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RELATIONS BETWEEN THE STRUCTURE OF LANDSCAPE AND ITS POTENTIAL AT THE TERRITORY OF LAST GLACIATION IN POLAND

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Abstract

The most widely accepted paradigm in landscape ecology is the one linking the structure of landscape with its potential. Landscape structure is defined as a combination of elements, their location and mutual relations. Landscape potential encompasses the quantity of resources and values useful from the view point of human activity. The main task of this paper is to verify the above mentioned paradigm.

The case study area was the Elk region (330 sqkm), situated in the NE part of Poland. The structure of landscape has been analysed at the base of homogenous territorial units - geocomplexes (approx. 200 patterns and ca. 11,000 units). The relief, surficial lithology and the land use were the criteria for geocomplex delimitation. In the next step about 600 geosystems have been distinguished, the borders of these were at the same time the borders of the elementary catchment basins. This part of the work has been done ot the maps in scale 1:25,000.

During the studies of landscape structure for patterns of geocomplexes, 4 parameters were determined: number, area, average area of geocomplex in a given pattern and the index of internal coherency. For the geosystems such indices as: area, location in catchment cascade, index of landscape type, average area of geocomplex in geosystem, average internal coherency, landscape contrast, relative entropy of landscape were calculated.

For each geocomplex, thus for each geosystem, we determined the values of seven partial potentials, i.e.: biotic productivity, recreational built-up, mineral resources, water supply, atmospherical and self-regulation. The author also calculated the coefficient of variation for values of partial landscape potentials for each type of geocomplex. At this base it was found that vertical structure of geocomplexes, expressed by relief, surficial lithology and land use, indicates with high degree of reliability the values of water supply, atmospherical and biotic productivity potentials.

The measures of linear correlation displayed the relations between the structure of landscape and the potentials, for example the indices of landscape type and internal coherency are inversely proportional to the value of recreational potential, whereas they are directly proportional to the built-up potential. It shows that in the Elk Region, standard landscapes are good for housing and industry, less typical for recreation and tourism.

Achieved results of studies only partially corroborated the thesis concerning the relations between the landscape structure and potential.

Objective

In landscape ecology, like in many other sciences, there exists a group of statements which are regarded as paradigms. An important one concerns the link between the structure of the landscape and its potential.

The main goal of my work was to confirm (or to negate) the presence of such relations. The first stimulus was the observation I made during studies regarding the structure and the potential of landscape in the North-Eastern part of Poland. At that time my attention was drawn to such things as the influence of the diversity of landscape features and landscape contrastiveness effect upon the value of its potential. I noted some relations between the hydrology of given areas and their potential, but both the types of area (young & old glacial) as well as a small (1:200,000) scale of maps did not allow at that time for any closer examination of the achieved results. That is why later on I decided to do it in a larger scale (1:25,000) and for an area of pure young glacial geomorphology.

The results were expected to give answers to questions such as:

1. How strong are the relations between the internal structure of geocomplexes and partial landscape potentials?
2. Do they exist at all, and if so, how strong are relations between the spatial arrangement of geocomplexes and the values of its partial landscape potentials?
3. Does the relation between the hydrological situation of an area and the value of its potential exist, and how strong is it?

The term: the structure of landscape is used in the meaning of a set of landscape elements, their mutual situation, the relations and interdependencies.
Landscape potential it is the capability of a landscape for providing for human needs and keeping itself in balance, which results in its resources and quality.

My investigations were carried out in the area of 330 km^2, in the vicinity of the city Elk (Masurian Lake District, NE Poland - fig. 1) and they focused on:

1. Delimitation of the spatial landscape units with the analysis of the spatial structure of landscape, to which mathematical and statistical methods were used.
2. Estimation of the quality of partial landscape potentials with the application of the methods developed by the author.
3. Calculation of the strength of the relations between the features of landscape structure and its potential.

Methods

The studies were done both through map analysis (topographical, soil-agriculture, forest, hydrogeological) and field investigations. The review of the methods applied to such studies in the areas of young glacial geomorphology disclosed that relief, lithology, plant cover or land use are most often used as the keys for delimitation of geocomplexes . The first two are widely regarded as the leading ones, whereas plant cover is, in common opinion, the best indicative element in landscape.

I also reviewed the methods in landscape potential studies which were applied in

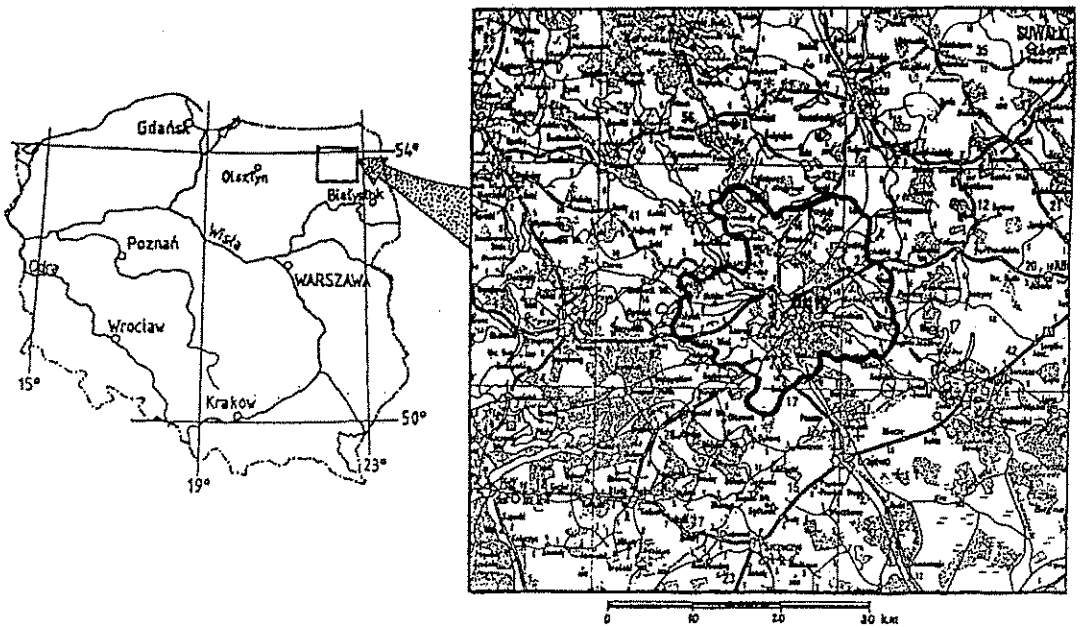

Fig.1. Location of the study area.

Germany (Haase, 1978; Haase, 1983; Mannsfeld, 1983), Slovakia (Polaćik, et al., 1983), Russia and Poland (Richling, 1992; Kistowski, in press). This review showed that, as a rule, two main groups of the potentials are defined:

1. Potentials which control landscape equilibrium (the so-called selfregulation-resistance potentials).
2. Potentials of usefulness.

As elementary fields for estimations making serve natural units such as geocomplexes, regions or catchment basins and there were expressed in 3-5 degree quality classes.

In the case of my studies, geocomplexes were used as elementary spatial units for the studies of the landscape structure. Geocomplexes were delimited with the method of overlapping of boundaries of partial geocomplexes, based on elementary landscape testing, and were supported with the examination of lithological properties of surficial deposits and land use investigations.

A characteristic feature of elementary landscapes is an intensive surficial circulation of the matter, which strictly depends on the relief of the area. As a base for their delimitation I adopted Perelman's (1971) scheme, with some minor modifications of his terminology. As a result, 6 types of elementary landscapes were defined:

1. Landscape of alimentation (autonomous) /I/.
2. Landscape of transition (with lower /II/ or higher /III/ intensiveness of processes).
3. Compound landscape /IV/.
4. Landscape of deposition (partially /V/ or entirely /VI/ closed).

Lithological properties of the surficial deposits (shallow geology) were encompassed in 8 classes:

1. Gravel and loose sands /A/.

2. Sands underlain with tills and muds /B/.
3. Organic deposits underlain with sands, muds and tills /C/.
4. Consolidated (heavy) tills and clays underlain with sands, muds and loose tills /D/.
5. Sands, muds and loose tills underlain with heavy tills and clays /E/.
6. Consolidated (heavy) tills and clay /F/.
7. Organic deposits (peat's) /G/.
8. Man-made deposits (banks) /H/.

Among land use/land cover pattern of the area under investigations, I defined:

1. Arable lands /1/.
2. Meadows and pastures /2/.
3. Peat bogs and mires /3/.
4. Forests /4/.
5. Grass on sands /5/.
6. Villages and settlements /6/.
7. Degraded areas /7/.

The lakes were regarded as a separate type of geocomplex.

Besides of the geocomplexes, I also delimited elementary catchment basins, which were regarded as geosystems. The term geosystem is used here 'sensu Armand' (1975), i.e. as a system in which the internal relations are stronger than the external ones, and the boundaries along which run the zones of the least intensity of the matter end energy transfer.

The landscape structure analysis was carried out separately for the types of geocomplexes and later on for the geosystems. For all defined types the following were calculated: number of units of a given type, total area and mean area of geocomplex in a given type, as well as a coefficient of internal coherency of the landscape.

In order to estimate the value of the landscape potential, I engaged my own methods, which I developed during the studies of the environmental management in North-Eastern Poland (Kistowski, 1994). Seven potentials were taken into consideration, i.e.:

1. Potential of biotic productivity.
2. Potential for recreation.
3. Potential for building construction.
4. Potential of mineral resources.
5. Potential of water supplies.
6. Potential of atmosphere.
7. Potential of selfregulation and resistance.

At the beginning of my work in 0-3 scale, I estimated the value of potential for each delimited geocomplex. Further, I calculated mean values of potentials for elementary catchment basins, with respect to weights connected to the areas of the individual geocomplexes.

For estimation of the values of potentials I applied a few dozens of tests which defined quality and resources. For example, in order to estimate a potential of a given geocomplex for building construction, I analysed the data concerning: carrying capacity of surficial deposits, the depth to the first horizon of the ground water, the angles of slopes, the presence of outflowless depression. Whereas for estimation of the value of the ground water supply subpotential (a part of general water supply potential) such things as: the thickness of aquifer, its yield, the thickness and lithology of aquifer isolation were taken

into consideration.

For landscape structure - landscape potential analysis - statistical measures such as standard deviation, coefficient of linear correlation and coefficient of variability were used.

Results

In the area of investigation I have delimited 10,978 geocomplexes, which are gathered in 190 types (fig. 2a). Among them there are 75 types of episodic character, which means that each of them covers no more then 0.02% of the total area and comprises no more than 4 individual geocomplexes. Altogether they cover only 1% of the total area.

Preponderant are geocomplexes of the types IB1, IIB1, IVB1, i.e. units situated in different types of elementary landscapes (alimentation, transitional of low intensity of process and compound) at the uniform sandy-tilly lithology used as an arable land. Altogether they encompassed 3,157 individual geocomplexes, which makes up 29% of the total.

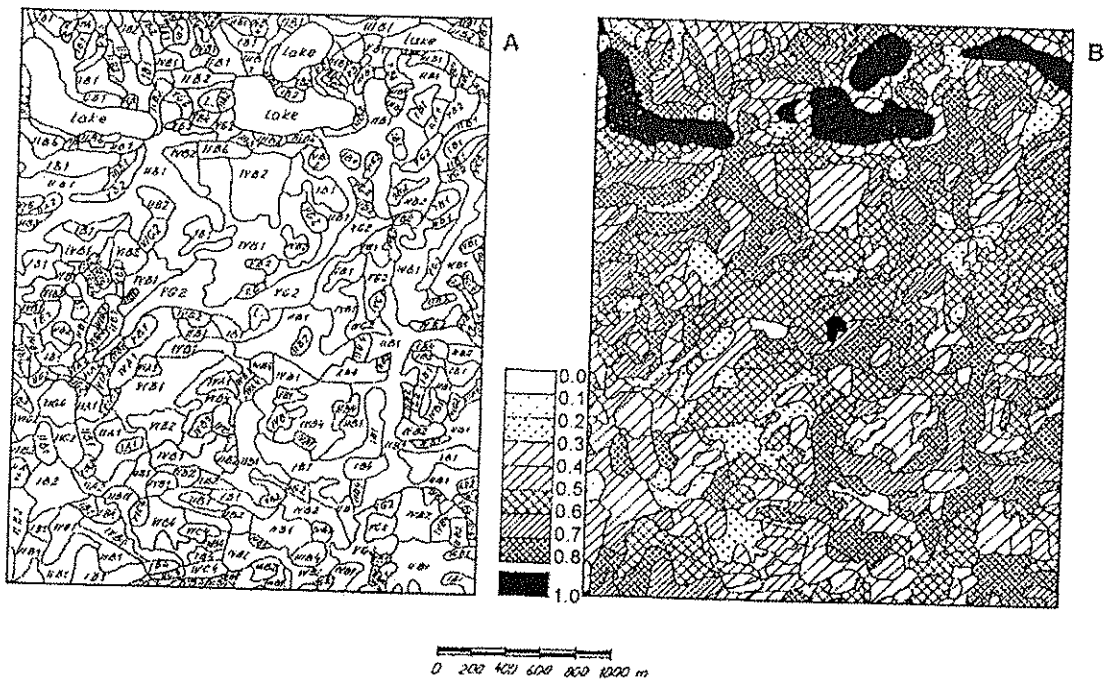

Fig.2. The fragments of landscape maps of the vicinity of Ełk.
(A) Map of geocomplexes (explanations in text);
(B) Map of the coefficient of the internal coherency for geocomplexes.

Types IVB1 and IIB1, plus lakes, cover 32% of the area. An average area of a geocomplex for the entire area reached 3 ha, and the largest geocomplexes are lakes (59.3 ha) or the types situated in compound landscapes.

The coefficient of the internal coherency for geocomplexes ranges from 0.132 to 1.0 (lakes). Its highest values (except lakes) 0.749 has, for example, type VG3 (peat-bogs on organic deposits in a landscape of partly closed deposition), or type IVH6 (villages and

settlements at the man-made bank deposits in compound landscapes) (fig. 2b). The lowest values are those of types IIG4 (forests on organic deposits in transitional landscapes with low intensity of processes) - 0.132 and of type IIA2 (grass on sandy-gravely deposits in the landscapes described in the latter type) - 0.168. The results like those shown above seem to be more the measures of landscape persistence than of its stability.

In the next step I delimited 578 catchment basins, which were the base for further studies on landscape structure. Among them 198 (32.25%) were outflowless basins. An average area of the catchment is 57 ha, and areas of the particular basins range between 2.8 to 1,875 ha.

The analysis of the structure of landscape of the geosystem revealed that most of them are typical at an average degree (fig. 3a). Characteristic for most geosystems, and especially for those situated at morainic plateaus, is their average area. High value of the area is typical for geocomplexes in the geosystems, which contain lakes and vast peat-bogs. Inversely proportional is the relation between the average area of geocomplex and the coefficient of landscape contrastness. The lowest in the geosystems of lakes and peat-bogs or on the outwash plains, the highest in the areas of morainic origin. But the coefficient of the internal coherence of landscape for geosystems displays mean values of 0.4-0.6 for 78%, i.e. 454 geosystems.

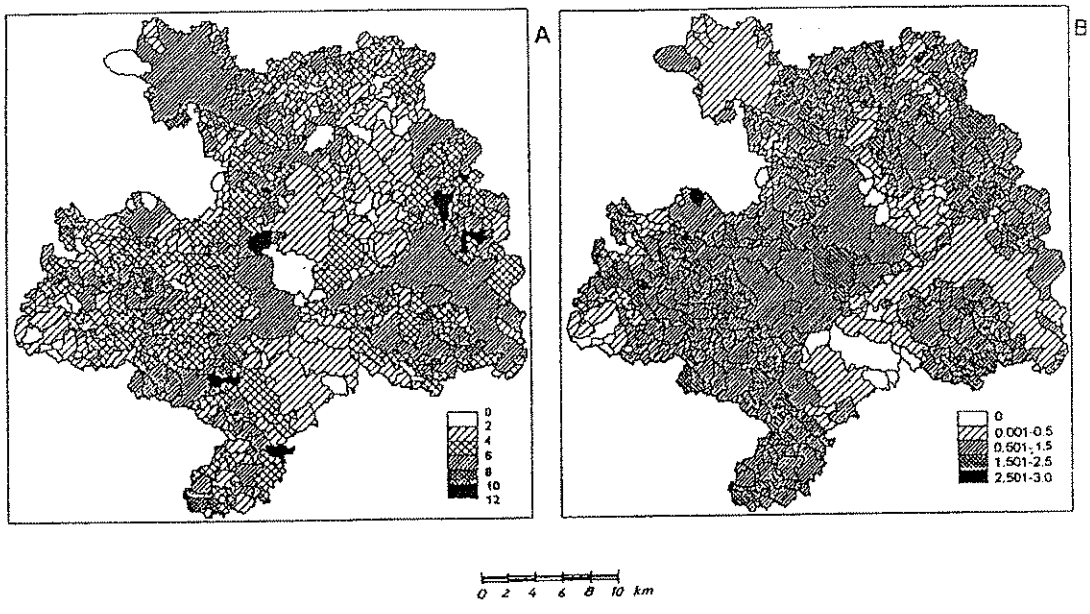

Fig.3. The examples of maps of landscape indicator and partial landscape potential for geosystems in the vicinity of Ełk. (A) Coefficient of the landscape type; (B) Potential for building construction: 1-no potential, 2-very low, 3-low, 4-moderate, 5-high.

High, as a rule, were the values of the coefficient of relative landscape entropy (0.7), which indicates a high degree of landscape heterogeneity in the vicinity of the city of Ełk, especially in those parts which are situated on morainic plateaus.

The estimation of the geosystems landscape potential for the same area gave

interesting results. Biotic productivity potential - mean values. Potential for recreation - low, mean only around the lakes. Potential for building construction - low (fig. 3b). Potential of mineral resources - very low. Water supply potential - low (mean only in catchments of the lakes). Atmospherical potential - generally high. Potential of selfregulation-resistance - mainly mean.

The closer examination of the relations between the landscape structure and its potential started from recognition of the relations, which link the composition, and arrangement of the geocomplexes with their potential. For particular types of geocomplexes mean values of seven partial potentials, a standard deviation from this value and its coefficient of variability were calculated.

The assumption was made that the internal structure of geocomplexes, defined on the basis of elementary landscapes, lithology and land use, is a good indicator of the value of potential whenever the coefficient of variability is less than 20%, and a sufficiently good one for the values of 20 to 50%. This way it became obvious that the composition of geocomplexes is a good indicator for atmospheric potential because 57 of 114 analysed types had the coefficient of variability less than 20%, and for 57 others the values varied between 20 and 50%. For water supply potential, 26 types have values of the coefficient less than 20%, for the rest they varied 20-50%.

Unfortunately, the composition of geocomplexes appeared a very weak basis for the conclusions concerning biotic productivity, and totally useless for estimating such potentials as the ones for: building construction, recreation and mineral resources.

These relations are presented in a landscape profile (fig. 4) which shows that in a quickly changeable are potentials of biotic productivity, for building construction, atmospheric and selfregulational, in slow way perform changes of such potentials as recreational, resources and water supply.

I did not discover any relations, which link the number and the area of geocomplexes of a given type with the coefficient of the internal coherence of the geocomplex type and the values of partial potentials of the landscape. The examination of the relations between the characteristics of the landscape structure of geosystems and their potential exposed some relations of the correlative nature.

Directly proportional relation links the coefficient of the landscape type and the potential for building construction (coefficient of correlation 0.6) (fig. 5a), inversely proportional recreational potential (coefficient of correlation -0.5) (fig. 5b).

Based on these results, one can say that in the vicinity of Ełk the more typical the landscape, the less its usefulness for building construction, and the less typical the landscape, the higher its potential for rècreation.

Conclusions

Summing up all the results, I can say that the assumption concerning the relations between the structure of landscape and its potential are confirmed weakly or only within very constrained limits. For the area under investigation and on the basis of the data which served for the analysis of the internal composition of geocomplexes, delimited with the use of the test which included elementary landscapes, lithology of surficial deposits and land use, one can indirectly define the values for potential such as: atmospheric, water supply

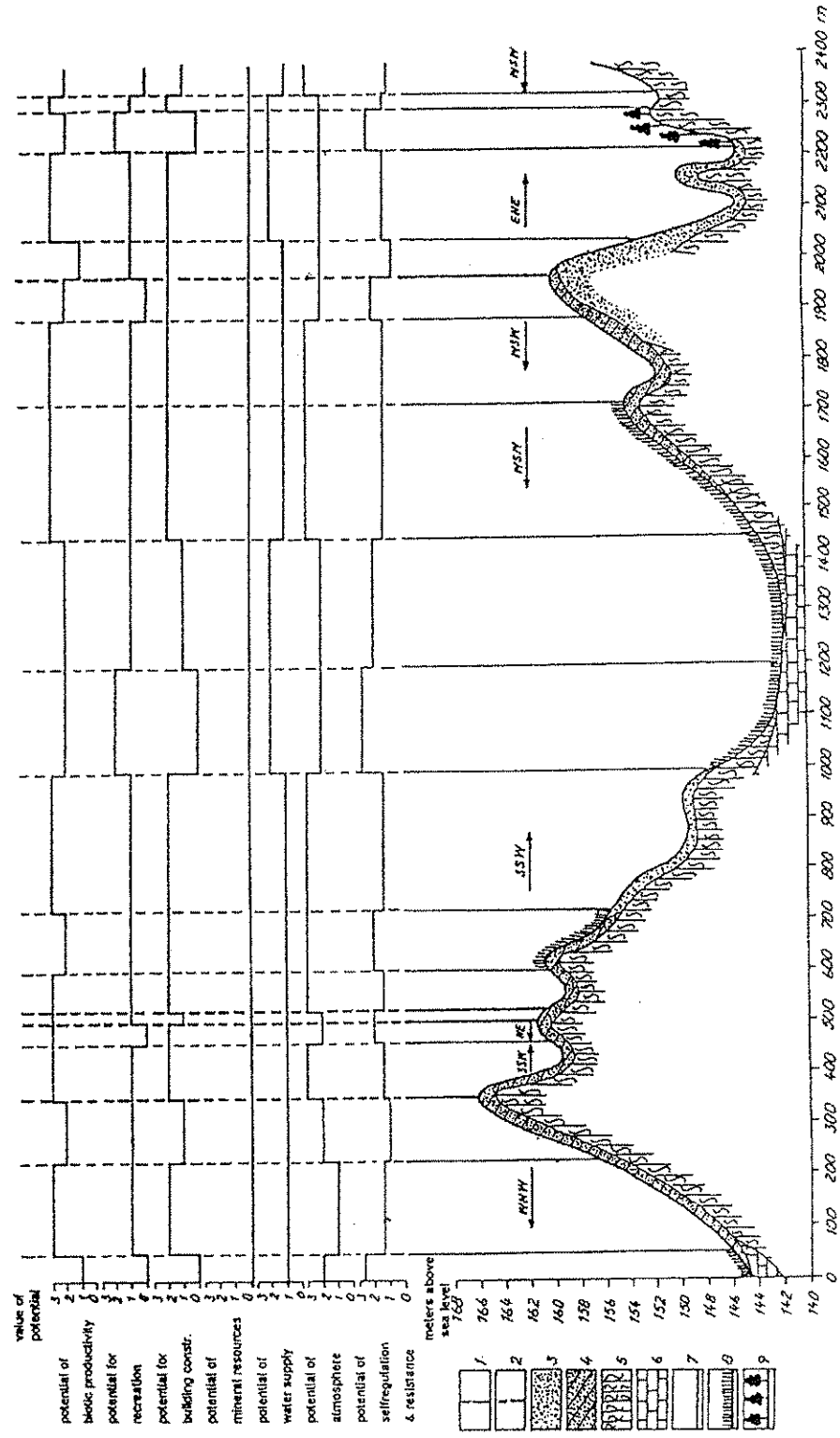

Fig.4. Landscape profile of the vicinity of Etk (example).
Borders of: 1-geocomplexes, 2-geosystems. Surficial deposits: 3-gravel and loose sands, 4-loomy sands, 5-clays, 6-peats. Land use: 7-arable lands, 8-meadows and pastures, 9-leafy forests

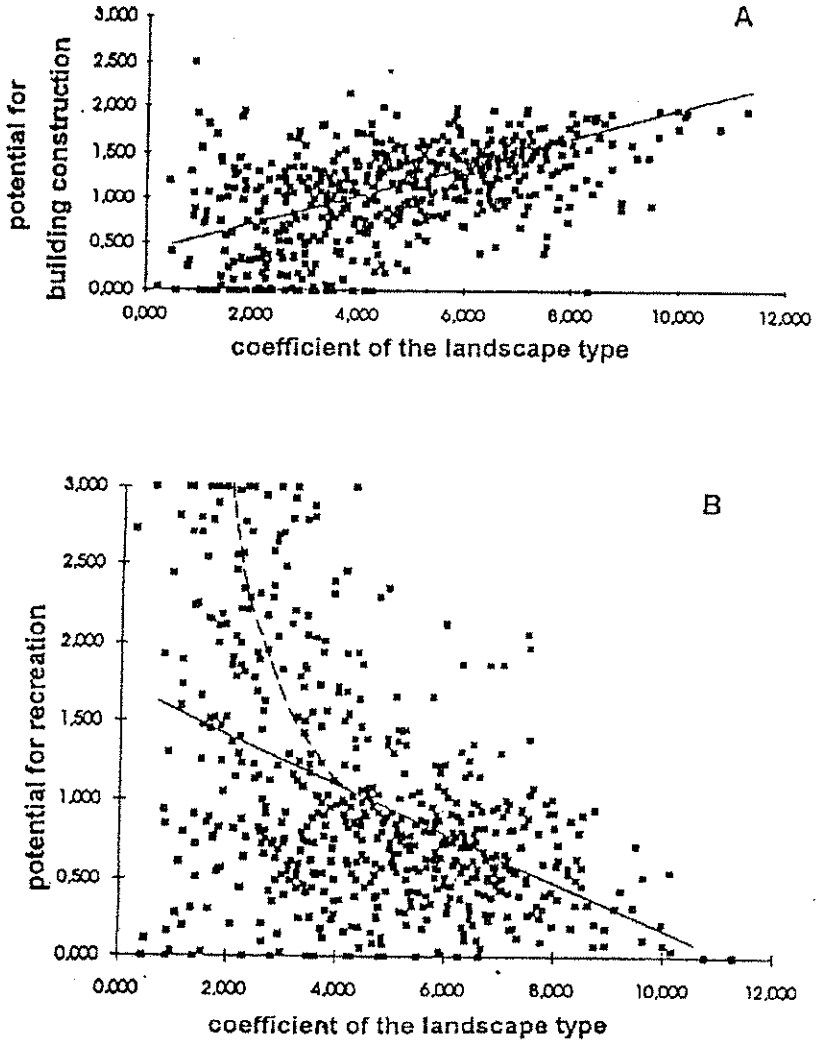

Fig.5. Correlation between coefficient of the landscape type and potential for building construction (A) and recreational potential (B)

and biotic productivity (with an approximation). But in the case of indirect estimation of the potentials for building construction and recreation it is far better to apply the indicators of the landscape type or the coefficient of the internal coherence. And, when doing so, it is necessary to keep in mind that the coefficient of correlation for these relations is rather low (0.5-0.6), which, in turn, makes it impossible to accept the coefficient of typicality as a sole test for the estimation of the values of these potentials in an indirect way.

The above statements concern the vicinity of Elk in North-Eastern Poland, thus their significance is local only. Further studies are needed for their extrapolation onto other areas of young glacial landscapes. It can be a very useful task, especially under the circumstances of general lack of results of direct field studies, which are indispensable for rational planning of the environmental management.

References

Armand, A.D., 1975. *Tieorija pola i problema wydielenija gieosistem.* In: Koliczestwiennyje mietody izuczenija prirody. Woprosy gieografii, 98, Moskwa.

Haase, G., 1978. *Zur Ableitung und Kennzeichnung von Naturpotentialen.* Pettermanns Geogr. Mitt., 122.2.

Haase, G., 1983. *Concept and methodical outlines of a medium-scale landscape survey of the German Democratic Republic.* In: Landscape Synthesis. Geoecological Foundations of the Complex Landscape Management. Veda, Bratyslava.

Kistowski, M., 1994. *Land use planning: Potential conflicts and landscape stability in the North-Eastern Poland.* In: Landscape Research and Its Applications in Environmental Management. Warsaw University, IALE, Warszawa.

Kistowski, M. *Zastosowanie koncepcji potencjałów częściowych krajobrazu do oceny przyrodniczych podstaw zagospodarowania przestrzennego obszarów młodoglacjalnych.* Przegl. Geogr. (in press)

Mannsfeld, K., 1983. *Results of geo-ecological investigations of natural potentialities as foundation to planning and management of the landscape system.* In:Landscape Synthesis. Geoecological Foundations of the Complex Landscape Management. Veda, Bratyslava.

Perelman, A.J., 1971. *Geochemia krajobrazu.* PWN, Warszawa.

Polaćik S., Otáheľ J., 1983. *Quantitative analysis of the landscape potential functions (suitabilities) of the Tatranska Lomnica model territory.* In: Landscape Synthesis. Geoecological Foundations of the Complex Landscape Management. Veda, Bratislava.

Richling A., 1992. *Kompleksowa geografia fizyczna.* PWN, Warszawa.