II. PLANT COVER IN TOWNS

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Outline of the floristical-ecological method of estimating environmental changes in the zone of a town's influence

Abstract. The aim of this paper is to describe a method, which is based on natural conditions. Essential for this method is detailed knowledge of the dynamics of changes and the spatial structure of the flora of the vascular plants, which occur or occurred wild in the town. In this method flora is used as a bioindicator of changes occurring in the abiotic environment. The measures of this process are floristical-ecological indices. The basis for the construction of indices enabling an assessment of the flora, with respect to its reaction to human activity are classifications in which geographical-historical, dynamic, biological and ecological criteria are taken into account. The method and results of using the method described are shown here in relation to Poznań (West Poland).

INTRODUCTION

A town is an ecological system – ecosystem (SUKOPP 1973, ZIMNY 1977) or ecogeosystem (BARTKOWSKI 1981). It consists of elements of natural subsystem (flora and plant communities, fauna, components of inanimate nature) and constituents of the technical infrastructure (of town-planning, industrial and transportation). In this ecological system man plays an exceptionally important part. By continually expanding the technical-architectural subsystem he transforms the natural environment.

The great complexity of the ecosystem of a town is reflected in the many different methods of estimating the extent of its transformation. Until now no compact and comprehensive classification of the changes has been worked out. According to ZIELONY (1991) methods of estimating anthropopressure can be divided into three groups: technical, natural and planning. Other authors lay emphasis on the value of the methods which take into account social criteria (WOŹNIAKOWSKI 1991) or economic ones (PAWLAK 1991).

The aim of this paper is to point out a method, which is based on natural conditions – on the results of detailed analysis of all the species in the flora.

Floristic studies in towns have been carried out for decades. First, the behaviour of adventitious plants was taken into account, i.e. species of foreign origin which are spread by human activity. Systematic research into the flora of towns in Central Europe has been carried out from the early 1960s. Rapid increases in the information

about the flora go hand in hand with the development of scientific methods. Changes to the flora resulting from urbanization are commonly expressed numerically – more precisely with the help of different parameters and numerical indexes (e. g. FALIŃSKI 1971, KUNICK 1974, 1982, KRAWIECOWA, ROSTAŃSKI 1976, WITTIG, DURWEN 1981, KLOTZ 1987, 1989, 1990, SUDNIK-WÓJCIKOWSKA 1987, 1992, KOWARIK 1988, 1990, BRANDES 1989, CELESTI et al. 1989, JACKOWIAK 1989, 1990a, b).

In the papers which consider broadly the methodological problems there is discussion over the definition of the object of the studies, the rules and criteria of classification of species and the value of numerical indexes describing the various stages in the transformation of the flora resulting from anthropopressure. But there is lack of discussion relating to the whole procedure, comprising all the stages of scientific process. It seems reasonable and timely to present such a proposal. However, the size constraints of this paper make it possible to deal only with the essence and the main rules of this procedure. It is being used in the way described in studies carried out by the author on the area of the town of Poznań (e. g. JACKOWIAK 1989, 1990a, b).

PRINCIPLES AND THE ESSENCE OF THE METHOD

The floristical-ecological method of estimating the results of human influence on the urban environment is based on natural conditions. This method depends on detailed recognition of the dynamics of changes and the spatial structure of the vascular plant flora, which occurs or occurred wild in the area of the town. Unlike, for instance, the techniques for measuring physical or chemical pollutants or noise levels this, a more complex, although very general, method allows an estimate of the state of environment. In the flora of the town are reflected both direct influences on vegetation and indirect effects which are channelled through the abiotic environment (climate, soil, water etc.).

The essence of the floristical-ecological method relies on a statement: that there is a correlation between the dynamics and the spatial structure of the flora and changes taking place within the limits of other components of the ecosystem of the town. The flora is used here as a bioindicator of changes occurring in the abiotic environment. The measures of this process are defined as floristical-ecological indices.

CHARACTERISTICS OF THE MAIN STAGES OF THE STUDIES

The procedural stages for these studies, which aim to estimate the changes to the environment due to urbanization, are:

1. Collecting archival data and up-to-date observations on the occurrence of vascular plants in the town, which is itself divided into natural, semi-natural and artificial spatial units. The sources of historical data are herbarium collections, which are examined to check the accuracy of identification, also publications and other reliable works. Actual data about distribution and conditions of occurrence of species are collected as floristical-ecological releves. A relevé consists of a list of

species and characteristics of a studied area. These include, among others, an estimation of the degree to which it has been changed through human influence and in which the scale of hemeroby is used (SUKOPP 1972). To maintain the rule of ecological unity of the studied area, releves are spaced regularly and at the same time their location is placed in one of the accepted spatial divisions of the studied area.

2. Compiling of a catalogue comprising general information on each individual species (from literature) and the data about its occurrence in the studied area.

3. Arranging the data in a table, which includes a list of all species (in the first column) and some of their ecological characteristics, and also data referring to the occurrence in the study area (in the next columns).

4. Working out numerical indices for the general flora. The general flora comprises all species of vascular plants observed in the wild state – even though irregularly – in the area studied. These parameters are used in describing the so called elementary structure of the flora. They are a basis for the characterisation of the vegetation of the town and at the same time they are a reference point in different types of comparative analysis.

5. Comparison of the floristical-ecological indices in the succeeding stages of the town's development. Any study of changes caused by urbanization would not be complete without recognising the dynamic nature of the flora. For this purpose the floristical-ecological indices are compared over succeeding time intervals. In this way a total balance of changes described through analysis of the general flora is extended by an essential component in the equation – the rate of transformation of the town's environment.

6. Analysis of the spatial structure of the flora of a modern town. The local ranges of plant species are a base for the structural organization of the flora of the town. Urbanization changes their shape and character in ways which can be used to estimate transformation caused by the urban environment. A better picture of these changes may be achieved by comparative analysis of the full set of species for the basic study units. Investigative procedure which gives information about the spatial structure of the flora and the spatial differentiation of the level of degradation of the environment is poorly described. In the Poznań methodological model, a procedure comprising the following stages is carried out:

– arrangement of numerical data in a table consisting of a list of all spatial units (in the first column) and floristic characteristics (in the next columns);

– statistical analysis of variability of floristic characters (single or multiple character analysis);

– choice and description of the function of similarity for a set of objects;

– choice of the method of classification and description of the structure of similarity;

– analysis of the structure of similarity: variant selection of classes of objects, choice of the best solution (realisation of a typological classification);

– cartographic representation of the results of analysis of the spatial structure of the flora.

7. Essential interpretation of the time and spatial variability of the floristical-ecological indices in comparison with the dynamics and the spatial differentiation of abiotic factors of the ecosystem of the town.

CRITERIA OF CLASSIFICATION AND PRINCIPLES FOR THE CONSTRUCTION OF INDICES

Classifications based on different characteristics of the plants are the basis for constructing floristical indices. These characteristics are the sum of many characters derived from systematics, chorology, biology and ecology. The structure of the database is improved as the amount of information about the flora is increased. In the latest descriptions it includes over 30 characters of many types (FRANK et al. 1990). Potentially there are many ways of constructing floristic indices. With the aims of the floristical-ecological method of estimating environmental transformation in the town in mind, the most important are: geographical-historical classification; dynamic division of the flora; scale of hemeroby of species and sociological-ecological divisions in the flora; and also classification of living forms (Tab. 1).

Table 1. Survey of the main classifications of species used in the studies of anthropogenic transformation of the floras of towns. [1] – MIREK (1981), [2] – JACKOWIAK (1990), [3] – WITTIG et al. (1985), [4] – KOWARIK (1988).

Classification	Main criteria	Names of the main categories
geographical-historical	• origin of a species • time of arrival • degree of naturalization	• native species • nonsynanthropic • apophytes • anthropophytes • metaphytes • archeophytes • kenophytes (neophytes) • diaphytes [1, 2]
dynamic	dynamic tendencies of species in urban conditions	urbanophobes, urbanophiles, urbanoneutrals [3] or hemerophobous plants and hemerophilous plants [2]
scale of hemoroby	ecological range or optimum of a species shown in an agreed upon scale describing the degree of degradation of ecosystem	ahemerobes, oligohemerobes, mezohemerobes, euhemerobes, polyhemerobes [2] or with the help of index numbers from 0 to 9 [4]
biological, – Raunkier's living forms	placing of reviving buds on a plant	phanerophytes, chamephytes, geophytes, hydrophytes, hemicryptophytes, terophytes
sociological-ecological	synecological optimum of a species	e. g. 18 sociological-ecological groups according to KUNICK (1974)

Results of these classifications are usually presented in the following ways:

– in a form of absolute frequency of occurrence of a given character (e. g. in a flora of 1000 species, 300 anthropophytes occur);

– by relating one characteristic to others, generally as a proportion relating the frequency of one manifestation of a character to all its manifestations (e. g. 30 percent of the flora is anthropophytes);

– in a form of a relation (e. g. index of modernisation of the flora, i. e. relation of kenophytes to archeophytes (KORNAŚ 1977)).

Until now no standard procedure for constructing floristical indices has been developed. Also there is lack of any comprehensive analysis of the values of different plants as indicators of the degree of environmental transformation. Priority of some parameters over any others in estimating the direction, speed and range of the changes occurring in the flora is given rather intuitively.

APPLICATION OF THE FLORISTICAL-ECOLOGICAL METHOD OF ESTIMATING CHANGES IN THE URBAN ENVIRONMENT

The way and results of using the method described are shown here in relation to Poznań. The town covers an area of over 220 sq kms and has a population of nearly 600,000. The vegetation of the town of Poznań has been studied by the author since 1980 (JACKOWIAK 1989, 1990a, b).

Table 2. Percentage of native and alien species in the synanthropic flora of the varying types of settlements in Poland (cf. FALIŃSKI 1971).

Type of settlement	natives	aliens
forest settlements	70–80%	20–30%
villages	70%	30%
small towns	60–65%	35–40%
medium towns	50–60%	40–50%
cities	30–50%	50–70%

Table 3. Comparison of the proportion of anthropophytes in the floras of Poznań, Berlin (West) and selected Polish towns.

Town	General flora %	Synanthropic flora %
Poznań	35.8	57.1
Berlin	39.9	52.8
Warszawa	33.6	50.5
Gdańsk	–	52.5
Szczecin	–	51.4
Kraków	–	49.1
Opole	–	48.6

By way of example the occurrence of anthropophytes in the flora (i. e. an index being the result of a geographical-historical classification (Tab. 1)) has been accepted as a basis for estimating the changes taking place in the urban environment. That index is commonly regarded as one of the best in assessing anthropogenic changes in the flora. Usually it has been applied to show the relative proportions between the

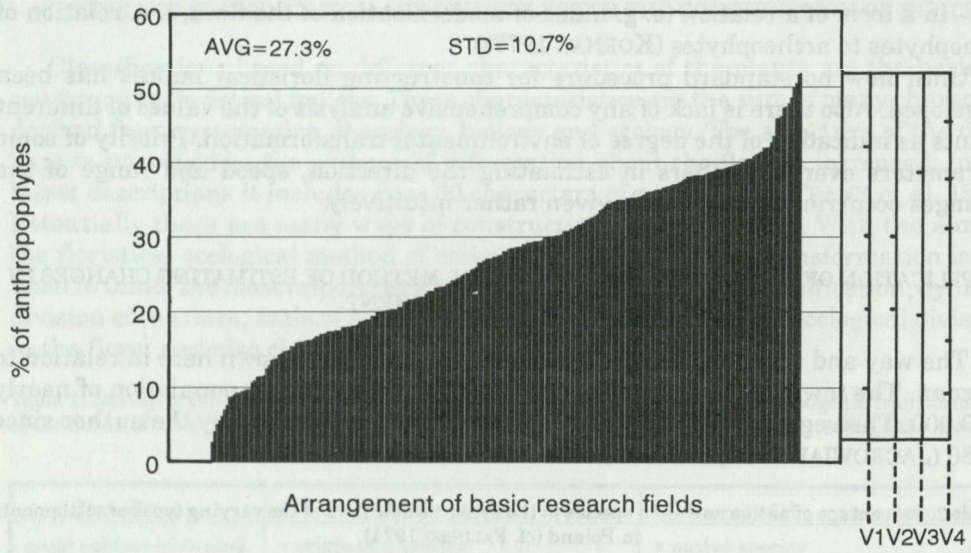

Fig. 1. Arrangement of the fields of a cartogram in order, according to increasing participation of anthropophytes: a, b, c, d – points of discontinuity in a link; V1, V2, V3, V4 – variants of classification.

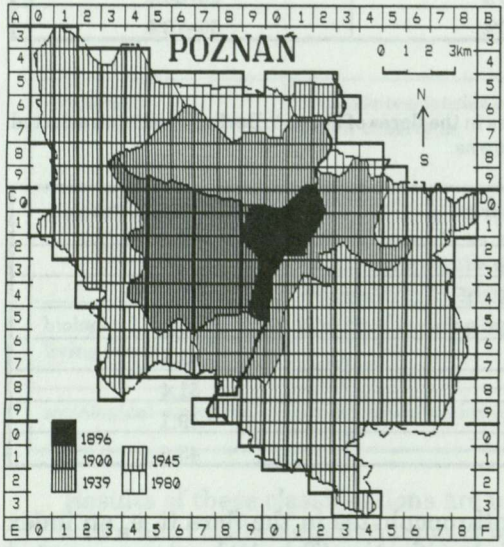

Fig. 2. Stages in the spatial development of the town of Poznań in the years 1896–1980.

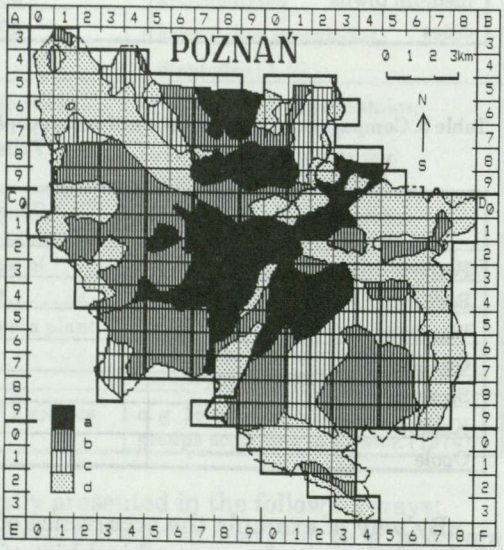

Fig. 3. Division of the town according to the types of building (land-use categories): a – high buildings (of a tenement-house and of a block), b – low buildings, densely developed, c – low buildings, dispersed development, d – areas without buildings or buildings very scattered.

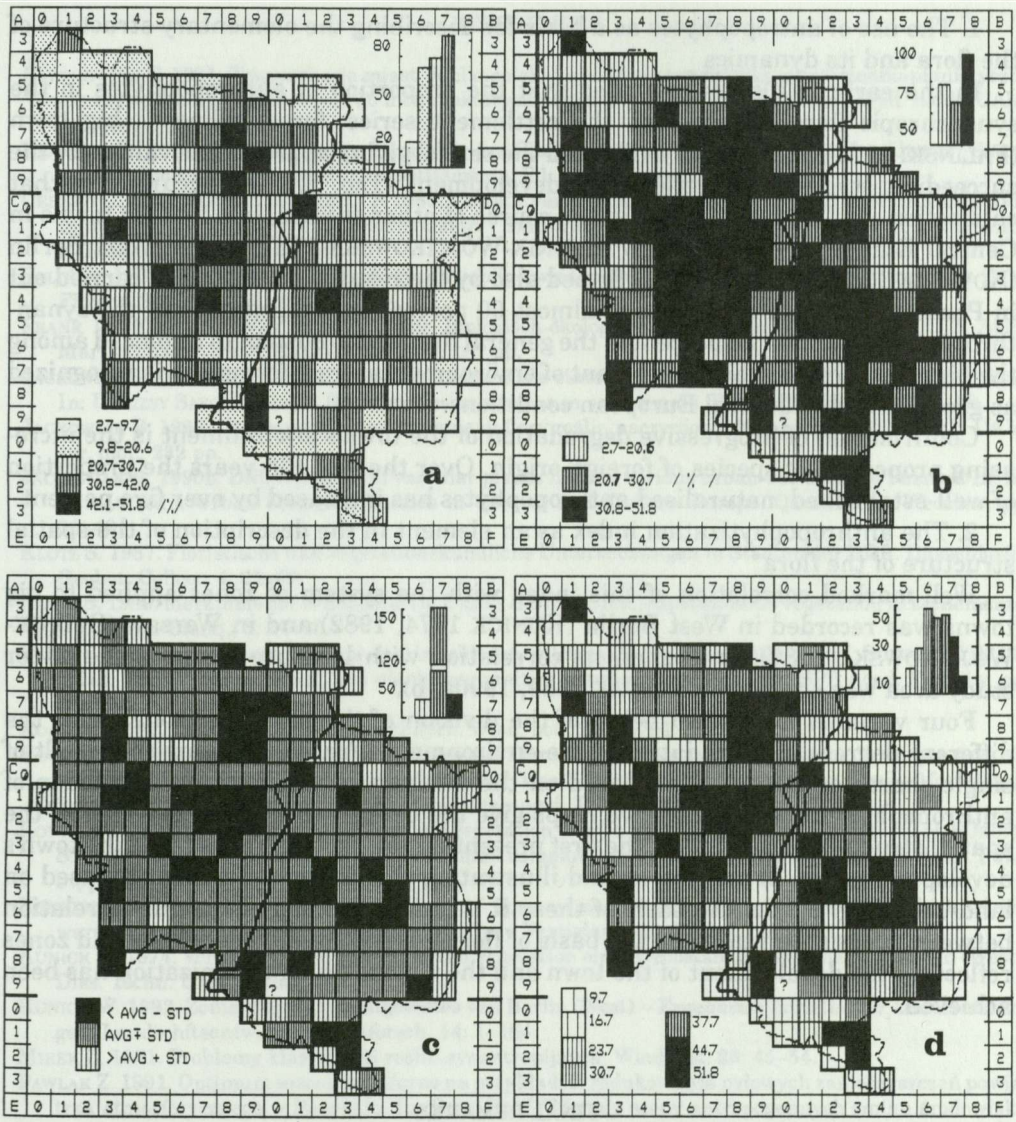

Fig. 4. Cartograms of transformation of the urban environment worked out on the base of the analysis of the spatial variability of the index of anthropophytization of the flora: a – variant 1, 5-class partition based on the analysis of discontinuity in a link, b – variant 2, 3-class partition created by linking of extreme classes from variant 1, c -variant 3, 3-class partition based on the analysis of average (AVG) and standard deviation (STD), d – variant 4, proportional 7-class partition.

total flora and the synanthropic flora. The latter comprises all wild-growing species excluding plants of local origin which occur only in natural habitats.

According to the procedure proposed here in analysing variability both time and spatial aspects have been taken into account.

1. The use of antropophytes as a basis for describing the elementary structure of the flora and its dynamics

In the early 1970s it was stated that the proportion of anthropophytes in the synanthropic flora increases in the settlement series: forest village – big town (FALIŃSKI 1971). This author calibrated the series, giving approximate values for the succeeding stages of a settlement's development (Tab. 2). The accuracy of that calibration was confirmed later in the course of other studies, in a few big towns in Central Europe, e. g. in Warsaw (SUDNIK-WÓJCIKOWSKA 1987) and in West Berlin (KOWARIK 1988). It has been confirmed also by the results of the studies carried out in Poznań (Tab. 3). Proportions of almost 60 percent anthropophytes in the synanthropic flora and over 35 percent in the general flora allow Poznań to be placed among the biggest towns in which the extent of environmental transformation is recognized as greatest under Central European conditions.

Confirmation of progressive degradation of the town's environment is the increasing proportion of species of foreign origin. Over the last 135 years the proportion of well-established, naturalised anthropophytes has increased by over five percent.

2. The anthropophytization index as an element in the description of the spatial structure of the flora

Well-marked correlation of this index with the system of zones applied to big towns was recorded in West Berlin (KUNICK 1974, 1982) and in Warsaw (SUDNIK-WÓJCIKOWSKA 1987). In Poznań its correlation with land-use zones in the wider study area was shown (JACKOWIAK 1989, 1990a, b).

Four variants are shown below of the division of the town into zones with the different degrees of degradation of the environment (Fig. 4). They are the result of single-character classification based on the analysis of variability of the index of anthropophytization (Fig. 1). Two maps give the background for the analysis of the spatial structure of that index: the first presenting the successive stages in the town's development (Fig. 2) and the second illustrating the division of the town based on land-uses (Fig. 3). On the basis of these it is possible to show a useful correlation between zones delimitated on the basis of floristical-ecological conditions and zones reflecting the development of the town and the way in which urbanization has been achieved.

FINAL REMARKS

The general direction, speed and the range of synanthropization of the flora, and its consequences in European towns, are already well known. Nevertheless there is still lack of any broader discussion on the way in which the results of these studies can be given practical appreciation. In this paper the author set out to show that the floristical-ecological conditions can be used to indicate the extent of a town's environmental transformation. An outline of the research procedure, the way of making such an assessment possible, and the results of the analysis of one of the basic floristic indexes have been shown. Many problems indicated here need greater attention and fuller illustration but it was not possible to do so in this study.

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