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THE RELATION OF FOREST AND AIR POLLUTION WITH HUMAN HEALTH IN URBAN TERRITORIES OF LITHUANIA

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The aim of this study was to determine the correlation between the forest, air pollution and human health in eight Lithuanian urban territories. The links between forest coverage, forests remoteness and recreational forests with quality of life parameters and population density were evaluated using Redundancy (RDA) and correlation analysis. The RDA analysis showed a positive relationship between forest coverage and disorders of psychological development. Forest coverage was closely associated with air quality (pollution with particulate materials, carbon monoxide, nitrous oxide, gasiform and liquid materials). The correlation was determined between forest remoteness, nitrous oxide, carbon monoxide, solid, gasiform and liquid materials. Forest remoteness is associated with congenital defects of the nervous and blood circulation system and disorders of psychological development. Presents of recreational forests are connected with asthma, disorders of psychological development and visits to medical institutions.

Key words: Forest coverage, forest remoteness, recreational forests, dwellers' wellness.

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INTRODUCTION

Currently, approximately 10% of the Lithuanian area is covered with rapidly expanding urban territories. Higher concentration of population in urban areas, as compared with rural areas, causes a variety of ecological problems. Urban areas are frequently expanded by reducing the surrounding green spaces. Rational planning of infrastructure and accessibility of green spaces has a positive impact on people's living environment and their health. (Gražulevičienė 2002, 2004, Adevi & Grahn 2011, Annerstedt et al. 2010, Jakovlevas-Mateckis 2008). Therefore, it is extremely important to create life conditions suitable to work, life and rest in the urban landscape.

A variety of studies have been conducted in order to find solutions to the arisen problems (Prapiestienė 2003, Baubinas et al. 2003, Hansmann et al. 2007, Zaleckis & Matijošaitienė 2012, Peschardt et al. 2012, Dadvand et al. 2012, Schifano et al.2013, Agay-

Shay et al. 2013, Gianicolo et al. 2014). They showed that natural environment has a positive impact on human health, wellbeing and physical activeness, creates favourable conditions to the dwellers, reduces stress, eliminates physical and mental fatigue, lifts the mood, reduces the risk of congenital heart defects (Grahn & Stigdotter 2003, 2010, 2011, Annerstedt et al. 2010, Dadvand et al. 2011, 2012, Adevi & Grahn 2011, Thompson et al. 2012, Agay-Shay et al. 2013).

Public parks and recreational spaces are an important foundation of human life quality. They form a healthy and aesthetic environment, improve the composition of air, reduce air pollution, improve the microclimate, reduce noise, obstruct the wind and reduce its speed, dispel fog, increase humidity, prevent soil erosion, suspend airborne dust, affect the urban climate (Gražulevičienė 2002, 2004, Baubinas 2003, Jakovlevas-Mateckis 2008, Annerstedt et al. 2010, Gražulevičienė et al. 2014). Research of landscape is very important in order to achieve sustainable development and find a path leading to harmonization of the relationship between the humanity and the nature (Godienė 2013).

Currently, the "Phenotype" (Positive Health Effects of the Natural Outdoor Environment in Typical Populations in Different Regions of Europe) project is being implemented in Lithuania. It aims at establishing a scientific relationship between the natural environment, people's physical activeness and their health by examining various population groups. The research is more focused on public parks and other small green spaces. Research of urban forests is quite new and this field has not yet been thoroughly studied either in Lithuania or Europe.

The aim of this study was to determine the correlation between the forest, air pollution and human health in urban areas.

Fig. 1. Investigated 8 urban territories of Lithuania (Alytus, Kaunas, Klaipeda, Palanga, Panevezys, Siauliai, Vilnius, Visaginas urban municipalities).

Table 1. Characteristics of the forest, air pollution and human health indicators

Indicator	Mean	SD	Min	Max
Forest coverage, %	26.53	17.79	1.40	56.80
Forest remoteness, %	45.82	24.82	9.50	82.48
Recreational forests, ha/1000 inhabitants	32.19	61.21	1.04	182.75
Pollution with solids, kg/km^2	1054.83	832.91	174.70	2859.70
Pollution with sulphur dioxide, kg/km^2	904.80	813.72	84.20	2688.90
Pollution with carbon monoxide	6289.22	4532.55	1715.61	13905.37
Pollution with gasiform and liquid materials, kg/km^2	16483.19	12224.24	6619.04	41826.32
Pollution with nitrous oxide, kg/km^2	3699.57	2951.28	375.41	8329.20
Pollution with volatile organic compounds kg/km^2	5944.91	7470.16	398.08	22126.11
Mood (affective) disorders, cases/1000 inhabitants	3.70	1.92	1.93	7.99
Stroke, cases/1000 inhabitants	1.33	0.37	0.91	1.79
Acute upper respiratory infections and influenza, cases/1000 inhabitants	232.05	27.84	201.45	291.20
Obesity, cases/1000 inhabitants	1.85	0.67	0.50	2.56
Depression, cases/1000 inhabitants	3.61	1.89	1.85	7.84
Disorders of psychological development cases/1000 inhabitants	3.49	2.44	0.52	8.85
Asthma (asthmatic condition), cases/1000 inhabitants	2.44	0.48	1.68	3.00
Congenital defects of the nervous system, cases/1000 inhabitants	0.11	0.05	0.05	0.20
Congenital defects of the blood circulation system, cases/1000 inhabitants	1.52	0.88	0.36	2.86
Visits to medical institutions, cases/1000 inhabitants	8.74	1.21	6.46	10.28
Population density, number of inhabitants/1km^2	1398.06	668.69	205.24	2117.43

MATERIAL AND METHODS

For the analyzes of forest, air pollution and health indicators eight urban Lithuanian areas with more than 15 thousand inhabitants and population density greater than 190 inhabitants per km^2 were selected (Fig. 1).

The following forest indicators were used: forest coverage (%), part of recreational forests (ha per 1000 inhabitants), forest remoteness (%); air pollution indicators (kg/km^2) - solids, sulphur dioxide, carbon monoxide, gasiform and liquid materials, nitrous oxide, volatile organic compounds; human health indicators (cases per 1000 inhabitants) - mood disorders, stroke, acute upper respiratory infections and influenza, obesity, depression, disorders of psychological development, asthma (asthmatic condition), congenital defects of the nervous and blood circulation system, visits to medical institutions; population density was also used as an indicator (number of inhabitants per 1km^2).

The selected indicators were obtained from the Department of Lithuanian Statistics (Statistics Lithuania), the State Forest Service and Health Information Centre of the Institute of Hygiene. The analyzed mean averages of the data were taken from the period of 2004-2013. The forest remoteness indicator was determined by applying GIS technology in accordance with the methodology adopted in Finland and other European countries: the part of urban area which is located from forests/parks larger than 1.5 ha at the distance greater than 300 m (Faehnle 2012).

300 m is regarded to be an optimal distance for a city dweller to walk to forest daily (Harting et al. 2003). In order to determine correlations between the indicators RDA (redundancy analysis) (ter Braak & Šmilauer 2002) and correlation analysis were applied. Redundancy analysis models dependent variables as the functions of independent variables. It is a form of ordination, which analyses the degree at which one set of variables is explained by another set of variables of the variation. By means of RDA, indicator data were standardized centralized. RDA was carried out using PC-ORD software package, whereas correlation analysis was performed with STATISTICA software package.

RESULTS AND DISCUSSION

Variability of the indicators is presented in Table 1. Average forest coverage in the analysed urban areas was 26.53 %, the lowest – 1.4 %, the highest – 56.80%. The average distance from the dwellers' place of residence to the nearest park/forest park was 45.82%. The largest area of recreational forests per 1000 inhabitants in the urban areas constituted 182.75 ha, the smallest – 1.04 ha. Standard deviation of recreational forests from the mean average (32.19 ha) was large as it comprised 61.21 ha, thus proving that the green infrastructure is not planned properly in the urban areas. In the analysed urban areas, air pollution with solids was the lowest and air pollution with gasiform and liquid materials was the highest.

High pollution indicators show that the analyzed urban areas include cities with well-developed industry and transport network. The highest morbidity rate was that of acute respiratory infections and influenza, i.e. 235.05 cases per 1000 inhabitants. Relatively high morbidity with mood (affective) disorders, depression and psychological development disorders was observed, respectively 3.70, 3.61 and 3.49 cases per 1000 inhabitants. Congenital defects of the nervous system were determined least often.

The average population density was /1398.06 inhabitants per 1 km^2. In the most densely populated area this indicator was 2117.43 inhabitants/km^2, in the least densely populated area – 205.24.

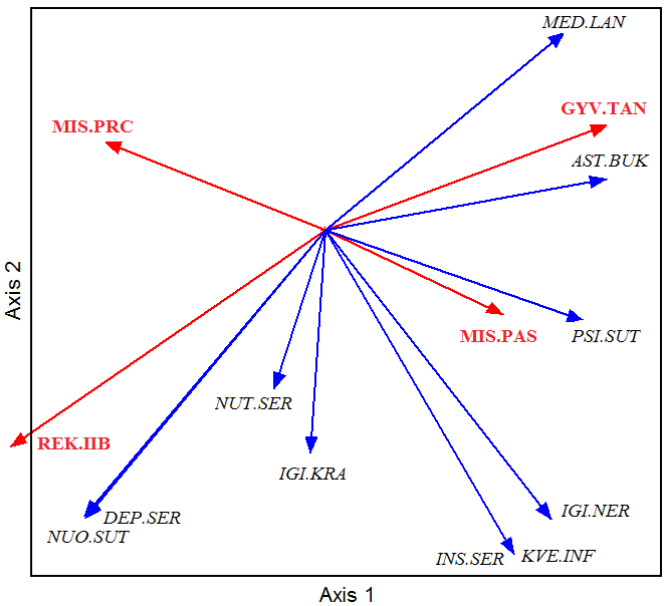

Fig. 2. The correlation between the forest and human health indicators.

RDA results showed the main relationship of forest coverage, forest remoteness, recreational qualities of the forest with inhabitants' health, air quality and population density (Fig. 2).

REK.IIB – the area of recreational forests in the municipality, 1000 inhabitants; MIS.PRC – forest coverage, %; MIS.PAS – forest remoteness (forest distance from residential areas): the part of urban area (%) which is located from forests larger than 1.5 ha at the distance greater than 300 m; GYV.TAN – population density at the beginning of the year, 1km^2; KVE.INF – acute upper respiratory infections and influenza, 1000 inhabitants; MED.LAN – average number of one inhabitant's visits to outpatient clinics and inpatient units, times; INS.SER – stroke, 1000 inhabitants; NUO.SUT – mood disorders, 1000 inhabitants; DEP.SER – depression, 1000 inhabitants; AST.BUK – asthma, asthmatic condition, 1000 inhabitants; PSI.SUT – disorders of psychological development, 1000 inhabitants; IGI.KRA – congenital defects of the blood circulation system, 1000 inhabitants; IGI.NER – congenital defects of the nervous system, 1000 inhabitants; NUT.SER – obesity, 1000 inhabitants.

In the ordinate diagram, first two axes explained interrelation variation of 73.6 % of air pollution (in italics) and forest (in bold) indicators and 62.4 % of health (in italics) and forest indicators (in bold). RDA results showed that disorders of psychological development are related with the percentage of forest coverage in the urban area. Recreational forests may be linked with depression, mood disorders, obesity and visits to medical institutions. Due to high remoteness of parks and forest parks in the urban area, there are more inhabitants suffering from asthma, disorders of psychological development, congenital defects of the nervous system, stroke, respiratory infections and influenza. RDA results do not show the relationship of forest coverage and forest remoteness with depression, mood disorders and visits to medical institutions. Pollution with solids, gasiform and liquid materials, volatile organic compounds, NO and CO was related with the population density and high remoteness of green spaces (Fig. 3).

REK.IIB – the area of recreational forests (group 2B) in the municipality, 1000 inhabitants; MIS.PRC – forest coverage, %; MIS.PAS - forest remoteness (forest remoteness from residential areas): the part of urban area (%) which is

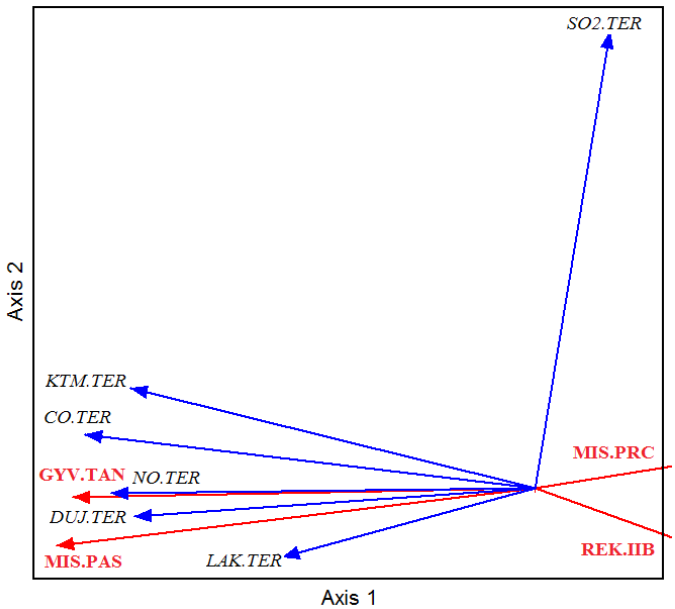

Fig. 3. The correlation between the forest coverage and air pollution indicators.

Table 2. Correlation coefficients between the forest coverage, air pollution and health indicators

Indicator	Correlation with forest coverage	Correlation with forest remoteness	Correlation with recreational forests
Pollution with solids	**-0.54**	**0.57**	-
Pollution with sulphur dioxide	**0.57**	-0.44	-
Pollution with carbon monoxide	**-0.65**	**0.72**	-
Pollution with gasiform and liquid materials	**-0.54**	**0.57**	-
Pollution with nitrous oxide	**-0.70**	**0.69**	-
Pollution with volatile organic compounds	-0.24	0.26	-
Mood (affective) disorders	0.21	-0.19	**0.91**
Stroke	-0.30	0.18	0.03
Acute upper respiratory infections and influenza	0.39	-0.26	-0.24
Obesity	0.27	-0.16	0.30
Depression	0.22	-0.20	**0.91**
Disorders of psychological development	-0.40	0.42	**-0.53**
Asthma (asthmatic condition)	-0.29	0.17	**-0.63**
Congenital defects of the nervous system	**-0.77**	**0.73**	-0.26
Congenital defects of the blood circulation system	-0.43	**0.51**	0.16
Visits to medical institutions	-0.48	0.22	**-0.77**
Population density	**-0.77**	**0.67**	**-0.77**

located from forests larger than 1.5 ha at the distance greater than 300 m; GYV.TAN – population density at the beginning of the year 1km^2; CO.TER – carbon monoxide emissions, kg/km^2; KTM.TER – solid emissions, kg/km^2; SO2.TER – sulphur dioxide emissions, kg/km^2; DUJ.TER – gasiform and liquid materials, kg/km^2; NO.TER – nitrous oxides, kg/km^2; LAK.TER – volatile organic compounds, kg/km^2.

Forest coverage may be associated with the pollution with NO, CO, solids, gasiform and liquid materials. RDA diagram shows that forest indicators are not related with the pollution with SO_2. In order to determine the relation between the analysed parameters, the correlation coefficients were calculated. Significant correlation was determined between the forest coverage and pollution with nitrous oxide r=-0.70, carbon monoxide r=-0.65, solids r=-0.54, gasiform and liquid materials r=-0.54 (Table 2).

When the percentage of the forest coverage of the urban area is increasing, pollution with carbon monoxide, nitrous oxide, solids, gasiform and liquid materials is decreasing respectively. When the forest coverage of the urban area is increasing, there are less visits to medical institutions, correlation coefficient r=-0.48, and less cases of congenital defects of the nervous system r=-0.77. The number of people with disorders of psychological development is also decreasing r=-0.40. The forest coverage is related with the population density r=-0.77. The issue of forest remoteness is also related with human health. The more forests are remote from the residential place, the more cases of congenital defects of the nervous system (r=0.73), congenital defects of the blood circulation system (r=0.51), disorders of psychological development (r=0.42) are observed. Remoteness of forest parks/forests from the residential place is related with more

frequent visits to medical institutions. When the recreational area in the urban area per capita is increasing, the number of visits to medical institutions is decreasing r=-0.77. Also, there are less cases of disorders of psychological development r=-0.53 and asthma r=-0.63 (Table 2).

In Lithuania the forest is an important element in the urban area due to its sanitary hygienic functions. The more evenly forests are distributed in the urban area and the closer located they are to residential areas, industrial facilities and roads, the less pollution there is and it is distributed more evenly throughout the entire area. Green zones of forests positively affect the city air, clean it, improve the microclimate, suspend airborne dust, thus improving the health of the inhabitants. About 40 % of Lithuanian residents throught that the city's environmental quality was negatively impacting their health (Baubinas et al, 2003). Therefore in this study, we would like to attract attention to the fact, how closely urban green spaces and urban forest are related with air pollution and dwellers wellness. On the one hand, air pollution is closely associated with the population density and high remoteness of green zones/urban forests; on the other hand, the health of city dwellers depends on the pollution level and the possibility to visit closely located natural areas to improve their health, relax and regain the strength. Our study confirmed, that area of recreational forests was related with mood disorders and depression. According to the results of a survey of city dwellers in Sweden, the respondents who claimed to be less stressful visited green spaces 4 times a week on average. Those respondents who lived at the distance of 50 m or less from the green spaces pay visits there 3-4 times a week. When the distance from the green spaces was about 300 m, the residents visited them 2.7 times a week (Grahn and Stigsdotter, 2003). When the green spaces were located 1 km from the residential place, the residents visit them only once a week.

More closely located forests with recreation infrastructure create better life conditions, thus having a positive impact on the city dwellers' health. Our research supported that in Lithuania health condition of city dwellers is closely connected with number of recreational forests visits. Walks in the park had a greater positive impact on patient with coronary artery disease and affected heart function (Grazuleviciene et al., 2014, 2015). Professor Grazuleviciene established that green spaces, located close to the residence, had positive influence on women's blood pressure. Bigger distance from the residence to the city's green spaces were associated with an increased risk of various cardiovascular diseases. The study showed that forest remoteness and number of green area visits was connected with congenital defects of the nervous and blood circulation system and had great influence on pregnant women. An interesting study was performed by Spanish researchers. The results showed that the higher educated mothers lived in distance 500 meters near green spaces, their babies born weight was higher compared to the weights of infants born to mothers living further than 500 m from the green spaces (Dadvand et al., 2012). Faber et al. (2009) analysed how greenness reduced symptoms of children attention deficits disorder.

Undoubtedly, the natural environment is an essential element and a health basis for everyone. Therefore, it is significant to develop not only the infrastructure of the city, but also to create new parks and to maintain existing ones. It is important to create equal conditions for all residents to attend the city green spaces.

CONCLUSIONS

Higher forest coverage of the urban area has a positive effect in terms of air pollution, it also has a positive impact on the dwellers' health, thus reducing the number of cases of congenital defects of the nervous and blood system, disorders of psychological development, asthma and visits to medical institutions.

When the forests are remote or located in one area, inhabitants visit them, or do sports and go for a walk there less often. More even spatial

distribution of green areas has a positive impact on health and ambient air as the air pollution is reduced. City dwellers that spend more time in natural environment are healthier, get ill less often.

Remoteness of recreational forests is associated with asthma and disorders of psychological development. Inhabitants of urban areas with more recreational forests per capita visit medical institutions less often, most probably due to better conditions for visiting the forest.

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