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MONITORING THE ENVIRONMENT OF AGRICULTURAL BASINS BY MEANS OF COMPUTER PROGRAMMES

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A b s t r a c t. The present study presents a method for monitoring the environment of agricultural river basins supported by a system of specialists computer programmes. It is related to the traditions of complex environmental studies and the processes of water circulation in different types of study basins (representative and experimental). It consists in current monitoring of mutual relations between: 1. Geographical conditions of the basin, 2. Hydrological conditions of the outflow (including hydraulic parameters of river bottoms), and 3. Physico-chemical water properties as a function of the growing area of river basin (calculated along all the possible outflow routes, water-runs and rivers). The method presented by the author assumes a description of the basin conditions in a raster type of square plots with an assumed size. The NIT system (Numeric Information on Terrain) together with some chosen computer programmes has been chosen for the process of data collection and processing.

K e y w o r d s: agricultural basins, computer programmes, monitoring the environment

INTRODUCTION

River basins are hierarchical, complex "hydroecosystems" that are inter-connected in a cascade way. They consist of many components, both organic (biosphere), and non-organic (geosphere), as well as man-made elements (anthroposhpere). As relatively isolated systems, they nevertheless remain in constant touch with the environment: among others they absorb and transform solar energy and heat energy of the Earth, are subjected to the influences of gravitation, undergo global and regional circulation of air masses. As geosystems they function thanks to the outer exchange and inner balance of the streams of energy and matter controlled and sustained by means of a complicated net of feedback. River basins are moreover subjected to the influence of anthropogenic factors. As a result of human activities physiographic and hydrodynamic properties change in an evolutionary and sometimes rapid (catastrophic) way.

Increasing anthropopressure makes monitoring and balancing of all the possible migration routes and circulation of pollution in the spatial system of basins necessary [1,4,9,11]. There is a growing need for continuous monitoring of the condition of the basin environment, and to evaluate the level of danger that threatens it. Collection of large amounts of geographic data combined with quick data processing (in real time) becomes more and more common. It can only be possible with wide application both in practice and in scientific research of specialist numerical programmes and GIS systems.

The present study is related to the concept of Integrated Monitoring of Natural Environment based on the contemporary measuring systems for river basins and numerical programmes - methods of identification and analysis of the conditions in the agriculturally utilised basins.

BASIC ASSUMPTIONS OF THE METHOD OF HYDROLOGICAL MONITORING

River basins as study object are characterised by an infinite variety of possible features and geographic conditions (Fig. 1). That is why any attempts to map their real situation must be simplified; it depends, to a large extend, on the choice of basic parameters for the description, assumed net of measuring points and basic spatial units (partial basins). In each of the cases the method and density of sample collection is decisive for the level of detail obtained, whereas the number of properties taken into account and the system used for coding the measuring scale is crucial for the accuracy of the information recorded. A lot of methodological issues and problems should be considered in the hydrological studies of agriculturally utilised basins during the process of modelling of both the course of individual elements and integral water circulation systems (see Appendix). In the measuring range it is important to recognise both geographic conditions of the basin, hydrodynamic conditions of outflow and qualitative (physico-chemical) properties of rivers in the system of assumed partial basins or chosen "longitudinal basin profiles" delineated along some determined outflow routes. It also seems necessary to aim at a wider application of the method of hydrological analogy for the evaluation of the characteristic flow levels and qualitative properties of water on the basis of periodical (synoptic) measurements carried out in the densely localised pre-fixed hydrometric profiles. Hence, the process of proper choice of observation points should be proceeded by the specialist terrain carting that would aim at establishing typology of natural and man-made elements of water net (river beds, canals, melioration systems) and would be carried out on the basis of some chosen hydraulic parameters. It should also depend on the structure of outflow net and spatial distribution of the areas and points that are the source of pollution for water in rivers, as well as on the degree of accuracy of the studies carried out. The established density of the measuring points should enable correct extrapolation of data and evaluation of outflow and water quality at the individual study points (sections) of the river net at the same time taking into consideration results of observations carried out at the datum points that take continuous recording of all the necessary data (meteorological, hydrometric, and hydrochemical). The results and terms of current observations should moreover take into consideration variability of meteorological and hydrological situation in time, and especially periodical sequences of low and high water.

When enough sufficiently representative sample data has been gathered, the process of data collection should be the basis for further analysis that would consists in establishing reduction indices or regression equations that enable an easy transfer of hydrological data from the datum points to the chosen measuring points. Another important task of the proposed method is preparation of basin description using computer GIS systems (Geographic Information System). It should make mathematical modelling of water circulation processes and pollution spreading in the natural environment easier. In practice it means that it is necessary to prepare a spatial data formed from the various information sources (mainly maps, and satellite and aeroplane photos) a base that would contain, among others, information on the structure of land utilisation and conditions of agricultural basin usage, and on the type of soil and geological formations. A description of a basin will also contain necessary phenological, agrotechnical, meteorological information, as well as basic morphometric characteristics - inclinations and exposures obtained from the numerical model of the terrain.

An indispensable condition for the application of the proposed monitoring method is a possibility to carry out automatic identification of the outflow line and borders of partial basins, and to average or sum up some chosen geographic properties of the basins as well as to design anamorphic maps and graphs accordingly.

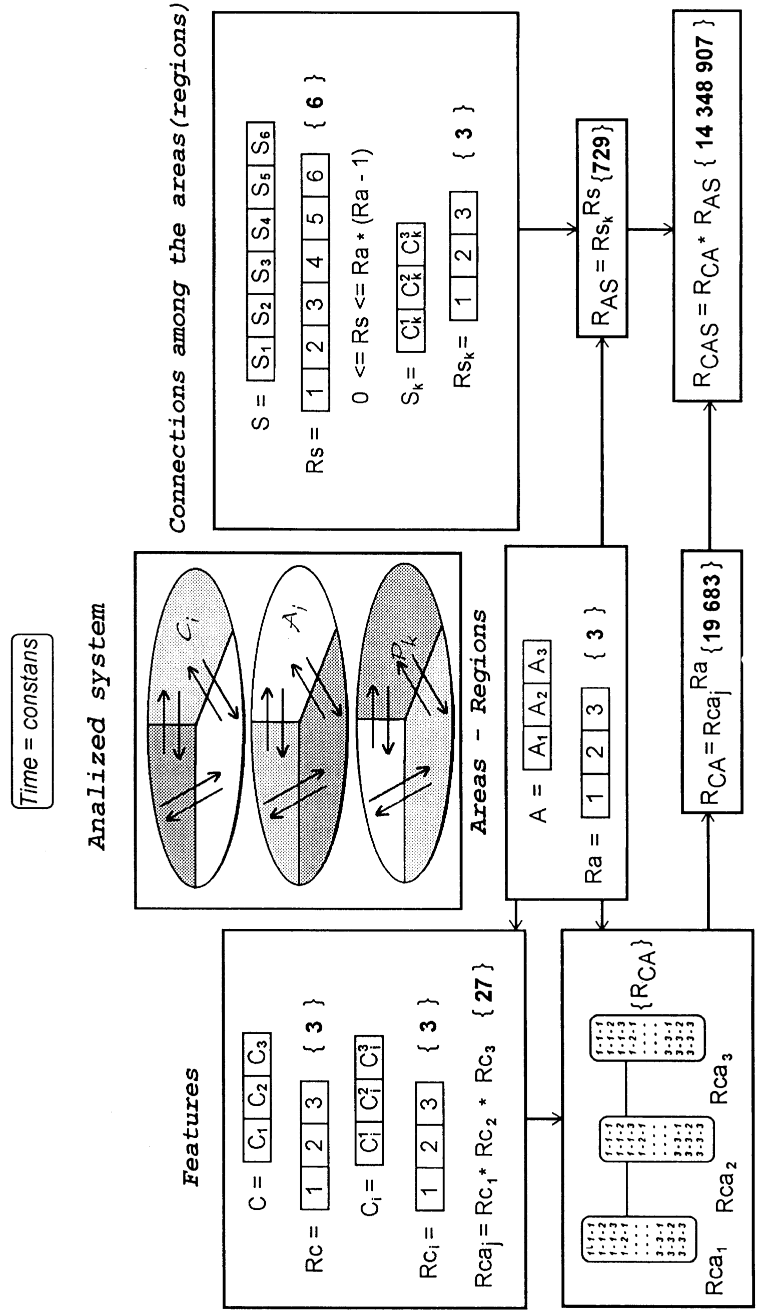


Fig. 1. Differentiation in the basin conditions - A scheme of a basin consisting of three interconnected subplots described with three parameters. It assumes that the levels of properties and intensity of interconnections are measured in a three-grade scale. Variety of combinations in the basin conditions are expressed by the figures presented in the scheme, and the total number of possible combinations is 14 348 907.

COMPUTER PROGRAMME TO SUPPORT MONITORING OF RIVER BASINS

A numerical system of the information on terrain (NIT) [10,12] is proposed for the description and analysis of the condition of basin environment. It assumes that variation in time and space (geographic) in the basin can be approximated (recorded) with sufficient accuracy in the regular pattern of square plots with specific size that had been adjusted to the requirements of the studies carried out. The main basis of the NIT system is used for storing continuous information that cover the analysed basins. Whereas information on the objects that are treated as isolated points or ranges with specific spatial extend are recorded in the IBI base (Information of the Significant Study Objects), and data on the course in time that represent results of measurements are recorded in the SEC base (Systemic Editor of Time Sequences).

Beside the software package for running and control of the above mentioned data bases with that content that give a static or dynamic image of the geographic condition of a basin, a suitable set of processing procedures have also been included in the structure of the NIT system in order to monitor the environment of the agriculturally utilised basins. The following programmes are regarded as most important: NURT (Numerical Analysis of Terrain Relief), IDEM (Indentification of Possible Outflow Routes), and RZUT (Variation of Basins in the Topographic Aspect). The a.m. programmes when interconnected, assure interpretation and description of a basin in a form of a geographical model that consists of a set with linear outflow spheres that are determined perpendicularly to level lines. They start in the water division and finish in the designated key profile, water reservoir, or water run of a higher level.

Among the three programmes mentioned above, NURT determines basic morphometric parameters of the basin (inclines and slope exposition), identifies the structure of the outflow net (in the framework of Horton-Strahler scheme) and executes automatic procedure for hydrographic division, i.e., separates partial basins of an assumed size. The IDEM programme enables easy selection of chosen basin set from the NIT data base when their co-ordinates and closing profiles are given. It also determines all the possible routes and lengths of surface water outflow ways in the designated borders of the basin. Thanks to the above the programme allows for an easy preparation of the chosen (in fact all possible) longitudinal basin profiles that depict the actual geographic conditions or degree of basin transformation, or else the balance of environmental reserves (potentials) in the form of simple or structurally complex topic graphs [11]. The last of the three programmes, i.e., RZUT, calculates the values of the so-called topographic index, that can be used for designing specific anamorphic maps of the basin. The general principle of their construction is a targeted change of original spatial relations and presentation of some specific geographic properties in a transformed and abstract way. In the case considered in the present study, the transformation procedure applied takes on an extreme form, as it consists in projection and reduction (by averaging, integration or differentiation) of the chosen spatial basin properties to the size of single points (pixels) that represent profiles that close these basins. Thanks to this method of map generation outer geometrical borders of the basins remain unchanged, and the spatial (anamorphic) distortion are manifested only inside its contour in the form of transformation of the shape of primary class ranges (qualitative separation) or disturbances in the actual pattern of gradients and values of qualitative features. The underlying aim for the generation of this type of basin map is obtaining a picture of differentiation in the analysed geographic properties of the "multi-dimensional space" of all the hydrographic units that can be isolated in a given area. Hydrological interpretation of this type of cartographic pictures is natural and conceptually understandable as each point on the map denotes a chosen key profile, and a graphic sign denotes a characteristic value of the studied geographic feature in a given basin determined by the profile mentioned above in the assumed scale of symbols.

Beside the typical hydrological programmes that have been described above, and in relation to the idea of monitoring, it is worth to mention procedures that enable identification of physiographically uniform basins and the need for quality evaluation (valorisation) of the chosen area (basin) from the point of view of its agricultural utilisation.

The first task that consists in the numerical classification of the chosen objects (elemental plots, basins, periods) can be carried out by means of the AKD (Automatic Data Classification) programme. It uses a modified algorithm of the so-called geometrical sequential classification [12] with a recurrence course. Sequential classes (agglomerations) are formed gradually, each of the feature vectors that characterises an unclassified object is compared to the centres (centroides) of the groups of the objects established before. The algorithm described here uses a known "city block" metrics and requires standardisation (unitarisation) of the feature variation range and preliminary determination of two empirical parameters that decided on the uniformity and number of classes of objects obtained. Primary "one course" version of the sequential classification prepared by Rzymowski and Stachura [13] has been supplemented by further possibilities of secondary classifications. In the course of further runs new class media are established according to the exactly the same rules as in the primary run. Assuming that processing of the data set has been carried out a predetermined number of times, "new" class centres become "old" after secondary run for the next run. It is worth stressing that before each secondary run, as well as after the primary run, an intuitive (subjective) class selection can be done and the generated agglomerations can be removed if they are undesirable in any sense (i.e., if they contain very few objects). Property vectors that belonged to the removed classes are subjected to the remaining classes in the further course of calculation according to the rule of the "closest neighbourhood". The results obtained by means of AKD programme can be verified and evaluated by means of the initial set generated by it using heuristically defined indices that describe degree of wash-out (indeterminacy) of the classes obtained (Fig. 2).

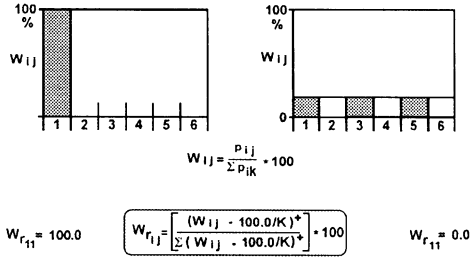


Fig. 2. Schematic diagram of the evaluation of the wash-out condition of the (Wr_{ij}) class - p_{ij} means a similarity and w_{ij} normalised similarity of the "i" object to the centroid of the "j" class.

An important monitoring task of basin quality or value assessment for agricultural purposes or evaluation of any area chosen from the data base is possible using PRW programme (Comparison of equation to the standard). The programme assumes that standard conditions (quality or threat classes) of the natural environment can be defined (projected and given) directly by the user or they can be the objects chosen by him and known to him (analogues) that can be found in the initial information set of the data base. The programme determines a numerical measure of similarity to the standard that fulfils three conditions: 1° - easy automatic determination and statistical calculations, 2° - scalar properties, i.e., possibility to express as on number, 3° - compatibility with the subjective evaluation of quality (threats and pollution) which is related to the variability range limitation of the index to the finite range of values (e.g.,<0-100>). The very idea of index assessment can be useful in a number of situations (e.g., for the determination of a new index - that would be far better than the ones used so far [5,6] - for the evaluation of quality or pollution classes for surface water reserves). It takes into consideration three types of features: "stimulants" (that positively influence evaluation of environment), "di-stimulants" (negative form the point of view of evaluation), and "nominants" (that are included into a certain range - section). The calculated index values can be obtained from the following formula:

$$W = \frac{\sum_{i}^{N} MIN\,(V_i,1)}{N}$$

where for the stimulant V_i denotes quotient of the value of the i-th feature of (C^0_i) object and (C^W_i) standard.

$$V_i = C_i^0 / C_i^W,$$

Its interpretation for the di-stimulant is reversed:

$$V_i = C_i^W / C_i^0.$$

Whereas for a nominant, establishing adequate value thresholds is required: F_i^{Wd} - F_i^{Wg} and logical control of the conditions for the compatibility of descriptions of the standard and object:

$$V_1 = 1 \text{ if } F_i^{Wd} \leq C_i^0 \leq F_i^{Wg},$$

$$V_i = 0 \text{ in other case.}$$

A separate group of processing programmes in the NIT system are graphic programmes. They are used for generating and printing computer maps (MAPIX) and axonometric graphs (GRAF 3d). A list of possible procedures is supplemented by INTPIX that is used for the spatial extrapolation of the shape of chosen objects (e.g., pattern of lines - rivers, points - wells) by determination of the spheres of equal distances from these objects and measurement results from the discreetly distributed points (observation stations) for the linear interpolation for the whole basin area covered by the data recording in the main system base.

A few other systems of auxiliary character use geographic information contained in the NIT system bases. These programmes are used for, e.g., graded maps of terrain relief, estimated balance sheets of balance equations for radiation and heat exchange, estimation of the size of potential yields, and evaluation of the degree of erosion threats for the basin [12].

EXAMPLES OF THE APPLICATION OF SOME CHOSEN COMPUTER SYSTEMS

Some chosen elements of the monitoring of agricultural basins supported by the numerical systems described have been presented on the basis of two examples: the Bystrzyca basin located in the area of fertile brown soils originating from loess and limestone, and the Piaseczno basin in the area of poor soils and intense recreation activities in the Łęczyńsko-Włodawski Lake District. In both cases the basic set of information gathered covered data on terrain relief, hydrography, geological structure, soils and utilisation of the basin. Data was recorded in the net of square plots with various resolution - 500x500 m for the Bystrzyca basin and 25x25 m for the Piaseczno lake basin.

A review presentation of the results of analyses of the geographical conditions of both study basins was limited to some characteristic maps and computer graphs prepared by means of the graphic MAPIX programme and EXCEl. Most of the presented maps were obtained by means of joint application of the previously analysed programmes such as: NURT, IDEM, and RZUT. Automatic identification of the partial basins related to the elemental outflow spheres was carried out by means of the NURT programme (Fig. 3A). Possibilities of water "escape" from the area of Piaseczno basin without outflow by a conventional "outflow profile" at the maximum depth of the reservoir were assumed. The map of isolines denoting equal distances from the lake boundary - calculated that take into consideration inclines of the topographic surfaces - were established by means of the IDEM programme. The above calculations were carried

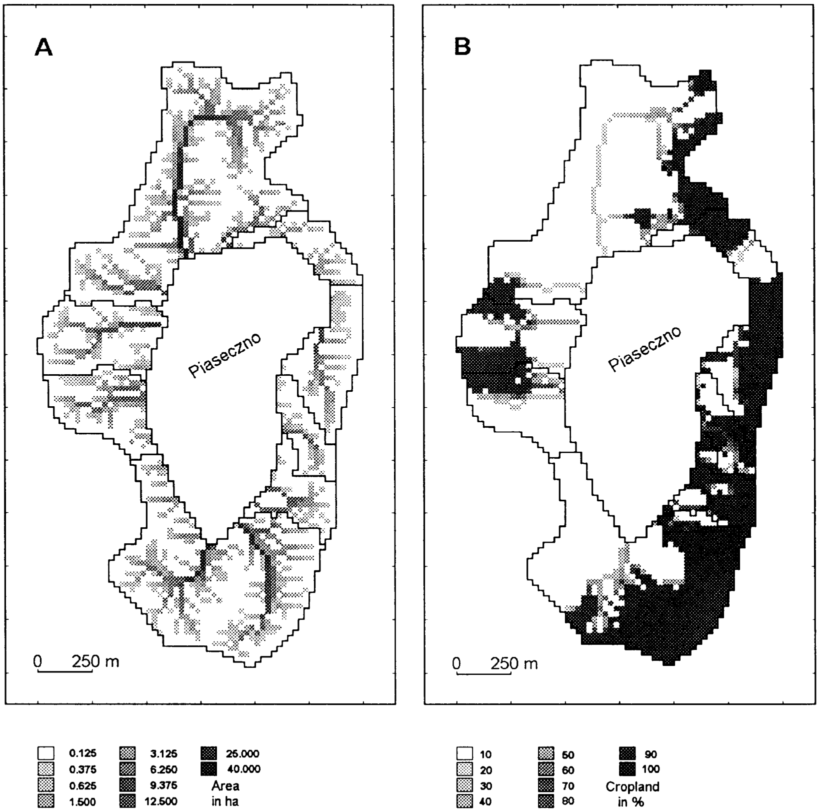


Fig. 3. A map of the surface outflow spheres (A) and anamorphic picture of the arable land distribution (B) in the area of the Piaseczno lake basin.

assuming localisation of the outlets of outflow spheres in the border belt of the square plots (pixels) the delineate the outlines of the lake bowl (Fig. 4B). Presentation of the examples of study results was also extended by the demonstration of a anamorphically transformed map of arable areas (Fig. 3B). A polar diagram of differentiation of the integrated indices of pollution expressed by means of ammonium nitrogen charge ($N\text{-}NH_4$) in the pattern of distance and directional sectors of pollutant inflow (Fig. 4B) was also placed. A general size of charge in individual spheres of distance from the lake was established according to the assessed data on the number of inhabitants and farm animals and standards of incoming charges for agricultural lands (arable lands and meadows) and forests taken from the information in literature [2,3,15]. The following equations were used for the calculations:

- for inhabitants and farm animals:

$$\text{Ł}_u = SL_u N_u,$$

- for arable areas and forests:

$$\text{Ł}_p = \Sigma A_p N_p,$$

where Ł_u and Ł_p denote evaluations of charges for the group of "point" users L_u and "surface" A_p. Whereas, N_u, and N_p are assessed unit charge standards according to the assumed user groups. Conventionally specified sectors of charge outflow can be determined in any plausible way including a physical method. In the case described here, they were specified automatically. To this end the following steps were taken: a geometrical centre of the lake was found; it was recognised as an initial point of the polar co-ordinate system, an then local transformation of the pattern of Cartesian

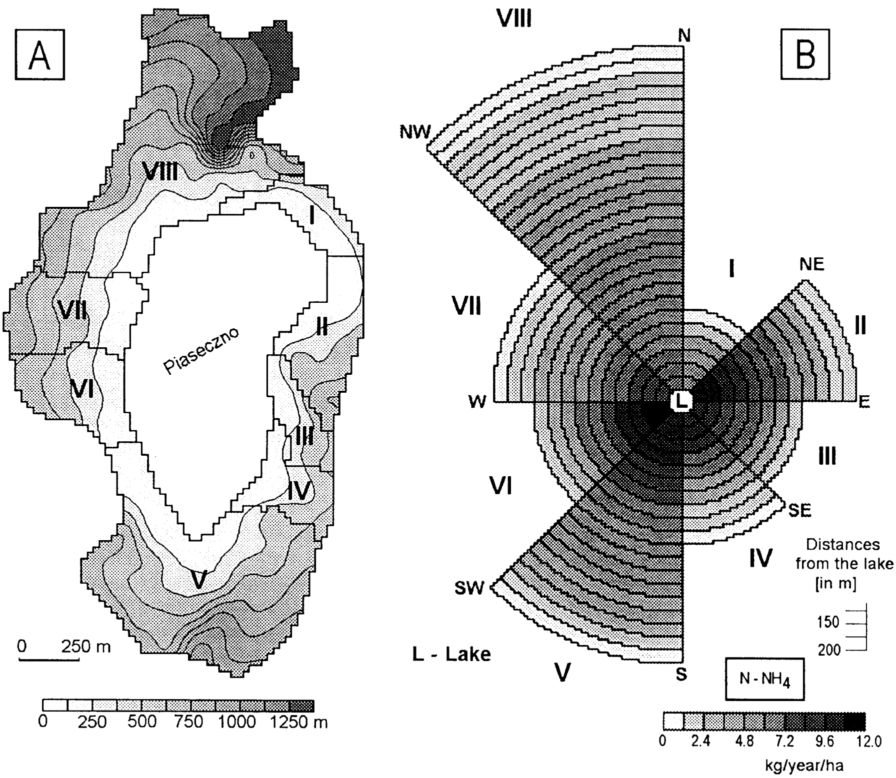
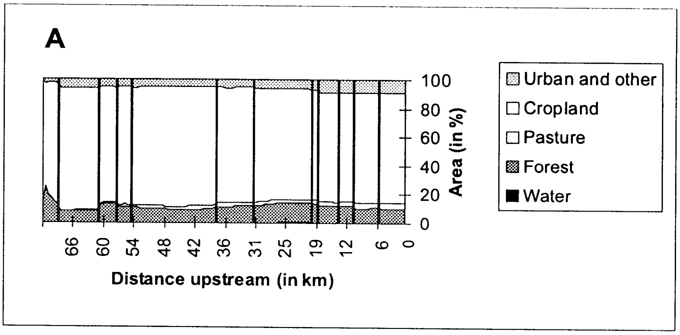


Fig. 4. Distribution of some chosen sectors of feeding and the lines of equal outflow length in the Piaseczno lake basin (A) and a synthetic diagram of the spatial variation of mean $N\text{-}NH_4$ charges in the polar co-ordinate systems - distance, directions of the world (B).

co-ordinates was carried out, and points of intersection of cardinal directions of the sides with lake circuit (shore). Finally, decision was taken to assume that they determine the distinguished sector of surface water outflow and potential pollution charges.

To supplement the results of analysis of the conditions in the basin an longitudinal graph (Fig. 4) of differentiation of the utilisation structure in the form of averaged values of basin areas (Fig. 5A) and also in the differential form taking into consideration partial basins (Fig. 5B) was presented. A graph (Fig. 6) presenting spatial variation of soils of mother rock in the Bystrzyca basin and a graph (Fig. 7) presenting, among others, variation in the average length of outflow routes as a function of growing area of the Bystrzyca basin were also introduced. This measure is used for various types of erosion models and can also be understood as an average length of slopes and hills. The described graph (Fig. 7) presents also the conditions of dangers for water relations in the basin that results from the intensity of underground water uptake (determined on the basis standards of water usage per person and balance of water requirements assumed for water-consuming plants) as well as the quality of water from rivers measured by chloride content calculated from the empirical relations as function of the land development in the basin.

The enclosed set of maps supplements the picture of location of physiographically uniform partial basins in the Bystrzyca basin (Fig. 8A). It was automatically obtained (by means of the AKD programme) on the basis of multi-dimensional analysis of the full set of



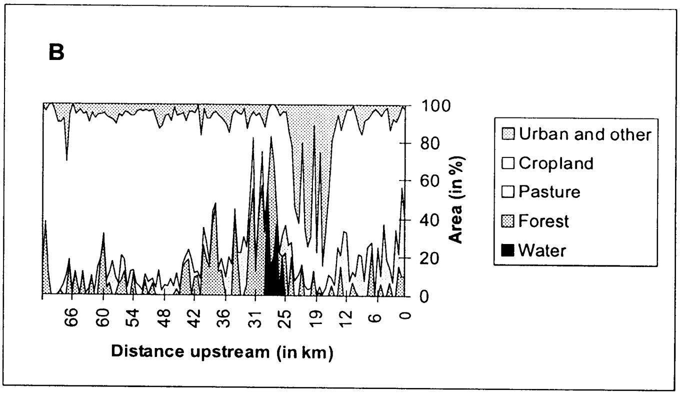


Fig. 5. Differentiation in the structure of land utilisation in the Bystrzyca basin. Values: A - mean values related to the increase in the basin size, B - in the differential form taking into consideration partial basin (vertical lines denote the outlets of the main outflows).

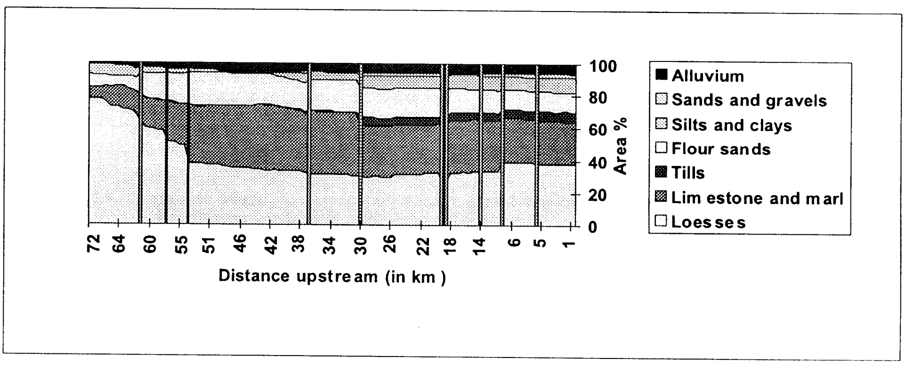


Fig. 6. Differentiation in the type of mother rock of the soils in the Bystrzyca basin as a function of its run.

basins described by vectors with co-ordinates were related to various geographic features (soil utilisation classes, type of soils, geological separation, inclinations, average depths of underground waters, etc.). Most of the seven classes of basins that have been distinguished, are predominantly agricultural. Contribution of the arable land in the basins (classes: 1,4,6,7) exceeds 85%. In the class 3 there is a high proportion of grass land (>15%) beside the predominant arable land. The remaining two classes are: class 2 - a urbanised basin type (building cover 80% of area), and class 5 - forest basin (the area of forest is >72%). Beside a map of typology an example of a "wash-out" picture the basin affiliation to a chosen type that has been considered a relatively uniform physiographically (Fig. 8B).

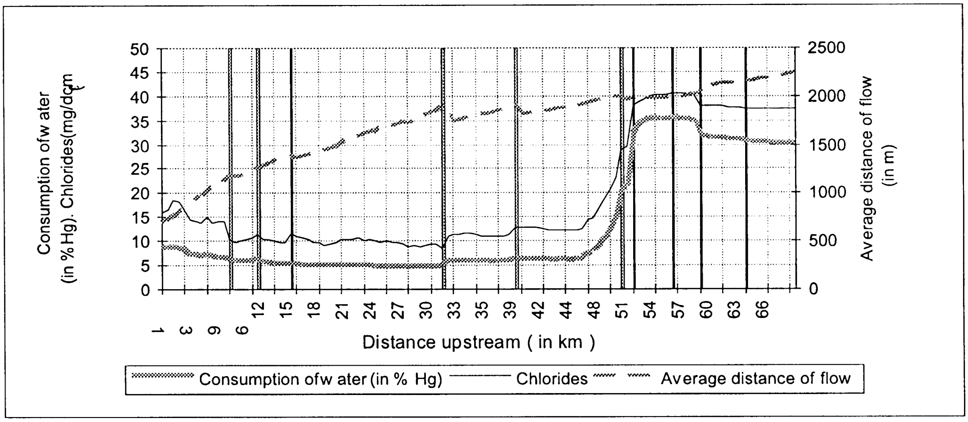


Fig. 7. Differentiation in some chosen geographic properties of the Bystrzyca basin as a function of its flow (Hg - ground outflow).

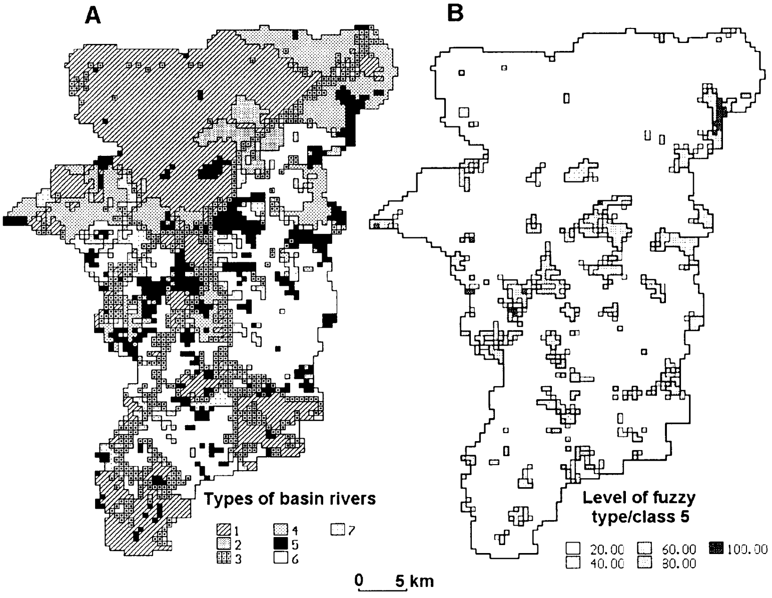


Fig. 8. Hydrological typology of the Bystrzyca basin (A) and the image of the washout affiliation to the "relatively uniform" type 5 of the partial basin (B).

CONCLUSIONS

The proposed method for monitoring agricultural basins supported by a system of specialist compter programme consists in the parallel observations of mutual relations between:

1. Geographical condition of the basin.
2. Hydrodynamic conditions of the outflow (including hydraulic parameters of river beds).
3. Physico-chemical properties of waters as a function of growing basin area (as measured along all the possible outflow routes, water runs and rivers).

NIT (Numerical Information on Terrain) system has been found to be useful for data collection and processing together with some chosen processing programmes.

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APPENDIX

Studies on the processes of water circulation in the agricultural basins are shown on Fig. 9.

General remark: A net of interconnections of the distinguished blocks (research programmes) is a large extend generalised. Vertical connections distinguish methodological and intersection problems and cover the following topics: - description and analysis of the water circulation structure, - organisation of measurements in the framework of "integrated monitoring" of water circulation processes, - hydrological modelling, - problems of evolution and transformations in the water circulation caused by natural factors and anthropogenically controlled. A pattern of horizontal interconnections stresses "monographic" research problems with individual water circulation processes. Combination of the first three blocks "in rows" of the scheme: upper one denotes observations and measurements of the processes together with model identification, and the lower ones - model specification and modification of the observation system. The lines that link the remaining elements in the rows denote symbolic projects and activities in the environment (upper links) and structure verification and operational properties of the models (lower link). "Bracket" links, types of feedback connections aim at pointing to the mutual relations between engineering practice (column 4) and theoretical hydrology (1 and 3) and applied hydrology (2 and 3).

1. A simplified diagram of water circulation in the basin - The structure of the diagram changes in relation to the geographic location of the basin - the study object (geographical extension, distance from the oceans, height above the sea level). It depends also on the assumed degree of generalisation - spatial scale (zonal and non-zonal factors) and time scale (variation of climate) and on the degree of economic exploitation of the object. Organisation of the scheme is related to non-drying basin with plant cover. Elements situated in the central axis distinguish sequential processes, whereas the remaining ones denote parallel (synchronic) processes. Elements situate on the left and in the centre of the scheme reflect mainly the vertical direction of water

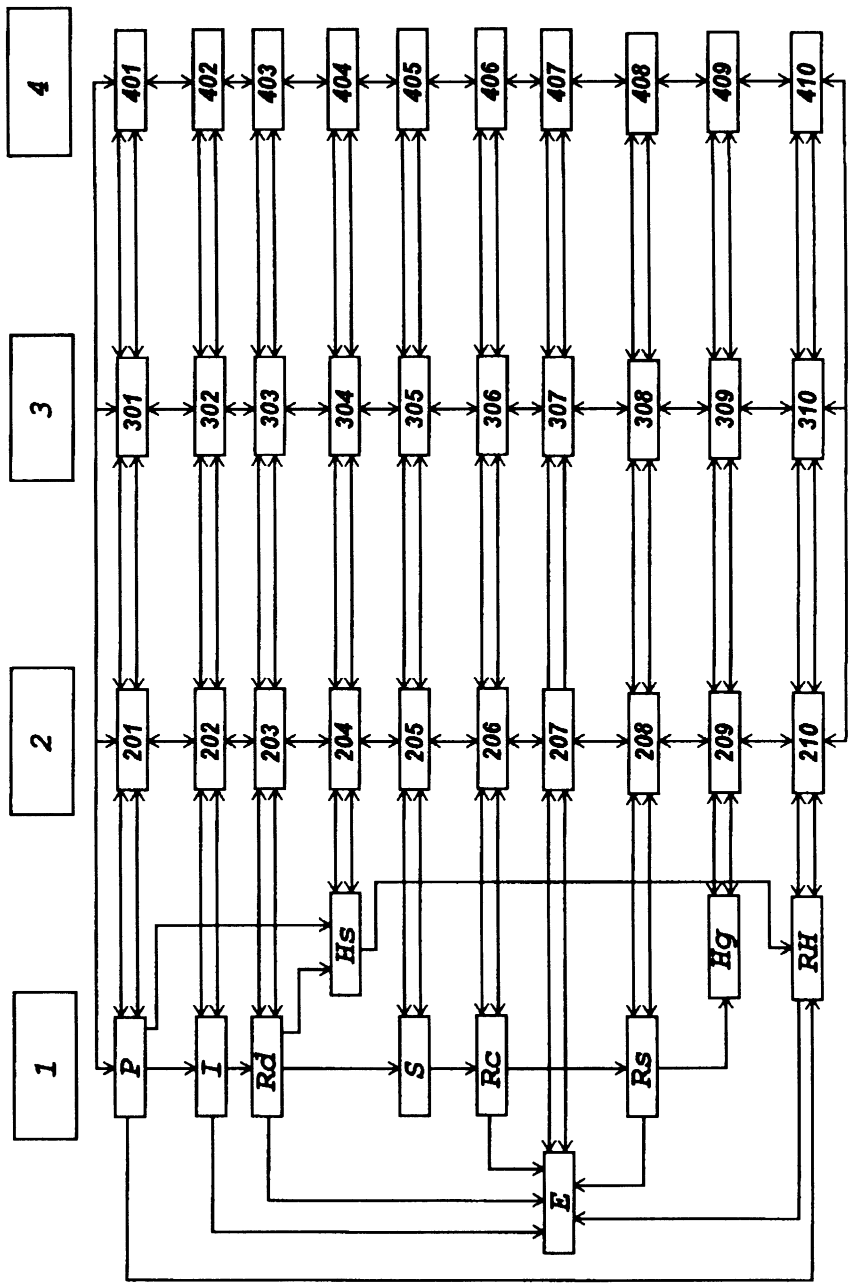

Fig. 9. Schematic picture of research problems.

movement, and those on the right - horizontal water movement.

2. Measuring system (monitoring) and parametric description of the water circulation processes - Monitoring of water circulation processes can be considered in the framework of metrology in the broad sense of the latter. It covers both technical problems (quality and type or gauges, degree of automation of measuring systems, application of teledetection, etc.) as well as organisation of an observation net in various spatial scales (location and density of measuring stations, principles of measurement standardisation assumed, etc.). The choice of observation calendar is very important: continuous, seasonal observations, adjusted to the situation (e.g., limited to the recording of the course of water level increase - floods, and low waters). The system of monitoring of water circulation results from the observations on the course of its components and is to a large extend an empirical generalisation. Whereas, a parametric description (closely related to the measuring system) is the effect of generalised, theoretical knowledge based on the constitutive equations from mathematical physics and fulfils the role of the vector of the co-ordinates of the conditions of water circulation.

3. Modelling of water circulation processes - the subject of modelling in hydrology are all the processes of water movement and storage in the natural environment. According to the criteria that can be distinguished the following properties: various structures (related to individual processes, elements of the basin, have the properties of integral models or global models), different way of approaching time (static and dynamic models), use different approaches and methods (the models of "white, grey, and black box"), assume different properties of the operator (linear-non-linear, stationary - non-stationary, models with agglomerated-scattered parameters). The models used in practice are not unique as to the way they describe processes and accuracy of results obtained (deterministic, conceptual-empirical models, and stochastic-probabilistic models). The scheme presented is not a complete review of models applied in practice and theoretical research. It only presents a few examples.

4. Effects of the water circulation processes and anthropogenic control for the natural environment - This part of the scheme concentrates in an abbreviated (slogan) form on some of the mutual reaction (interactions) between water circulation processes and natural components of geographic environments. The problem of human influence on water relation and water circulation in the natural environment was also stressed.

Meanings of the denotations applied and description of some chosen blocks: P - precipitation, **I** - interception, **Rd** - plant dripping and soil retention (detention), **Hs** - surface and hipodermic outflow, **S** - infiltration, **Rc** - retention in the sphere of aeration, **E** - evapotranspiration, **Rs** - retention of the sphere of saturation, **Hg** - ground outflow, **RH** - retention in the river beds and water reservoirs and river outflow.

201 - net of pluviometric stations, measurements of deposits (horizontal rainfalls), snow cover, physico-chemical characteristics of rainfalls, radar observations, meteorological satellites (e.g., NOAA - canal, AVHRR) ... - typology of rainfalls, probability, parametric characteristics of the rainfalls (mainly jet-streams), chemical/physical parameter of the snow cover, thawing processes... **301** - stochastic models (processes and random blocks) weather generators (LARS-WG, EPIC, and others), simulation and prognostic models of total circulation GCM (e.g., UKTR), weather forecasts ... **401** - erosion by water drops and soil silting-up (warping), insulation role of the snow cover, the problem of "acidic" and polluted (radioactive) rainfalls. Excess rainfall - "crop sinking and flooding", endangering erosion and flooding, etc., with no supply - eolic erosion, the phenomenon of soil draught, plant wilting ... - direct and indirect regulation of pluviometric relations (generation of artificial rainfalls, feeding, dust emission, etc.),

202 - observations carried out in the experimental basins (air and satellite photos of plant cover) ... - maximum capacity of interception reservoir, index of plant content (degree of ground coverage, ratio of leaf surface to the ground area covered with plants), plant development stages... **302** - Rutter's, Horton's models ... **402** - interception is a function of type and plant development phase, captures part of the rainfall and makes evaporation easy, influences the balance of radiation and energy, reduces surface outflow and seepage... - capacity of a reservoir (retention) of interception depends on: types of crops, agrotechnical treatments applied, transformation of the active surface (buildings), and soil conditions (e.g., by drainage, watering, fertilisation) forestation or deforestation, etc.,

203 - measurements in the net of experimental plots, observations on slopes, measurements of snow cover, terrain microrelief, observations of depression retention from afarair and satellite photos of the surface conditions of the basin ... - maximum level of the surface retention capacity, parameters of basin geometry, thickness of the snow cover, water snow equivalent, ground inclination, friction coefficients (roughness) ... **303** - from the equations of water balance, **403** - the process of surface retention delays surface outflow, makes evaporation and seepage (infiltration) easier, is a component of "small retention", sometimes creates economic losses - crop flooding and sinking ... - capacity of the surface retention reservoir is a function of ground utilisation, depends on the type of crops, agrotechnical treatments (e.g., ploughing along slopes, terracing of the slopes, etc.), transformation of the active surface, e.g., urbanisation, densification of the water net, deforestation ...

204 - experimental plots, measurements of surface macrorelief, inventory of erosion cuts, observations by teledetection ... - effective rainfall, capacity of surface retention, thickness of the outflow layer, length of the outflow routes along the slope inclination, slope inclination, Manning's coefficient of roughness... **304** - models by Duband, Nash, Lambert, Manning's and Sain-Venant equations, *et al.*, **404** - surface outflow + hipodermic outflow (rainfall, thawing). Decide on the erosion threats (avalanches, streams of mud, canyon cuts, etc.) and rising water levels - floods, result in soil degradation, often lead to considerable economic losses (catastrophic floods) ... - limitation of surface outflow can be obtained by different methods, among others by building small and large retention reservoirs, systems of polders, by means of suitable anti-erosion systems, rational soil cultivation (correct crop rotation, type of ploughing, fertilisation system, etc.,

205 - lysimeteric observations, geological and soil **206** - measurements, granulometric analyses, pF curves, etc... - maximum retention capacity of the root sphere, soil initial moisture content, sorption and soil hydraulic conductivity, infiltration cumulated after a certain period of time .. **305** - Richards' model and Philip's equation with two parameters, **405** - infiltration depends on the constant and changeable properties of the basin (soil type, permeability, terrain inclination, plant cover), decide on the underground water supply and plant transpiration, reduces endangering underground outflow and direct water losses (evaporation from the ground) ... controlling intensity and size of infiltration is possible by means of a correct management of the basin (mainly agricultural areas and spheres at the terrain top levels, reducing slope inclinations, slope terracing, etc...),

206 - pits and geological profiles, measurements of soil moisture levels and moisture levels of soil substrates, laboratory analyses (granulometric composition, physical and chemical soil properties ... **306** - quantitative models of water reserves in an unsaturated porous medium, models of soil water capacity and others, ... - **406** - static water reserves in the aeration area fix the initial conditions for water permeability, influence the size of evapotranspiration ... - shaping of the analysed reserves can be indirect (by the type of crop, agrotechnical treatment, buildings, etc.) and direct (drainage, watering) ...,

207 - evapometers, lysimeters, phytometers, potetiometers, heat-radiation balance, turbulence diffusion,.. - constant and changeable meteorological parameters (net radiation, the stream of energy exchange with atmosphere and substrate, temperature, cloud cover, actual and saturated steam pressure, wind velocity, aerodynamic resistance of steam transportation, hidden heat of evaporating water, psychometric constant and others) ..., **307** - models by Penman, Penman-Monteith and others, **407** - evapotranspiration is a "negative outlet" in the hydrological model of the basin; it is a kind of balance losses that determines the level of the remaining components of the circulation... - the size of evapotranspiration can be actively shaped by changes in the active surface (e.g., buildings, melioration, phytomelioration, etc.) ...

208 - a net of piezometers and observation wells, hydrological profiles, vertical structure of the water-bearing and unpermeable layers, their hydraulic parameters... **308** - retention models of the saturation sphere - analysis of underground water, models of time sequences (trends, seasonal and random changes)... **408** - static reserves of underground waters are connected with surface waters (dynamic reserves) and reserves in the unsaturated sphere (in that, also soil water reserves - the size of the analysed reserves are formed by natural and artificial factors). Human activity plays an important role by direct water uptake in the uptake net (dug and drilled wells) and indirectly by melioration, drainage, watering, soil cultivation and transformation of the natural properties of the active layer...

209 - division of the flow hydrogram, hydrological measurements (piezometers, control wells, water uptake points) - physical constants (filtration coefficients, conductivity) elastic features of the medium ... **309** - Darcy's law, equations by Laplace, Bousinesque, the law of continuity and preservation of mass ... **409** - underground outflow is a basic dynamic reserve of the basin, it determines to a high extend exploitation possibilities for these reserves and water quality features. Its size, as well as the size of static reserves of underground waters, are formed by the same natural factors and anthropological activities ..

210 - a net of hydrometric points - observations of water levels and flows, water physico-chemical properties, movement of debris, glaciations, covering river beds with vegetation... - hydraulic parameters of river beds (average and maximum depth, width, inclination, moistened circumference, roughness of river bed, etc.) hierarchical structure of the river net and typological indices according to the Horton-Strahler's theory ... **310** - model of wave transformation in the river bed (according to the model by Maskingum), models by Dubanda, Nash, Lambert and equations by Manning and Saint-Venant *et al.*, **410** - level of filling up - flooding of the valley - flood, intensity of drainage, oozing, movement of the debris, maintaining biological vitality of the river, transportation of pollution, navigation potential, etc., hydrotechnical constructions (melioration ditches, banks, dams and reservoirs) - adjustment of inclination, water condition, small retention, construction of reservoirs, polders, etc.