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# MODELLING OF THE SPATIAL DISTRIBUTION OF POPULATION IN SLOVAKIA AND JAPAN

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**Abstract:** In the study we have analysed and compared the spatial distribution of population in Slovakia and Japan using traditional indicators and ways of demogeographic research. Besides this, the modelling of the spatial distribution of population in both countries was carried out on the basis of less traditional methods, i.e. with the help of interpolation techniques and interaction or gravitation models in the GIS environment. In terms of some methodical aspects of the creation of demographic statistic fields (surfaces) in the form of potential population models, the deeper analysis was carried out.

**Keywords:** distribution/density of population, GIS, population potential model, population surfaces.

## 1. INTRODUCTION

The spatial distribution of population in geographical space is considered to be one of the main tools for understanding of demogeographical events and processes. Methods and techniques used on this occasion have very often a dual character. On the one hand, the information on the population size and its distribution in individual spatial units (e.g. continents, states, regions) supply us with knowledge on the population distribution based on the absolute statistical data in definite territorial (administrative) units. Other ways of analyses assume the application of techniques, where the population distribution is studied in relationship with the other geographical elements of the space, based on relative data (such as population density, its distribution according to the altitude, climatic zones, transportation systems, etc.).

One of the main characteristics of the population distribution in the world is its extraordinary disproportion and differentiation, which are manifested either on global and regional levels. Furthermore, the differentiation of population is multilaterally affected by variety of historical, natural, political, socio-economic events and processes, manifesting differently in different regions. Weber and Benthien (in Mládek 1991) divided factors that influence distribution of population into four groups:

- economical and social factors, including superstructure functions (the level of the economic development, political structure, the influence of religion),
- physical and geographical factors (climate, vegetation, the relief morphology, geographical position, etc.),
- historical factors (i.e. peculiarities in historical territorial distribution of population)
- population factors (mainly the regional differentiation in natural and mechanical movement of population).

The analysis of reasons for different population distribution requires deep examination of the relevant factors. At the same time, such an analysis is a matter of the long-term research. That is why in our study we have focused on the basic comparative analysis of the spatial distribution of population in the Slovak Republic and Japan using traditional methods of research. Our main goal was to outline some possible forms and non-traditional ways in modelling of population distribution with the help of empirical gravitation models and some interpolation techniques in the environment of geo-information technologies. With enhancing utilisation of geo-information technologies and geographic information the creation and utilisation of these models is becoming far more accessible for their users.

## 2. TRADITION WAYS OF EVALUATION OF THE SPATIAL DISTRIBUTION OF POPULATION

The most widely used methods for analysis of population distribution are traditional statistical methods for evaluation of population density, which include the absolute and relative indicators.

The absolute indicators of the population distribution depict the absolute amount of inhabitants in the different statistical spatial units, such as e.g. settlements or districts.

The relative indicators of the population distribution mainly represent the general features of *the population density*. They define the amount of residents per unit area (usually per 1 $km^2$) or the opposite value (the number of square kilometres falling per one inhabitant), whereas the *specific population density* relates to specific factors, such as the amount of economically active inhabitants or those employed in industry, agriculture and/or other branches of economy per unit area, or the amount of residents, which inhabit the individual unit areas with different geographical (geomorphological) and/or socio-economical conditions (rural and urban areas, etc.).

Dynamic indicators of the population distribution allow us to monitor and analyse the population development in determined time periods or moments and to present them in the form of different absolute and relative values (indexes) of the population growth or decline in the relevant spatial units.

These indicators can be currently visualised in the form of thematic choropleth or diagram maps, quite simply carried out in the digital form with the help of variety of the desktop GIS programs, such as MapInfo, ArcView, etc, which provide their users with sufficient cartographic techniques. As to the graphic techniques, it is recommended to apply for representation of the absolute population density the graded symbols or localisation graphs, and for visualisation of the relative indicators – a method of the dot density and different choropleth maps. The aforesaid indicators may be processed using some other, though, less conventional procedures for modelling and analysis of the population distribution based on the mathematical statistical methods for modelling, and analysis of the population structures and fields in the form of iso-grid maps.

Our study, using the available data from the territory of Slovakia and Japan, compares the development of population growth in Slovakia and Japan during period 1920-1999. The indicators of general density of population in both countries were sorted out from the data of spatial statistical units of the level II, i.e. in case of Slovakia these were districts and in case of Japan prefectures (level I – regions, level III. – municipalities). The graphic interpretation of the general density of population is shown and by means of the Witthauer graphs, where co-ordinates in logarithmic scale represent the absolute values of the population density and the territory of statistical units (districts/prefectures) in selected time cuts.

The general density, however, does not supply information about the quality of the population's life, but being combined with the other structural features, it may submit useful information, e.g. about the socio-economic or environmental conditions, etc. Specific population density in Slovakia and Japan relates to the categories of the land use (e.g. number of inhabitants per rural/urban area). However, the indicators from both countries are not completely consistent, due to the different methodologies used for determination of these categories.

The altitude of the territory above the sea level (a.s.l.) is considered as an important factor for population distribution. Analysing it, we have used figures about the amount of inhabitants living in the individual geomorphologic units per respective territorial unit, i.e. districts in Slovakia (in 1991) and prefectures in Japan (in 1985). On the territory of Slovakia, we have distinguished 3 types of geomorphological units (lowlands, basins and mountains) attached to the two factors: the altitude above the sea level and the georelief slope. The lowlands are characterised by 0 – 300 m a.s.l., and by 0 – 3° slopes, basins by 300 – 700 m a.s.l. and 0 – 6° slopes and mountains by 700 m a.s.l. and more and 6° slopes, however, the highest mountains are characterised by the slope relief of more than 24°. Regarding the territory of Japan, the geomorphologic units (lowlands, highlands, lower mountains and higher mountains) were selected on the basis of the slope relief (0 – 3°, 0 – 8°, 8 – 30°, 30° and more), though the lower and higher mountains were assigned to one morphological unit.

## 2.1 The analysis of population distribution in Slovakia and Japan – a traditional way

It can be mentioned, that it is not the easy task to analyse the population of Slovakia and Japan from the point of view of spatial distribution. It is because we face the two different countries, with different geographical, economical, cultural and historical background.

Slovakia is situated in the Central Europe and together with the other post-communist countries develops its new-age history. Before 1918, Slovakia was the part of the

Austro-Hungarian Empire. It became a part of the common state of the Czechs and Slovaks – the first Czechoslovak Republic in 1918. During the World War II (1938-1945), it gained independence, but since 1945 to 1992, it was again united with the Czechs to form joint state – the Czechoslovak Socialist Republic. On January 1, 1993, the state was peacefully split into the two parts – the Czech Republic and the Slovak Republic. From the administrative point of view, Slovakia is divided into 8 regions, 79 districts and 2921 settlements with the explicit status of the two largest cities: Bratislava in the west (the capital) and Košice in the east. The last substantial change of the administrative division of the country occurred during years 1989 – 1996 when the number of regions increased from 3 to 8, and the number of districts from 37 to 79.

Japan is the island country which, being for centuries isolated from the outside world, developed very individually and was always independent (with exception of the very short period after the World War II – the occupation of Okinawa). The economical and population development changed after the country had opened itself to the rest of the world at the end of $19^{th}$ century, but the most expressive changes happened during the second part of the $20^{th}$ century. Territorially and administratively, it is divided to 9 economic regions, 43 prefectures (ken) and 4 administrative areas, such as Tokyo-to (the capital), Osaka-fu and Kjoto-fu and the province Hokkaido-do, which hierarchically are on the level of prefectures. The lowest administrative units are municipalities (settlements).

Japan, as the ninth most populated country of the world, has almost 24 times more inhabitants (126,92 mln.) than Slovakia (5,4 mln.), that live on the 7 times larger territory (377 873 $km^2$,) than it is in Slovakia (49 034 $km^2$). The average population density in Japan (as to 1999) is 335, meanwhile in Slovakia it is 110 persons per $km^2$, what is 3 times more. What is common for both countries – is the extreme irregularity in the population distribution and some features of geographic characteristic (the high ratio of mountains with considerable dissection of the relief), which is the limiting factor for occupancy of the territory.

## 2.2 Evaluation of Slovakia

The basic data for analysis of population development in Slovakia were taken from the period 1921 – 1999 (Fig. 1, 2). At this time, the population of the Slovak Republic increased from about 3 mln. to 5,4 mln., moreover this growth was rather inconsistent, depending on significant social and political changes in Slovakia (arising of the first Czechoslovak Republic, the period of the World War II, the post-war period, constituting of SR). The period between 1921 and 1950 is characterised by more complicated population development, when the population increased only by 448 000 persons.

In 1921 – 1930 the population increased by 330 000 and in 1930 – 1950, due to the war and its social, economical and political consequences, it increased only by 118 000 persons. This decline was partly caused by the low natural increase of population and partly by the high emigration rate. The period from 1950 to 1999 was characterised by the relatively high population growth, comparing to the previous periods.

From 1950 to 1999 the total population growth reached 1 956 000, when the average growth between the two subsequent census periods made 484 000, falling, however, between 1991 – 1999 to 124 000 inhabitants. The maximum increase was recorded in 1950 – 1961 (the total growth by 671 000 inhabitants) and the minimum increase – in 1980 –

1991 (283 000 inhabitants). For the whole post-war period, the high natural growth of population was typical: not only due the high natality, but also owing to the low mortality rates. The periods with accelerated population growth in Slovakia strongly correlate with the periods of high natural increase of population, as the factor of out-migration during the socialist era was negligible. Slowing down of the population growth in 80's and 90's, is connected with decline of the natural increase of population.

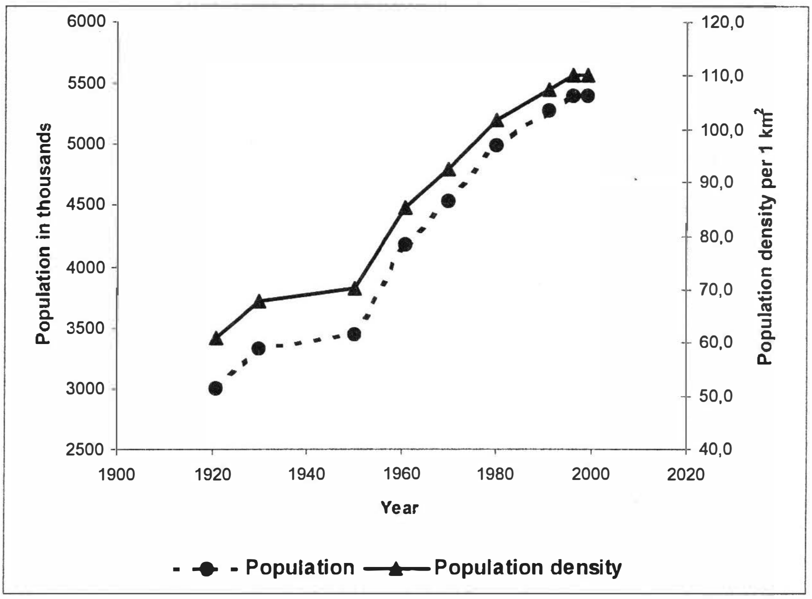



**Figure 1** Development of population and of the population density in the Slovak Republic in 1921 – 1999

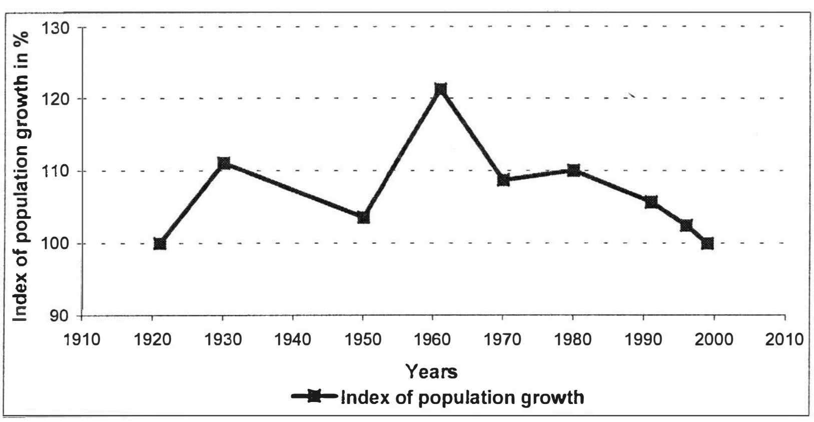



**Figure 2** Development of the index of population growth in the Slovak Republic in 1921 – 1999

The development of population density, actually, corresponded with of the population development. During the period from 1921 to 1999, the population density increased from 61,1 to 110,1 persons per km². The highest growth of population density was recorded in 1961 (85,1), when this value increased comparing to the year 1950 (70,2) by almost 15 persons per km².

Not only the population density throughout the country increased, but the density had also increased in the districts. In 1921 – 1950, the population density reached 40 – 60 persons per km² in the majority of districts (the average density in SR was 66 inhabitants per km²). The exception in this period made only the two districts: Bratislava and Košice, where the density values in 1921 were 332 (Bratislava district) and 259 (Košice district), rising by 1950 to 570 persons per km² in Bratislava and to 309 in Košice. In 1960 – 1996, the districts recorded the growth of population density: in majority of them the population density increased to 70 – 80 persons per km².

In 1961, the population density in 11 districts exceeded 100 persons per km². Their number rose to 13 in 1980 and to 15 in 1996. During this period, the population density in Bratislava increased from 709 to 1230,4 persons and in Košice from 397,7 (in 1961) to 989,1 (in 1996) persons per km². The 1996 Act on the Administrative Division of SR raised the number of the districts from 38 to 79 enhancing so the number of districts with comparatively equal population density to its average level in SR (110 persons per km² – in 1999). To the districts with the highest population density belong the urban districts of Bratislava (I – V) and Košice (I – IV), whereas the absolutely highest population density in the Slovak Republic is in the Bratislava I urban district (4 608 per km²). The lowest population density reports the district Medzilaborce (35,7 inhabitants per km²).

In 1921, the highest population density was recorded in urban districts of Bratislava and Košice and in some western and central districts of Slovakia. The lowest population density was at that time in some northern, eastern and southern districts of Slovakia (Fig. 3).

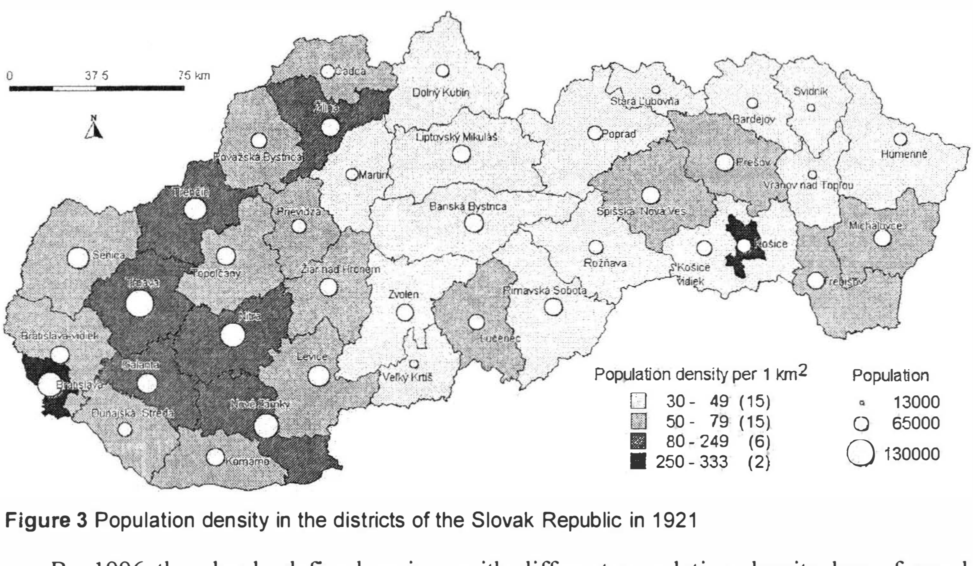



**Figure 3** Population density in the districts of the Slovak Republic in 1921

By 1996 the clearly defined regions with different population density have formed. Logically, the highest values were reached in the urban areas of Bratislava and Košice, followed by the belt of districts in western and north-western Slovakia. Further lower values were reported by majority of districts in Central Slovakia (with the exception of the district Liptovský Mikuláš), and by southern districts. North-western districts of Slovakia, with exception of Svidník and Humenné districts reached similar densities in this period. Among the east Slovakian districts (except for the already mentioned Košice), the densities comparable with the populous regions in Považie were reached only by the Prešov district. Only the Bratislava district exceeded the value of 1000 persons per km$^2$, while the Košice district has almost approached this value in 1999 (Fig. 4, 5).

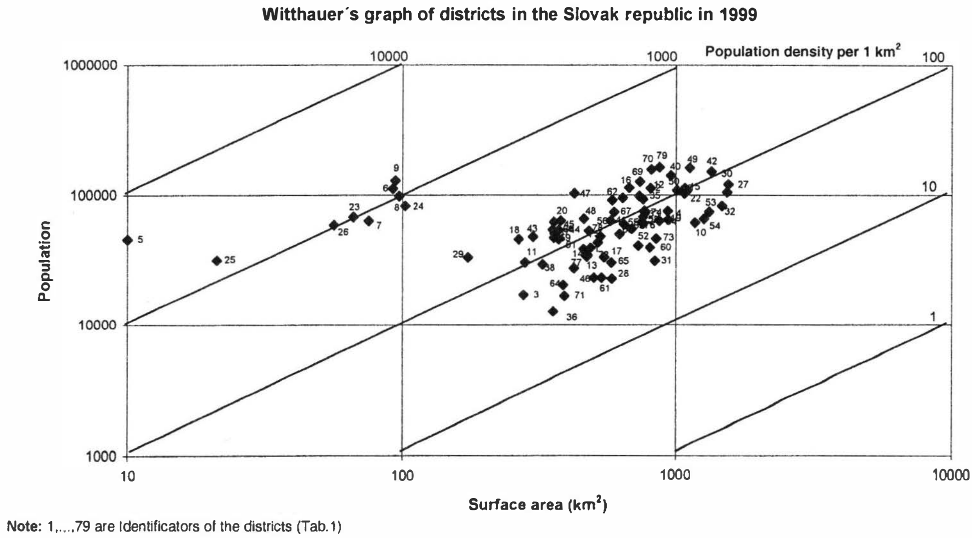



**Figure 4** Witthauer's graph of the districts of the Slovak Republic in 1999

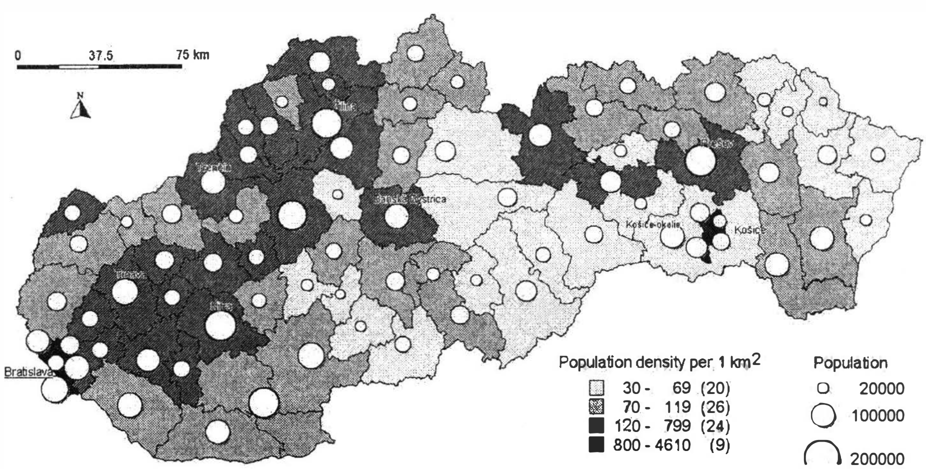



**Figure 5** Population density in districts of the Slovak Republic in 1999

**Table 1** Population, surface area and population density per 1 km² in districts of the Slovak Republic in 1999

| ID[1)] | District | Population | Surface area (km²) | Population density |
|---|---|---|---|---|
| | **Slovak Republic** | **5 398 657** | **49 034** | **110.1** |
| 1 | Bánovce nad Bebravou | 38 638 | 462 | 83.6 |
| 2 | Banská Bystrica | 112 736 | 809 | 139.4 |
| 3 | Banská Štiavnica | 17 061 | 278 | 61.4 |
| 4 | Bardejov | 75 607 | 937 | 80.7 |
| 5 | Bratislava I | 46 080 | 10 | 4608 |
| 6 | Bratislava II | 111 792 | 92 | 1 215.1 |
| 7 | Bratislava III | 63 616 | 75 | 848.2 |
| 8 | Bratislava IV | 98 146 | 97 | 1 011.8 |
| 9 | Bratislava V | 128 658 | 94 | 1 368.7 |
| 10 | Brezno | 65 827 | 1 265 | 52.0 |
| 11 | Bytča | 30 489 | 282 | 108.1 |
| 12 | Čadca | 92 869 | 760 | 122.2 |
| 13 | Detva | 33 712 | 475 | 71 |
| 14 | Dolný Kubín | 39 442 | 490 | 80.5 |
| 15 | Dunajská Streda | 112 348 | 1 075 | 104.5 |
| 16 | Galanta | 94 796 | 641 | 147.9 |
| 17 | Gelnica | 30 314 | 584 | 51.9 |
| 18 | Hlohovec | 45 817 | 267 | 171.6 |
| 19 | Humenné | 65 173 | 754 | 86.4 |
| 20 | Ilava | 62 234 | 359 | 173.4 |
| 21 | Kežmarok | 62 230 | 840 | 74.1 |
| 22 | Komárno | 108 566 | 1 100 | 98.7 |
| 23 | Košice I | 68 366 | 87 | 785.8 |
| 24 | Košice II | 82 480 | 81 | 1 018.3 |
| 25 | Košice III | 31 748 | 21 | 1 511.8 |
| 26 | Košice IV | 59 280 | 59 | 1 004.7 |
| 27 | Košice okolie | 104 841 | 1 530 | 68.5 |
| 28 | Krupina | 22 901 | 585 | 39.1 |
| 29 | Kysucké Nové Mesto | 33 416 | 174 | 192.0 |
| 30 | Levice | 120 730 | 1 551 | 77.8 |
| 31 | Levoča | 31 331 | 357 | 87.8 |
| 32 | Liptovský Mikuláš | 74 649 | 1 322 | 56.5 |
| 33 | Lučenec | 73 133 | 771 | 94.9 |
| 34 | Malacky | 63 925 | 872 | 73.3 |
| 35 | Martin | 97 971 | 736 | 133.1 |
| 36 | Medzilaborce | 12 728 | 427 | 29.8 |
| 37 | Michalovce | 108 928 | 1 019 | 106.9 |
| 38 | Myjava | 29 468 | 326 | 90.4 |
| 39 | Námestovo | 55 366 | 690 | 80.2 |
| 40 | Nitra | 163 418 | 871 | 187.6 |
| 41 | Nové Mesto nad Váhom | 63 922 | 580 | 110.2 |
| 42 | Nové Zámky | 151 121 | 1 347 | 112.2 |
| 43 | Partizánske | 48 219 | 301 | 160.2 |
| 44 | Pezinok | 54 036 | 375 | 144.1 |
| 45 | Piešťany | 63 907 | 381 | 167.7 |
| 46 | Poltár | 23 303 | 505 | 46.1 |
| 47 | Poprad | 103 074 | 1 123 | 91.8 |
| 48 | Považská Bystrica | 65 862 | 463 | 142.3 |
| 49 | Prešov | 161 269 | 934 | 172.7 |
| 50 | Prievidza | 141 242 | 960 | 147.1 |
| 51 | Púchov | 45 918 | 375 | 122.4 |

Table 1 – continue

| | | | | |
|---|---|---|---|---|
| **52** | Revúca | 40 974 | 730 | 56.1 |
| **53** | Rimavská Sobota | 82 508 | 1 471 | 56.1 |
| **54** | Rožňava | 61 764 | 1 173 | 52.7 |
| **55** | Ružomberok | 59 913 | 647 | 92.6 |
| **56** | Sabinov | 53 294 | 484 | 110.1 |
| **57** | Senec | 50 729 | 361 | 140.5 |
| **58** | Senica | 60 654 | 761 | 79.7 |
| **59** | Skalica | 47 265 | 359 | 131.7 |
| **60** | Snina | 39 592 | 805 | 49.2 |
| **61** | Sobrance | 23 263 | 538 | 43.2 |
| **62** | Spišská Nová Ves | 91 484 | 587 | 155.9 |
| **63** | Stará Ľubovňa | 50 434 | 624 | 80.8 |
| **64** | Stropkov | 20 469 | 389 | 52.6 |
| **65** | Svidník | 33 437 | 550 | 60.8 |
| **66** | Šaľa | 54 475 | 356 | 153.0 |
| **67** | Topoľčany | 74 048 | 597 | 124.0 |
| **68** | Trebišov | 102 826 | 1 074 | 95.7 |
| **69** | Trenčín | 113 785 | 675 | 168.6 |
| **70** | Trnava | 126 500 | 741 | 170.7 |
| **71** | Turčianske Teplice | 16 823 | 393 | 42.8 |
| **72** | Tvrdošín | 34 723 | 479 | 72.5 |
| **73** | Veľký Krtíš | 46 636 | 849 | 54.9 |
| **74** | Vranov nad Topoľou | 75 813 | 769 | 98.6 |
| **75** | Zlaté Moravce | 43 483 | 521 | 83.5 |
| **76** | Zvolen | 68 190 | 759 | 89.8 |
| **77** | Žarnovica | 27 633 | 426 | 64.9 |
| **78** | Žiar nad Hronom | 48 318 | 532 | 90.8 |
| **79** | Žilina | 156 921 | 815 | 192.5 |

**Note:** [1] Identificator of the district

**Source:** Bilancia pohybu obyvateľstva Slovenskej republiky podľa obcí v rokoch 1996 – 2000
(Balance of population migration by municipalities of the Slovak Republic in 1996 – 2000)
Štatistická ročenka o pôdnom fonde v Slovenskej republike k 1. 1. 2000
(Statistical Yearbook of land fund in the Slovak Republic as of 1. 1. 2000)

Comparing the spatial distribution of population in 1921 and 1999, the highest dynamic of monitored indicator was manifested by the Čadca, Žilina and Považská Bystrica districts, further – by the Nitra and Trnava districts and the Prešov districts in the East. An exceptional status belongs to the urban areas of Bratislava (growth from 332 to 1230 pers/km$^2$) and Košice (growth from 258 to 989 pers/km$^2$). The lowest dynamics reported some districts of central, southern and eastern Slovakia.

When explaining these values, we have take into consideration several assumptions. As we have already mentioned, the density change is the result of the total increase of population, which depends as well on its natural movement and migration. Almost tripled growth of the population density in urban areas of Bratislava and Košice is mainly the result of immigration concerned with the urbanisation, especially after the World War II. In the northern region of Považie (including Žilina, Považská Bystrica, Martin, etc.) and in some other districts the dynamics have increased due to the industrial development, which undoubtedly caused the strong in-migration movements. The population changes have massively affected by population density. It may be also considered that in depopulated regions, e.g. Rimavská Sobota, the migration and the lower increase of population occurred simultaneously, what had been manifested by the extraordinary low dynamics of density.

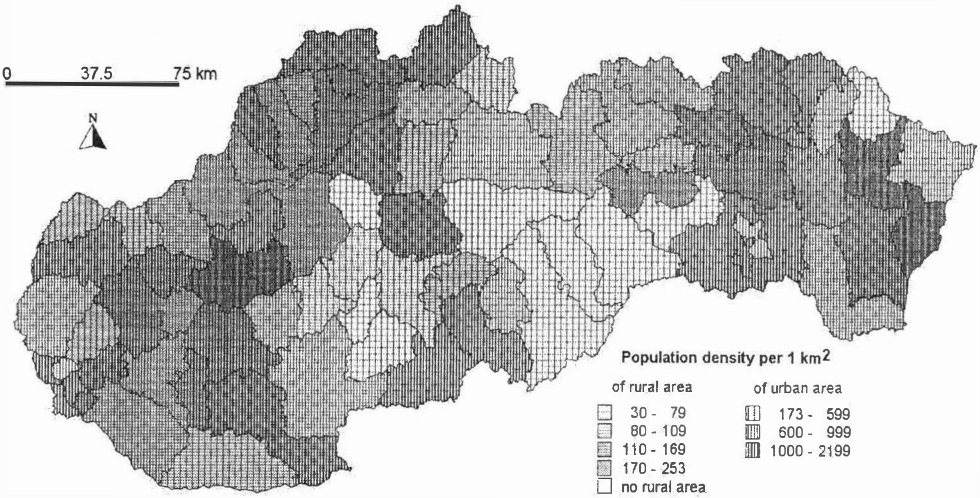



**Figure 6** Population density of the urban and rural areas in districts of the Slovak Republic in 1999

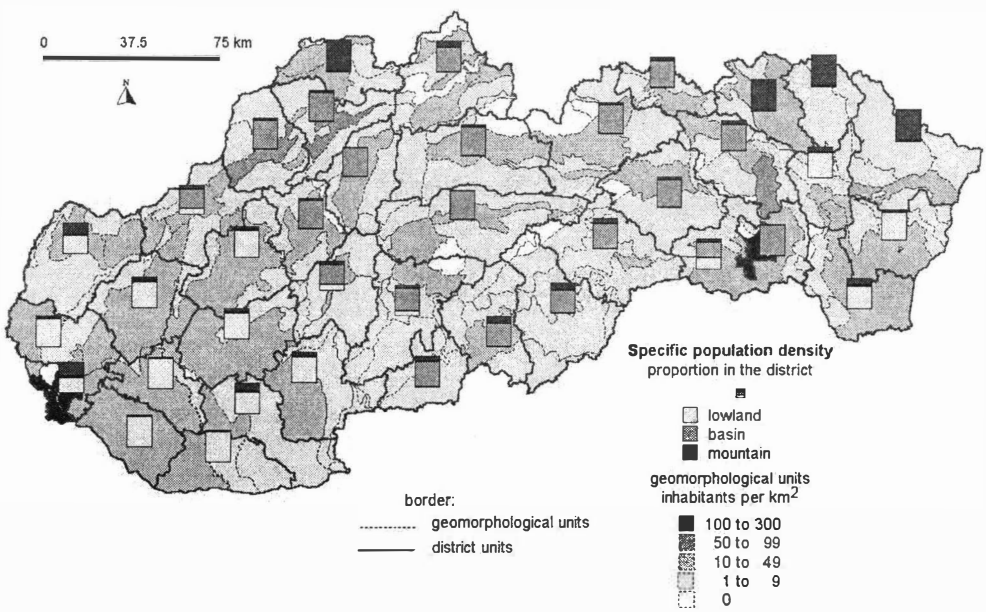



**Figure 7** Population density of the geomorphological units in districts of Slovak Republic in 1991

Very interesting appeared to be the map of the population density per unit of the agricultural land. Here the highest values belong to the districts of north-west Slovakia, where the high general density is reported, together with the relatively small areas of agricultural land and the relatively high employment in the industry (Fig. 6).

The evaluation of population density according to 3 basic types of the geomorphological units – lowlands, basins and mountains, has produced quite clear spatial picture: the highest population density is in basins, especially in Žilina and Považie basins (more than 370 persons per km$^2$), a little bit lower values are in Žiar, Zvolen, Turiec, Upper Nitra and Košice basins. Among the basins the lowest values, which are almost equal to the lowlands, are in our highest basins – Liptov, Poprad, Hornád and Orava. The lowest population density is obviously in the mountainous areas, though, even here we can see the differences in population density in the lower mountains and mountains belonging to the middle and higher highlands (Fig. 7)

## 2.3 Evaluation of Japan

The amount of population in Japan in monitored period from 1920 to 1999 has increased 2,2 times (from 55,963 mln. to 125,570 mln.). Till 1975, with exception of the period from 1940 to 1945, the average annual growth has fluctuated around 1%, falling gradually to only 0,16% in 1999. The greatest increase of population occurred after the World War II in 1947 – 49 and in 70's (the children boom). The highest values were registered, for example, in Kanagawa, Saitama, Chiba, Tokyo, Osaka and Aichi prefectures, whereas the lowest ones in Shimane, Kochi and Tokushima prefectures. Rapid increase of population in this period was mainly caused by the high natality rate. Then it has gradually declined and finally – stabilised. The boost of economy in 70's, when Japan has become the third greatest economy of the world, was reflected in growth of the living standards, in changes of the population structure and in other phenomena, which are concerned with the 2$^{nd}$ demographic transition. Unlike Slovakia, the influence of emigration and immigration flows in this period can be characterised as negligible (Fig. 8, 9).

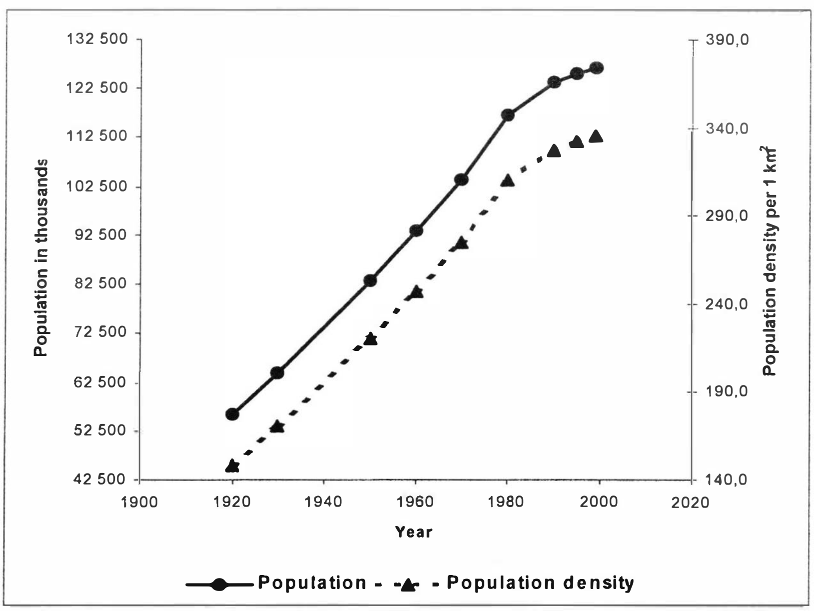



**Figure 8** Development of population and of the population density in Japan in 1920 – 1999

**Table 2** Population density per 1 km$^2$ in prefectures of Japan in 1999

| ID[1)] | Prefectures | 1999 | Surface area (km$^2$) |
|---|---|---|---|
| | **Japan** | 335.5 | 377 553 |
| **1** | Aichi | 1 361.6 | 5 147 |
| **2** | Akita | 103 | 11 613 |
| **3** | Aomori | 153.6 | 9 605 |
| **4** | Ehime | 263.9 | 5 673 |
| **5** | Fukui | 198.4 | 4 188 |
| **6** | Fukuoka | 1007 | 4 965 |
| **7** | Fukushima | 154.9 | 13 781 |
| **8** | Gifu | 199.9 | 10 598 |
| **9** | Gumma | 319 | 6 364 |
| **10** | Hiroshima | 340.3 | 8 473 |
| **11** | Hokkaido | 68.3 | 83 408 |
| **12** | Hyogo | 654.3 | 8 381 |
| **13** | Chiba | 1 148.3 | 5 156 |
| **14** | Ibaraki | 492.7 | 6 093 |
| **15** | Ishikawa | 283.4 | 4 185 |
| **16** | Iwate | 92.6 | 15 274 |
| **17** | Kagawa | 548.9 | 1 875 |
| **18** | Kagoshima | 194.7 | 9 182 |
| **19** | Kanagawa | 3 531.4 | 2 391 |
| **20** | Kochi | 114 | 7 104 |
| **21** | Kumamoto | 252 | 7 400 |
| **22** | Kyoto | 570.9 | 4 612 |
| **23** | Mie | 322.8 | 5 775 |
| **24** | Miyagi | 324 | 7 284 |
| **25** | Miyazaki | 152.1 | 7 733 |
| **26** | Nagano | 163.6 | 13 585 |
| **27** | Nagasaki | 373 | 4 089 |
| **28** | Nara | 392.6 | 3 690 |
| **29** | Niigata | 197.9 | 12 581 |
| **30** | Oita | 193.5 | 6 336 |
| **31** | Okayama | 275.5 | 7 111 |
| **32** | Okinawa | 579.6 | 2 264 |
| **33** | Osaka | 4 675.4 | 1 882 |
| **34** | Saga | 362.5 | 2 439 |
| **35** | Saitama | 1 824.6 | 3 797 |
| **36** | Shiga | 331.8 | 4 017 |
| **37** | Shimane | 115.3 | 6 626 |
| **38** | Shizuoka | 485.4 | 7 779 |
| **39** | Tochigi | 314 | 6 408 |
| **40** | Tokushima | 200.3 | 4 143 |
| **41** | Tokyo | 5 421.5 | 2 183 |
| **42** | Tottori | 175.5 | 3 498 |
| **43** | Toyama | 265 | 4 246 |
| **44** | Wakayama | 227.4 | 4 722 |
| **45** | Yamagata | 134.1 | 9 323 |
| **46** | Yamaguchi | 251.8 | 6 109 |
| **47** | Yamanashi | 200 | 4 465 |

**Note:** [1)] Identificator of the prefectures

**Source:** Statistics Bureau, Management and Coordination Agency

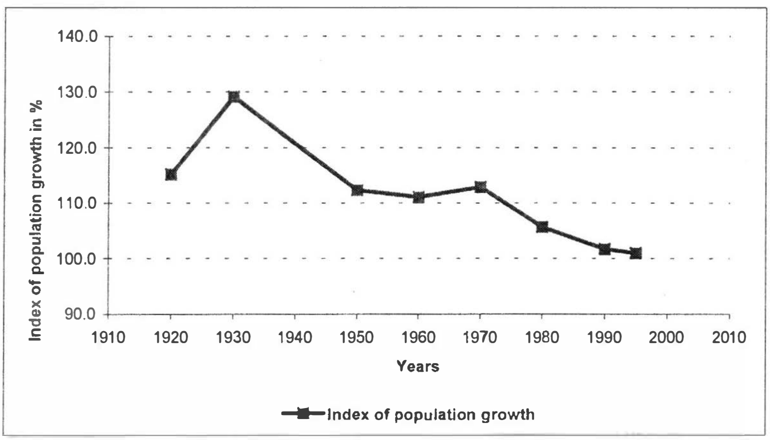


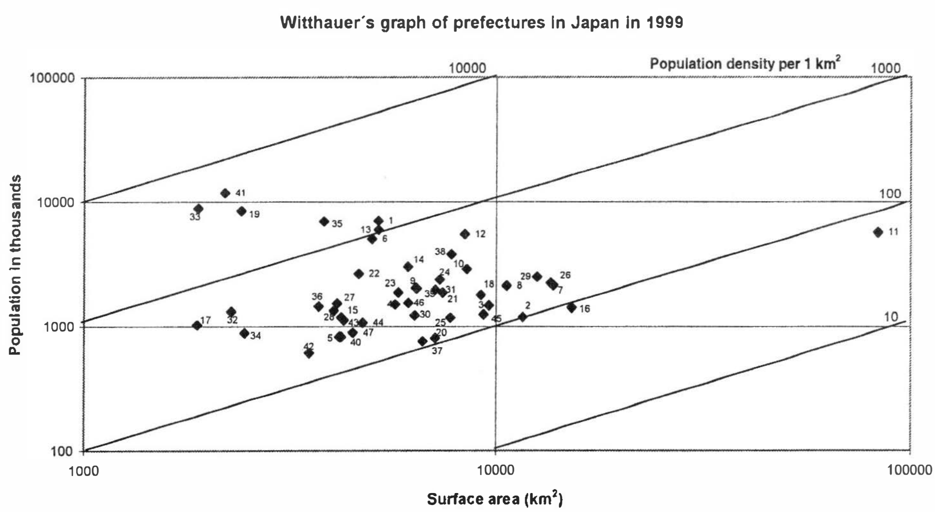

**Figure 9** Development of index of population growth in Japan in 1920 – 1999

Analysis of the individual economic regions of Japan from the viewpoint of demographic census shows that population in Japan concentrates very strongly in urbanised areas and in 3 metropolitan areas (Tokyo, Nagoya and Osaka), where about the half of the population lives (Nakagawa 2002). Except this, the most populated are Kjushu and

Okinawa isles, where considerable increase of population occurred mainly in 70's (reunion of Okinawa with Japan in 1972), though proportion of their participation on the total amount of population has fallen from 15,6 % in 1920 to 11,7 % in 1995. Despite the large extent of this territory (46 000 km$^2$), the population density here is approximately equal to the nation-wide average value: 335,5 inhabitants per km$^2$ (in 1999).

The South-Kanto on Honshu, which includes Tokyo, Saitama, Kanagawa and Chiba prefectures, is the region with the highest number of inhabitants on Honshu isle. Their total share in the population of Japan has raised from 13,7 % in 1920 to 25,9 % in 1995. However, the North Kanto, which is adjacent to it, belongs to the most depopulated areas with only 5,5% (in 1995) share in the total population of Japan (in 1920 it made 6,2%). The same character as in Kanto have the further regions on Honshu, e.g. the West-Kinki and the East-Kinki, where the population size has changed from 11,0% to 13,4% and from 3,5% to 3,0% respectively. The East-Kinki is at the same time the less populated region in Japan. In the economically developed regions – the West-Kinki and Tokai the number of inhabitants increased, as the consequence of in-migration from the neighbouring regions. On the largest isle Honshu, which takes 61% of the territory of Japan, there lived 74,9% (in 1920) of the total population of Japan and even 80,3% in 1995. On the Hokkaido isle, which is the largest prefecture with the surface area of 78 400 km$^2$, lived in 1920 only 4,2% and in 1995 only 4,5% of the total population of Japan.

Similarly to Slovakia, in Japan we can also see a considerable differentiation of population density in individual prefectures (Fig. 10). In general, prefectures with the largest cities, concentrated in the seaside areas, which are geomorphologically situated in basins/uplands, show the highest values. However, the largest Hokkaido prefecture has the low population density with the highest values around Sapporo and in the east part of the isle.




Note: 1,...,47 are identificators of the prefectures (Tab.2)

**Figure 10** Witthauer's graph of the prefectures of Japan in 1999

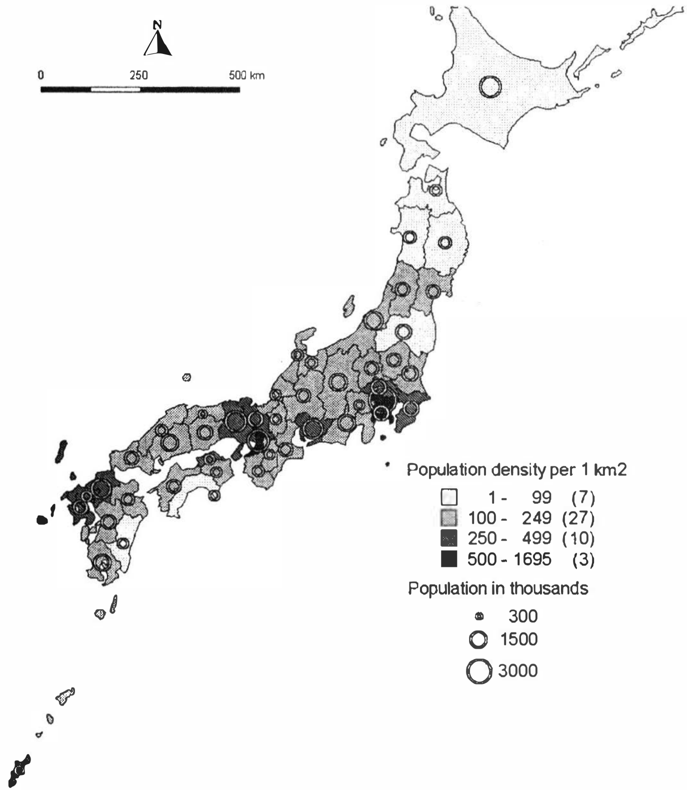



**Figure 11** Population density in prefectures of Japan in 1920

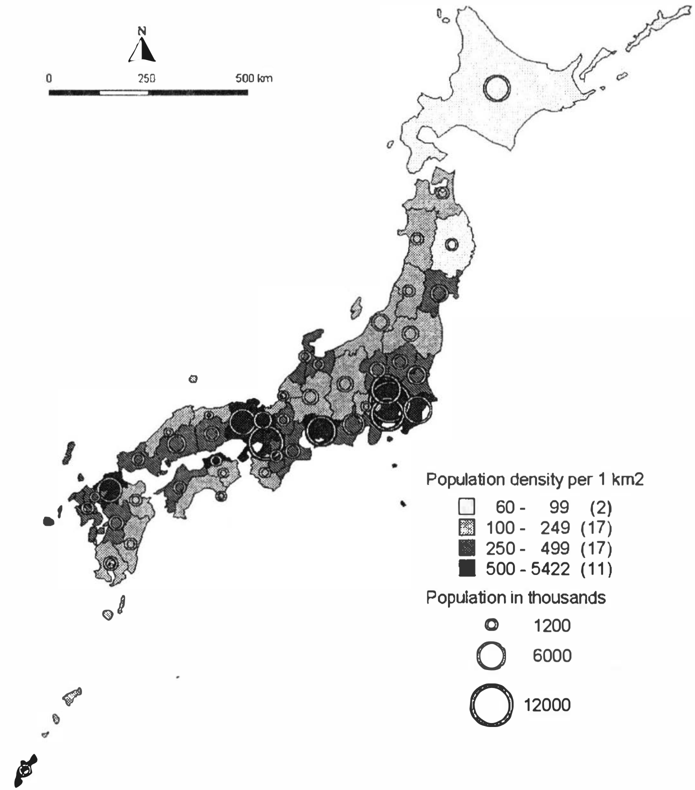



**Figure 12** Population density in prefectures of Japan in 1999

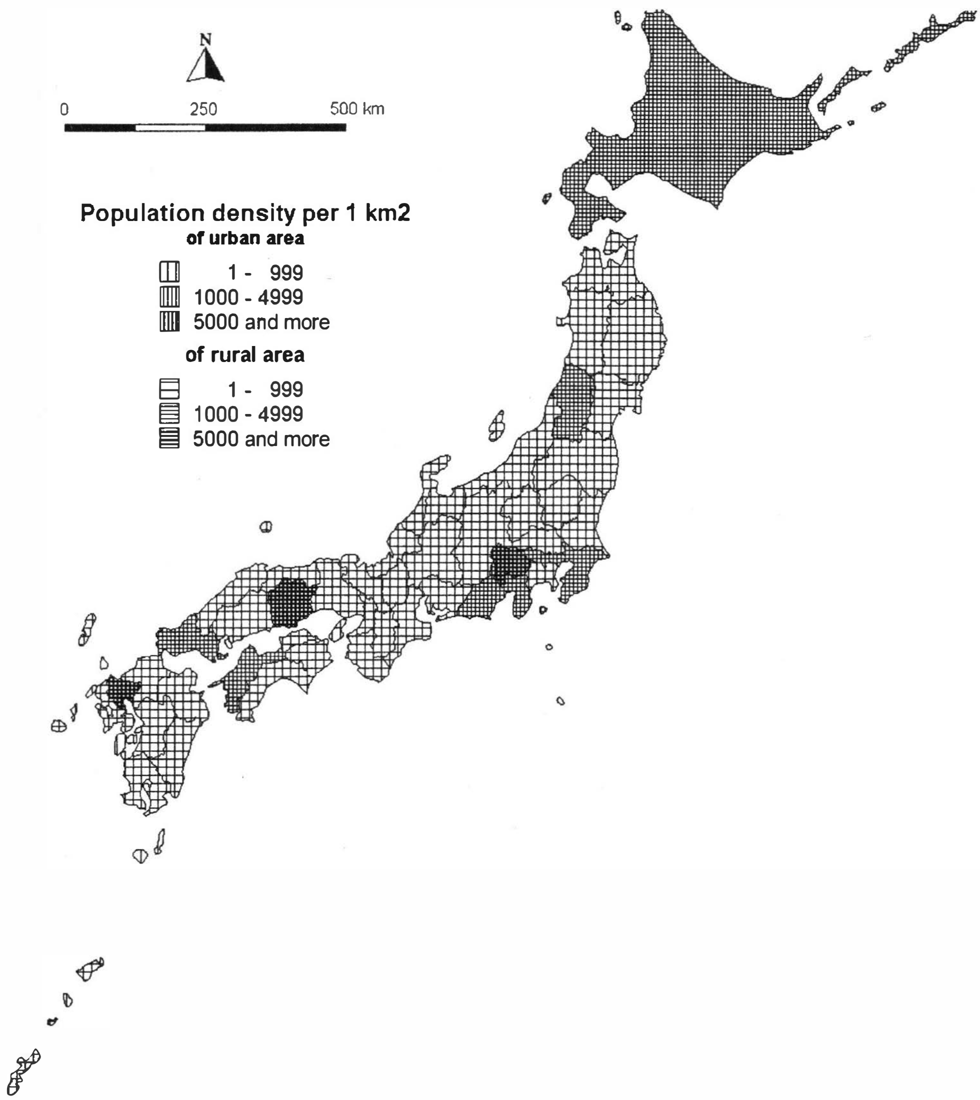



**Figure 13** Population density of the urban and rural areas in prefectures of Japan in 1999

In 1920 – 1999, the most expressively the density has increased in such prefectures as Tokyo (from 1694 to 5 421), Kanagawa (from 553 to 3 531), Osaka (from 1374 to 4 675) and some others, where in 1999 it exceeded 1000 inhabitants per km$^2$ (Aichi, Fukuoka, Chiba and Saitama) (Fig. 11, 12). Apparently, it is the result of urbanisation processes, as in Slovakia. Urbanisation itself characterises the whole post-war demographic development. The industrial boost induced the decreased of population in rural regions and its migration to the rapidly developing urban centres (Kobayashi 2002). Already in 1980, in the metropolitan areas of Tokyo, Nagoya and Osaka lived 42% of the total population.

This characteristic is well expressed by the specific population density per 1 $km^2$ of the urban and rural area (Fig. 13). Totally in Japan, it makes 1 332 for urban and 493 for rural areas, increasing in prefectures Tokyo of urban density and Osaka of rural density. The highest values of the both indicators are recorded in Osaka, Tokyo, Kanagawa, Saitama, Chiba, Aichi, Fukuoka, Kyoto, Shizuoka and Hyogo prefectures. High value of the urban density is also reported in Kagawa, Tokushima, Okinawa and some other prefectures. The lowest urban population density is in Iwate. Values of the population density for rural areas are more differentiated. The lowest values have Hokkaido and Iwate prefectures.

Analysis of the population density according to the geomorphological units (according to the territory of prefectures), reveals that most densely populated are mountains, uplands and highlands in the south part of Japan, lowlands around Tokyo and neighbouring areas and finally some prefectures in the southern part of the isles Honshu, Shikoku and Kyushu (Fig. 14).

## 3. MODELLING OF THE POPULATION SURFACES OF SLOVAKIA AND JAPAN

Computer and map-based data processing is less difficult problem today, than in the recent past, created spatial models are far better, mainly due to application of more intelligent technologies for the data collection and processing (e.g. the global positioning systems, monitoring systems for the earth remote research, etc). Besides this, the georeferenced socio-economic data have become much more accessible and, in addition to this, their spatial resolution has currently been increasing. The GIS systems itself integrate tools for the computer processing and statistic analyses of the data, cartographic modelling, simulation of the processes (virtual modelling), the image analysis and other techniques, which create a user's framework.

The most frequently used GIS tools focusing on creation and analyses of the geographical (and population) models comprise tools for the spatial processing (manipulation) of data, their subsequent analyses. Moreover, it is a great advantage for the user, if the data stored in the GIS are processed then by means of the statistic methods, currently in-built to the GIS in the form of specialised sub-programs, so the results of the research can be visualised dynamically (on-line).

To such GIS programs (being actually used in our application) belong, for example, the Vertical Mapper with MapInfo, which offers different methods of evaluation of the spatial characteristics of the geographic dots and spatial objects (analysis of the dot density and distance, analysis of the nearest neighbour), spatial aggregation and cluster analysis of the dot representations, geointerpolation techniques (natural neighbour, kriging, and others), generalisation techniques and comparative techniques.

Statistical surfaces themselves represent the individual part of the GIS used for modelling of spatial extension of the landscape elements, or their parameters, which could be described functionally. As the function model it could be presented by the following equitation:

$$z = f(x,y,),$$

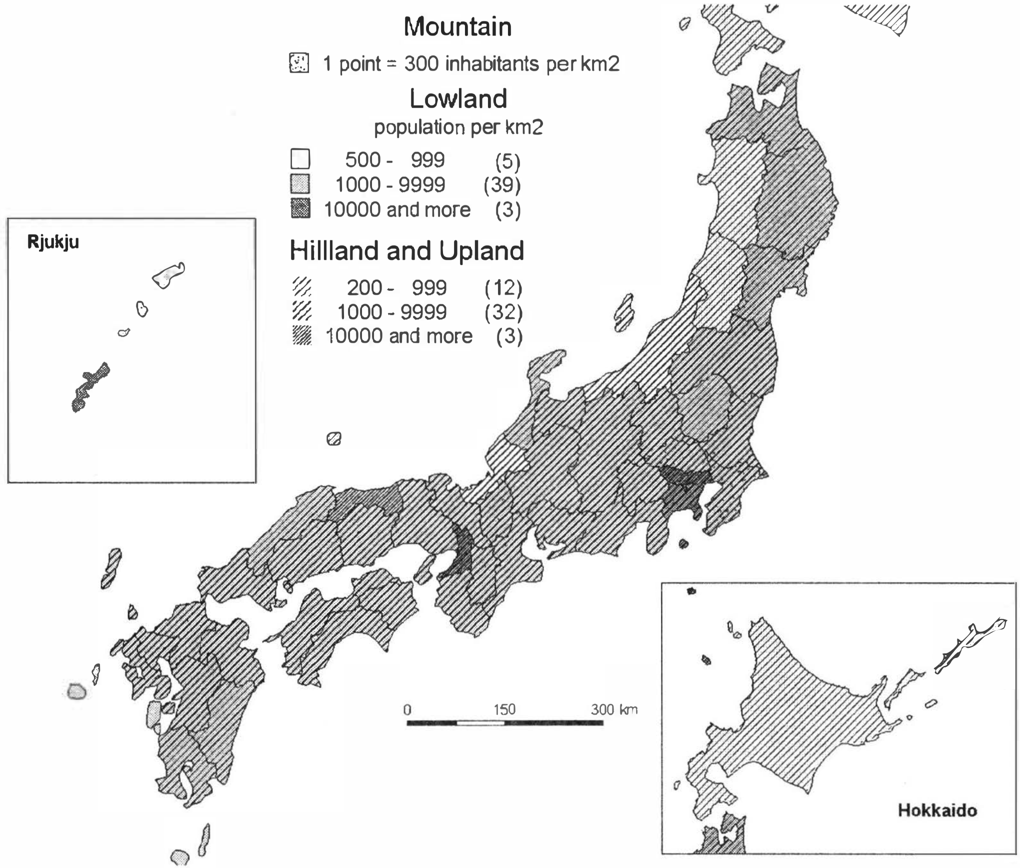



**Figure 14** Population density of the geomorphological units in prefectures of Japan in 1985

where $f$ is a function of a spatial allocation of modelled phenomenon, or an object in the space co-ordinate $x$ and $y$, whereas $z$ is it's content feature, i.e. it's value.

The surface model is used for modelling not only the scalar fields in nature such as elevation of the earth surface, but also for modelling the scalar fields generated by spatial operations from the other types of spatial phenomena, say, the population distribution. The comprehensive modelling of surfaces assumes approximation (global model) or interpolation (local model) of the surfaces in the form of derived parameters (e.g. slope or orientation) and their consequent analysis and cartographic interpretation.

In order to visualise and analyse the distribution population of Slovakia and Japan, we have used the surfaces of the population distribution through the geo-interpolation techniques, namely the *natural neighbour method*, which is appropriate for modelling of demogeographical events with characteristic clustered or linear allocation in space. The natural neighboured interpolation (NNI) is the local interpolation method designed for dealing with values in the neighbourhood to the data point, where the size of the neighbourhood is determined by the grid of Voronoi diagrams or Thiessen polygons (polygons having the geometric property of containing within them areas that are nearer to the enclosed point around which they are constructed then). The „*natural neighbour interpolation*" function is as follow (1):

$$Z(x_0) = \sum_{i=1}^{n} w_i \,.\, Z(x_1),$$

*where* $Z(x_0)$ is the interpolated value in the point $x_0$, $Z(x_1)$ is the value of the neighbouring (nearer) points $x_i$, $i=1,..n$, $w_i$ is the weight which is equal to proportion of the allocation area of neighbours $i$, $i=1,..n$ belonging to the polygon of the point $x_0$.

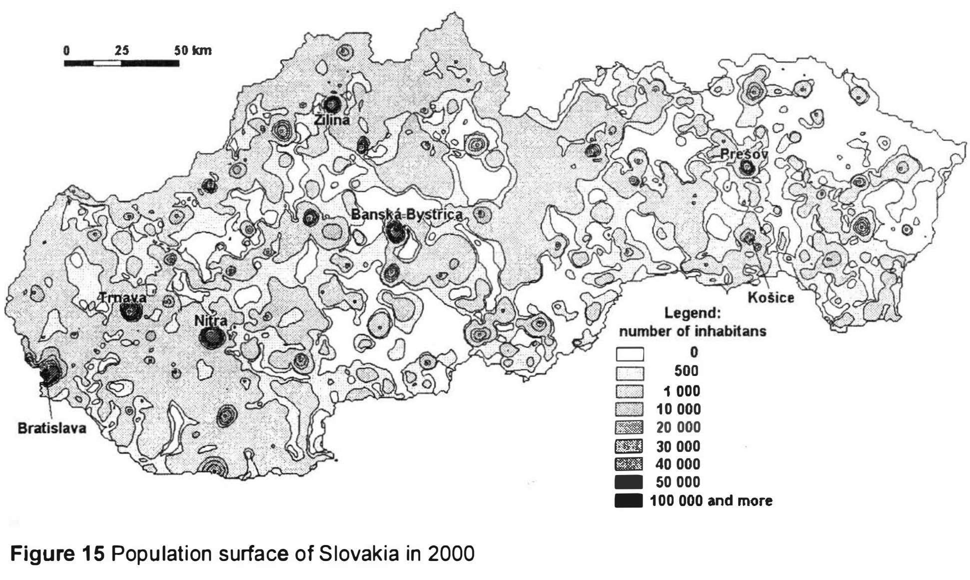



**Figure 15** Population surface of Slovakia in 2000

This method enables creation of the exact interpolation grid/surfaces, where we have to set around the data points the grid of polygons, which interpolate the new neighbouring points with the average value Z (height) weighted by proportion of the allocation area in the polygon. Simply said, the NNI uses the area-weighting techniques to determinate the new values for every grid cell/node. In more details, this method is analysed by Sárközy, F. (1998). Creation of the Voronoi diagrams is available on the WEB site http://www.voronoi.com.

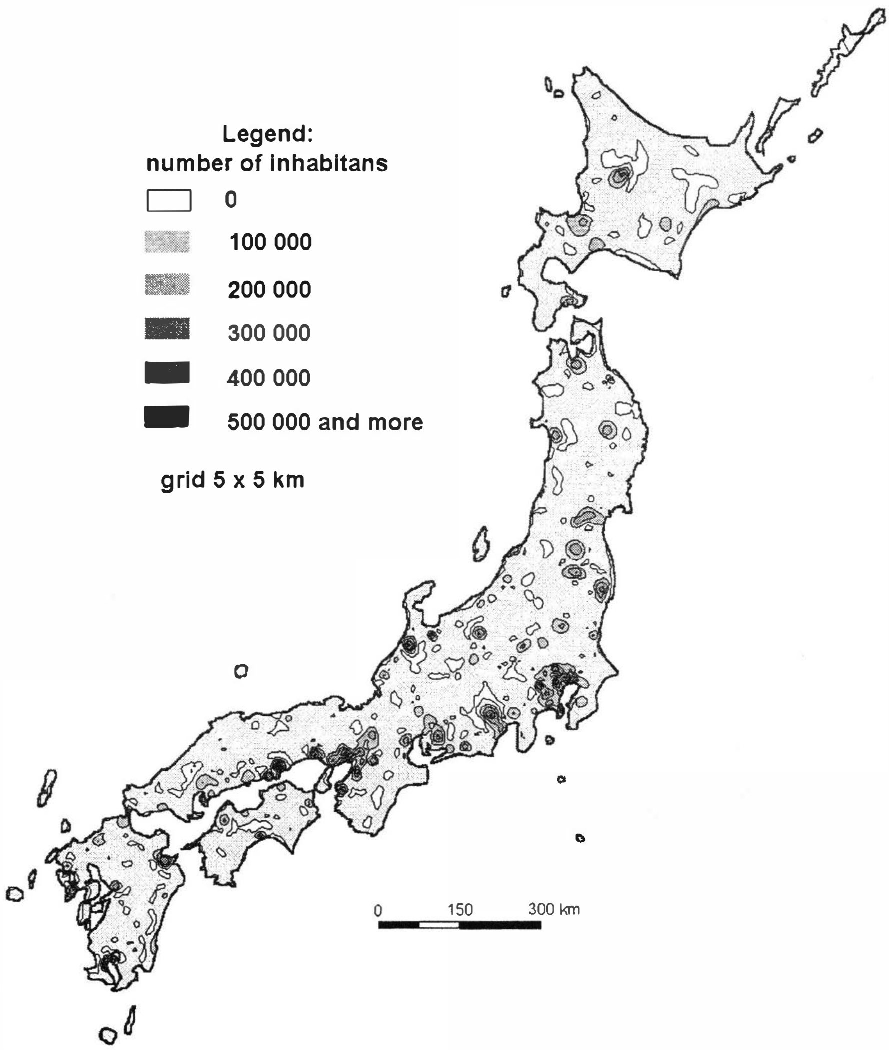



**Figure 16** Population surface of Japan in 2000

We have used the interpolation method of the nearer neighbour for creation and visualisation of the population distribution in Slovakia and Japan, where the data points were centroids of settlements and the number of its inhabitants as per the year 2000 (Fig. 15, 16). The relevant parameters of the interpolation grid were derived from the previous statistical analysis (quadratic census) of centroid distribution, where the grid size per cell was chosen 1 km for Slovakia and 5 km for Japan. Only this size of the pixel provides the condition of random and consistent allocation of the points in the grid and represents the inputted data in the process of their griding, i.e. their transformation from irregular to regular data. The subsequent interpolation process runs on this adjusted point surface.

Analysing the point objects (settlements), we have used the quadrant and the nearest neighbour analysis modules, in order to determine the way of their allocation on the territory of Slovakia/Japan and to define the optimum size of the grid (raster) for the further analysis of the settlements' allocation in Slovakia and Japan.

## 4. THE MODELS OF THE POPULATION POTENTIAL OF SLOVAKIA AND JAPAN

The population potential model is a macro-model concerned mainly with demand for determination of the objective indicators of the spatial relationship between discrete geographical phenomena and objects in the related area. Generally, the theory of physical fields is used as a starting point for design of the potential and the gravity models.

Usefulness of the potential population model and population maps in a function of the probability statistical indicator of population distribution has already been defined earlier (Warntz 1964, Kosinski 1965, Chojnicky 1966, Rich 1980, Jevtejev 1969). The later studies fully proved their analytical and informative value, which became even more apparent in the scale of the larger spatial units, such as districts, regions or states (Dziewoński et al. 1974, Glezer 1983, Czyż et al. 1996).

The population potential of a point (the centre of a settlement) is a measure of the nearness of people to that point, i.e. of the intensity of possibilities of interaction between that points and all other points in a system. In general, the potential exerted at a point $Pi$ is defined as (2):

$$P_i = \sum_{j=1}^{n} \frac{M_j}{d_{ij}},$$

where $M_j$ is the population located in the point $j$, $d_{ij}$ is the distance between points $i$ and $j$ and $n$ is the number of points (municipality units) in the examined spatial system (state).

The population potential model has three dimension – the area (the territories of Slovakia, and Japan), the mass (the amount of inhabitants) and the distance (i.e. air, road accessibility or the other function of distance, i.e. the cost). The standard distance is the straight (air) distance calculated on the basis of the known formula:

$$d_{ij} = \sqrt{\left(x_i x_j\right)^2 + \left(y_i y_j\right)^2} \; ,$$

where $x$ and $y$ are co-ordinates of the centroids (for example local government units). In terms of the distance, mainly the air and road accessibilities were used. The calculation of the road accessibility was conducted on the basis of the connective matrix ($n$ x $n$) of the length of neighbouring edges (ways), which characterised the real connections between the graph nodes (settlements) according to the formula:

$$D_i = \sum_{j=1}^{n} d_{ij},$$

where $D_i$ is summarised lengths of the (minimal) ways from node $i$ to node $j=1,...n$ (according to the theory of graphs); in case of the metric accessibility (in km).

The accessibility produces the overall indicator, which indicates how is the certain place accessible from the other places of the space/territory. The accessibility weighted by number of the inhabitants corresponds with the population potential (Kusendová 2000).

In the further stage of modelling of the population distribution in Slovakia and Japan by means of the population potential, we tried to create a modified local population model, which can be used for identification of approximate regions of influence of the population centres. With this aim, we have used the gravity Huff model (Huff 1963). Though calculation of its values was restricted to the distances to neighbouring settlements, where we assumed the greatest probability of the population interactions (Fig. 17, 18). In our case, we have considered the average air accessibility of the district centres in Slovakia (31,5 km) and prefectures in Japan (218 km) as such a distance.

The probability population model depicts regions with possible spatial competition of settlements. On the maps, we can see the most populated areas of Slovakia and Japan, together with the spatial representation of their population centres, where the potential for creation of interactions is the highest.

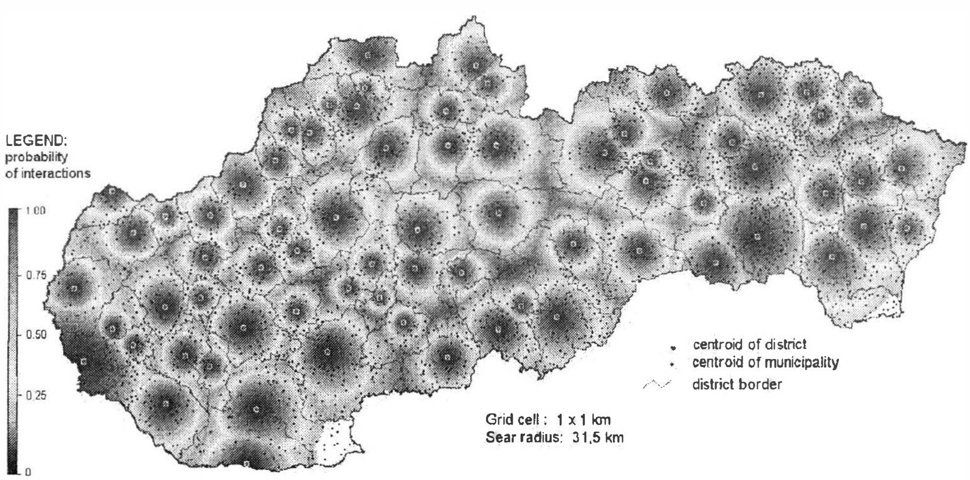



**Figure 17** Probability interaction model of the population of Slovakia

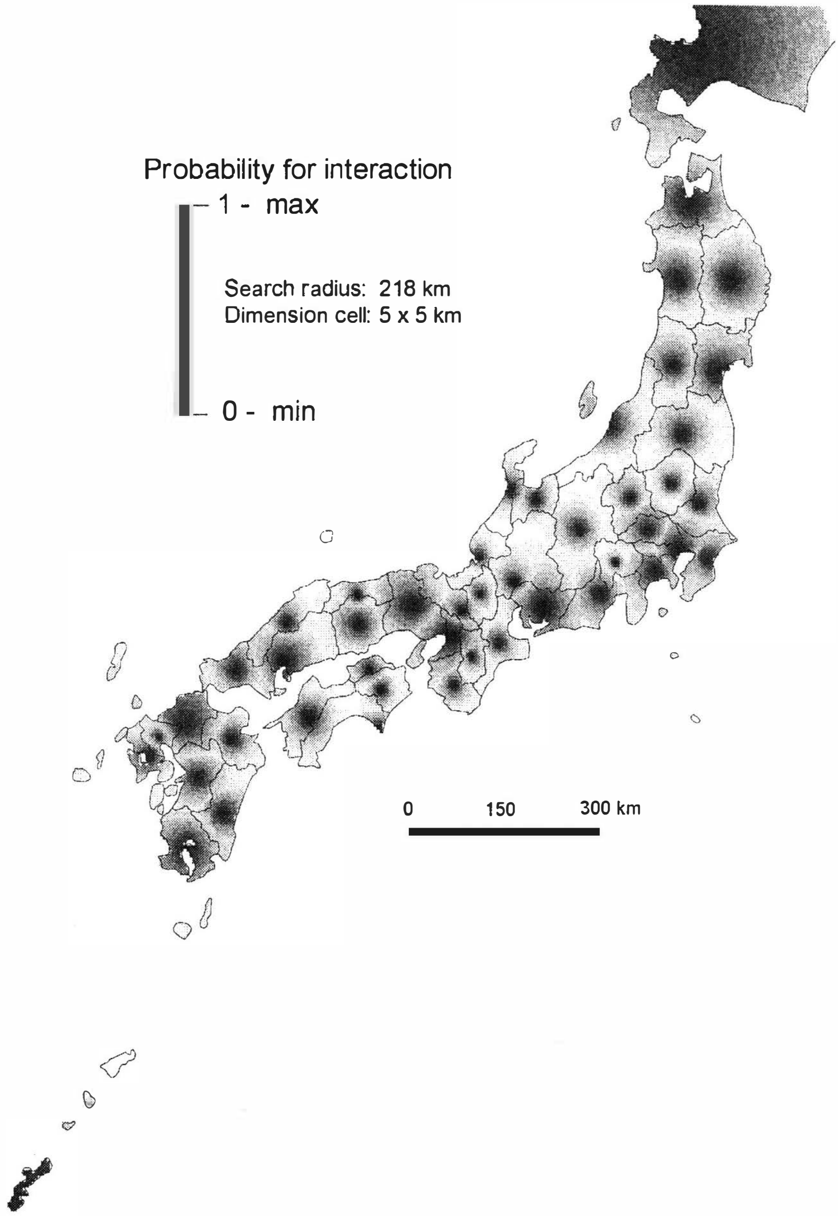



**Figure 18** Probability interaction model of the population of Japan

## 4. SUMMARY AND CONCLUSION

The study addresses the two main topics. In the first one, after brief methodical introduction, we tried to analyse and compare the development of the spatial differentiation of populations in Slovakia and Japan, based on evaluation of the density values and by other traditional ways of the demogeographical research in written, graphic and map forms.

The second topic is concerned with theoretical issues and contemporary trends in the spatial differentiation of population, based on less traditional and less used ways, i.e. with the help of interpolation techniques and interaction or gravitation models in the environment of the GIS technologies. In more details, we have analysed methodical aspects of the creation of demogeographic statistical fields (surfaces) of Japan and Slovakia in the form of potential population models and their modifications.

Having evaluated the procedures used for modelling of the population distribution by the GIS tools and in the GIS environment, we recommend to apply, besides traditional indicators (the population density, indices of population increase, etc), the spatial models of the population potential in more variations, using them not only for calculation procedures, but also for analyses and representation.

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## Resume

### Modelovanie priestorového rozmiestnenia populácie Slovenska a Japonska

V našej štúdii bol na základe dostupných dát z územia Slovenska a Japonska porovnaný vývoj počtu obyvateľov Slovenska a Japonska v rozmedzí rokov 1920 – 1999 (obr. 1, 2, 8, 9). Všeobecná hustota populácie oboch krajín bola indikovaná z dát viažucich sa k priestorovým štatistickým jednotkám II. stupňa, t. j. v prípade Slovenska k okresom a v prípade Japonska k prefektúram (I. stupeň – kraj/region, III. stupeň – obec/municipality). Grafickú interpretáciu všeobecnej hustoty populácie obyvateľstva analyzovaných krajín poskytujú obr. 3, 5, 11, 12 a Witthauerove grafy, v ktorých súradnice logaritmickej stupnice uvádzajú absolútne hodnoty počtu obyvateľov a rozlohy územia štatistických jednotiek (okresov/prefektúr) vo vybraných časových rezoch (obr. 4, 10).

Špecifické hustoty populácie Slovenska a Japonska sa viažu na kategórie využitia zeme (počet obyvateľov na jednotku poľnohospodárskej a zastavanej/urbánnej plochy – obr. 6, 13) a na geomorfologické jednotky odpovedajúce príslušným územným jednotkám, t.j. okresom Slovenska ( v roku 1991 – obr. 7) a prefektúram Japonska (v roku 1985 – obr. 14), pričom ukazovatele z oboch krajín nie sú úplne konzistentné v dôsledku rôznej metodiky stanovovania týchto kategórií.

Spoločnou črtou oboch krajín je veľká nerovnomernosť rozmiestnenia populácie a podobné príčiny, z ktorých popri iných sú najvýznamnejšie fyzicko-geografické pomery (vysoký podiel pohorí s veľkou členitosťou reliéfu a z nich vyplývajúce obmedzenia pre vývoj osídlenia).

Podobne ako pri okresoch Slovenska aj v Japonsku môžeme hovoriť o pomerne značnej priestorovej diferenciácii ukazovateľa hustoty podľa prefektúr. Vo všeobecnosti najvyššie hodnoty v dôsledku urbanizačných procesov dosahujú prefektúry s najväčšími mestami sústredenými do prímorských oblastí, ktoré geomorfologicky predstavujú nížiny.

S cieľom vizaualizovať a analyzovať rozmiestnenie obyvateľstva Slovenska a Japonska sme vypočítali populačný povrch pomocou geointerpolačnej techniky – interpolácie metódou najbližšieho suseda (1), ktorá je vhodná na modelovanie demogeografických javov s charakteristickým zhlukovým alebo lineárnym rozmiestnením v priestore, a to pomocou nástrojov programov GIS – Vertical Mapper a MapInfo. Interpolačnú metódu sme použili na tvorbu a vizualizáciu rozmiestnenia populácie Slovenska a Japonska, v ktorej vstupné bodové pole tvorili centroidy obcí s hodnotou/atribútom rovnajúcim sa počtu obyvateľov v roku 2000 (obr. 15, 16). Relevantné parametre interpolačného gridu/siete boli odvodené z predchádzajúcich výsledkov štatistických analýz (kvadratického cenzu)

rozmiestnenia centroidov, pričom bola sieť optimalizovaná na rozmer bunky 1 km pre Slovensko a 5 km pre Japonsko.

V ďalšej etape modelovania rozmiestnenia obyvateľstva Slovenska a Japonska pomocou populačného potenciálu (2) sme sa pokúsili vytvoriť modifikovaný populačný model, ktorý sa dá v praxi použiť, napr. na rámcovú identifikáciu hraníc spádových oblastí centier populácie. S týmto cieľom bol realizovaný výpočet pomocou gravitačného „Huffovho modelu" s obmedzením sa na najbližšie obce do vzdialenosti, v ktorej je väčšia pravdepodobnosť na realizáciu interakcií medzi sídlami. V našom prípade bola za takúto vzdialenosť považovaná priemerná vzdušná vzdialenosť medzi centrami okresov Slovenska (31,5 km), resp. prefektúr Japonska (218 km). Pravdepodobnostný populačný model znázorňuje oblasti možnej priestorovej konkurencie obcí. Na mapách (obr. 17, 18) vidieť významné centrá osídlenia Slovenska a Japonska spolu s priestorovým vyjadrením ich pravdepodobných spádových oblastí, v ktorých je potenciál pre tvorbu interakcií najvyšší.

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## スロバキアと日本における人口空間分布のモデル化

ダグマール・クセンドヴァー

本研究では、スロバキアおよび日本に関して入手が可能となったデータを用い、1920〜1999年における両国の人口増加の展開を比較した（グラフ1、2、8、9）。普通人口密度（general density of population）を示す指標を、レベルIIの空間統計単位のデータから抽出した。これは、スロバキアの場合はokres(=district(英語))、日本では都道府県である（レベルIはregionないし地方、レベルIIIはmunicipalityないし市町村)。普通人口密度のグラフィック表現は、図3，5、11、12に示した。また、ウィトハウアーグラフ(Witthauer graph)による図示も行った(グラフ4、10)。ウィトハウアーグラフでは、座標は対数尺度で、軸は各々、ある時点における人口密度の絶対値、統計単位(okresないし都道府県)の領域を表す。

特定人口密度(specific population density)を、土地利用（例えば、村落/都市地域ごとの住民数 － 図6、13)、および土地形状の分類と関連づけた。これは、領域単位ごと、つまりスロバキアではokres（1991年、図7)、日本では都道府県（1985年、図14）ごとに行った。ただし、ここで用いた指標は、両国で完全に対応しているわけではない。分類の特定にあたって、各々異なる手法を用いたためである。

両国に共通しているのは、人口分布や、いくつかの地理的特徴の分布が、非常に不規則な点である（山地の割合が高く、平面の寸断される場所が多いことが、領域の広がりを制約する要因となっている)。

スロバキアと同様、日本でも、個々の都道府県で人口密度はかなり異なる。一般に、大都市のある都道府県は、海沿いに集中し、地形学的には低地/台地に位置するが、こうしたところでは、都市化が進行した結果として、人口密度が最も高い。

スロバキアと日本の人口分布を視覚化して分析するため、人口分布傾向面を地域補間 － 自然近隣補間 natural neighbour interpolation（1）－の手法により計算した。この手法は、クラスター状ないし線形の分布を特徴とするような人口地理学的事象をモデル化する場合に妥当な手法で、GISのプログラムであるVertical MapperおよびMapInfoのツールにより実行できる。ここでは、2000年時点での集落の重心と住民数を点データとして、スロバキアと日本の人口分布図を補間法により作成・視覚化した（図15、16)。

関連する補間グリッドのパラメータは、先に行った重心分布の統計解析（quadratic census）から引き出した。各セルのグリッドサイズは、スロバキアでは1km、日本では5kmが選ばれた。

人口分布のモデル化を、人口ポテンシャルの方法を用いてさらにすすめ、修正人口モデルの作成を試みた。このモデルにより、人口中心地のおおよその影響圏を識別することができる。このためには、ここでは重力ハフモデルを使用した。ただし、値の計算は、人口の交流確率が最も高いと想定される近隣集落への距離に限定して行った。こうした距離として、本研究で考察対象としたのは、スロバキアではokresの中心地、日本では都道府県の平均的な近接性（空路、それぞれ31.5km、218km）である。

確率人口モデルにより、集落間の空間的競合が起こりうる範囲が描かれる。図17、18により、スロバキアと日本で最も人口稠密な地域はどこか、また人口中心地が空間的にどう表現されるかが分かる。これらの地域では、交流がうまれる可能性が最も高い。