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LIMNOLOGIC STUDIES ON ANTHROPOPRESSURE IN THE LIGHT OF CARTOGRAPHICAL RESEARCH METHOD

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ABSTRACT

Numerous studies, carried out in relation to problems of degradation and protection of environment, use in various ways cartographic research method. Anthropopressure is one of the issues widely discussed here. Among its numerous symptoms, pollution of surface still waters should attract greater attention, as it leads to changes in water systems, intensive eutrophication and acceleration of natural processes of trough decline.

The objective of this study is the presentation of opportunities of obtaining wide specter of data by applying cartographical research method in the course of limnological research on the question of anthropopressure. To use both static and dynamic potential of map to its full capacity, various methods of map analysis, including visual analysis, cartometric research, statistic and mathematical analysis and other methods were applied. On the course of research not only the most popular method of direct analysis of individual maps was applied, but also a complex analysis of maps on various topics

INTRODUCTION

Anthropopressure is one of the issues subject to wider analysis in environmental research, due to its degrading impact on natural environment. Surface waters pollution, determined by extensive anthropopressure, is one of its most hazardous symptoms as it leads to changes in water systems, intensive eutrophication and degradation of lake basins. Natural process of trough decline is rapidly accelerated, thus leading to shortening of life span of these objects. Main purposes of that ongoing process are to be indicated in intensive emissions of industrial and municipal wastewaters, growing tourism, intensified animal farming, excessive use of chemicals in farming and forestry, but also in changes of conditions in drainage basins, mainly structure of land use and melioration. The power of interaction of those factors depends upon the lake characteristics, inter alia, morphometric conditions of lake basin and of water supply pattern, but also depends upon the characteristics of its drainage basin: its size and share of hydrologically active areas. The issue is very complex and uneasy for overall analysis. Such extended research requires application of cartographic research method.

VISUAL ANALYSIS

Visual analysis is a most commonly applied research method based on a map. It enables distinguishing particular characteristics of forms, comparison of objects' size, determining regularities of location or revealing of spatial correlations (Saliszczew 1984). In limnology this method is mainly used for a selection of objects for research.

Selection criteria for objects for particular research are various and strictly dependent upon analysis objectives or research concept. Limnologic studies in anthropressure analysis are most frequently related to:

- Groups of lakes located within a given lake district or a region or in drainage basin of a superior hydrologic unit
- Single lakes distinguishing themselves due to their environmental conditions or significant danger of anthropopressure.
- Specific lakes, representative for a given area, where characteristic features, with accordance to which the selection is done, are up to a researcher.

The visual analysis is applicable with the first two types of studies mentioned above. In first type of study, among the selection methods mentioned, topographic maps in various scales are used, as well as airplane and satellite photos and cartographic studies related to regionalisation. But analysis of many map sheets is laborious and time-consuming. Alike is also when analysing a hydrologic map, available in Poland in the scale of 1:50,000. Therefore studies separating limnologic components from contents of primary map are very helpful. 'The Catalogue of Polish Lakes" (Katalog jezior Polski), covering the area of Poland, deserves special attention. That atlas in three parts

subsequently presents natural lakes of the size of above 1 hectare situated in three lake districts: Pomorskie, Mazurskie and Wielkopolsko- Kujawskie with the rest of the country. The author applied conversion of cartographic image by simplification of a map. First chapter of each part presents location of lakes, according to topographic maps in the scale of 1:50,000, thus giving the basis for calculations of morphometric data. Each lake within a map sheet has its own number, enabling its swift identification, even if it hasn't got a name. For better orientation, also sizeable surface water flows and towns were placed on maps, as well as division lines of main watersheds. Thus this study is indispensable for a quick search for each lake in given area, but precise location of a lake in regional unit or secondary watersheds is impossible. Ideal study for localisation of lakes broken down into separate drainage basins is "Hydrologic Division of Poland' (Podzial hydrograficzny Polski). It presents natural as well as artificial lakes (infrequently shown in most studies), but due to relatively small scale (1:200,000) it is not suitable for locating smaller lakes directly on a map, thus restricting significantly its application, as the lakes of area 1 to 5 hectares stand for 46 per cent of total number of lakes in Poland.

The easiest localisation of study objects subject to intensive anthropopressure is on the basis of sozologic map, thanks to included elements describing:

- land surface degradation (land subject to degradation, liable to floods or storms, grounds transformed by a man);
- soil, forests, surface and ground waters degradation (with regard to water quality class and to excess of pollution ratios; points of wastewater emissions);
- changes of water condition due to anthropogenic activities (cumulations of water, industrial water basins, fishery basins, disturbances in hydrologic system of a surface water flow caused by human activity);
- air degradation (including gas, dust, noise and vibration emitters),
- investments with extremely negative impact on environment, wastewater emitters,
- solid waste dumps, fuel and raw material depots,
- areas transformed due to mining activity: excavations, dumps, post-excavation deformations; also information on investments harmful to environment.

Basing on visual analysis of cartographic data, to meet the objectives of this study, the Lake Dabrowskie was selected. It is a small, young, postglacial lake, located in the system of postglacial channels in Kaszubskie Lake District. The catchment area is linked with the river system, being currently in the development stage, and the whole area in abundant in hydrographic elements. There are numerous marshes, temporary and permanent, and bogs, forming entire systems and also there are areas without flow. The catchment of the Lake Dabrowskie is an area of varied land use. There are vast areas covered by forests, farmlands and also areas antropogenically transformed, with considerable ratio of vacation buildings. These are farmlands and holidaymaking areas, which represent the greatest danger for lake systems located beyond metropolitan or industrial areas.

CARTOMETRIC RESEARCH

Measurements and calculations based on map refer to a wide spectre of phenomena. Cartometry, applied in a traditional way, can be used in limnologic research, which is mainly based on a search for morphometric data for individual lakes. Most precise data on morphometry of Polish lakes can be obtained directly from bathymetric plans and from cards attached to them, elaborated in sixties of last century in Inland Fishery Institute in Olsztyn (Instytut Rybactwa Srodladowego). But, due to lack of overall summary and lack of publisher's edition, the data availability is impeded, only few of them were used in limnologic studies. Attached cards contain many useful items of information, suitable as the selection criteria for objects of studies. They precisely locate objects according to administrative division (voivodeship, county), geographic longitude and latitude, as well as to location in river catchment (a sequence of river names is used there from main river to small intakes) They enable a selection of the lakes with similar morphometric characteristics, such as: area of waters, area of islands, maximum depth, average and relative depth, depth index, volume, maximum length and width, average width, maximum effective length and width, length of a lake and islands shoreline. Based on those data a full identification of limnologic system of a lake can be made, which enables define difference of energetic characteristics, water exchange conditions and quality assessment of water environment. These are important aspects of anthropopressure analysis, for many processes occurring in lakes are, to some extend, dependent upon morphometric parameters. On their basis we can expect occurrence of certain hydrodynamic and thermal phenomena. We can also describe the progress of sedimentation process, and also circulation and production of organic matter, and subsequently susceptibility to eutrophication. Recognition of morphometric parameters is also important for water balance of a lake and of its catchment as well as for the assessment of water resources and their changes.

Individual parameters may be aggregated in two groups:

- describing external dimensions of a lake, derived from a map
- describing a bed of a lake, on a basis of bathymetric plan

Ratio analysis referring to the Lake Dabrowskie allows describe full characteristics of that lake. Although some ratios are based on the same values, but they are complementary to each other, and their analysis gives an opportunity to assess the status of analysed lake according to various morphometric classifications.

On the basis of morphometric data of the Lake Dabrowskie, listed in the Figure 1, it can be stated, that it is a lake of an average size. Although its area is by 50 per cent greater than the average for Polish lakes, but relatively it is not a big lake. The length of that lake is insignificant and close to effective length, which leads to increase in capacity to generate waves and to deeper location of the wave base, resulting in mixing of water layers. The mean depth suggest that wind mixing concerns the greater part of water, and spring and autumn mixing should result in mixing of the whole volume of waters. Exposure ratio allows drawing conclusions upon the influence of external factors on the lake, mostly climate factors, meaning thermal and circulation conditions of the lake's body: it is justified to judge about their restricted influence, due to small area of the lake. Water volume parameter is important to estimate the size of water resources cumulated in the lake trough. The size of the Lake Dabrowskie doesn't allow to cumulate large amount of waters, thus reducing its retention capacity.

Parameter		Value
Describing surface of a lake	Area [$10^4 m^2$]	64,3
	Length [m]	2370
	Maximum effective length [m]	2330
	Maximum width [m]	470
	Average width [m]	271
	Maximum effective width [m]	470
	Extension ratio	5,0
	Shoreline length [m]	5615
	Shoreline length development [m·ha]	87
	Shoreline length development	1,98
Describing bed of the lake	Maximum depth [m]	15,2
	Average depth [m]	6,4
	Relative depth according to Halbfass	0,0189
	Relative depth according to Ivanov	0,0741
	Relative depth according to Hutchinson [%]	1,6799
	Depth ration (bed shape)	0,42
	Volume development	1,26
	Exposure ratio [$10^4 m$]	10,05
	Density ratio [m]	0,064
	Water volume [$10^3 m^3$]	4114,6

Figure 1: Basic characteristics of the Lake Dabrowskie

MATHEMATIC AND STATISTIC ANALYSIS

Statistic studies based on maps are one of basic working tools for limnologists. They allow assessment of an environmental impact on water basins and determine leading factors. They facilitate identification time and spatial relationships with anthropopressure. It is difficult to interpret current state of a lake without a reference to its surroundings, whose characteristics determine the volume and time of supply of various forms of matter and energy to a lake. Impact of catchment on a lake is undoubted, and its restriction may result only from natural immunity of a lake. That statement refers not only to its proximate part, being in evident contact with a lake, but also to entire catchment, affecting a lake through inflows. Level of impact of entire catchment on a lake can be characterised by following parameters:

- Ohle's coefficient: quotient of total area of a lake catchment and of area of a lake;
- Schindler's coefficient: relation of combined area of a lake and its catchment to lake's volume, characterising mutual relations between those objects;
- Size of a part of catchment area participating in matter supply to a lake: a degree of the lack of outflows from a given area – correct identification of hydrologic structure of the catchment, in particular of active and passive areas, is important because steady and direct supply to a lake takes place from active areas, while passive areas do not participate in supplying a lake or that supply takes place under ground, so that waters flowing into a lake are subject to filtering and thus their characteristics are subject to transformation;
- Average declivity of catchment: it characterises the velocity of running water flow and subsequently, intensity of chemical denudation in drainage basin;

- Percentage share of each type of land use within the area: determines quantitative and qualitative characteristics of surface waters inflow.

On the basis of available cartographic sources, with analysis of land configuration, hydrologic objects location, type of geological bedding and type of land use, a hydrographic map of the catchment of the Lake Dabrowskie and a map of its spatial development were elaborated. The cartographic image, transformed in this way, made an analysis possible with regard to characteristics of catchment impact on a lake, which were listed above.

Research prepared in such a manner-enabled analysis of structure of catchment use, broken down into entire and proximate catchment, as well as active and passive catchment. Results are presented in the Figure 2.

Structure of land use in proximate catchment is quite similar to that of entire catchment. Most of the area is covered by forests. These are mostly coniferous plantations at the age of more than 30 years. There are also pine forests grown on mineral subsoil and small areas of young forests and marsh forests. Considerable hydrologic activity has no significant meaning,. Forests grow evenly in virtually entire area, excluding only southwest outskirts. Nearly 30 per cent of the area is covered by farmlands, situated mostly in eastern and southern part of catchment. There are arable lands as well as pasturelands, but those cover only small percentage of farmlands. Luckily most of arable and pasturelands are situated in passive areas. Waters cover 8 per cent of the area and are evenly located over the entire area. Two main lakes mostly make up that percentage. Antropogenic activity is visible in village buildings, communication roads and also land development for tourism, but covers only a small part of the catchment. The rest is covered by barren land with peat-bogs and marshes.

Land use type	Structure of catchment use											
	Proximate catchment						Entire catchment					
	active		passive		total		active		Passive		Total	
	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
Forests	1,663	46,0	2,108	53,5	3,771	49,9	3,636	60,8	4,114	68,3	7,751	64,6
Waters	0,643	17,8	0,029	0,7	0,672	8,9	0,986	16,5	0,038	0,6	1,024	8,5
Arable land	0,807	22,3	1,263	32,0	2,070	27,4	0,807	13,5	1,263	21,9	2,070	17,3
Pastureland	0,209	5,8	0,408	10,3	0,616	8,1	0,241	4,0	0,466	7,5	0,706	5,9
Other	0,292	8,1	0,135	3,4	0,427	5,7	0,308	5,2	0,137	2,2	0,445	3,7

Figure 2: Structure of land use in the Lake Dabrowskie catchment

Low, 18.7 Ohle's coefficient shows little activity of catchment against the lake, due to high share of areas with no outflow, which are passive or slightly active against the lake. Also low surface waters' supply, due to low density of river network and forestry as a dominant form of land use, against small agricultural transformations, reduce the degree of influence of catchment on the lake itself. Occuring here quite high value of Schindler's coefficient is treated as proportional to the ratios for water quality, because it sets relationship of area, between the quantity of pollutants absorbed to water quantity in which pollutants are dissolved, yet with no regard to passive part of catchment, described earlier.

Type of spatial development in catchment area is also reflected in the size of chemical denudation. Denudation depends upon the size of erosion taking place in a given area and that depends upon the quality of spatial development. The size of chemical denudation for hydrologically active entire catchment of the Lake Dabrowskie is shown in the Figure 3.

XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI-IV	V-IX	XI-X
9,9	4,8	14,1	8,6	49,1	16,7	16,1	12,8	81,8	4,6	59,0	4,3	103,2	178,7	281,9

Figure 3: Estimated size of chemical denudation in $t \cdot km^{-2}$ in the Lake Dabrowskie catchment

High numbers for denudation arise mostly from a share of farmlands in entire catchment. Within the farmland areas erosion is the highest, according to Kajak (1979), up to 17,000 $kg \cdot ha^{-1} \cdot year^{-1}$, compared to 200 times lower forest erosion or 20 times lower pasturelands' erosion, which actually have very minor impact on the process of denudation. So, calculated on the basis of coefficients mentioned above, total size of erosion in hydrologically active part of the

entire catchment stands for 1423,291 $t \cdot year^{-1}$, which gives the numbers for denudation close to the result of calculations, equalling to 238,1 $t \cdot km^{-2} \cdot year^{-1}$.

Due to the type of land use in the catchment area, dominant type of pollutants emitted to the lake are biogens. The assessment of the actual size of nutrients' inflow from external sources is based on estimated, empirically set, annual units of flow described in $kg \cdot ha^{-1}$. Based on the size of inflowing load of total phosphorus as described by Kajak (1979) for areas of diverse land use, the following numbers were taken for annual flows from a hectare: 0.1 kg for forests, 0.3 kg for meadows and pastureland; 1.0 kg for arable land, while for antropogenically transformed lands: 15.0 kg. The areas adjacent to lakes and in river drainage basins were identified as active. Actual load, estimated in this way is, for proximate catchment, $541{,}6 kg \cdot ha^{-1} \cdot year^{-1}$ and $44{,}69 kg \cdot ha^{-1} \cdot year^{-1}$ for catchment elevated above the lake, thus giving the aggregated value of $586{,}29 kg \cdot ha^{-1} \cdot year^{-1}$. Comparing those numbers to the values for permissible and dangerous loads, calculated on the basis of Vollenweider's formula (1976), which are, respectively, 303,6 and $607{,}86 mgP \cdot m^{-2} \cdot year^{-1}$, clearly visible is significant excess of permissible, but also dangerous loads. It can be then assumed, that, as a result of pressure from catchment, the Lake Dabrowskie is subject to intensive eutrophication, resulting mostly from anthropogenic activity within the studied area.

FINAL CONCLUSIONS

Cartographic research method is widely and diversely applied in limnologic research. It enables researches conduct an introductory phenomenal analysis and is an introduction to a further research, with contribution from other sciences, such as chemistry, biology or physics.

Cartographic research method not only enables an analysis of spatial allocation and of regularity of a given phenomenon, but also helps revealing their relations. It is an important tool in studying the impact of anthropopressure on lakes: during introductory stage of research objects' selection, as well as during morphometric analysis of lakes' beds and during determining mutual relations of lakes and their catchments. So it fulfils its assumed application of maps for description, analysis and scientific perception of phenomena, with special regard to cognitive function, serving the spatial phenomenal research .

Use of cartographic research method in limnologic studies takes advantage of not only its static potential, through the information on map, but also of the dynamic potential. A map is a model of reality, on which studies and analyses are based, leading to a wider recognition of reality.

REFERENCES

1. Choinski A., 1991-92, Katalog jezior Polski, Wydawnictwo UAM, Fundacja „Warta", Poznan
2. Kajak Z., 1979, Eutrofizacja jezior, PWN, Warszawa
3. Podzial hydrograficzny Polski, 1980, praca zbiorowa, IMGW, Warszawa
4. Saliszczew K.A., 1984, Kartografia ogolna, PWN, Warszawa
5. Vollenweider R.A., 1976, Advances in defining critical loading levels for phosphorus in lakes eutrophication, Mem. Ist. Ital. Idrobio. Dott. Marco Marchi, 33

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