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ASSESSMENT OF ENVIRONMENTAL LOAD ON URBAN AREA IN THE CASE OF KOLOZSVÁR (CLUJ) VIA ANALYSIS OF SPATIAL DISTRIBUTION OF LICHENS AND ARBOREAL VEGETATION ALONG THE ROADS

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Introduction

The most important tasks of urban ecology are to reveal the environmental problems and confrontations within urbanized area via the evaluation of various ecological parameters in the city, the development of an environmental cadastre and the decision making support for ecology-based urban development (MUCSI, 1996). The so-called environmental bioindicators have crucial importance in estimation of anthropogenic effects in urban settings (JÓRI et al., 2002). NYLANDER (1866) discovered in the middle of the 19th century that lichens are highly sensitive to the air quality and in this way they are excellent bioindicators of air pollution.

Lichens as bioindicators

Lichens usually dwell on trees, rocks, soils, as well as plant and animal remains, but they also appear on anthropogenic materials (tiles, bricks, concrete, cement) as well. Their extraordinary sensitivity to the air quality can be explained by their unique structure: the creature itself is made up of several algae cells embedded into a thick network of fungi fibers, covered by a dense layer of hygroscopic hyphae on the outside. This hyphae layer soaks up water like a sponge, including moisture in the air along with its dissolved content transporting it freely into the inner parts of the thallus. The moisture accumulating among the fibers ensures the aquatic conditions required by the algae cells. Thus the dissolved acidic ions present in them are especially harmful to these. The leaves of higher order plants are protected by a thick epidermis, preventing them from such damages in fairly polluted air while lichens have no similar protective layer. Furthermore they are also unable to filter out these harmful substances from the thallus. Due to their slow growth rate, the positive effects of air quality improvements are detectable on them only with a 4-6 year delay. However, they very rapidly react to worsening conditions causing sometimes the complete decease of certain species even within a span of a few months, due to their high sensitivity.

Polluted air acts as a stress factor in the habitat, tolerated by different lichens to differing degrees. Based on the mithridatism of individual species and measured air pollution values the species collected in the vicinity of air quality monitoring stations can be ranked on a sensitivity scale. (HAWKSWORTH et al., 1970).

The top of such scale systems are occupied by extensive, bush-like lichens, which are generally missing from the urban areas, being especially sensitive to dry, dusty, and polluted air conditions prevailing in the cities.

Some leaf-shaped lichens turn up in the cities. However, it's only some epiphytic lichens that can tolerate highly polluted air to a certain extent. After this level of air pollution the so-called lichen desert phase appears, characterized by the general lack of lichens on tree trunks, yet these life forms are still preserved on the roofs and limestone surfaces. The general aridity of urban air is another negative factor for lichens besides air pollution. Among humid conditions, certain taxa are more tolerant to poor air quality than in drier conditions. The city can be divided into normal, conflict as well as desert zones on the basis of the distribution of lichens (SERNANDER, 1926). The desert zone more or less coincides with the center of the city, lichens being most sensitive to sulphur- and nitrogen dioxides, as well as a load from heavy metals. This zone is encircled by the next confrontation zone, where the degradation of lichen communities via the decay of the thalluses lead to a decrease in the diversity of lichen species as well as the changes in the general composition. Only the so-called toxic tolerant taxa are capable to survive here (*Buellia punctata, Lecanora conizaeoides, Physcia aipolia, Physconia grisea.* This confrontation zone can be further subdivided into an inner and outer part (VARESCHI, 1936). The outer part forms the undisturbed normal zone, where the size, shape and color of lichen communities are not altered.

Based on their style of living lichens can be classified into the following groups: tree dwellers (epiphites), wall dwellers (epilithic), soil dwellers (epigeionic) (WITTIG, 1991). Epilithic species are usually strongly attached to the substrate and sometimes can dissolve and absorb the carbonates present in them, enabling the neutralization of acids in the "inner solution" of the lichens reducing its harmful effects. However, the seemingly similar tiles, mortars and cement surfaces are characterized by highly differing buffer capacities. Thus the lichens populating them not necessarily reflect the actual conditions of air quality in all cases.

In case of the epiphytes, the buffer capacities are less influenced by the substrate they dwell on. Consequently, these species were taken into account for the preparation of a lichen-based air quality map in our work.

The general climatic and geographical characteristics of the study area

Kolozsvár is a medium-sized city with 340,000 inhabitants located in the terraced valley of the river Kis-Szamos at the interface of three medium landscape units, the Mid-Transylvanian Mountains (Erdélyi-szigethegység), the Mezőség and the ridge of the Szamos River (Szamos-hátság), about 300 and 500 m ASL. The city itself occupies several geomorphological horizons (floodplain, terraces, nearby hills). According to TREWARTHA's classification system, the climate is temperate continental with long summers. According to a 40-year meteorological record taken between 1957 and 1997, the major climatic parameters of the city can be given as follows: mean annual temperature 8.4 °C;

the maximum potential intensity of heat island calculated from the comparison of minimal temperature values is 8.1°C (UNGER, 1996); the maximum calculated value of the heat island, by taking into account the physical properties of artificial materials and the extent of communal areas is 7°C (GÉCZI et al., 1998); the mean January and July temperatures are -4.6 and 19.3 °C; the rate of annual mean precipitation is 619 mm; the annual duration of sunshine is 1978 hours; the mean annual relative humidity is 74%; the prevailing winds are westerly with almost 90% frequencies, blowing parallel with the course of the river Szamos (this is often complemented by the valley winds of the Gyalu Mts.). The unique road network of the city composed of streets running in an east-west direction can be attributed to these latter two factors. The high frequency of atmospheric inversion is also worth noting (sometimes reaching the annual value of even 100 days, the majority being restricted to the period between October and February). Potential pollution sources are located in the eastern parts of the city in the form of industrial centers. However, pollution from transportation must not be neglected either.

Materials and methods

As a first step of data collection the study area has been covered by a reference grid with 200 m resolution. The so-called wandering method was applied for data gathering (SZABADOS, 1997). Samples were collected from 5-6 different types of trees per cell yielding a total of 20-25 different arboreal species, then the digitized information provided input variables to Arc/Info 7.0.3 GIS (Geographical Information System) software. Mapping the observed information in digital form and using GIS tools in further analyses the spatial distribution of individual lichen taxa could have been qualitatively and quantitatively assessed and compared. The results were displayed on thematic maps. The systematic comparison of these thematic maps finally led to the construction of the lichen-based air quality map of the area containing the three mentioned zones or regions of normal, conflict and desert zones.

Results

26 lichen taxa are present in the city of Kolozsvár. Most of these are restricted to the area of the city's botanical garden (22), the Házsongárd cemetery (13), and the marginal parts of the woodlands surrounding the city (10-11). In the the green areas and ecological corridors of the city harbor about 3-5 different lichen species are living. In the area of Sétatér (a square), only two taxa (*Xanthoria candelaria* and *Physconia grisea*) are present due to the nearby streets and boulevards, characterized by a very heavy traffic. Along the highway to Torda, enjoying heavy traffic as well, again two species could have been identified on the bark of a *Robinia pseudoacacia* (*Xanthoria parictina, Physcia ascendens*). The highly toxic-resistant *Buellia punctata* also turns up in the central parts. The presence of these numerous lichen taxa in the central downtown areas must be attributed to the relative proximity of extensive green belts (**Map 1.**).

The most extensive urban forms of lichens are those tolerating slightly polluted air conditions as well such as *Xanthoria parietina* and *Physcia ascendens.*

In contrast to the Central European cities, the most resistant forms are present to a lesser degree in the flora (*Buellia punctata, Lecanora conizaenides*).

The species *Parmelia furfuracea, Parmelia exasperata, Caloplaca sp., Ramalina farinacea*, preferring clean air are also present in low numbers, appearing usually outside the communal areas. According to POP (1996), the distribution of lichens in Kolozsvár is just the opposite of the system of SERNANDER (1926). Namely, the number of species decreases as we move away from the center. However, the referred author based his statement regarding the city of Kolozsvár on a total misconception.

Partly, because he considered the area of the botanical garden located in a terrace about 60-75 m ASL, it is a part of the city center. On the other hand, he also failed to recognize the importance of the high frequency of climatic inversions and that of the summer valley breezes in his concept. The high heavy metal and sulphur-dioxide concentrations must be the main reason of the development of desert zone in the city of Kolozsvár, the latter having concentrations around 0.0125 mg/m^3 as well. Based on other opinions the reason is the decreasing humidity for the decay of urban lichens and the development of desert zones (RYDZAK, 1968).

However, this assumption can also be refuted on the basis of the following evidences: on the one hand, deserted areas, regarding the appearance of lichens, more frequently appear in those places of the city, which are characterized by more humid conditions. On the other hand, they are not exclusively restricted to the central areas of the city but also turn up in the vicinity of isolated pollutant sources as well (industrial objects, thermal power plants).

The relative poverty of the lichen communities in the industrial areas compared to the communal areas, as well as the complete lack of the mountainy *Usnea* taxa in the city due to acid rains seem to corroborate the assumption according to which the presence of lichen desert zones are not a factor of air humidity primarily, but rather that of air quality.

The study of tree-lined roads

The general conditions of trees located along roads and highways can also reflect the general ecological conditions of a city, similarly to lichens. The characteristics of age and species distribution of these trees may also be used as bioindicators in urban ecological studies (WITTIG, 1991). Urban tree stands either represent the original woodland communities of the area or those of managed woodlands. The new environment poses them new factors to cope with, and the less resistant forms quickly decay in an urban environment. They are also subjected to frequent mechanic injuries in this new urban environment.

The survey of the city management office of Kolozsvár talks about the presence of 81 290 trees in the city in 1989, while this value was only 75 747 in 1995 (FEKETE, 1995). Today approximately 58,000 trees can be found along roads and highways in the city. The dominant species of these is silver lime (*Tilia tomentosa*) with 13599 specimen, making up about 23.3% of planted trees.

The stands of locust-tree (*Robinia pseudo-acacia*) with 11,141 specimens come second. While lime species in total (*Tilia tomentosa, T. cordata* and *T. plathyphyllos*) make up almost one third of the total stands. (**Table 1.**).

If we consider the distribution patterns of *Tilia sp.* and *Robinia pseudoacacia* within the city, the following conclusions can be drawn: the suburban and central areas are primarily dominated by limes. While the ancient suburbs, marginal areas and industrial areas of the city are prevailed by the stands of locust-tree.

A similar pattern can be observed for elm (*Ulmus campestris*), white mulberry (*Morus alba*) and walnut (*Juglans regia*). These latter species are common to the rural quarters of the city and the dirt roads leaving the city. Conversely, the central roads enjoying much traffic are generally populated by stands of elm. The species *Aesculus hippocastanum*, *Catalpa bignoides*, and *Acer platanoides* are present in relatively equal proportions in the area of the city.

Table 1. The species composition of tree-lined roads in Kolozsvár

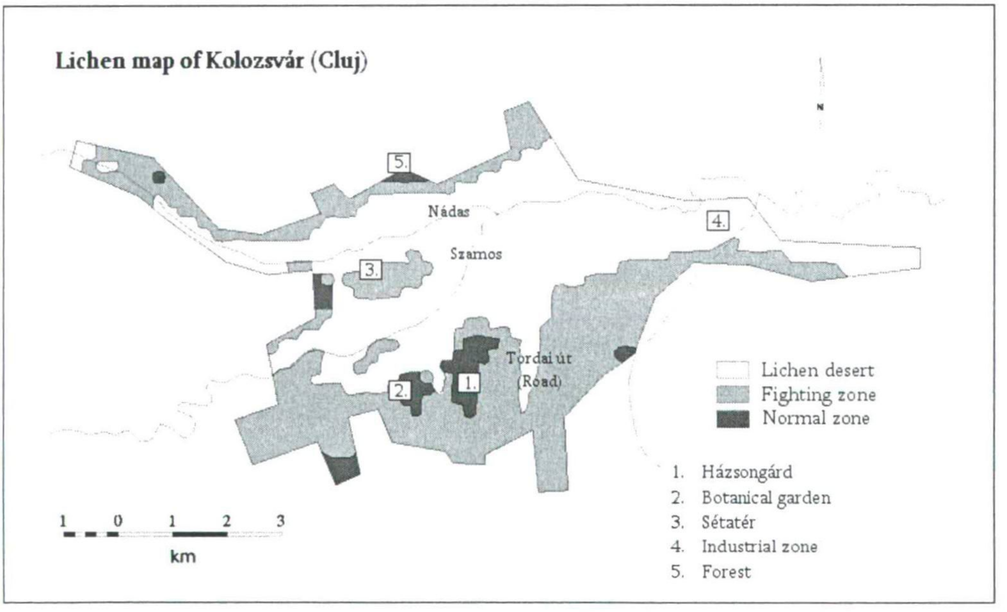
Species	Percent (%)	Absolute value (pc)
Tilia tomentosa	23.3	13599
Robinia pseudoacacia	19.1	11141
Ulmus campestris	8.6	5013
Aesculus hippocastanum	7.1	4139
Morus alba	6.5	3789
Juglans regia	4.9	2876
Acer platanoides	4.4	2565
Tilia cordata	3.2	1867
Tilia plathyphyllus	1.7	991
Other species	21.2	12359
Total	100	58339

Approximately one fifth of the newly planted trees perish within the span of a couple of weeks (FEKETE, 1995). The volume of the canopy of an adult tree growing among natural conditions usually exceeds 2500 cubic meters, while that of a young tree is only around 20-25 cubic meters (GORDON, 1990). Thus only 125 young trees can make up for the loss of an old tree. During the past 4-5 years several old trees fell victim of the ongoing road and other construction works as well as that of general city management. However, the plantation of new tree-lines along the roads lags behind. The problem is further intensified by the use of not quite successful stands in one place as well as the complete disregard of spatial and volumetric proportions. The conditions after modernization works implemented in 1995 in the central areas stand as clear examples of what have been said before: the stands of *Tilia tomentosa* originally occupying four lanes were logged down and after the completion of road widening they were substituted by stands of *Picea pungens*, which species is not quite ideal for this purpose being less tolerant to air pollution on the one hand.

On the other hand, the low and wide canopies of the planted stands prevent the easy free flow of the traffic on the road as well. Furthermore, the stands of *Betula verrucosa* mixed with the pines was also not an ideal choice for an urban setting, turning yellow even as early as June. Rather the introduction of xerophyte and thermophyte elements should be advocated in the city centers and industrial quarters. In our case only the species *Robinia pseudoacacia*, *Tilia sp.* and *Celtis occidentalis* belong to these groups. All this seems to imply, that the canalization of the Szamos and its tributaries as well as its diversion into an artificial concrete riverbed initiated a process of gradual increase in aridity.

The hygrophilous floodplain taxa were greatly reduced (*Salix, Alnus, Populus*) in numbers, appearing in artificially humid and abandoned areas alone today.

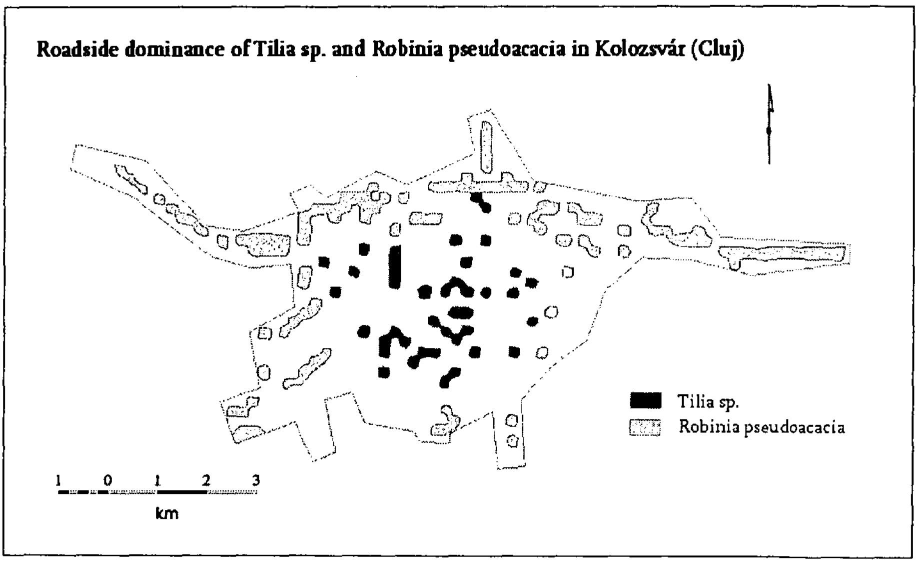
According to the information of the tree cadastre for the city, the majority of the downtown trees are damaged and decaying, or has already perished. The young stands tend to be more sensitive to these factors. The survey was implemented in June, so that the degree of damages could be relatively accurately assessed on the basis of the observed characteristics of newly shooting leaves. Since these are not yellow in healthy trees during this time of the year.



Map 1. The lichen distribution map of Kolozsvár

One fifth of the trees have a decaying canopy, showing clear signs of necrosis. However, in places harboring smaller, bigger relatively uniform green area, in our case for example a minor park, very few trees were damaged. In these cases trees located at the marginal parts of these green spots are the most prone to the harms of pollution.

According to the results of a study implemented in a square characterized by very high traffic in one of the city's natural terraces, trees located at crossroads are the most prone to the harmful effects of pollution. Thus even the smallest green spots have some sort of a moderating effect on pollution even in road crossings with the heaviest traffic and the most polluted air. Thus they may serve as a starting point for establishing better ecological conditions within the city. These points are to the possible dangers of establishing communal areas in the places of these minor biotopes on the one hand. On the other hand, it also clearly exemplifies the way the negative environmental effects can be moderated via rational intervention. The increase in the environmental load of trees located along the roads is a clear factor of traffic intensity. There has been an almost fourfold increase in the intensity of the traffic and the quantity of the participating motor vehicles in Kolozsvár since 1982, with 290 cars per 10,000 people in 1982 increasing to 340 in 1980 and 1341 today. A similar increase is observable in the traffic intensity measured as the number of vehicles participating the traffic of a downtown street in an hour-from 130 to 690.



Map 2. The map depicting the species composition of tree-lined roads

Summary

With support of the prepared lichen map the major polluted areas, signified as desert zones, could have been easily delineated in the city of Kolozsvár. These desert areas are restricted to the low-lying terraces, the downtown area on the floodplain of the Szamos, the Nádas valley and the eastern industrial areas. Based on our study it became apparent that the desert zones appear in the lower-lying geomorphological units of the city (floodplain and three lowermost terraces) characterized by the lack of general air currents and the prevalence of inversions with an average annual frequency of 70-80 days.

The other major desert zone is located in the eastern part of the city, where most of the polluting industrial objects are present, and the purifying effect of the valley breeze on the air is relatively negligible.

Similar conclusions can be drawn from the results of cadastral studies done on the city's trees: the increased decay of trees implies a larger environmental load on the low-lying areas and the increasing in the elevation accompanies by general decrease in the air pollution.

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