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# SPATIO-TEMPORAL DIFFERENTIATION OF CANCER INCIDENCE IN SLOVAKIA

**Abstract**. Coping with the prevention, diagnosis and therapy of cancers is a challenging medical task with continuing consequences for the development of population health status and economy of health in each country. The occurrence of cancers shows an upward trend in the world. A comprehensive fight against cancers should involve the spatial aspect which is best applied in the field of medical geography. The key indicators for the surveillance of cancers include mortality and incidence, but also prevalence. Incidence plays a more and more important role in the period of an increase in cancers. In the investigation of this issue specific analytical methods were used, such as spatial autocorrelation. Standardized cancer incidence in Slovakia was analyzed in the case of men and women. The years 1997, 2009 and the period 1997–2009 were chosen to compare the incidence. The results of partial analyses show the situation in districts of Slovakia from the perspective of incidence development and its spatial differentiation.

**Key words**: cancer, standardized incidence, mortality, Slovakia, medical geography.

## 1. INTRODUCTION

A man who lives his life in good health has usually better conditions to achieve his goals than an individual that is afflicted with physical and psychological difficulties. For many people health is the most valuable possession, but it can be quickly lost due to various negative phenomena. Moreover, internal and external factors play an important role. The health status affects almost all aspects of life. It affects social status as well as economic activity and *vice versa* – these factors affect human health (Džambazovič and Gerbery, 2015). A systematic surveillance

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of mortality, morbidity, priority risk factors as well as spatial disparities in the population is necessary for a long-term strategy of improving population health status with the use of targeted health-intervention and social measures. Targeted surveillance of socially serious non-infectious diseases has lagged behind in Slovakia compared to infectious diseases with a long tradition of surveillance. After the stabilization of mortality and morbidity from infectious diseases, thanks to the implementation of the National Cardiovascular and Oncology Program in the 1980s , the circulatory system diseases and cancers have become a forefront social interest (Baráková *et al.*, 2004).

The fact that many risk factors and conditions affect everyone and the fact that malignant cancers can occur in anyone at any time led us to take an interest in this issue. The aim of the paper is to assess the standardized cancer incidence in Slovakia by means of spatial autocorrelation. In this paper an attempt was made to identify regions which were singled out based on the criterion of homogeneity for the studied indicator of standardized cancer incidence. The study area is the Slovak Republic and the research was focused on the districts. The paper tried to find answers to the following research questions:

1. Standardized cancer incidence among men and women in Slovakia is growing.
2. The values of standardized cancer incidence are higher among men.
3. Increase in cancer incidence in the population of Slovakia is partly influenced by the socio-economic level of the population.

## 2. THEORETICAL ASPECTS OF CANCER INCIDENCE

Since the end of World War II, the whole of Europe has gone through considerable changes in mortality rates. In general, for a long time the lowest mortality was achieved by countries in Western and Northern Europe whereas the countries of Southern and Eastern Europe lagged behind quite significantly (Meslé and Vallin, 2002). However, in the mid-1960s both groups came considerably closer towards each other. This was mainly the result of reducing mortality from infectious diseases in childhood in Southern and Eastern Europe. The population of Slovakia has gone through a similar development. Mortality from cancers and cardiovascular diseases has become crucial for development in Europe. In the period from the late 1960s until the beginning of the 1990s the differences in mortality among European countries increased again. A significant improvement in mortality rates west of the Iron Curtain was mainly the result of a decrease in mortality from cardiovascular diseases (so-called cardiovascular revolution) and some forms of cancers. A completely different situation arose in the countries East of the Iron Curtain. Its main signs included stagnation or only slight improvement of mortality rates. Although Slovakia also ranked among countries with declining mortality, in terms of dynamics it rather belonged to countries with average or below-average decrease (Meslé, 2004).

A very important aspect regarding the analysis of mortality, its development and existing differences is therefore surveillance of leading death causes. They not only provide information on the main cause of death, but also enable indirect assessment of the health status of the surveyed population. On the other hand, they affect mortality itself and create conditions for differences in mortality characteristics among individual populations. This fact is based on endogenous as well as exogenous factors which affect individual death causes (Caselli *et al.*, 2006).

Health status surveillance includes many indicators that can be surveyed and assessed. One of the possible assessment indicators, based on which the problem areas can be identified, is the incidence rate of selected type of disease. The indicator of incidence is defined as the number of newly created cases of a given disease (in this case it is the incidence of malignant cancers) in selected population for a certain period of time (Vokurka and Hugo, 2009). Spatial assessment and analysis of incidence rates of malignant cancers belong to issues of medical geography. According to Brown *et al.* (2009), the studied phenomenon can be interpreted in two aspects in terms of this discipline. One of them examines geographic factors that contribute to poor health status and the other deals with geographic factors that influence access to health care. Moreover, it is the discipline that uses the concepts and techniques of geographical disciplines (Meade and Earickson, 2005).

Therefore, surveillance and assessment of incidence belongs to the most common research areas of this scientific discipline. The global aspect of incidence assessment in five continents was characterized by Forman *et al.* (2014). The main aim of this study was to provide comparable data on cancer incidence in selected countries of the world. This phenomenon was analyzed in 68 countries (Africa – 7, Central and South America – 10, North America – 2, Europe – 30, Asia – 14, Oceania – 3). The authors focused on information about carcinoma which were diagnosed in these countries over the period from 2003 to 2007.

According to Ward *et al.* (2004), spatial differences of cancers can be specified either from the aspect of incidence/mortality rate or in relation to race and socio-economic status of the population. The results of their research show that inhabitants in poorer areas (20% of the population live below the poverty threshold) have higher mortality rates from cancers (among men by 13% and among women by 3%) compared to wealthier countries (less than 10% of the population live below the poverty threshold). Racial and gender specificities of cancer were studied in 8 health regions of South Carolina with emphasis on breast, cervix, colon, lung and prostate cancer. Racial differences were recorded in all types of cancer. The biggest racial differences were recorded in breast and prostate cancer (Hébert *et al.*, 2009). The social environment may affect different types of cancer in different ways. About 80 types of cancer whose incidence is related to the socio-economic class of population have been recorded so far. For example, breast cancer is more common in higher socio-economic classes and among women whereas lung cancer is more common in lower classes and mainly among men who smoke. On the other hand, cancers do not generally show such a strong relation to social classes as cardiovascular diseases (Hiatt and Breen, 2008; Tian *et al.*, 2011).

Mapping the distribution of malignant cancers in the context of world and European countries is carried out through atlases of malignant cancers e.g. in the Czech Republic, England, USA, India and others. In Slovakia, such work was created by Pleško *et al.* (1989).

At present, European Union countries are experiencing changes in mortality rates that are specific for each country, but at the same time they have a common feature which is a dominant position of mortality from cancers. Ferla *et al.* (2013) studied trends in development of incidence and mortality rates of selected types of malignant cancers in 28 European Union countries. By means of statistical models, they singled out four types of cancer (lung, colon, breast and stomach) with the most progressive increase for the next 20 years. An important role in surveillance, planning and assessment of national action plans is played by national cancer registries as well as introduction of the programme called 'Europe Against Cancer'. In addition to the increase in cancers, there are also spatial contrasts regarding malignant cancers in European countries. This phenomenon was characterized for Southern Europe by Jensen *et al.* (1990).

With the exception of a common feature- (high mortality from cancers in the European Union countries), there are also differences according to individual types of cancer. For example, as analyzed by Znaor *et al.* (2013), the countries of South-Eastern Europe are characterized by an increase in incidence and mortality from cancers. They focused on 17 most common types of cancer in new member states of the European Union. The study confirmed the fact that mortality in this area is also dominated by lung and prostate cancer and an increase in colorectal cancer among men in Croatia, Serbia and Bulgaria. As for women, mortality from breast cancer dominates, which was, however, reduced in Slovenia, Croatia and Malta.

Spatial disparities in mortality from cancers in 8 European countries (Croatia, Czech Republic, Hungary, Romania, Poland, Slovakia, Serbia and Montenegro) are documented by the fact that for the last 20–40 years the most common type of cancer among men in all surveyed countries was lung cancer followed by colon and prostate cancer; however, with the exception of the Czech Republic. As for women, the dominant position was maintained by breast cancer followed by colon cancer. The exceptions were Romania and the central part of Serbia where the cervical cancer was the second most common type of cancer. Significant differences in the risk of various types of cancer are often linked to the geographical area of their occurrence (Vrdoljak *et al.,* 2011).

As reported by Ferlay *et al.* (2012), it is mostly middle-aged and older people that are threatened by their incidence and deadly potential. According to the authors, there are 20 large “areas” in the world with a predominance of mortality from cancers. Great heterogeneity in mortality from various types of cancer can also be seen in Central European countries. Malignant prostate cancers had the dominant position in mortality among men e.g. in Austria and Switzerland. As for women, high mortality from malignant breast cancers was recorded e.g. in Germany and Slovakia (Lutz *et al.*, 2003).

The study of spatial disparities in cancer incidence in Slovakia is a relatively new subject of interest focusing on their specific features and assessment of risk factors. The cancer incidence rate is very often linked to the quality of the environment. An example is the PCB contamination in the environment and food chain in relation to the incidence of individual cancer types in districts of Eastern Slovakia which was analyzed by Pavúk *et al.* (2000). This negative phenomenon which is a product of chemical industry (Chemko Strážske company) causes an increased rate of gastrointestinal cancers as well as an increased risk of ovarian cancer and cervical cancer in this region. Contamination of drinking water by nitrates, which can undergo endogenous reduction, very often shows to involve powerful carcinogens. Ecological study in the district of Trnava documented a dependence on the amount of nitrates in water in correlation to gastrointestinal cancer and urinary cancer. However, a direct correlation of increased amount of nitrates and incidence of the studied cancers was not confirmed (Gulis *et al.*, 2002). A very often discussed topic is the study of the intensity of impact of the nuclear power plant on cancer incidence in populations living in its surroundings. Letkovičová *et al.* (1999) conducted a research in the surroundings of Mochovce nuclear power plant focusing on indicators of general mortality, mortality from malignant cancers, incidence of malignant cancers, tuberculosis incidence and prevalence of chronic lung diseases. The results point to the fact that whole area of the Mochovce nuclear power plant is influenced by increased mortality, especially high mortality from malignant cancers.

In addition to risk factors, it is important to point to spatial distribution of various types of cancer. An example is the mortality from prostate cancer among men which was studied at the level of districts of Slovakia (Kážmer and Križan, 2010). Spatial differentiations in mortality from cancers at the local level in Slovakia were characterized by Vilinová (2012). As noted by Konečný *et al.* (2008), it is important to study cancers also through other indicators such as prevalence which was analyzed in the Czech Republic.

One of the application methods of medical geography, which is used very often in practice, is to visualize cancer incidence on maps. It is a useful tool for assessing and quantifying their geographic disparities. Distance or accessibility is also important because cancer patients who live in rural areas have limited access to oncological care (Coory and Baade, 2005). These inequalities need to be quantified. By using the visual presentation of cancer incidence through their spatial distribution, it is possible to identify their location and thus deduce the causality.

## 3. METHODS

The topic of spatial autocorrelation is often used in scientific research. Already in the 1940s , Cruickshank pointed to the presence of positive spatial autocorrelation in relative cancer mortality rate in England and Wales (Cliff *et al.*, 1975). Other examples of scientific studies focusing on spatial analysis of data on cancers are e.g. Fei *et al.*(2016), Al-Ahmadi and Al-Zahrani (2013), Rosenberg *et al*. (1999), etc. According to Boscoe *et al*. (2004), spatial analyses are primarily used for studying the relation between geography and health.

The spatial autocorrelation model is the spatial equivalent of the time series model. The only difference is that time dependence is reverse while the dependence in space is multi-directional. For example, this method was used for the assessment of mortality from nine types of cancer in the basin of one of Chinese rivers (Zhang *et al.*, 2016). Spatial autocorrelation has an important position in the study of spatial statistics and spatial econometrics which fall into the field of spatial analysis (Getis, 2008). It is considered a specific type of correlation where a relation of one variable in space and time is assessed within one observation. Spatial autocorrelation is often used in the field of geography where it is a relation between phenomena or events separated by certain spatial or time intervals (Slavík *et al.*, 2011). If similar phenomena or attributes are found in space closer, there is a positive spatial autocorrelation and if there is a cluster of significantly different values, it is a negative spatial autocorrelation. If the data are located in the space so that the close values are not a part of any relation, the analyzed values are statistically insignificant. In the context of the methods applied, Moran's index and Geary's coefficient are commonly used for continuous data analysis. According to Odland (1988), the effectiveness of Moran's index is generally slightly better than Geary's coefficient.

Unlike local Moran's statistics, Geary's coefficient assesses only positive spatial autocorrelation. Therefore, the variable was analyzed by Moran's index which is represented by the following formula:

$$I = \frac{n\left(\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \bar{x})\left(x_j - \bar{x}\right)\right)}{\left(\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\right)\left(\sum_{i=1}^{n}(x_i - \bar{x})^2\right)}$$

where:

$n$ – is the number of spatial units (in this case it is the number of all districts of Slovakia);

$x_i$ – is the value of the variable in the region $i$ (standardized cancer incidence);

$x$ – is the arithmetic average for the given variables;

$w_{ij}$ – is the spatial weight.

Values of Moran's index (*I*) range from -1 to +1 . The more the value is closer to 1, the more positive spatial autocorrelation is indicated. Moreover, the more the value is closer to -1, the more negative spatial autocorrelation is indicated. Different degrees of spatial autocorrelation can be present within the same set. Furthermore, even the positive and negative autocorrelation at the same time can be found in the same set.

Global Moran's test assesses whether there is a spatial autocorrelation for a given set of regions or a certain area. Further development of the global test of spatial autocorrelation singled out a series of local indicators called LISA (Local Indicators of Spatial Association) which are used for detecting local clusters of positive and negative autocorrelation. There can be five different scenarios within the LISA (Anselin, 1995):

1. Spots with high values and similar neighbours (high-high), also known as 'hot spots', showing the scenario of positive spatial autocorrelation;
2. Spots with low values and similar neighbours (low-low), also known as 'cold spots', again showing the scenario of positive spatial autocorrelation;
3. Spots with high values and with neighbours of low values (high-low), potentially 'spatial outliers', meaning potentially spatial distant values, symbolizing negative spatial autocorrelation;
4. Spots with low values and with neighbours of high values (low-high), again 'spatial outliers' showing negative spatial autocorrelation;
5. Spots with no significant local spatial autocorrelation.

Before the use of spatial autocorrelation, it was necessary to create a spatial weighing scheme which significantly influences the resulting values of autocorrelation statistics. In this case, the spatial weight was generated using the criteria of neighborhoods (particularly neighborhoods of the 'Queen' type) when the critical value is not specified and the neighborhood (1st order) is defined also by one common point on the boundary of two spatial units. It is important to note that the size of Moran's index itself does not indicate the statistical significance. Statistical significance of the calculated values which rejects the null hypothesis of non-existence of spatial autocorrelation was verified by the permutation method using the software GeoDa when all values are considered statistically significant at 1% level of significance.

By the method of spatial autocorrelation, the standardized cancer incidence was assessed in the districts of Slovakia in 1997, 2009 and in the period 1997–2009. Data on cancer incidence in the districts of Slovakia were provided by the National Health Information Centre of the Slovak Republic. The last available data were from the year 2009. Therefore, the incidence could not be analyzed over a longer period of time. Moreover, this indicator was analyzed both for men and women.

## 4. CANCER DISEASES IN SLOVAKIA

Mortality is a complex phenomenon in terms of statistics, demography and health status assessment. It is the phenomenon which occurs unevenly in different age categories with significant differences in both genders. Different age categories of population have different prerequisites to certain death causes. These preconditions are different in different geographical conditions. Types of death causes are also dependent on time, development of society and on its state during the period for which the mortality is assessed. There were different death causes fifty years ago and their structure is different now. It is influenced by social development, changes in lifestyle, life expectancy and a whole complex of negative and supporting health factors (Rapant *et al.*, 2010).

Due to ageing of population, most developed countries face health and clinical problems resulting in the structure of death causes. There is a clear dominance of mortality from circulatory system diseases while the second most important group of death causes is represented by cancers which in the European context do not create significant differences among the countries of the former Eastern and Western Bloc (Sullivan *et al.*, 2011).

Cancer incidence and cancer mortality have globally an upward trend which can also be observed in Slovakia. This is due to several reasons which include: increase in average population age, improper lifestyle, stress factors, etc. Cancers belong to important society-wide problems due to high incidence, frequency of disability and high mortality.

More than 99% of cancers of which Slovaks died were malignant. The number of deaths from malignant cancers during the first decades of the 20$^{th}$ century accounted for only a small proportion of the total number of deaths rom. It was mainly due to high mortality from infectious diseases (especially tuberculosis) and high mortality in childhood that the increasing age as one of malignant cancers natural risk factors was not taken into account. Moreover, the low proportion of malignant cancers in the past had also another objective reason which was the lack of cancer diagnosis. The mortality data were important for the study of epidemiology, basic orientation of health care and research on cancer which culminated in the 1970s. This effort affected the identification as well as objectification of deaths from malignant cancers which led to their increase in developed countries during the 20$^{th}$ century (Pleško *et al.*, 1979). Data on mortality from malignant cancers in Czechoslovakia from the early decades of the second half of the 20$^{th}$ century had high quality and were often used in surveillance of trends and geographic distribution of malignant cancers at the European as well as global scale (Campbell *et al.*, 1980). The high quality data on mortality in Czechoslovakia, which were recorded separately for the Czech Republic and Slovak Republic, were obtained because of relatively early introduction of actual revisions of the

International Classification of Diseases, respecting procedures to determine the main cause of death, as well as determination of death cause by doctors with a relatively high proportion of autopsies on deceased persons. The introduction of mandatory reporting of diseases and deaths due to malignant cancers began in 1951. Use of the common revision of the International Classification of Diseases and regular publication of data was the first step to get a complete overview of the occurrence of diseases caused by cancers in Slovakia. Gradually, it became clear that this problem can only be solved by establishing national or regional cancer registries such as in former German Democratic Republic, Poland, Hungary and former Yugoslavia. In the Czech Republic and Slovakia, the decline of reporting discipline along with the recorded number of diseases without long-term registration of accurately identifiable patients led to gradual underestimation of incidence surveillance (Pleško *et al.*, 1991). In 1976 the Slovakia National Cancer Registry was founded. Its extensive activity focused on new types of cancer reporting and controlling reports. This comprehensive approach made it possible to obtain information on cancer incidence for experts in the field of oncology and it was the basis for planning costs for cancer treatments. Furthermore, it is important for the creation of comprehensive cancer programs aimed at tackling this issue at the local level of Slovakia (Pleško *et al.*, 2005). Slovakia is one of the four European countries that lack a National Cancer Control Programme which is necessary to know exactly how to plan and invest.

Based on Fig. 1, death causes in the Slovak population between 1997 and 2014 had an almost identical structure which was dominated by circulatory system diseases. They were followed by mortality from cancers, respiratory diseases, digestive system diseases and external causes. As for the mortality structure in 1997 and 2014, there was a decrease in mortality from circulatory system diseases by 6%, while deaths from cancers recorded a 4% increase (Mészáros, 2008).

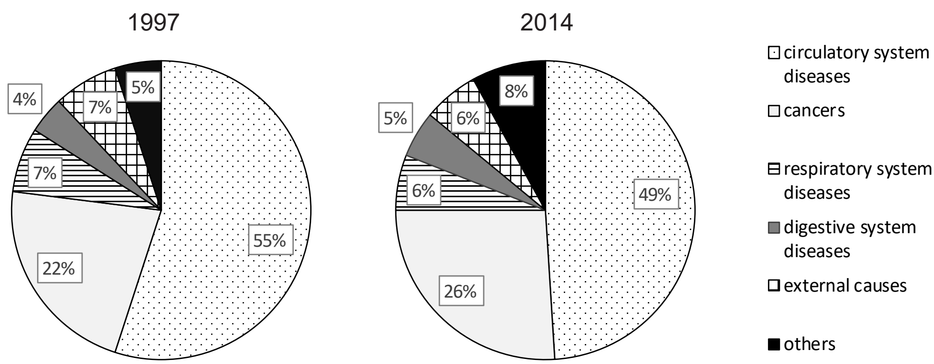


Fig.1. Population mortality by causes of death
Source: Statistical Office of the Slovak Republic, 2015

On the other hand, proportions of deaths from malignant cancers in the total number of deaths among men and women in Slovakia varied. Changes in relevant years in the period from 1929 to 2014 are documented in Fig. 2. As it can be seen, deaths from malignant cancers in Slovakia in the 1920s were quite rare. It is important to note that until the beginning of the post-war period, the proportions of deaths from malignant cancers among women were higher than among men. Around the year 1947 the share of malignant cancers in the total number of deaths started to be higher among men, which was conditioned by a significant increase in lung cancer. Since then, there has been predominant mortality from malignant cancers among men compared to women (Pleško *et al.*, 1979).

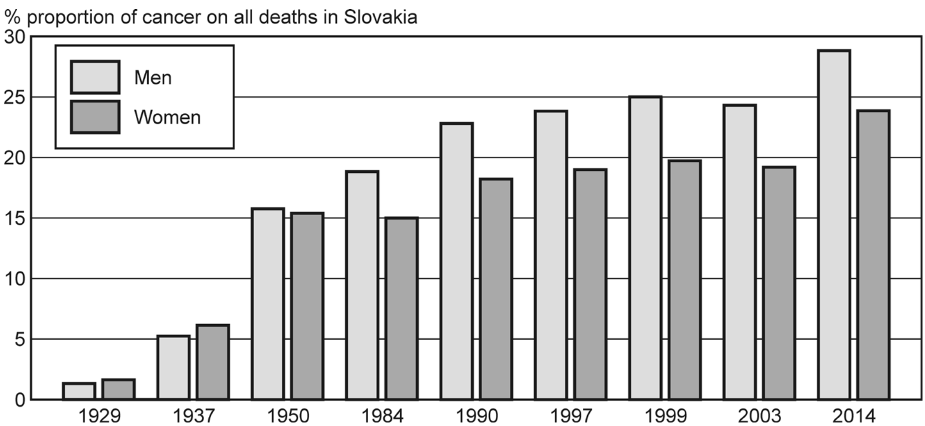


Fig. 2. Changes in proportion of cancers in all death causes in Slovakia among men and women during the period from 1929 to 2014

Source: National Cancer Registry, 2015

A significant factor in assessing the relation between the incidence and mortality in the studied period is the difference between their values over time. This course is referred to as ‘open scissors phenomenon’. The size of an angle between the two indicators can be widened by either decrease in mortality (thanks to progress in the fight against cancers especially in diagnosis and treatment) or increase in incidence of malignant cancers as a reflection of increased prevalence of risk factors that determine the clinical forms of cancers on the one hand and early finding of new cases on the other. The decrease in incidence may also result from a real reduction of risk factors in the context of targeted intervention programs aimed at primary prevention or screening (Baráková *et al.*, 2004).

## 4.1. Cancer Diseases among Men in Slovakia

In the past decade, compared to the previous period, there was a stabilization and even a decreasing tendency in the overall standardized mortality from all malignant cancers in both genders. Special attention was paid to the structure of mortality among men by death causes between 1997 and 2014. The structure did not change during the studied years because the mortality was dominated by circulatory system diseases whose share in total mortality decreased in 2014 by 6% (Fig. 3). The upward trend in mortality from cancers was observed also among men with a 5%. increase in mortality rate. As can be seen, cancer mortality in Slovakia is high especially in male population. In fact, until the end of the 1990s we can see a slight and irregular increase in the values of standardized cancer mortality rate and incidence rate by which Slovakia moved away from its relatively favorable position in the 1970s. The following decrease, however, did not manage to balance the previous negative development. Compared to Sweden, men in Slovakia die from cancers approximately 1.7 times more often (Bleha *et al.*, 2013).

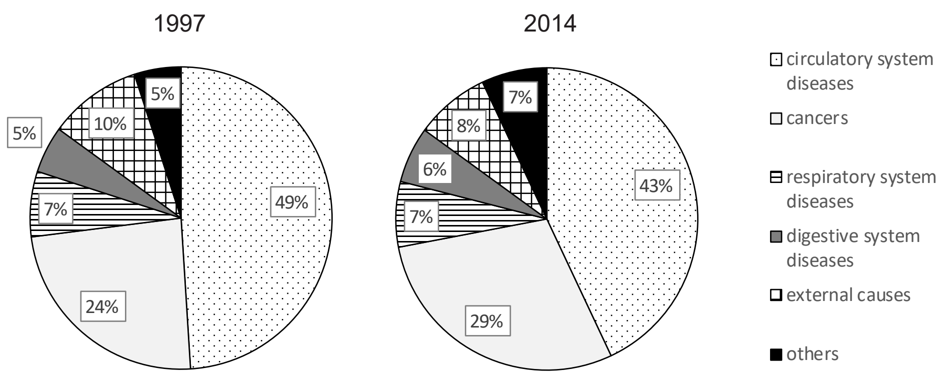


Fig. 3. Mortality among men by causes of death

Source: Statistical Office of the Slovak Republic, 2015

In Slovakia, increase in the incidence of malignant cancers from 1997 to 2009 corresponded to the secular type of development which is characterized by slow, gradual changes. The latest processed data on the incidence are available for the year 2009, which reflects their delayed processing. With the exception of the increasing number of new cases of cancer each year (which is obviously based on long-term trends), the delay of processed data is mainly caused by not respecting the reporting obligation. The liquidation of policlinic departments of clinical oncology represents another problem. Their activities were taken over by employees of the Slovakia National Cancer Registry (Diba, 2015).

Slovakia is a country with significant regional disparities resulting from historical, geographical and cultural differences, but mainly from different levels of economic development or different nationality structures of the population, which influences the educational, social and overall economic levels of regions. The result of these differences is a fundamentally different way and quality of life in highly developed regions located mainly in Western Slovakia, such as Bratislava, Trnava, Trenčín, Nitra. The accessibility of medical services in these areas is good and cancer diagnosing and treatment is carried out in well-equipped specialized facilities. In underdeveloped regions of Southern and Eastern Slovakia the situation is completely different with the exception of the cities of Košice and Prešov (Korec, 2005).

The standardized incidence of malignant cancers in Slovakia has significant spatial differences which are related to the time period in which the incidence was studied as well as to the structure by gender. Spatial differences of standardized incidence among men are documented by Fig. 4a–c. Until 2009, there was a significant increase in the incidence among men because 60% of districts in Slovakia recorded the value of standardized incidence of more than 410.1/100 thousand men. As compared to 1997, the incidence among men increased in 46 districts.

The use of spatial reference data on cancer incidence in the districts of Slovakia facilitayes the understanding of spatial and analytical links in this study area. By using the method of spatial autocorrelation, clusters of regions in terms of the studied indicator can be defined. The spatial autocorrelation of malignant cancers among men in the years 1997 and 2009, but also in the period from 1997 to 2009, identified locations with different intensity of incidence. It can have the form of positive or negative spatial autocorrelation. In order to specify the incidence of malignant cancers among men in 1997 in more detail, it can be stated that the problematic (high-high quadrant) group includes seven districts of Žilina Region (Námestovo, Tvrdošín, Dolný Kubín, Žilina, Martin, Ružomberok, Turčianske Teplice). In terms of environmental quality, this compact region (Fig. 5a) belongs to the regions that are characteristized by a slightly disturbed environment mainly in the surroundings of Žilina and Ružomberok towns. Especially the paper industry (the companies Tento, a.s. Žilina and Mondi SCP Ružomberok) and related activities may contribute to the increased incidence rate of malignant cancers among men in this region. Moran's diagram for the indicator of malignant cancer incidence among men in 1997 showed a value of 0.155703, which means that there is a slightly positive spatial autocorrelation (Fig. 6a). This value induces the clustering of similar values of standardized cancer incidence (high with high, low with low). However, as it was mentioned, the global Moran's index itself does not reveal different degrees of spatial relations within a single data set. The contrary cases are districts of Nové Mesto nad Váhom and Piešťany, which are located in Western Slovakia. The cancer incidence values in these districts belong to the low-low quadrant.

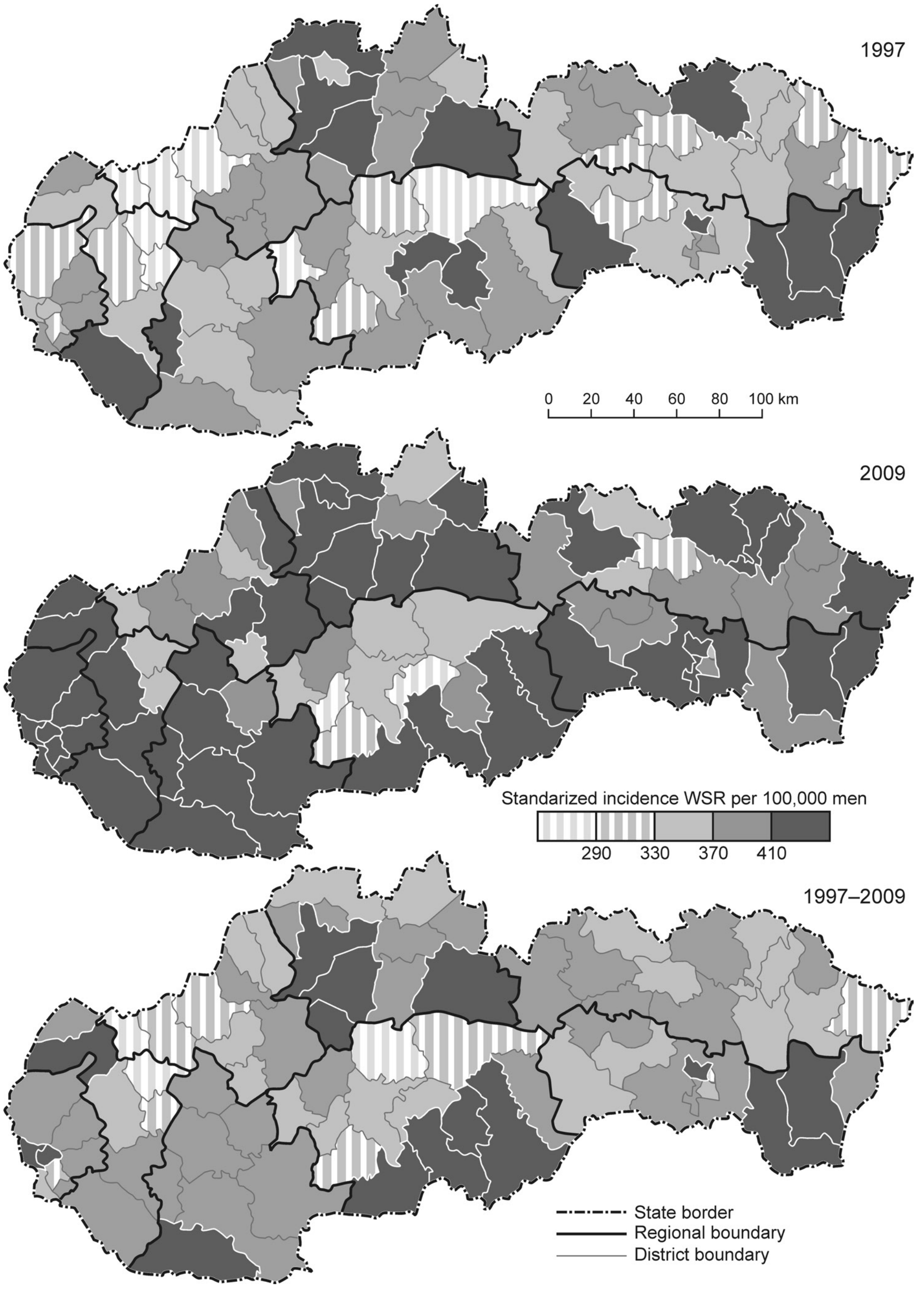


Fig. 4. Standardized cancer incidence among men in Slovakia in 1997, 2009 and 1997–2009

Source: Statistical Office of the Slovak Republic, 2015

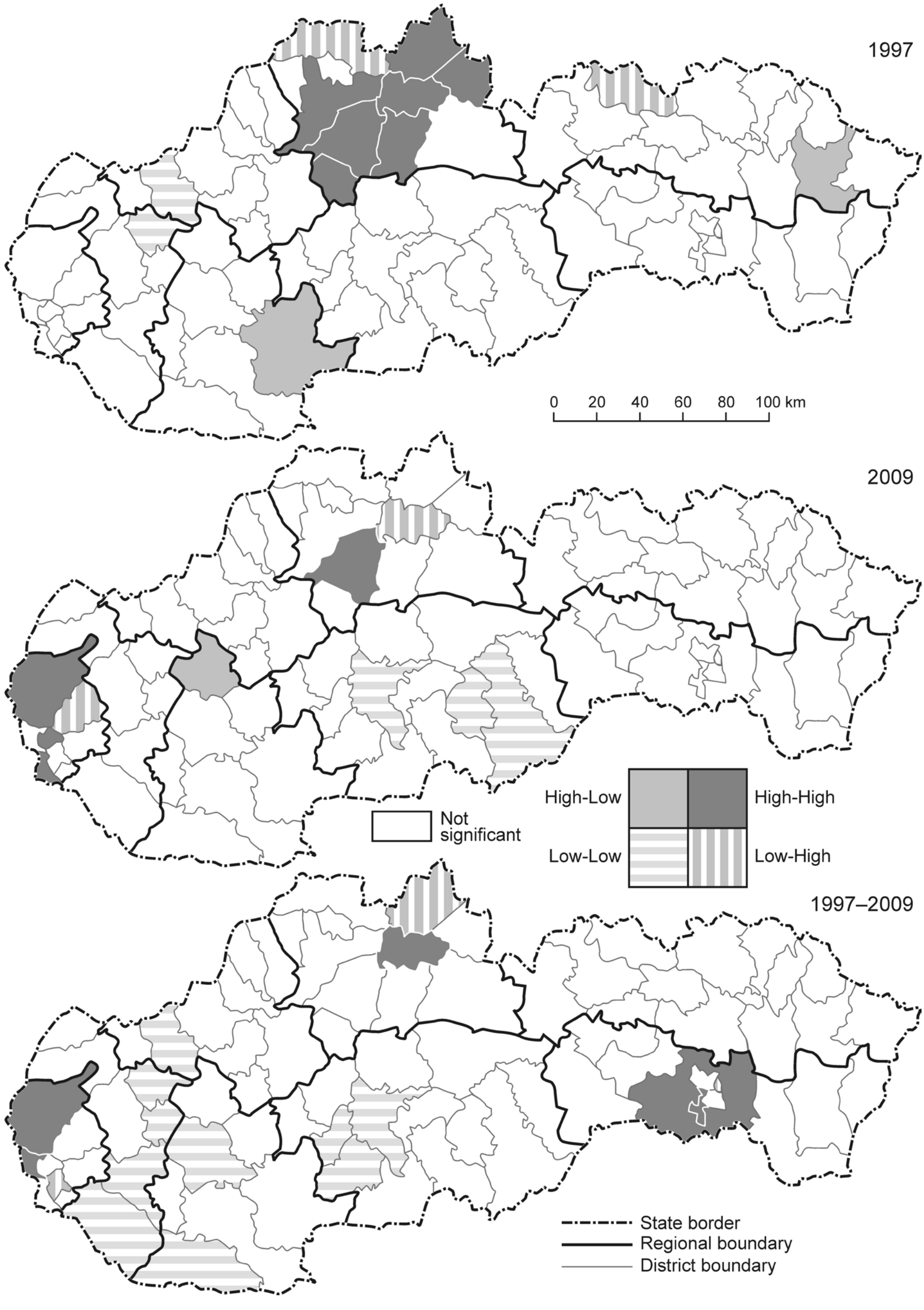


Fig. 5. Regionalization of Slovakia based on the LISA analysis for standardized cancer incidence among men in 1997, 2009 and 1997–2009

Source: Statistical Office of the Slovak Republic, 2015

In 2009 the situation changed significantly in terms of the studied indicator. The high-high quadrant position was retained only by the district of Martin, followed by the districts of Malacky, Bratislava I, Bratislava III and Bratislava V in Western Slovakia (Fig. 5b). On the other hand, the low-low quadrant included three districts of Central Slovakia – Rimavská Sobota, Poltár and Zvolen. The Moran's diagram showed a value of 0.0918364, which means that there was a positive spatial autocorrelation although in this case it had a lower value than in 1997 (Fig. 6b).

The change in cancer incidence among men occurred also in the whole period 1997–2009. Based on spatial autocorrelation, districts in the high-high quadrant are isolated in different parts of Slovakia. For example, Eastern Slovakia includes the districts of Košice-okolie and Košice II. They have strongly a disturbed environment mainly because of metallurgy (company US Steel Košice). Another example of districts in the high-high quadrant includes the districts of Malacky, Bratislava I and Bratislava IV. The industrial activity in this region (e.g. chemical industry – Slovnaft, etc.) may have some impact on incidence rates. In Northern Slovakia this quadrant is represented only by the district of Dolný Kubín (Fig. 5c). The Moran's diagram showed a value of 0.359858, which is again positive spatial autocorrelation (Fig. 6c).There is a significant cluster of districts with low values of incidence which stretches from the north to the south including the districts of Nové Mesto nad Váhom, Piešťany, Hlohovec, Nitra, Galanta, Dunajská Streda and Komárno. A smaller cluster of low values concerns also another three districts – Zvolen, Krupina and Banská Štiavnica.

These spatial differences are closely linked to a number of factors that are difficult to identify. In view of the fact that cancers belong to multi-factorial diseases, it is difficult to specify factors that are conducive to the occurrence of this disease. Direct dependence on the risk factors cannot be clearly identified. Despite this fact, the most important risk factors may include the quality of environment, stress, lifestyle, population age structure, and poverty rates.

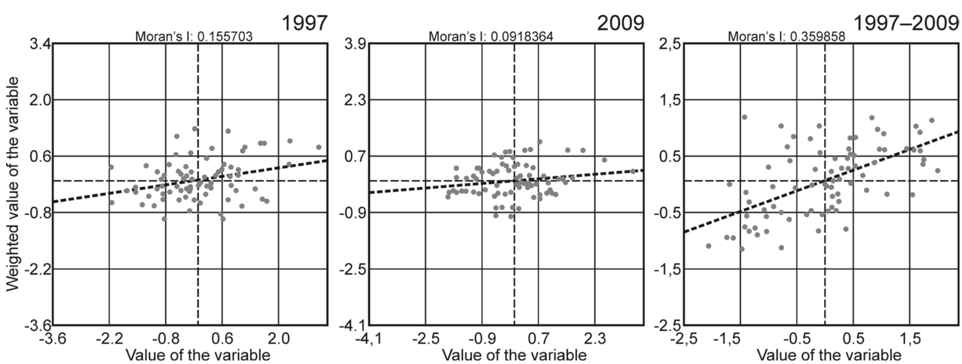


Fig. 6. Moran's diagram for standardized cancer incidence among men in Slovakia

Source: Statistical Office of the Slovak Republic, 2015

## 4.2. Cancer Diseases among Women in Slovakia

As for the female population in Slovakia, the situation is much more favorable in terms of mortality from cancers (Baráková and Hlava, 2003). The minimum value of mortality from cancers in Europe has not undergone dramatic changes so far and currently is about 105 deaths per 100 thousand persons. It is about 1.3 times lower than current mortality from cancers among women in Slovakia (Bleha *et al.*, 2013). As documented by Fig. 7, the structure of mortality among women in 1997 and in 2014 is almost identical. The circulatory system diseases maintain dominance with a decrease by 6% in 2014. In contrast, mortality from cancers among women increased from 19% to 24%.

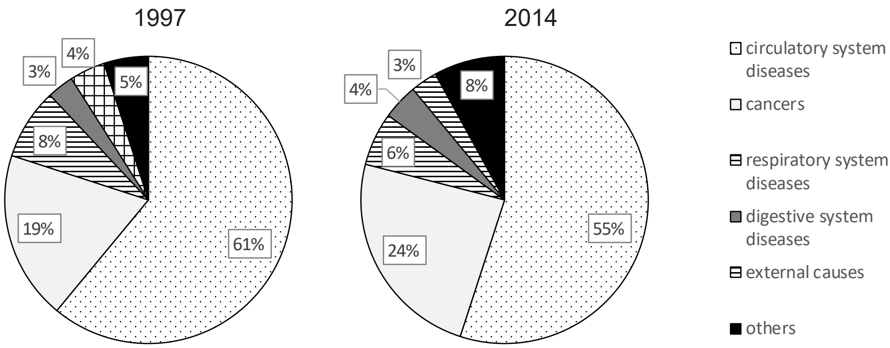


Fig. 7. Mortality among women by causes of death
Source: Statistical Office of the Slovak Republic, 2015

Social factors (unemployment, poverty, high share of marginalized groups, etc.) are distributed very unevenly in Slovakia. This is reflected in the level of socio-economic development, which is strongly differentiated regionally, and is partly linked to increased incidence rate. It concerns mainly the districts located in Southern and Eastern Slovakia. Moreover, some districts (e.g. Spišská Nová Ves, Levice, Rimavská Sobota, Bardejov, etc.) are burdened with old landfill sites or abandoned buildings of former agricultural or industrial facilities that need to be disposed of in order to prevent further contamination of soil and groundwater. Figures 8 a, b, c point to the content as well as the spatial aspect of regional differentiation of standardized cancer incidence among women in Slovakia. Contrary to men, the maximum value of standardized incidence among women is lower than among men and reached the value of 295/100 thousand women. It is noteworthy that in 1997 many districts reached lower values than the average for Slovakia (250/100 thousand women). Based on these findings, it can be claimed that incidence among women has lower values than among men, which confirms one of the hypotheses. A different situation occurred in 2009 since 49 districts of Slovakia reached the maximum incidence value of 295/100 thousand women.

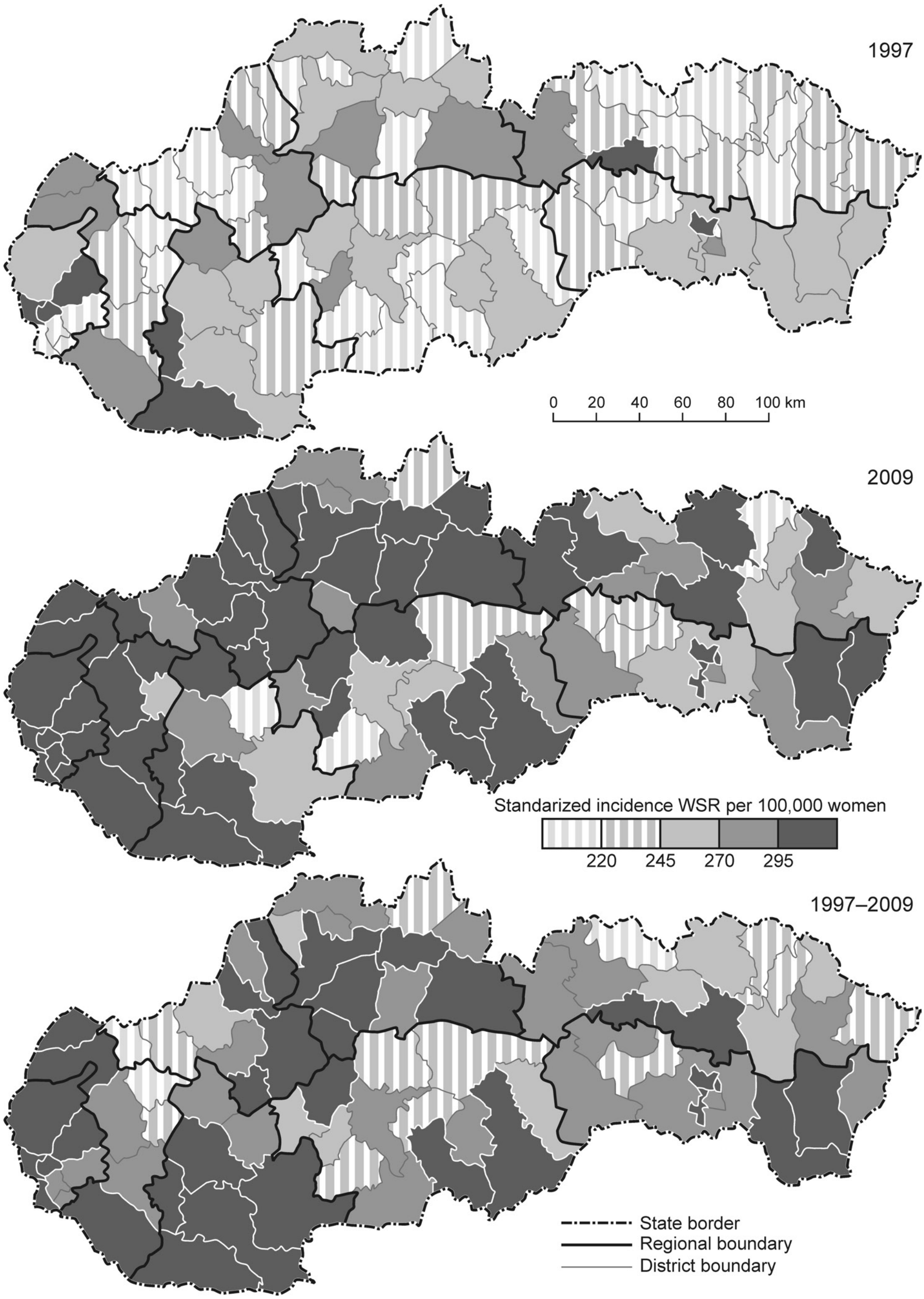


Fig. 8. Standardized cancer incidence among women in Slovakia in 1997, 2009 and 1997–2009

Source: Statistical Office of the Slovak Republic, 2015

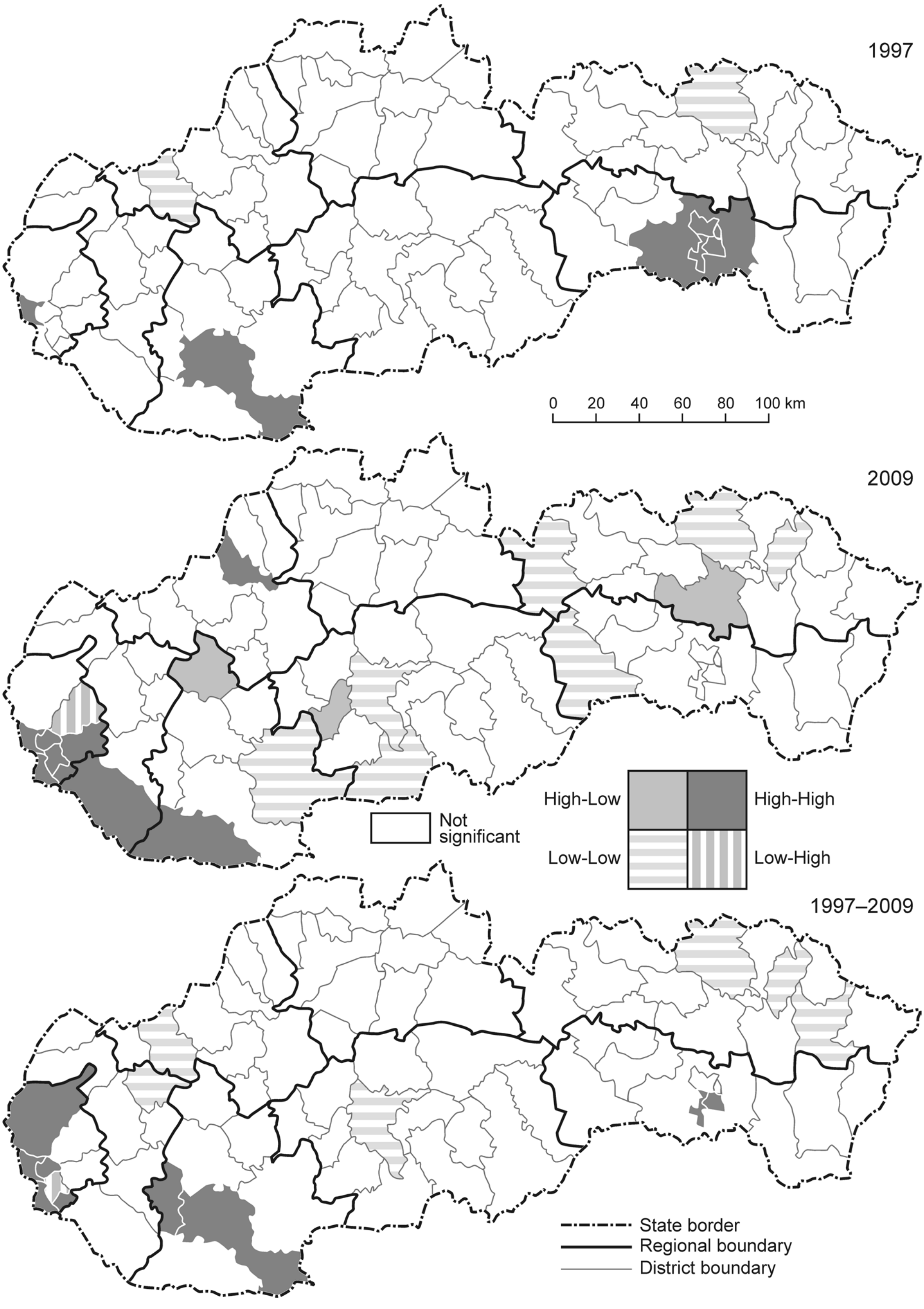


Fig. 9. Regionalization of Slovakia based on the LISA analysis for standardized cancer incidence among women in 1997, 2009 and 1997–2009

Source: Statistical Office of the Slovak Republic, 2015

When studying the spatial dependence of standardized cancer incidence among women in districts of Slovakia in the studied periods by using local Moran's statistics, there was positive but also negative spatial autocorrelation. According to Griffith (1987), positive spatial autocorrelation means that geographically close values of variable (standardized cancer incidence) tend to group with similar values of the variable on the map and thus high values tend to be located close to high values, medium values close to medium values and low values close to low values. In 1997, there was only positive spatial autocorrelation (Fig. 9a). The first cluster of the high-high quadrant was created around the second largest city of Košice including the districts of Košice I, Košice II, Košice III, Košice IV as well as Košice-okolie. This cluster is complemented by districts in Western Slovakia – Nové Zámky and Bratislava IV. The Moran's diagram showed a value of 0.199697 for this year (Fig. 10 a). The low-low quadrant includes isolated districts of Bardejov and Nové Mesto nad Váhom.

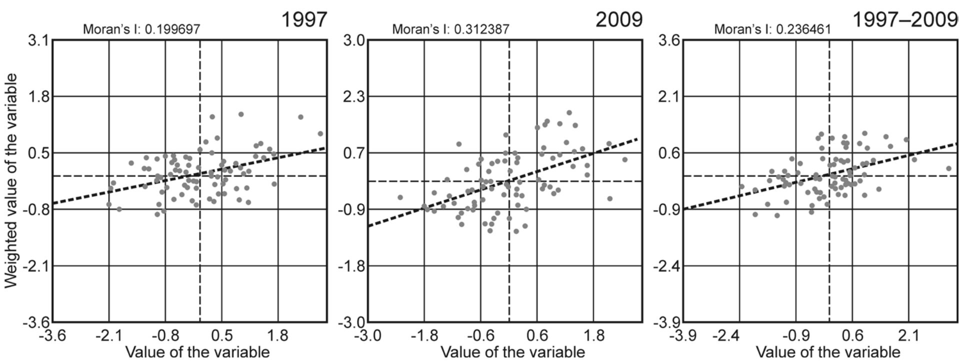


Fig. 10. Moran's diagram for standardized cancer incidence among women in Slovakia

Source: Statistical Office of the Slovak Republic, 2015

Based on the previous analysis, in 2009 there was also a negative spatial autocorrelation along with the positive one. The value of Moran's index increased to 0.312387 (Fig. 10b). Districts located in the southwestern part of Slovakia (Komárno, Dunajská Streda, Senec, Bratislava I, Bratislava V) as well as the district of Ilava are characterized by a positive spatial autocorrelation in the high-high quadrant (Fig. 9b). This region is typical for agricultural activities which may be reflected to some extent in increased incidence rate. The low-low quadrant is represented by the districts of Levice, Veľký Krtíš, Detva and eastwards it includes the districts of Poprad, Rožňava, Bardejov and Stropkov.

Regarding the positive spatial autocorrelation of cancer incidence among women in the period 1997–2009, the high-high quadrant includes the districts near Bratislava (Bratislava I, II, III, IV, V) along with the district of Malacky. This compact region is complemented by the districts of Šaľa and Nové Zámky and in Eastern Slovakia by the districts of Košice II and Košice IV. The low-low quadrant is represented particularly in Eastern Slovakia – districts of Bardejov, Stropkov and Humenné (Fig. 9c). In Central Slovakia it is the district of Zvolen and in Western Slovakia it is represented by the districts of Piešťany and Nové Mesto nad Váhom. In this period the Moran's index reached a value of 0.236461 (Fig. 10c).

## 5. CONCLUSION

Since 1989, the population of Slovakia has passed a dynamic and extensive transformation of the whole society with implications for its present and future functioning. One of the most significant changes is a shift in the nature of the reproductive behavior where mortality plays an important role. In terms of death causes, it is clear that greater approximation to demographically developed European populations is being slowed down particularly by unfavorable mortality rates from cardiovascular diseases and cancers (Pleško *et al.*, 2005).

Currently, malignant cancers represent a serious medical problem in Slovakia exceeding the average values for the European Union. In recent years, about 22,000 new cases were diagnosed annually along with about 11,000 deaths from malignant cancers. The malignant cancers represent almost a quarter of the total number of deaths and thus the second most common cause of death among the population of Slovakia right after the circulatory system diseases. This trend is mainly influenced by women whose standardized mortality rate from malignant cancers has stabilized in the last 30 years. It is due to the dominance of malignant cancers of breast and female genital organs (i.e. having a relatively good prognosis) as well as malignant lung cancers which have very low incidence values. Standardized cancer incidence among men has stabilized in recent years mainly due to decrease in standardized mortality from malignant lung cancers which strongly influences the standardized mortality from all malignant cancers. In the context of population ageing – increased life expectancy in relevant age categories – an increase in malignant prostate cancers in older men is expected. As for women, an increase in malignant breast cancers can be expected although in many developed countries mortality from this type of cancer was stabilized or even reduced by well-targeted secondary prevention despite the significant increase in its incidence. Based on the knowledge and experience of other developed countries, it is impossible to expect considerable improvements in mortality from malignant cancers without the application of appropriate and well-targeted intervention programs. An estimated dynamic decrease in mortality from cardiovascular diseases, through the implementation of efficient programs of primary and secondary prevention, will necessarily have a positive impact on the increase in life expectancy in relevant age categories mostly in the oldest population. On the other hand, it will condition the probability of an increase in incidence and consequently mortality from malignant cancers.

The rate of incidence and mortality from cancers among the population of Slovakia is affected by several factors. According to doctors' opinions, cancers are multi-factorial diseases where it is difficult to clearly identify the factors that are directly associated with this disease. Despite this fact, the most common factors include lifestyle, stress, eating habits, quality of the environment, etc. The issue of malignant cancers is very complex and it was not possible to process it in full extent, so the chosen indicator of incidence was used. The results indicate that the structure of mortality in Slovakia in the studied period remained almost unchanged although the percentage share in mortality from cancers increased. In Slovakia, mortality from cancers takes the second place among the causes of death. Incidence rates of malignant cancers among men as well as women in Slovakia show an upward trend, which confirmed one of the hypotheses. Furthermore, another hypothesis was confirmed as the values of standardized incidence are higher among men. The third hypothesis could not be clearly confirmed since high incidence rates occur both in developed and less developed regions of Slovakia. The results showed significant differentiation among districts of Slovakia. The analyses confirmed a significant spatial aspect of incidence distribution which is also reflected at regional level. Despite the fact that in Slovakia there are significant differences in several areas (e.g. social or economic) especially in the axis East-West, in the case of the studied indicator of incidence among men and women such differentiation was not confirmed. The increased incidence rate of malignant cancers was recorded in all regions of Slovakia. A negative fact is the lack of proper reporting of incidence values as the last available data are from 2009. In terms of spatial analysis of standardized cancer incidence, there are significantly different areas in Slovakia regarding both men and women. Identification of regions, based on standardized cancer incidence and method of spatial autocorrelation, is important in terms of creating actions in problematic regions. The analysis of values and trends in incidence and mortality in Slovakia points to the need to intensify prevention. Programs of primary prevention and education of population should be directed towards optimization of lifestyle, e.g. promoting non-smoking, physical activity, sun protection, fight against alcoholism and obesity. These measures along with high-quality and full-body screening aimed at detecting early stages of cancers can change the unfavorable development of incidence and mortality from malignant cancers.

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