1900 both population and farming system depended largely on the given physical resources: meadow - cultivated field - heathland for sheepgrazing, and these utilizations interplayed in a refined way (Jensen & Jensen, 1979); but how the resources were distributed, these rough areal data did not reveal.


### RESUME

Med anvendelse af simpel regressions- og korrelationsanalyse behandler artiklen sammenhængen mellem folkemængde og landbrugsressourcer i to danske landskabstyper. Sammenhængen er belyst på grundlag af modellen log P= a + b log R, hvor P = befolkning, R - ressourcer, a er en konstant som giver (logaritmen til) en bestemt befolkningstæthed eller bæreevne - forudsat, at konstanten *b* ikke afviger signifikant fra 1.0; i så fald er forholdene mere komplekse. Undersøgelsen er foretaget for 1850, 1900 og 1960. Materialet stammer fra den officielle statistik med sognekommuner som basisarealer. Som P er anvendt samlet folketal. Som R er anvendt 5 arealmål: A samlet areal, L omdriftsareal, S samlet landbrugsareal, H tønder hartkorn, og V vurdering af landbrugsareal. Undersøgelsen er foretaget for en sektor tværs over Jylland og opdelt i to delregioner: ØST, som består af moræne fra sidste istid og med forholdsvis frugtbar jord. VEST, som består af moræne fra næstsidste istid (bakkeøer) og hedesletter fra sidste, har betydelig ringere jord. Landbrugsmæssigt har ØST stort set været fuldt udnyttet gennem hele undersøgelsesperioden, medens VEST først for alvor blev lagt under plov i løbet af perioden (hedeopdyrkningen).

Korrelationen mellem befolkning og ressourcer var generelt signifikant høj. Regressionsmodellen synes at passe for alle 3 tidspunkter for ØST, men kun for 1960 for VEST. Denne forskel, og andre som blev observeret mellem de to delområder, må ses på baggrund af forskel i udnyttelsessystem. For ØST repræsenterer de anvendte mål for ressourcer rimelige skøn over de fysiske landbrugsressourcer. For VEST repræsenterer de grove arealmål derimod først i 1960, da udnyttelsessystemet havde nærmet sig ØSTs, anvendelige skøn over ressourcerne. Oprindeligt var udnyttelsessystem og befolkning nok så afhængige af fysiske ressourcer. Men her var systemet baseret på en komplex anvendelse af eng, ager og hede, og fordelingen af disse 3 ressourcetyper afspejles ikke i sognenes grove arealtal.



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