Georeferenced data as a tool for monitoring the concentration of population in Finland in 1970–1998

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Changes in the distribution of population in Finland over the period 1970–1998 are examined in terms of a co-ordinate system of 1 x 1 km grid cells. The results indicate that this system provides suitable areal units for a variety of statistical and GIS methods aimed at describing and explaining the spatial distribution of population. The system is capable of yielding more detailed information than heretofore on topics such as the concentration of population in the urban centres of Finland – a process that has been going on since the beginning of the last century, but has slowed down noticeably in the recent years.

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Introduction

Demographic research has a long tradition within geography and represents a discipline that is eminently suited to the study of the spatial distribution of population and its changes. The results of these studies are required for planning purposes in many sectors of the society, e.g. determination of the capacity and location requirements for various public services at the national, regional or local level. Although it is primarily the authorities that have been interested in the direction of demographic trends, it is by no means a matter of indifference for individual citizens or families whether they live in an area of expanding or diminishing population. The general image of an area is to a considerable extent shaped by trends in population, as well as with structural changes of the area. There is thus an obvious need for statistical data that are both up to date and geographically more detailed than earlier, and for precise interpretations of such data. This poses new challenges not only for the producers and users of the statistics but also for those engaged in developing and applying analytical and interpretative methodologies.

The geographical examination of population distributions and their temporal changes has typically relied on notions such as spatial concentration and deconcentration (Lipshitz 1996; Borgegård et al. 1995), or urbanization and counterurbanization (Håkansson 2000), while migration research has adopted perspectives such as that of the 'turnaround' phenomenon (Long & Nucci 1997; Lewis 2000). The actual terms in use vary not only according to the theoretical basis from which the research sets out but also in relation to the volume of migration concerned and its temporal duration.

Our picture of the spatial concentration and agglomeration of population in Finland has largely been shaped by the publications of Hustich (1977) and Alestalo (1983). More recently, however, the present authors have discussed changes in the settlement structure and the concentration of population with the aid of georeferenced data and GIS methods (see Naukkarinen et al. 1993; Rusanen et al. 1997).

As pointed out by e.g. Håkansson (2000), research into the distribution of population can be greatly affected by the employed geographical unit, so that models that apply at one spatial level do not necessarily hold good at another. One particularly difficult problem concerns boundary changes, which indicates that census statistics for different years do not necessarily apply to the same areal units and therefore, cannot be compared easily (Howenstine 1993; Openshaw 1995; Rees 1998).

The requirements placed on population statistics and the usefulness of the data available can vary greatly from one group of users to another. Public authorities, for instance, are accustomed to using statistical means and definitions expressed in terms of administrative areas and deductions made from these when they require information on which to base their decisions. Researchers, in contrast, prefer to go back to the sources of the original raw data in order to test their hypotheses and construct their models. For this reason we will attempt to analyse and examine demographic data using various methods in terms of both administrative and non-administrative areal units, and to evaluate the subsequent results.

Aims, data and methods

We set out here to describe 1) the changes in population that have taken place within the spatial and settlement structure of Finland by means of 1 x 1 km grid cell data, 2) the methods available for the analysis of population data, and 3) the factors highlighted by the grid cell method that cannot be identified when using administrative areal units. Finally, the usefulness of the resulting information for the purposes of demographic research will be evaluated.

Georeferenced data on Finland are available at many spatial levels. In practice, any individual citizen can be assigned a set of coordinates describing the geographical location of the house in which he or she lives. The resulting data can be aggregated to represent higher-level units, e.g. postal districts, parts of municipalities, whole municipalities, groups of municipalities or the NUTS hierarchy as used by the EU. It must be remembered, however, that the above-mentioned problem of comparability over time emerges in the case of these areal units whenever administrative areas are combined or boundaries are altered. On the other hand, the fact that the initial information is available at the individual level is regarded as a significant advantage of GIS methods (Martin & Higgs 1997; see also Openshaw & Turton 1996).

Thus, the principal units employed here are the 1 x 1 km grid cells defined in the data produced by Statistics Finland for the years 1970, 1980 and 1990–1998 (see Rusanen et al. 1997). These grid cells are of fixed location and are independent of any changes in administrative boundaries. Statistical information on human activities in Finland has been available annually since 1987. Current methods enable Statistics Finland to revise their georeferenced population data very quickly, so that figures for the population on 31st December are available by the end of the following February, together with statistics for the individual municipalities. This annual information is based on registers, so that no separate population census is necessary as in the USA, for example (see Crews 2000).

The second basic areal unit employed here is the municipality, or independent local government district. These districts have numerous rights and obligations that define them as administrative entities, including the right to levy taxes (Ministry of the Interior 2000). In accordance with the above principle, the populations of the municipalities are calculated here from the grid cell figures, and for this reason the figures differ slightly from those quoted in the official statistics, as for instance in 1998, 1.42% of the national population could not be assigned coordinates on the basis of their place of residence. However, this discrepancy can be assumed not to affect the results.

It should be noted that we are not concerned here with studying the potential factors responsible for demographic trends in particular areas, e.g. birth-rates, mortality or migration – topics which have traditionally been to the fore in population geography (Ogden 1998; 1999). Instead, we focus on describing solely the concentration of population. This is defined here in two ways: as an increase in population density per square kilometre when using grid cell data, and as an increasingly larger proportion of the population living in a progressively smaller number of municipalities.

Data on population changes in the 1 x 1 km grid cells and municipalities are analysed here by a number of methods, and assessments are made as to whether these methods yield similar or divergent results. The methods tested include the Gini Coefficient, which is more commonly used for analysing the spatial distribution of income

Table 1. Number of inhabited grid cells and mean population density in Finland in 1970–1998 (Data: Statistics Finland).

	1970	1980	1990	1992	1994	1996	1998
Number of inhabited grid cells	110477	104540	103242	103020	103036	103045	102873
Inhab./km^2	41.3	44.1	47.8	48.4	48.9	49.1	49.4

rates (see Chakravorty 1994) rather than population (see Bradford & Kent 1986; Lovell-Smith 1993). In addition, the concentration of population is described in terms of mean values and the Moran and Geary Indices used in version 8.0 of the Arc/Info software. Changes in population are also described by reference to deciles and by classification of the 'spatial demographic structure'. Long-term patterns are visualized by means of a rank size model and the kriging interpolation method contained in version 8.0 of Arc/Info. The Hoover Index that is frequently used in studies of population concentration (see Borgegård et al. 1995; Long & Nucci 1997) is not employed here, as the emphasis is on analysis at the grid cell level rather than at the municipality level.

Decile analysis involves ranking the data units in size order from largest to smallest with respect to the studied variable, and dividing them into ten equal groups in terms of population described by the variable, regardless of whether the areal unit is a grid cell or a municipality.

Population concentration as reflected in the Moran and Geary indices and the Gini coefficient

Population density in Finland in 1998 relative to land area was very low by European standards, only 16.9 inhabitants per square kilometre. If, however, we use the grid cell material to calculate the mean density for inhabited cells only, we see that the density has increased steadily over the period examined here, and is now approaching 50 inhab./km^2 (Table 1).

The Moran and Geary methods allow a spatial autocorrelation index to be determined for the grid cell material as follows: when the Moran Index is positive and the Geary Index varies in the range 0–1 the distribution of population can be described as 'similar', 'regionalized', 'smooth' or 'clustered'. If the Moran Index is negative and the Geary Index greater than 1, the corresponding

Table 2. Moran (I) and Geary (C) Indices in 1970–1998 (Data: Statistics Finland).

	Year						
	1970	1980	1990	1992	1994	1996	1998
I	0.543	0.531	0.568	0.570	0.581	0.590	0.597
C	0.427	0.435	0.400	0.394	0.384	0.377	0.370

terms are 'dissimilar', 'contrasting' and 'checkerboard' (for details, see Arc/Info User Manual 2000). In the present case, the gradual increase in the Moran Index and the simultaneous decrease in the Geary Index lend further support to the impression gained from the previous table of a process of consolidation of the inhabited area rather than a scattering or dispersal of population (Table 2).

One typical technique employed to describe evenness or concentration in the distribution of population is the Lorenz diagram (Alestalo 1983), or its derivative, the Gini Coefficient (Fainstein 1996). Regardless of whether we use grid cells or municipalities as the areal units, the obtained Gini Coefficients indicate a concentration of population (Table 3), although the higher value of the grid cell material as compared to the municipality level also indicates the essentially local nature of this concentration. The fact that the majority of the population of Finland is located within a relatively small number of grid cells is indicative of the low proportion of built-up areas within the country's total settled area.

Measured in both of the above ways, the rate of change was greatest in the 1970's, an observation that confirms the general impression regarding the concentration of population in Finland. It is consistent with the results of the examination by deciles published by Alestalo (1983). On the other hand, analysis of the trend over the last two decades in terms of the Gini Coefficient provides deviant results for the two sets of areal units. The rate of population concentration apparently has slowed down when assessed in terms of the grid

Table 3. Concentration of population as shown by the Gini Coefficients for the years studied and percentage change over the period 1970–1998 (Data: Statistics Finland).

	Year			
Areal unit	1970	1980	1990	1998
Grid cell	0.78558	0.83450	0.85365	0.86324
Municipality	0.59228	0.62145	0.62962	0.65186
	Change in Gini Coefficient (%)			
	1970–1980	1980–1990	1990–1998	
Grid cell	6.2	2.3	1.1	
Municipality	4.9	1.3	3.5	

cell data, being only 1.1% in the 1990's, whereas the figures for the municipalities indicate acceleration with a terminal rate of 3.5%.

The result obtained from the grid cell data may indicate a decreasing trend in population concentration in the densest areas, the pattern being attributable to the exclusion of uninhabited grid cells and the concentration of population in a constantly decreasing number of cells and a more restricted geographical area. This trend, which is largely internal to individual municipalities, fails to be reflected in the analyses based on municipalities as the areal units.

Decile analysis

Decile analysis employs divisions of the total material into tenth parts. It can be regarded as a flexible, non-given means of classification, and since the boundaries of the deciles tend to vary from one year to the next, the method is well suited to studies of concentration or dispersal, e.g. in population or incomes. According to Alestalo (1983), the population of Finland was fairly evenly distributed over the deciles at the end of the 19th century, the agrarian society of the time showing little agglomeration of the population into urban centres. From that time onwards, however, the population gradually became concentrated in a smaller number of municipalities (Table 4), so that by the 1970's, half of the country's population lived in 52 municipalities, 10.1% of their total number. The trend continued so that in 1998, the corresponding figure was 33 municipalities, i.e. 7.3% of the total. Part of this effect may be attributed to the amalgamation of municipalities within the system of local government, but the principal factor has without doubt been the actual concentration of population within a progressively smaller number of towns and cities (Rusanen et al. 2000).

Table 4. Concentration of population by deciles of municipalities in 1970, 1980, 1990 and 1998 (Data: Statistics Finland).

	Number of municipalities			
	Year			
Decile	1970	1980	1990	1998
1	1	1	2	1
2	4	4	3	3
3	6	5	5	4
4	15	10	10	9
5	26	20	18	16
6	38	29	27	23
7	50	42	40	38
8	66	58	57	56
9	97	88	87	88
10	212	204	206	214
Total	515	461	455	452

Is this concentration visible in the grid cell data? For answering this, a decile analysis comparable to that in Table 4 is presented in Table 5. The deciles indeed indicate a continuation of the concentration process, so that half of the country's population (the population of deciles 1–5) occupied a total of 1541 km^2 in 1970, 1167 km^2 in 1980, 1294 km^2 in 1990 and 1284 km^2 in 1998. The 1970's were a period of heavy population concentration, whereas from the end of that decade onwards Finland was affected by a 'turnaround' phenomenon, as noted by several authors (Kauppinen 2000). This process was experienced in many western countries, entailing above all a

Table 5. Numbers of inhabited grid cells by deciles in 1970, 1980, 1990 and 1998 (Data: Statistics Finland).

Decile	1970 N	1980 N	1990 N	1998 N	Inhab. km^2 in 1998
1 densest	47	66	84	82	4171–19172
2 settlement	116	133	159	158	2633–4170
3	207	200	234	234	1795–2632
4	384	297	336	334	1257–1794
5	787	471	481	476	881–1256
6	1 856	825	751	721	536–880
7	4 992	1 928	1 420	1 299	267–535
8	11 290	6 816	4 635	3 813	70–266
9 sparsest	22 331	19 590	16 579	14 980	20–36
10 settlement	68 462	74 209	78 561	80 770	1–19
Number of grid cells	110 472	104 535	103 240	102 873	

decline in the popularity of urban areas as living environments for families with children.

The inhabited area of Finland in 1998 amounted to ca. 30.4% of the total surface area of 338 145 km^2, with a consistent decline of this proportion from one decade to the next since 1970. The most pronounced decline, almost 6000 km^2, took place during the 1970's, although it has also been claimed that the material for 1970 contained some errors in the coordinates determined for individual dwellings and that the actual net decrease was not necessarily as great as this. It should also be noted that the trend was a relatively steady over the period 1990–1998 relative to the 1980's, although data on the final years of the decade are still lacking.

Changes may also be observed in the population densities for the deciles (Table 6). The highest densities of all were recorded in deciles 1 and 2 in 1970, when Finland was experiencing a pronounced migration from the countryside into the towns and also abroad, primarily to Sweden (see Kauppinen 2000). At that time the mean population density in the top decile was around 9700 inhab./km^2, whereas the corresponding figure in 1998 was about 6200. The maximum population density was reached in Helsinki, the capital. In the 1970 data the density peaked at 29 234 inhab./km^2, whereas the figure for 1998 showed a reduction of more than a third, 19 172 inhab./km^2.

A number of factors can be identified that contributed to the reduction of population density in Finland over the study period. The most significant factor was the transfer in the urban centres from dwellings to other uses, mainly offices and commercial premises. Other factors were changes in the structure of households, including reductions in the average family size and the number of families with children and an increase in the number of single-person households.

Table 6. Population density by deciles in 1970, 1980, 1990 and 1998 (Data: Statistics Finland).

Inhab. km^2 Decile	1970	1980	1990	1998
1	9703	6980	5876	6202
2	3932	3464	3104	3219
3	2203	2303	2109	2173
4	1188	1551	1469	1523
5	579	978	1026	1068
6	246	558	657	705
7	91	239	348	392
8	40	68	106	133
9	20	24	30	34
10	7	6	6	6

It should be pointed out, however, that the mean population density of the two most densely inhabited deciles began to increase again in the 1990's, partly on account of the efforts made to fill in the settlement pattern in built-up areas in accordance with the principles of sustainable development.

Andersson (1988) recognizes four stages in the development of towns in Finland: urbanization, suburbanization, disurbanization and reurbanization. Urbanization stage refers to the growth of a central urban nucleus, while the suburbanization stage involves a slowing down and eventually cessation of this trend. At the disurbanization stage, the trend is reversed, until the reurbanization stage marks new growth in the urban nucleus. It is interesting to consider how these stages might be reflected in an empirical decile analysis.

The urbanization stage seems to have taken place in Finland before 1970, as the population of the most densely inhabited central areas (deciles 1 and 2) began to decline after that time. Hence, the 1970's and 1980's may be assigned to the suburbanization and disurbanization stages, as these figures in particular declined markedly at first and then levelled out somewhat in the 1980's, when the changes were less pronounced in other respects, too. The 1990's represent the reurbanization stage, in which the population of the most densely inhabited areas again started to increase.

It is important to bear in mind when evaluating these findings that the stages are distinguished on the strength of only a single variable. A more precise consideration would call for an internal analysis of the structure of the ten largest cities, for example, and also other information relevant to the growth of urban areas, e.g. their development and planning policies.

Population changes by deciles in 1990–1998

Dual trends in population density and in the number of inhabited grid cells are observable during the 1990's, the cut-off point being reached in 1993. The minimum area occupied by half of the population of Finland, i.e. deciles 1–5, increased numerically over that time (Table 7a), implying a slight decline in population density in the urban nuclei and suburbs (Table 7b). From 1993 onwards, the trend towards denser communities can be observed, although not quite amounting to the figures recorded in 1970 and 1980.

The most sparsely populated rural areas (decile 10) increased in number throughout the 1990's, whereas their mean population density remained more or less stable. The increase may be attributed almost entirely to reductions in the population of some grid cells previously contained in decile 9, representing the rural areas proper, causing their transfer to decile 10.

The reversal in the trend in 1993 is probably linked to the fact that this was the worst year of the economic recession in Finland, i.e. the peri-

Table 7. Changes in the number of grid cells (A) and population density (B) in the 1990's (Data: Statistics Finland).

	A. Number of grid cells									Trend		
Decile	1990	1991	1992	1993	1994	1995	1996	1997	1998	1990–1993	1994–1998	1990–1998
1	84	85	86	86	85	84	83	82	82	+	–	
2	159	162	164	164	163	161	160	160	158	+	–	–
3	234	238	241	241	240	239	236	235	234	+	–	0
4	336	339	342	344	343	339	338	336	334	+	–	–
5	481	484	487	488	485	482	480	477	476	+	–	–
6	751	751	750	751	744	736	728	724	721	0	–	–
7	1420	1406	1400	1390	1364	1345	1329	1316	1299	–	–	–
8	4635	4500	4409	4332	4214	4096	4012	3915	3813	–	–	–
9	16579	16305	16105	15930	15746	15548	15380	15204	14980	–	–	–
10	78561	78815	79038	79314	79652	80007	80299	80583	80770	+	+	+
	B. Population density inhab./km^2											
1	5876	5840	5802	5831	5923	6015	6100	6191	6202	–	+	+
2	3104	3064	3043	3058	3089	3138	3165	3173	3219	–	+	+
3	2109	2086	2071	2081	2098	2114	2145	2160	2173	–	+	+
4	1469	1464	1459	1458	1468	1491	1498	1511	1522	–	+	+
5	1026	1026	1025	1028	1038	1048	1055	1064	1068	+	+	+
6	657	661	665	668	677	687	695	701	705	+	+	+
7	348	353	356	361	369	376	381	386	391	+	+	+
8	106	110	113	116	119	123	126	130	133	+	+	+
9	30	30	31	31	32	32	33	33	34	+	+	+
10	6,3	6,3	6,3	6,3	6,3	6,3	6,3	6,3	6,3	0	0	0

od in which the unemployment peaked. Similarly, housing production declined steadily, to reach its lowest ebb in 1994. This was followed by a period of economic recovery (SVT 1999), with a new stimulation of building activity, especially in the metropolitan area of Helsinki and other large municipalities. This trend was accompanied by a rise in population densities, as the housing capacity of the built-up areas increased while the land areas concerned remained more or less constant. The increased housing density was hence reflected in the population density.

The above observation demonstrates the usability of the grid cell data as an aid in monitoring changes in spatial structure, and potentially achieving detailed explanation. This method allows, for instance, observing small changes in population within a municipality very easily.

The spatial demographic structure in 1970–1998

The repeatability of the decile method allows it to be applied to any country or any areal unit, and any researcher can arrive at the same results. It should be remembered, however, that such accurate geofererenced data are available in selected countries only. We will turn our attention now to structural features of the spatial distribution of population and the changes detected in the distribution in the cross-sectional data for 1970, 1980, 1990 and 1998, with particular reference to developments during the 1990's. The classification employed may be referred to as the 'spatial demographic structure', as it represents an attempt to describe the relation between population density and settlement structure. Hence, it does not take into account the functional elements normally implied in the term regional structure, e.g. dwellings, jobs and the aspects of infrastructure that support these. The concept has been used earlier for classification purposes by Räisänen et al. (1996) and Rusanen et al. (1997). We will first consider the situation over the whole of Finland and subsequently concentrate the analysis on one specific region, Kainuu.

The interpretation provided here is based on the assumption that the character of a grid cell can be deduced from the size of its population. The classification concerned is not necessarily applicable to all areas or to all countries, and it has been constructed knowing well that the distinction between rural and urban is by no means unambiguous (see Malinen et al. 1994; Berry et al. 2000). It is impossible to build a model that would apply equally well to all countries and under all conditions. The following classification of spatial demographic structure is used:

Inhab./km²	**Element of spatial demographic structure**
1–5	Scattered settlement
6–20	Rural areas proper
21–100	Rural areas with built-up features
101–1000	Build-up areas and suburbs with mostly private housing
More than 1000	High-rise centres and suburbs of major cities

Examination of the situation in the years mentioned above indicates that the most densely populated areas, with over 1000 inhab./km², grew most rapidly in the 1970's, the rate of growth diminishing in the 1980's and reaching its slowest in the 1990's (Fig. 1). The areas of suburban private housing departed from this pattern somewhat, however, as these underwent their greatest population growth in the 1980's. By contrast, the transitional category between rural and urban conditions, that with densities of 21–100 inhab./km², declined in population throughout the period studied here, although most markedly in the 1970's and least so in the 1990's. The rural areas proper decreased substantially in extent, while the areas of scattered settlement increased somewhat in both total population and extent, largely as a result of contractions in the population of grid squares previously included in the category of rural areas proper.

The trend in population density over the whole country in the 1990's was polarized. The population of the densely inhabited areas increased steadily throughout the decade, amounting to a total rise of 4.6%, or 110 000 persons, between 1990 and 1998 (Fig. 2). The suburban private housing population grew in a similar manner, with the exception of a small decline in 1997. The population of the urban-rural transition zone with densities of 21–100 inhab./km², declined from 1993 onwards, however, and simultaneously the area contracted slightly. The category of rural areas proper declined in both population and total area throughout the studied period, whereas scattered settlement category increased slightly in both total population and area.

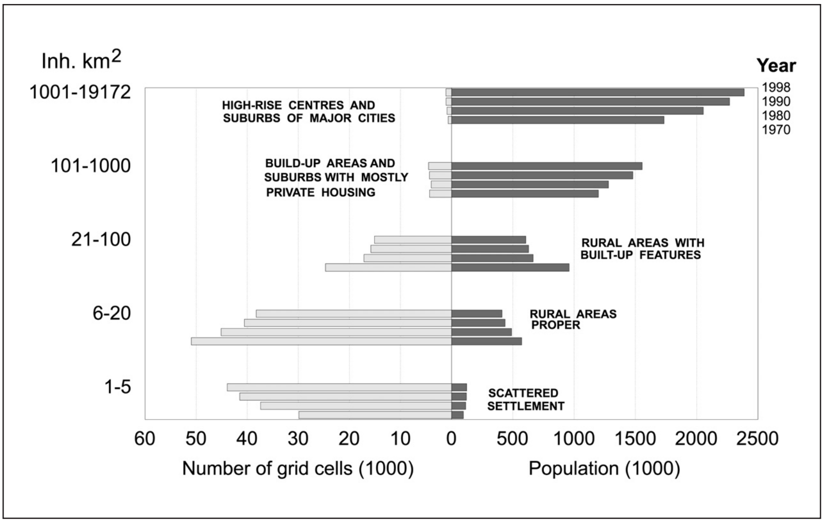

Fig. 1. Population changes in different parts of the spatial demographic structure over the whole of Finland in 1970–1998 (Data: Statistics Finland).

The Kainuu region in Northern Finland, selected here for more detailed examination, is characterized by economic and demographic recession. It belongs to the Objective 1 EU support areas on account of its low income levels and sparse settlement. Its population, which has been on the decline since the 1960, was 93 218 persons in 1998, and the region has consistently been one with pivotal unemployment in the whole country.

The demographic trend in Kainuu during the 1990's departed markedly from that obtained for the whole country (Fig. 3). The most densely inhabited areas experienced a population decline from 1992 onwards, and the same trend affected the private housing areas from 1996 onwards. Correspondingly, the transition zone and the rural areas proper lost population throughout the decade, as in the whole country, and the population increase in the areas of scattered settlement

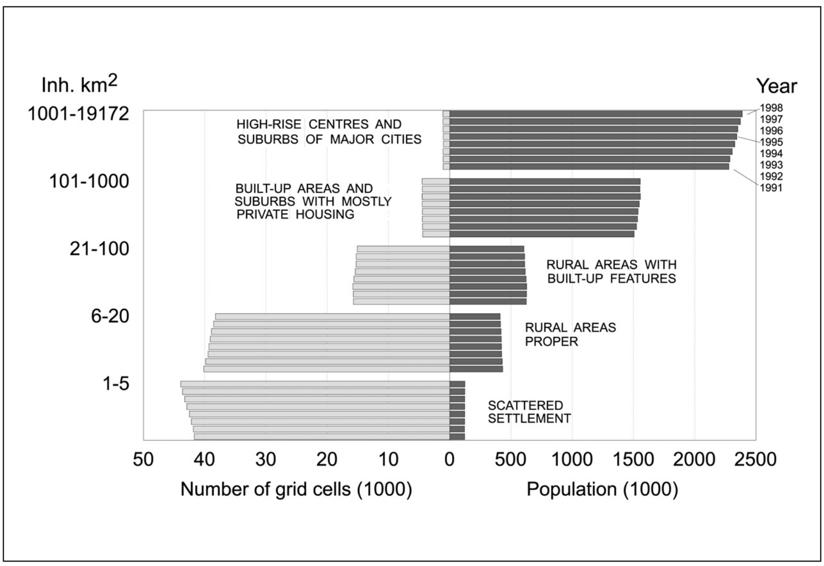

Fig. 2. Population changes in different parts of the spatial demographic structure over the whole of Finland in 1991–1998 (Data: Statistics Finland).

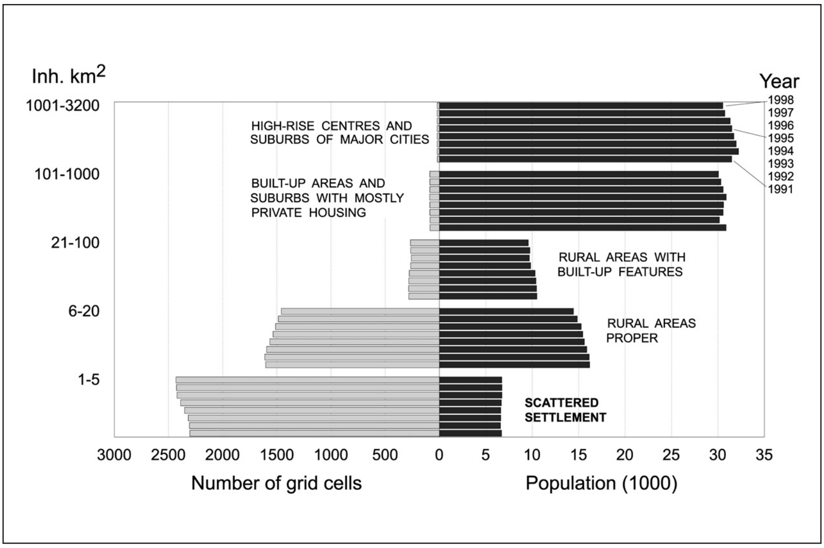

Fig. 3. Population changes in different parts of the spatial demographic structure in Kainuu in 1991–1998 (Data: Statistics Finland).

appears to have come to an end in 1998. This was probably the first occasion during the century when the population of Kainuu decreased in every single category of its spatial structure. It is probable that demographic trends in the sparse population density classes in Fig. 9 were the same as in Kainuu. Elsewhere they have resembled those of the whole country.

Finland became a member of the EU in 1995. Kainuu was an Objective 6 area in 1995–1999 and is currently an Objective 1 area for the period 2000–2006. Based on the above results one can argue that the development measures implemented in the region under the EU programmes have failed to improve the negative demographic trend in all elements of the spatial system.

Detailed analyses of population trends are possible only with the aid of georeferenced data that allow precise location of the population units. A 'sliding scale' evaluation of population density based on local level data helps avoiding the fallacies that arise when one examines the whole country or large aggregate areas (Martin 1991). The unravelled negative demographic trend in Kainuu serves as an example of the use of grid cell data for monitoring regional development.

The rank size model

Rank size models represent a well-established method of geographical research that has been applied to the study of hierarchical structures in various areal units and changes taking place in these structures. The units employed for this purpose are usually towns or other administrative or functional entities (see, e.g. Bradford & Kent 1986; Das & Dutt 1993). The method involves arranging the data units in size order and presenting the results in diagrammatic form. We intend to apply the rank size approach to the 1 x 1 km^2 grid cells, and use the density classes for describing the types of settlement and any changes in population. For comparison purposes, the approach was done at two levels: the whole country and the Kainuu region.

The 452 municipalities of Finland varied in population from a mere 100 up to 500 000 inhabitants in 1998 (Fig. 4). With the municipality level as the areal unit of interest, the rank size model indicates that about one hundred largest municipalities showed an increase in population over the period 1970–1998, while the others experienced population decline.

At the grid cell level, the rank size model fails to provide detailed information of spatial demographic structure as efficiently the classification (Figs. 5 and 6). It does, however, serve well in highlighting the decline in the total number of inhabited grid cells over the whole country, i.e. the contraction in the area of human settlement. Furthermore, it emphasizes certain major turning points such as the beginning of the decline in population in the most densely inhabited areas

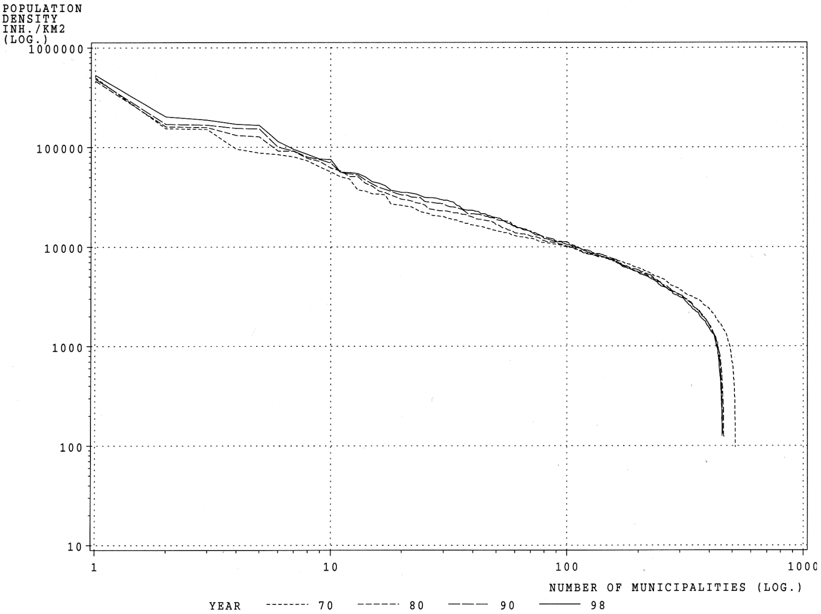

Fig. 4. Changes in population density over the whole country in 1970–1998 according to the rank size model, areal unit = municipality (Data: Statistics Finland).

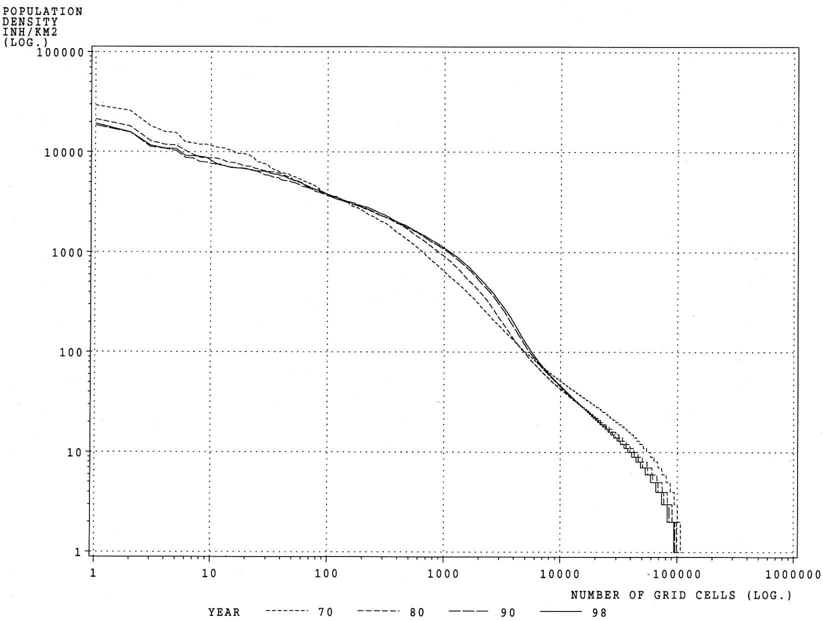

Fig. 5. Changes in population density over the whole country in 1970–1998 according to the rank size model, areal unit = grid cell (Data: Statistics Finland).

and the subsequent resumption of growth. Other well-presented features are the thinning of the population of the rural districts and the continued growth in agglomerations with a population of 80–3000 persons throughout the studied period. The points at which the curves intersect mark population thresholds of various kinds, with contrasting trends on either side.

The rank size model for the Kainuu region (Fig. 6) yields rather similar results to that for the whole country, the greatest difference being in the curve for 1998, which shows a decrease in pop-

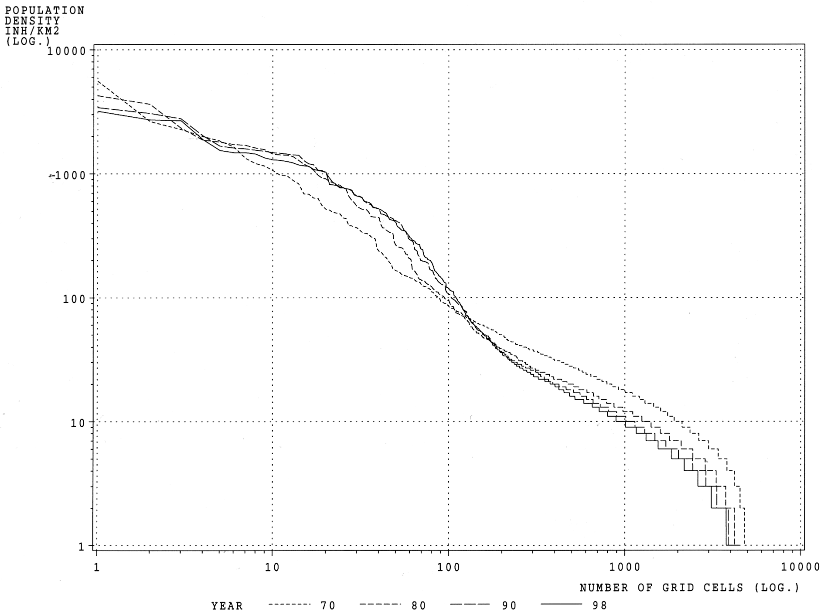

Fig. 6. Changes in population density in Kainuu in 1970–1998 according to the rank size model (Data: Statistics Finland).

ulation in the most densely inhabited grid squares as opposed to an increase at the national level.

According to polls, the most preferred form of living for Finns is a detached house on lakeside in the middle of a city. The rank size model for the whole country indeed seems to indicate that apartment blocks in areas with more than 3000 inhab./km2 are not considered attractive as places to live, since the model showed highest population growth in areas with population densities of 80–3000 inhab./km^2. It is the grid cells that fall into this category that may be regarded as the most popular and attractive living environments in recent decades, a situation which has been promoted further by contemporary urban planning measures. This impression is confirmed by the result of the Residents' Barometer survey carried out by the Ministry of the Environment in 1998. The survey showed that 57% of Finnish population preferred to live in a private house, 22% in an apartment and 20% in a semi-detached or terraced house. In reality, only 30% of the population in that year were living in a private house, 50% in an apartment and 20% in a semi-detached or terraced house (Ministry of the Environment 2000). In the light of the above figures, however, the observed increase in population in the most densely inhabited areas during the 1990's would appear to be inconsistent with the realities of the Finns' living habits and with the preferences that they have expressed.

The rank size approach also shows a decrease in population in the density class of less than 80 inhab./km^2. This must be partly attributable to the decline in the number of active farms, a trend, which has greatly accelerated since Finland joined the EU in 1995. This becomes evident from the fact that no fewer than approximately one quarter of the farms closed down between 1995 and 2002. The rural areas can no longer provide good opportunities for making a living. As a consequence their population is declining. On the other hand, Silvasti (2002) has examined the changing meanings of the countryside for rural and urban inhabitants, noting that for farmers the countryside is traditionally a space in which production takes place, while for urban dwellers it is becoming more and more a locus of consumption, a source of recreation and beautiful landscapes. In Holland, Haartsen et al. (2003) have developed an empirical method for measuring the interpretations placed on rural areas by persons of different ages (Muilu & Rusanen 2003).

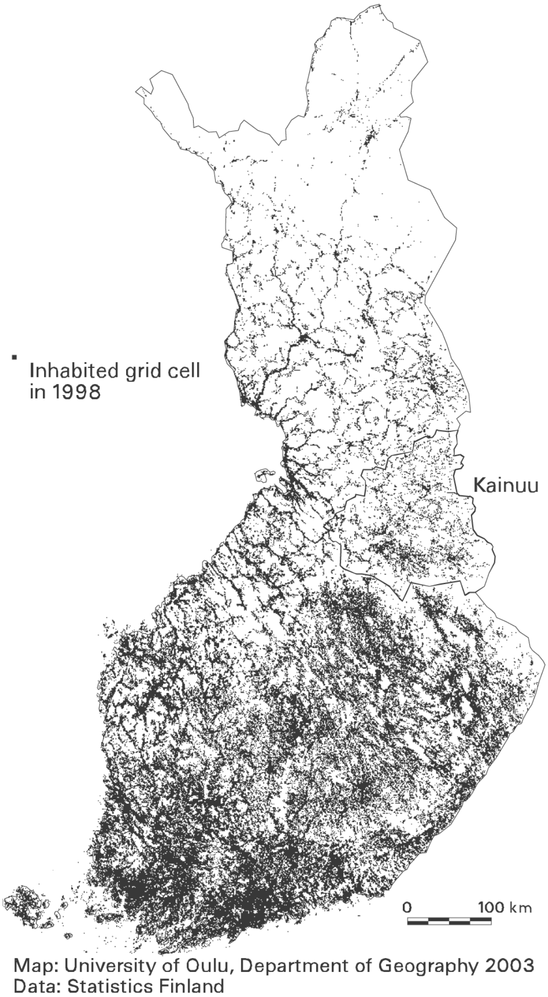

Fig. 7. Distribution of inhabited grid cells (at least one person per square kilometre) in Finland in 1998 (Data: Statistics Finland).

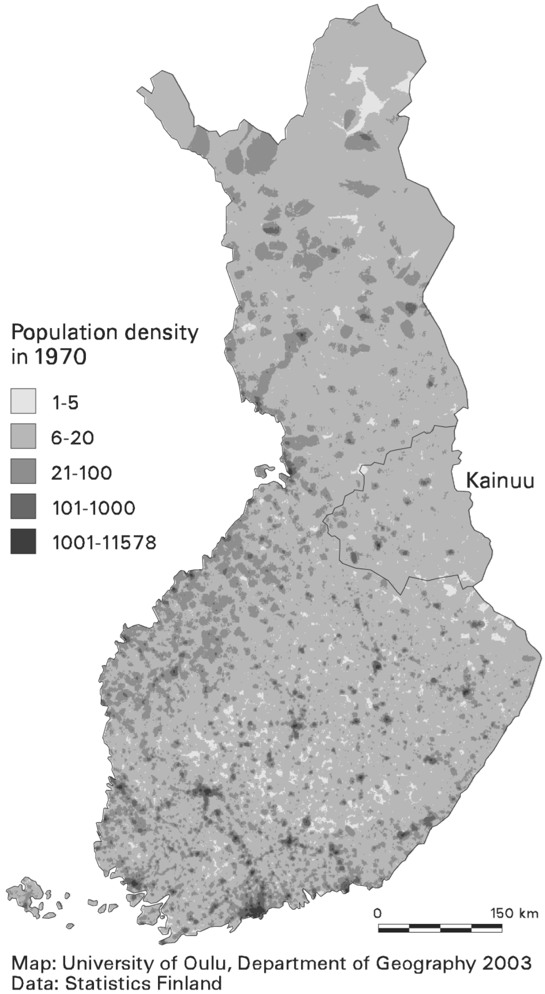

Fig. 8. Population density (inhab./km^2) in Finland in 1970 (Data: Statistics Finland).

Spatial distribution of population in 1970–1998

The most concrete, often the best and sometimes the only way of depicting spatial information is by means of a map, and a typical and popular way of depicting population data is on a choropleth map (see Bachi 1999). On the other hand, it is as well to bear in mind the comment of Langford and Unwin (1994) that "Where the purpose of a population map is to convey an accurate impression of density distribution the conventional choropleth map representation is a poor choice".

The map of the distribution of inhabited areas presented in Fig. 7 is derived from a coloured map of Finland and Sweden first published by Rusanen et al. (1997), based on the kriging interpolation method (Figs. 8 and 9) and a choropleth map. The information depicted by shading has been converted to a dot-based vector form before interpolation. For the sake of comparison, the population density data are presented on a conventional choropleth map in Fig. 10, employing municipalities as the areal units.

The pair of maps contained in Figs. 8 and 9 indicate detailed locations for the areas of pop-

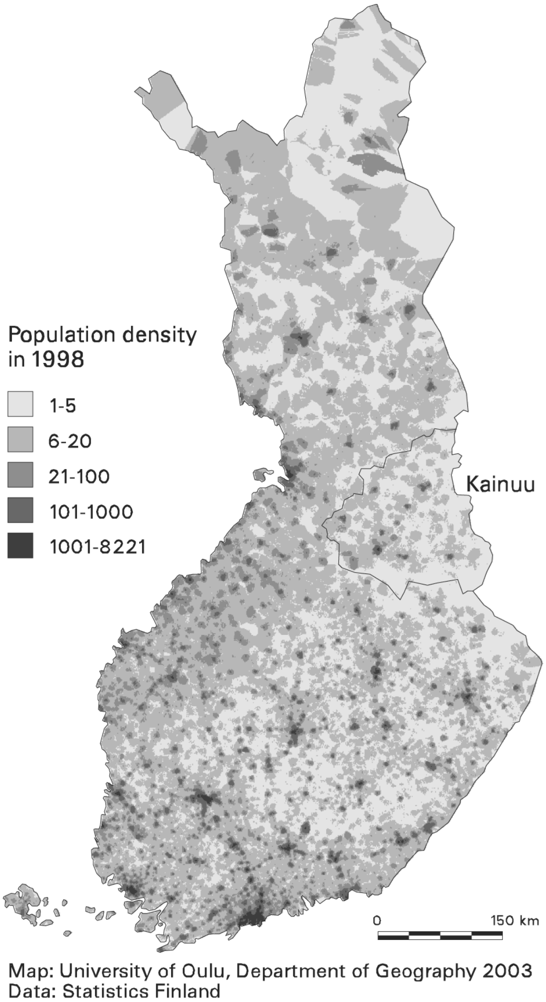

Fig. 9. Population density (inhab./km²) in Finland in 1998 (Data: Statistics Finland).

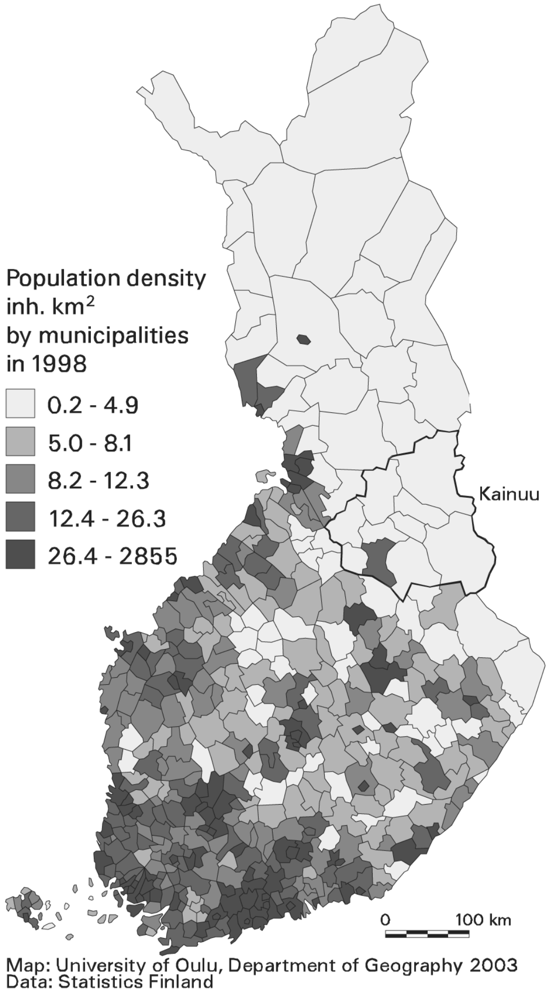

Fig. 10. Population density by municipalities in 1998 (Data: Statistics Finland)

ulation decline and serve particularly well to depict the pronounced expansion of the areas of scattered settlement. The extreme phenomenon that affects the settlement structure, namely the abandonment of the countryside, took place in Finland primarily in areas where habitation at present is sparsest. Future abandonment of dwellings and farms is likely to affect these same areas.

On account of the scale at which the two maps are reproduced, the concentration of population in the built-up areas does not stand out very clearly. They do, however, highlight relatively well the population growth that has taken place in built-up areas and their environs, the areas in which population concentrated in 1998 and the locations of municipal population centres.

The information contained in this pair of maps highlights the situation regarding permanent settlement. It does not, however, tell the whole truth about the potential use being made of the areas concerned for leisure purposes. Some of the areas of population decline, even ones that have lost their population entirely, have been transformed into a new kind of resource periphery, which people who have moved to the cities and urban areas of the south have begun to exploit for summer cottages and second homes.

Although the zonal maps in Figs. 8 and 9 are easy to interpret, the unfortunate aspect of them is that they give an impression of a wholly inhabited country. In contrast, the grid cell analysis indicates that in reality only 30.4% of its surface area had any permanent settlement in 1998 (Fig. 7) and that the focus of this settlement was explicitly in Southern Finland. The information contained in the zonal maps is nevertheless very detailed in comparison to the choropleth maps.

Evaluation of the methods used

Altogether 10 methods were tested in the course of the work at hand. Six methods involved numerical interpretation, four methods visual interpretation only. The rank size method yields diagrams, while the maps are descriptive in character. In terms of the hierarchy of potential areal units from the whole country to regions and further to municipalities, the grid cell is the most widely applicable data unit. It permits aggregation to all spatial levels and can be used with all the methods investigated. For reasons of scale, it is obvious that a classification used for the whole country will not necessarily be viable at the local level. The same holds true for classifications used in cartographic presentations, as these, too, have to be altered according to the scale on which one is operating.

The statistical mean, Gini Coefficient and Moran and Geary Indices provided numerical proof of the continuing process of population concentration, hence confirming the conclusions. In the case of the Gini Coefficient, the employed areal unit influenced the results quite substantially. The data for the municipalities showed continuing concentration at a more pronounced level than did the grid cell data. Decile classification proved to be an objective method capable of demonstrating changes in population density on a sliding scale from the sparsest to the densest forms of settlement. The spatial demographic structure proved the most adept at indicating what part of the spatial system is under examination – especially to those who are unfamiliar with the material. The last two classifications complement each other in the sense that the former is objective and the latter subjective. The rank size model and the use of maps both allowed visualization of changes in population equally well over the whole country and at the local level.

The methods can be regarded as complementary in population concentration studies. It would be difficult and unnecessary to try to select the best method. Each method has its own strengths, and each one brings out some new information on changes in population density. A few recently published papers have pointed to a decline in the use of maps in geographical articles (Wheeler 1998; Martin 2000), which is somewhat surprising, since GIS makes it relatively easy to present material in a map form. This trend may be regarded as an unfortunate one, since the present work and feedback received from the users of spatially analysed data indicate that maps, as a visual presentation technique, are the best means of describing spatial variations in place-bound phenomena. It is true, however, that one cannot visualize all the population changes taking place in a spatial structure by means of just a few maps.

The other methods used here should be treated as complementary to visualization and as capable of lending support to each other. In the end it is essential that the available data be as accurate as possible in its location properties, so that GIS or potential other methods can be applied freely in accordance with the needs of different user groups. The optimum situation would naturally be the use of coordinate data for individual persons without any spatial aggregation. This, however, is depicted difficult or impossible by the legislation protecting personal privacy.

Conclusions

Demographic trends are crucial variables for use in regional policy, regional planning and monitoring of regional development. Hence, the aim here was to investigate the distribution of population by a variety of methods. The results indicated that in Finland the process of population concentration in the early part of the 20th century, as identified by Alestalo (1983), continued up to the very end of the millennium. This finding is consistent with that obtained for Sweden, a country with very similar conditions for settlement (Borgegård et al. 1995). One significant result of the analysis of the grid cell material, however, was that the concentration trend is now slowing down. This finding became evident also in terms of both the Gini Coefficient and the classification by spatial demographic structure when the data units were grid cells, whereas more or less the opposite result was obtained when municipalities were used as areal units. In any case, the results do not correspond to the modest resurgence of population growth in non-metropolitan areas observed in the United States during the 20th century, a trend that can be regarded in the long term as representing a third decentralization phase (Long & Nucci 1997).

According to the equilibrium theories of regional economics, social structure will react to a disturbance by seeking a new state of equilibrium. In the light of its rates of change during the 20th century, the spatial demographic structure seems to be approaching such a state. At least the rate of population concentration has begun to slow down. The negative demographic trend obtained for the Kainuu region during the 1990's nevertheless demonstrates that various parts of the country are progressing according to quite distinct timetables, not to mention the situation locally, i.e. at the level of the municipality or some smaller areal unit. The results from Kainuu are comparable to most parts of Finland, especially Northern and Eastern and Central Finland, when the total land area is considered.

In Finland the availability of annual population statistics for 1 x 1 km^2 grid cells makes it possible to identify and monitor even quite small changes in different parts of the spatial structure, and thereby to quickly detect any violation of local or regional danger limits that are of importance for decision-makers and planners. It is also possible to use grid cell data for predicting changes in population, whereupon the use of variables representing the age structure of the population or aspects of human activity are expected to add greater depth to such analyses. Finnish georeferenced data can be subjected equally well to scrutiny over medium or short time intervals, as information is available from 1970 onwards and since 1987 on an annual basis.

Grid cell data can provide information on local conditions and can be used to analyse differences within municipalities. The ability to aggregate data to any grid size or areal system adds greatly to the applicability of the method. The permanence of the location of the grid cells is also an important advantage, as administrative boundaries tend to alter with time.

Georeferenced data are flexible in terms of areal unit, and are well suited to the analysis and visualization of features that are internal to given areas or regions. They bring information to the fore that could easily remain concealed were administrative units such as municipalities used. Similarly, georeferenced data allow analyses of spatial structures that cannot be distinguished in material based on municipalities, e.g. the urban-rural continuum.

Membership of the European Union involves a transfer of responsibility for regional development in Finland to the local level, where most of the data required for regional policy purposes had previously been compiled nationally. Georeferenced data can be of considerable value in these situations, as even quite detailed analysis, monitoring and prediction of demographic trends can be undertaken at any level whatsoever in the spatial hierarchy.

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