

EVALUATION OF THE IMPACT OF GEO-FACTORS ON SUSTAINABLE LIVING ENVIRONMENT

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Abstract. The need of incorporating the principles of sustainable development to land management as well as urban development decisions is widely discussed. Social, economic factors, visual quality of natural as well as man-made landscape are commonly evaluated. However, the influence of the living natural environment on the human health and psychic behavior is still little studied. The aim of the present study is to evaluate impact of different geo-factors on human diseases and psychic disorders. The area of the research is territory of Lithuania. Main geo-factors analyzed are gravity and magnetic fields, concentrations of geochemical elements in the soil, other geological factors (e.g. soil lithology), relief and landscape. Environmental factors are correlated with the spatial variations of somatic diseases and psychic disorders. The methods of mathematical statistics are applied and some significant correlations are identified that persuade the influence of geographical environment on the human health and living environment. The defined relationships can be applied in elaboration of methodical approach for ranking of different territories of favoring (or "problematic") environment using MCDM (Multiple Criteria Decision Making) approach for particular real estate development decisions. An example of ranking Lithuanian regions applying TOPSIS (the Technique for Order Preference by Similarity to Ideal Solution) method is presented.

Keywords: sustainable living environment, real estate development, geo-factors, human diseases, statistics, MCDM.

1. Introduction

The need for incorporating the principles of sustainable development to land management as well as urban development decisions is widely discussed. There is a lot of studies of basically three common subsystems, *i.e.* social, economic and ecological factors evaluated, while the implementation of sustainable development policy is one of the most complex tasks and challenges faced by the global community (Burinskienė and Rudzkiene 2009).

Incorporating geology and geomorphology in land management decisions in developing regions with limited financial, technical and data resources was presented by Andreas and Allan (2007). Furthermore, there is growing evidence and increasing realisation that the natural environment has a prominent impact on the health of a man. On the other hand, the influence of the living natural environment on the human health and behaviour is still little studied and mainly concerns specific regions showing anomalous natural conditions. Medical geology, the study

of the impacts of geologic processes on human health, is an emerging discipline to solve a wide range of environmental health problems (Bunnell *et al.* 2007).

The aim of the present study is to analyze relationship of different geo-factors and human diseases and psychic disorders and to elaborate the methodical approach for ranking of different territories of favoring (or "problematic") environment using MCDM (Multiple Criteria Decision Making) approach for particular real estate development decisions.

2. Impact of environmental factors on psychic disorders and somatic diseases in Lithuania

The Lithuanian territory is characterized by a relatively low variability of the geological conditions. Still, the territorial analysis of selected diseases shows some clear geographical patterns in Lithuania that is interpreted as an evidence of the impact of the living environment on the human health (see the example of cardiac-vascular disease rates and magnetic field maps in Fig 1).

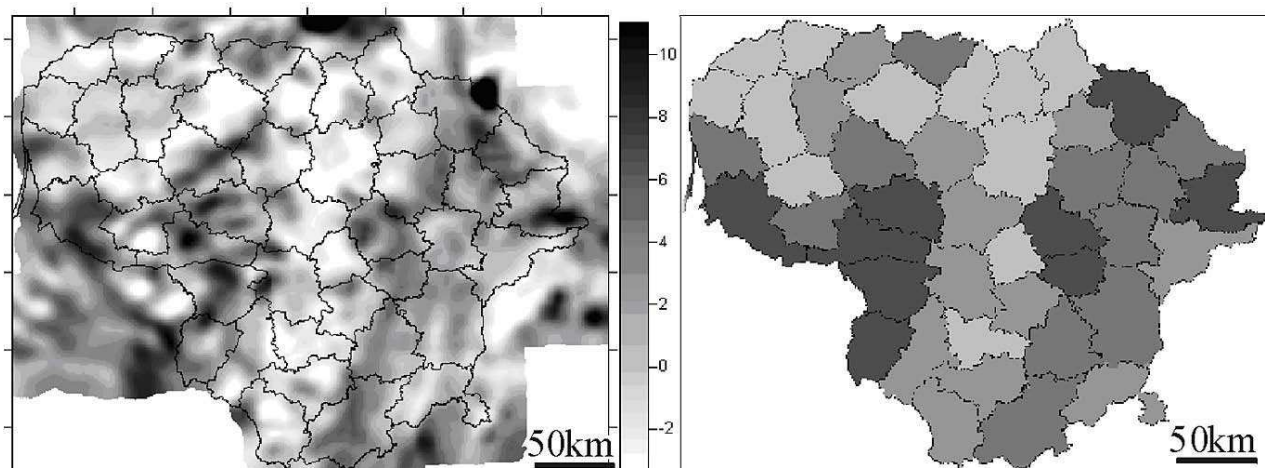


Fig 1. Magnetic field map (nT) scaled to administrative regions of Lithuania and cardiac-vascular disease rates (lethal events per 100,000 population) in different regions of Lithuania

The statistical relationship of different environmental factors to selected human diseases on a countrywide-scale in Lithuania was discussed by (Šliaupa *et al.* 2006a; 2006b; 2010). Main geo-factors analyzed were gravity and magnetic fields, concentrations of geochemical elements in the soil, different geological factors, relief and landscape. Environmental factors are correlated with the spatial variations of the schizophrenia, alcoholic psychosis, tuberculosis, cancer, infections, cardiac-vascular and respiratory diseases. The database of psychic disorders and somatic diseases incorporates the rates of diseases from 44 administrative regions of Lithuania. The different formats of geo-factors data were unified using GIS (Geographical Information Systems) techniques that enabled scaling of geological databases to administrative regions of Lithuania (Fig 1).

The statistical correlations between region-scaled environmental and health parameters were obtained. Only correlations with confidence level of 0.95 were considered to be consistent.

It was established that the mortality due to cancer has a consistent correlation with the magnetic field and some geochemical elements of the soil (Ti, Zr, Y, Yb).

Consistent relationships were identified for tuberculosis and pH with the strong reverse correlation. The drinking water containing increased amount of Ca and HCO₃ statistically has the remedying effect that also may have linked to pH factor.

The infections correlate with soil pH. It was shown that more acid soil associates with increased infection rates, possibly via food chain.

The mortality due to cardiac-vascular diseases strongly correlates with the drinking water chemistry. The lower disease rate associates with higher concentrations of Na and K.

As for the respiratory diseases, the relief seems to be of primary importance. The atmospheric currents and related chemical enrichment are strongly dependent on the relief that can explain the observed relationship. As for the potential fields, they have a direct influence on a

relief that is explained by strong impact of the deep geological structures on relief-forming processes.

For schizophrenia the important parameters are the sandy lithologies that are typically enriched in phosphorus which is known to have strong impact on brain function. The strong correlations were identified also for the chemical composition of the drinking water. The increased concentrations of Na, K, Cl associate with the lower disease rate.

The suicide level shows a surprisingly strong geographical control. A likely explanation is an impact of the landscape on the economic-social framework. On the other hand, direct involvement of the geofactors should not be neglected, as is hinted by the strong correlation of the disease rate with the drinking water chemistry.

The homicide rate did not show any consistent correlation with environmental factors; still, some interesting trends should be mentioned.

3. Methodical approach for ranking of territories

The established relations between environmental factors and diseases as well as physic disorders validate the need for elaboration of methodical approach for ranking the territories. Following methodic could provide additional data for real estate data bases, cadastre or for individual stakeholders. It could be helpful in a process of urban development concerning location of new buildings or rational redevelopment and reuse of existing structures considering sustainable and healthy living environment for human beings.

The presented methodical approach for ranking different territories is based on MCDM (Multiple Criteria Decision Making) methodology. The advantages of multiple criteria decision-making methods for similar tasks are obvious and were motivated by several scientific publications. Decision-making problems of the sustainable development type are characterized by a diversity of structures and processes, incommensurable variables, and conflicting development objectives and constraints. Different stakeholders with different interests and values that

interact with each other make the decision-making process much more complicated. If we are to look for a solution to a problem, then we should consider a multi-dimensional approach. Therefore, multi-criteria techniques seem to be an appropriate tool for the application of sustainable development principles to environmental planning and urban management problems.

It is proposed to apply the TOPSIS method (the Technique for Order Preference by Similarity to Ideal Solution) which is described in the following subchapter.

3.1. Algorithm of TOPSIS

The basic concept of the TOPSIS method (the Technique for Order Preference by Similarity to Ideal Solution) is that the selected alternative should have the shortest distance from the ideal solution and the longest distance from the negative-ideal solution. The algorithm of TOPSIS is presented with reference to Hwang and Yoon (1981) and Antucheviciene *et al.* (2010). The method evaluates the decision matrix, which refers to n alternatives that are evaluated in terms of m criteria. The member ij denotes the performance measure of the j -th alternative in terms of the i -th criterion.

The normalized decision matrix when the various criteria dimensions are converted into non-dimensional criteria is calculated as follows:

$$a_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^n x_{ij}^2}}, \quad (1)$$

where a_{ij} is the normalized value, $i = 1, 2, \dots, m, j = 1, 2, \dots, n$.

The weighted normalized value v_{ij} is calculated as

$$v_{ij} = q_i a_{ij}, \quad (2)$$

where q_i is the weight of i -th criterion, $i = 1, 2, \dots, m, j = 1, 2, \dots, n$.

The ideal and the negative-ideal solutions denoted respectively as A^* and A^- are defined as follows:

$$A^* = \left\{ \left(\max_j v_{ij} | i \in I \right), \left(\min_j v_{ij} | i \in I' \right), j = 1, 2, \dots, n \right\} \quad (3)$$

$$= \{ v_{1^*}, v_{2^*}, \dots, v_{n^*} \},$$

$$A^- = \left\{ \left(\min_j v_{ij} | i \in I \right), \left(\max_j v_{ij} | i \in I' \right), j = 1, 2, \dots, n \right\} \quad (4)$$

$$= \{ v_{1^-}, v_{2^-}, \dots, v_{n^-} \},$$

where $I = \{ i = 1, 2, \dots, m \}$ and i is associated with the benefit criteria, $I' = \{ i = 1, 2, \dots, m \}$ and i is associated with the cost/loss criteria.

The n -dimensional Euclidean distance method is then applied to measure the distances of each alternative

from the ideal solution S_{j^*} and the negative-ideal solution S_{j^-} :

$$S_{j^*} = \sqrt{\sum_{i=1}^m (v_{ij} - v_{i^*})^2}, \text{ for } j = 1, 2, \dots, n, \quad (5)$$

$$S_{j^-} = \sqrt{\sum_{i=1}^m (v_{ij} - v_{i^-})^2}, \text{ for } j = 1, 2, \dots, n, \quad (6)$$

where $v_{i^*} = \max_j v_{ij}, v_{i^-} = \min_j v_{ij}$.

The relative significance of an alternative is defined as follows:

$$C_j = \frac{S_{j^-}}{S_{j^*} + S_{j^-}}, \quad (7)$$

where $1 \geq C_j \geq 0$ and $j = 1, 2, \dots, n$.

The best alternative can be found according to the preference order of C_j .

3.2. Calculation example

Ranking of different territories according to favoring (or "problematic") environment for various human somatic diseases and physic disorders could be performed for the whole territory of the country or a particular group of regions can be compared and ranked. The application of the presented methodic is the same in the both cases.

In the present case-study, an example of ranking several regions according to possibilities of pattern of cardiac-vascular diseases is presented. Three alternatives and seven criteria are considered. The alternatives include Vilnius (alternative A_1), Klaipeda (alternative A_2) and Kairiadorys (alternative A_3) regions. Only the geofactors having significant relations with particular diseases are taken in consideration, namely correlations, observed in previous research of the authors, with confidence level of 0.95 are considered to be consistent. Accordingly, in the presented example the following criteria were taken into consideration, including the anomalies of gravitation field a_1 (mGal), horizontal gradients of gravitation field a_2 (mGal per km), lakes in proportion to the whole area of a region a_3 (%), sandy loam in proportion to the whole area of a region a_4 (%), mineralization of water a_5 (mg per l), gradients of magnetic field a_6 (nT per km), maximal height of relief a_7 (m).

The criteria a_1, a_4, a_6 and a_7 were associated with the cost (their smaller value was better), while the remaining attributes were associated with benefit criteria (their greater value was better).

Input data (evaluating a particular set of alternatives in terms of a set of decision criteria) for multiple criteria problem are presented in Table 1.

Multiple criteria analysis of initial data was performed applying TOPSIS method (1 – 7). Calculation results are presented in Table 1.

Table 1. Initial data and ranking results

Criteria	Correlation coefficients	Optimization direction	Alternatives		
			A ₁	A ₂	A ₃
x ₁	0.350	min	42.61	2.76	30.72
x ₂	-0.335	max	1.07	0.45	0.67
x ₃	-0.316	max	1.03	0.33	2.20
x ₄	0.336	min	5.59	6.53	5.85
x ₅	-0.306	max	793.15	784.53	772.50
x ₆	0.357	min	0.83	0.60	0.83
x ₇	0.353	min	291.31	142.17	250.01
Relative significances C _j			0.36	0.49	0.54

The presented example shows that Vilnius (alternative A₁) region compared to Klaipeda and Kaisiadorys regions is the most unfavorable for people suffering of or prone to cardiac-vascular diseases. Kaisiadorys region is evaluated as the best case in the analysed scenario.

4. Conclusions

The disease and mortality rates show some persistent geographical trends that are interpreted in terms of impact on living natural environment.

The obtained significant statistical relations persuade that geofactors influence the human health. The positive influence as well as the negative impact of certain natural factors for the human health was identified.

Accordingly, it is proposed to incorporate the peculiarities of various geofactors when evaluating sustainable living environment of population.

The methodical approach for ranking of different territories is proposed that is based on established statistical relations and multiple criteria decision making methodology.

A case-study of comparing and ranking of a particular group of regions seems to validate this approach. Ranking of different territories according to favoring (or "problematic") environment for various human somatic

diseases and physic disorders could be performed for the whole territory of the country in a similar way.

The recognition of above relationships and application of MCDM methodology can be taken into consideration for the territorial planning in Lithuania and other territories of specific geological conditions, adjusting to favourable conditions of particular regions.

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