LANDSCAPE-ECOLOGICAL INFORMATION SYSTEM for LVIV: The DATA BASE DESIGN and MODELING

Ivan Krouglov
(Ivan Franko State University of Lviv, Ukraine)

Due to the concentration of people, industries, and services urbanized areas tend to be the places of rather sharp environmental conflicts that directly involve a significant part of the planet's population -- city dwellers. As a result, nowadays city governments have to consider environmental factor in almost any planning or administrative decision. To do it efficiently they need an operative access to various data on the urban physical (natural) environment. including spatial ones. This requires, on the one hand, an adequate technology to store, process, and retrieve the above mentioned data; on the other hand, a reliable methodology for the collection, analysis and synthesis of environmental information.

The first part of the problem has been successfully solved by the application of computer technologies, particularly GIS. A solution of the second task tends to leg behind -- new powerful analytical tools put forward higher demands for the accuracy, integrity and compatibility of data, but traditional environmental information on separate land features, such as geomorphology, geology, potential vegetation, *etc.*, in many cases fails to satisfy the new standards. The "feature" maps that are mostly compiled in various scales and on different methodological principles produce big spatial error in multiple overlays (*e.g.*, Berry, 1994), and sometimes have logically unmatchable structure of attribute information.

Landscape ecology, or *landscape science* as it is traditionally called in the Eastern Europe, offers an integrated view on the geographic physical environment as a holistic spatial-temporal entity -- the landscape. It possesses concrete methods, including cartographic ones, for the inventory and assessment of the latter (*e.g.*, Isachenko, 1973, 1980; Zonneveld and Forman, 1990; Haase, 1991). Therefore, introduction of landscape-ecological principles into the practice of applied environmental studies, especially in such a complex primary-anthropogenic formation as urban areas, is an effective way to overcome the difficulty. Thus, ***landscape-ecological information system*** is a result of the integration of the landscape-ecological methodology and the GIS technology.

The above mentioned idea forms the methodological basis of a pilot project being carried out at the Department of Physical Geography, Lviv State University. At the moment, a landscape-ecological data base has been created for the Lviv downtown and some environmental models developed using the ARC/INFO and partially ERDAS software. The landscape-ecological data utilized in the GIS were obtained through the special interpretation of the previously available materials as well as additional studies *in situ* (Krouglov, 1992).

According to the historical-genetic approach the ***urban landscape*** is presented as a spatial-temporal combination of two geographic subsystems -- the ***primary basis*** and the ***anthropogenic cover***. The first one includes the remains of the landscape's primary features formed before the interference of man, the second one -- those material components of the urban area, which has been created by the human activities. A special study allows to determine probable character of the destroyed or significantly altered primary geocomponents such as vegetation and soil cover (Krouglov and Miller, 1993).

In accordance with this notion, the core of the ***primary landscape-ecological data base*** consists of only two polygon coverages corresponding to the above mentioned urban landscape's subsystems. The polygon attribute tables (PATs) contain diverse environmental information that can be represented choropleth maps (Fig. 1). The overlay of the two coverages conveys complete physical heterogeneity of the area, and can be used as the basis for further geographic modeling. Since the coverages are digitized from the maps compiled under the same methodology and in the same scale, they ensure much smaller spatial error propagation when overlaid than separate "feature" maps. The other advantage is absolute logical compatibility of the attribute information and more effective use of computer resources.

The primary data base also includes the transportation network coverages and a multispectral satellite image. It is planned to supplement it with a contour map/DEM, point sources of air and ground or surface water pollution, a catchment system, and some other features that convey the structure of the urban physical environment (see Fig. 1).

In many cases environmental data should be referenced to the social-geographic entities, like city or administrative district limits, parcel boundaries, or zoning codes. Therefore, the landscape-ecological data base has to be linked to the municipal GIS.

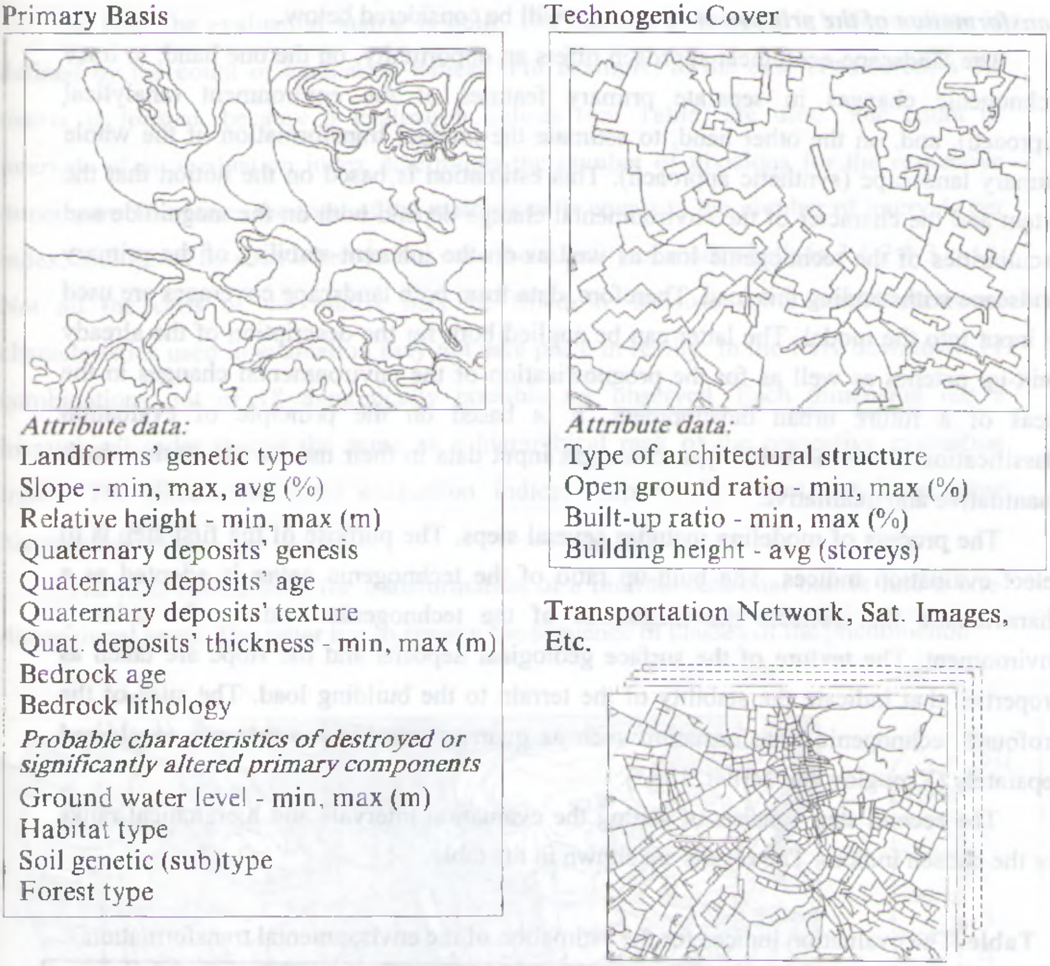

Figure 1. The structure of the primary landscape-ecological data base.

The ***derivative landscape-ecological data base*** contains geographic information obtained from the primary data base through query and modeling. The overlaid landscape coverages allow to make operative complex spatial queries, like allocation (*e.g.*, for construction purposes) of the non-built or sparsely built terrain with low surface gradients and favorable geological conditions. Supplemented with the transportation network data, the query can be elaborated by the economic location conditions (*e.g.*, the site should be within 100m from a main street), *etc*.

Environmental information of a rather high level of integration can be derived from the primary data base with the help of a special ***landscape-ecological modeling***. Since the procedure of the ***environmental assessment of residential areas*** in Lviv is discussed elsewhere (Krouglov, 1997), in this paper ***estimation of the integral technogenic transformation of the primary environment*** will be considered below.

The landscape-ecological approach offers an opportunity, on the one hand, to trace technogenic changes in separate primary features of the environment (analytical approach), and, on the other hand, to estimate the integral transformation of the whole primary landscape (synthetic approach). This estimation is based on the notion that the extent and the character of the environmental change depend both on the magnitude and peculiarities of the technogenic load as well as on the inherent stability of the primary landscape withstanding this load. Therefore, data from both landscape coverages are used as input into the model. The latter can be applied both for the description of the already built-up patches as well as for the prognostication of the environmental changes in the areas of a future urban development. It is based on the principle of evaluation classification (Isachenko, 1980), and accepts input data in their natural expression, both quantitative and qualitative.

The process of modeling includes several steps. The purpose of the first step is to select evaluation indices. The built-up ratio of the technogenic cover is adopted as a characteristic that reflects the magnitude of the technogenic load on the primary environment. The texture of the surface geological deposits and the slope are taken as properties that indicate the stability of the terrain to the building load. The sites of the profound technogenic transformation such as quarries and big mounds are considered separately (Krouglov and Miller, 1993).

The second step consists of setting the evaluation intervals and hierarchical ranks for the chosen indices. The results are shown in the table.

Table. The evaluation indices for the estimation of the environmental transformation

Hier. rank	Index name	Mesur unit	Intervals "Weakest"		"Strongest"
1	Built-up ratio (max.)	%	<= 15	> 15 and <= 25	> 25
2	Quaternary deposits' texture	None	Sand, loamy sand, loam		Mud, peat
3	Slope (avg.)	%	<= 10	> 10 and <= 20	> 20

If the operations in the first two procedures are conducted interactively by the expert in landscape ecology, the subsequent steps are a routine job that can be done in a batch mode. At the beginning, an overlay of the two coverages is made and a new polygon topology is established. Then, an additional item that will contain the results of the evaluation classification is created in the PAT of the newly synthesized coverage.

After this. the operations with the attribute data begin.

At first. the evaluation matrix is built. The number of the matrix's dimensions is defined by the count of evaluation indices. For example, in the case considered, a 3D matrix is formed. because 3 evaluation indices (see Table) are used. The count of intervals of an evaluation index determines the number of divisions for the respective dimension. Therefore, the total of the matrix's cells equals to the number of intervals per index, multiplied by each other. In our case the quantity of matrix cells is 3 * 2 * 3 = 18. Not all the cells of the matrix may be filled in, because some combinations of characteristics used in evaluation may not take place in reality. In the Lviv downtown 11 combinations out of 18 theoretically possible are observed. Each dimension has a hierarchical order that is the same as a hierarchical rank of the respective evaluation index. The dimensions (and evaluation indices respectively) must not have same hierarchical order.

The next operation is the transformation of a multidimensional matrix into a one-dimensional array. The latter has to convey the sequence of classes of the phenomenon

Figure 2. The integral transformation of the natural environment. (The values of transformation are from the "weakest" (1) to the "strongest" (12).)

under evaluation, ordered from the "weakest" ("worst") to the "strongest" ("best"), or vice versa. The array is formed through the sequential entering of the matrix's elements according to the hierarchy of dimensions. Each classification unit receives the value according to the position in the array. The values are written into the specially prepared column of the PAT.

After the evaluation classification is made, the final step is to make the synthesized coverage cartographically correct. The boundaries between the polygons with the same values of environmental transformation are dissolved; and sliver polygons are eliminated using thresholds on area and perimeter/area ratio.

The obtained map (Fig. 2) reflects the integral transformation of the natural environment.

References

Berry, J.K. 1994. Sprawling Uncertainty. *GIS World*, August: 26.

Haase, G. (Ed.) 1991. Naturraumerkundung und Landnutzung: Geochoro-logische Verfahren zur Analyse, Kartierung und Bewertung von Naturräumen. *Akademie Verlag, Berlin.*

Isachenko, A.G. 1973. Principles of landscape science and physical-geographic regionalization. *Melbourne University Press, Carlton.*

Isachenko, A.G. 1980. Methods of applied landscape studies. *Mysl, Moscow.* (In Russian)

Krouglov, I.S. 1992. History, modern state, and perspectives of development of landscapes of Lviv. *Unpublished Candidate of Sci. Dissertation.* (In Russian.)

Krouglov, I.S. and Miller, G.P. 1993. Some aspects of the geosystematic study of urbanized areas. *Russian Geogr. Society News*, 4: 29-33. (In Russian.)

Krouglov, I.S. 1997. Urban landscape-ecological information system. *Ukrainian Geogr. Magazine.* (Forthcoming in Ukrainian.)

Zonneveld, I.S. and Forman, R.T.T. (Ed.) 1990. Changing landscapes: An ecological perspective. *Springer-Verlag, New-York.*