SYSTEM POTOK: FOREST'S ECOSYSTEM COMPONENTS PROJECTION USING RELATIONAL DATABASE AND DIGITAL VECTOR MAPS

MAREK VALENTA[1] AND AGNIESZKA CZARNIECKA[2]

[1]Institute of Computer Science,
University of Mining and Metallurgy in Cracow,
Mickiewicza 30, 30-059 Cracow, Poland
valenta@uci.agh.edu.pl

[2]Department of Forest Engineering,
Agricultural Academy in Cracow,
29-go Listopada 46, 31-401 Cracow, Poland
czarnie@medprakt.pl

(Received 20 September 1999; revised manuscript received 1 December 1999)

Abstract: The contribution presents a prototype solution (system POTOK) of a complex problem such as advanced assistance for researches in hydrological terms of forest areas. The idea of system was based on a junction of two technologies: relational database and digital projection of space. The database is a ground of application that allowed creating ad hoc queries accomplished by advanced processing and also gives wide prospects of visualisation the results (in 3D). System could be used in similar branches of science.

Keywords: ecosystem, forest, GIS (Geographical Information System), hydrology, relational database

*In ecology (...) there is always a problem of missing general regularity behind lots of details, the problem called by CARREL "**missing the forest for the trees**"* — Maciej Sławomir Czarnowski

1. Introduction

Natural science development within last decade is connected with attempts at mathematical description of observed phenomena instead of most popular verbal description. The mathematical description allows projecting real systems using multidimensional models. Complex researches of entire factors forming ecosystems

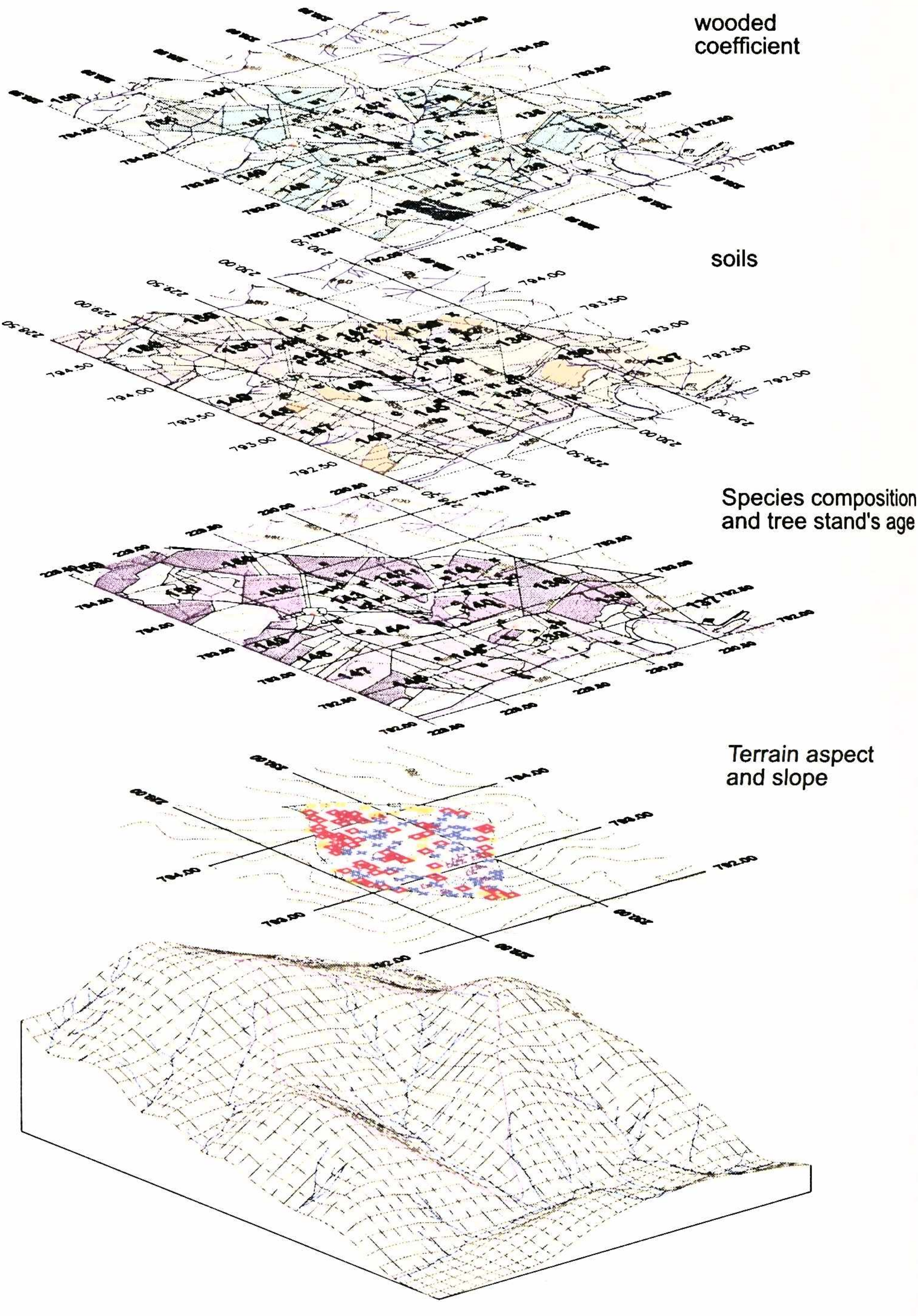

Figure 1. *Example of a three–dimension map from POTOK system. Nodes from the map represent particular attributes, here represented as layers above the main map*

became a rule in naturalist's work. Such a research needs not only gathering together large quantity of data but analysing this data to obtain some knowledge about properties of phenomena as well (Figure 1). Both gathering and especially analysing data is hard to imagine without computer technologies.

An example of ecosystem research is an attempt to project hydrological ratio including closed water circulation between atmosphere, tree crown, litter and soil in forest environment. Such a research could result in explaining the relationship between tree stand growth and conditions current in such ecosystems and, as a consequence, a more effective use of existing forest resources (the most important is to find optimum conditions for tree stand growth).

At the moment the Institute of Forest Engineering, Agricultural Academy in Cracow, is monitoring a few mountain forest communities. One of them is an experimental area in Vistula forestry district (Beskid Slaski) (Figure 2). Vistula's community has the biggest Spruce [*Picea Abies*] tree stand growth on Earth, which

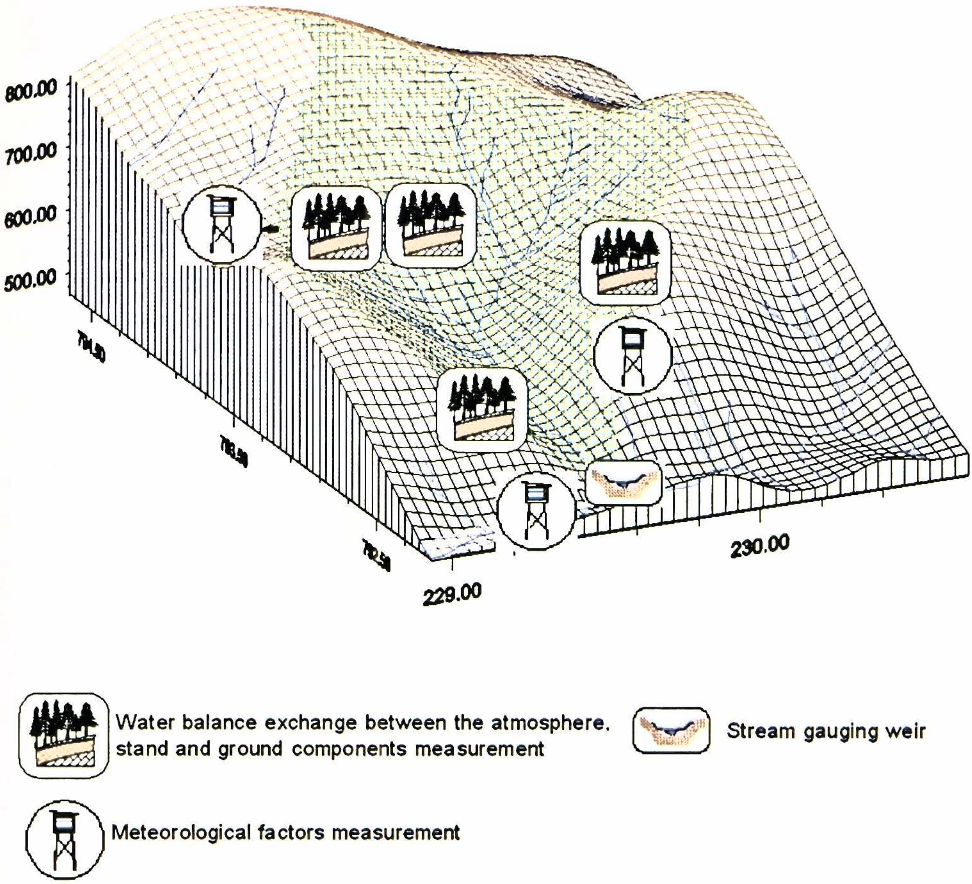

***Figure 2.** Distribution of measurement stations on Dupnianski creek valley*

is the reason for attempts at finding why this particular place is so favourable for tree stand.

Data from these places has been gathered for years (handmade archives) and because of inconvenient access to data on one side and impossibility of fast processing on the other side, it is not easily accessed scientific evidence, especially by large number of researchers. Yet high costs of gathering this data should be a reason for their effective use, which means easy access. This easy availability of research results is not the only problem limiting the possibility of measurement results use. If the gathered data about hydrological and meteorological situation from different stations is to be properly interpreted, there must be an additional possibility of projecting the space localisation of measurement stands and relating it to other terrain attributes, like for example tree stand characteristic or soil characteristic. Processing of the gathered data due to its variety and amount is rather a difficult task.

It is easy to predict that almost a panacea for problems presented above could be computer techniques based on database technology and all technologies used by GIS (Geographical Information System) systems. Computer Science Institute at Mining and Metallurgy University in Cracow in co–operation with the Institute of Forest Engineering Agricultural Academy in Cracow created a computer system that uses technologies mentioned above and is modified to fit the needs of hydrological research. The system named POTOK was designed for gathering data describing a character of experimental area with its water balance and allows processing data for: sorting, data selection based on each of the recorded attributes, preparation of statistical reports, exportation to formats commonly used during mathematical modelling and presentation of data as tables, graphs or maps.

2. Range of reality projected in the system

The term “experiment area” means the area including one creek catchment area: all of the main creek’s tributaries and the main creek as well must have their springs and mouths within the experiment area. Such an area is a closed ecosystem as regards water circulation — it is possible to balance water precipitation and water outflow from over the catchment area during a given time. Each measurement system prepared for one experimental area consists of a few stations. One station consists of about a dozen or so devices.

Logical data has been divided into two categories:

1. Geographical Data

It comes from map number 551.213/P. GUGiK Istebna scale 1:10.000. Data from the map is recorded as grid of plots, surfaced 10 per 10 metres each. For each surface there are given:

— average height;
— terrain aspect;
— terrain slope.

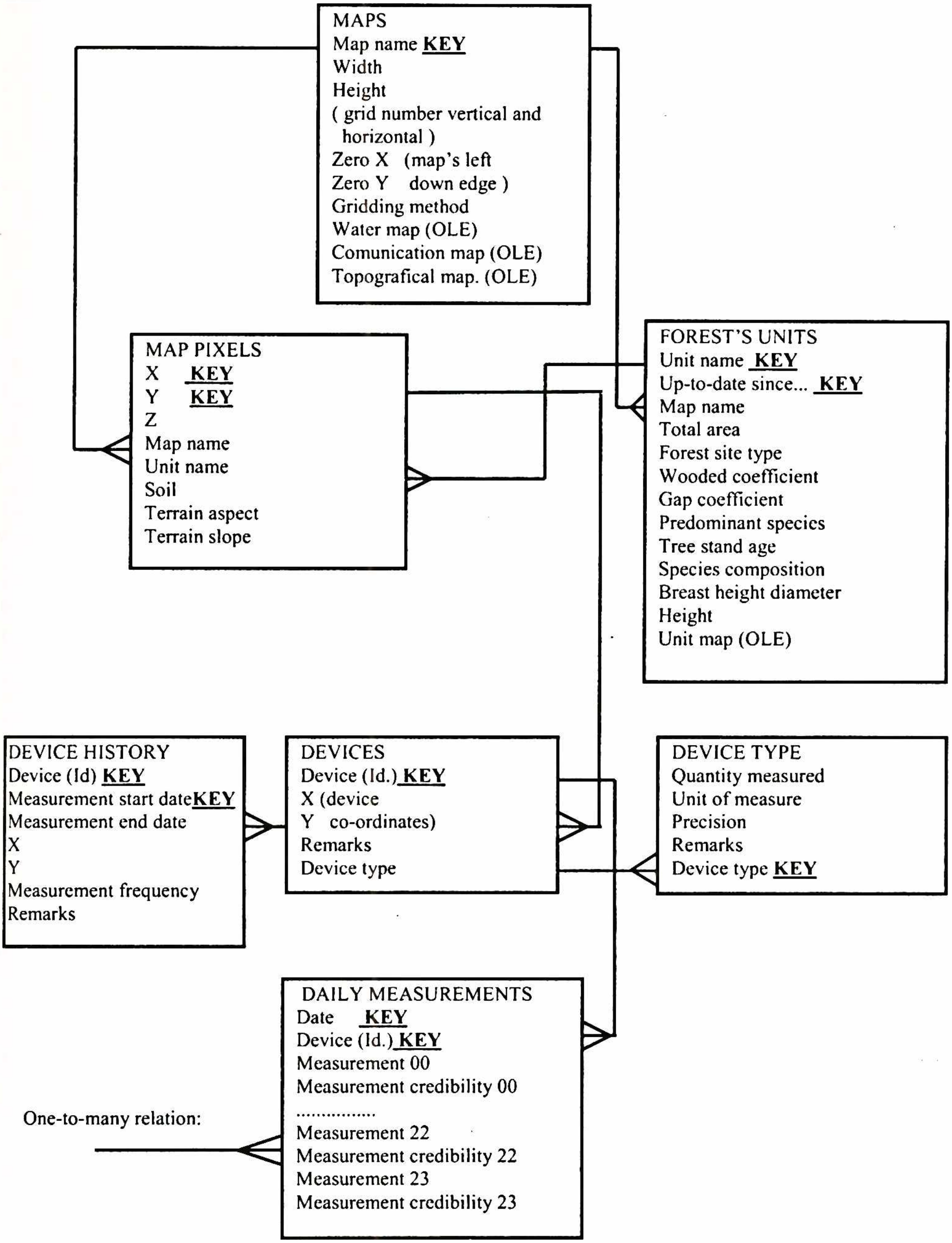

***Figure 3.** Database POTOK structure scheme*

Also each record contains information about:

- water system;
- road system;
- tree stands;
- soils.

2. Measurement Data
- Measurements are made on 8 stations:
  - meteorological stations (2) with 16 devices each;
  - slope stations (5) with 25 devices each;
  - creek station (1) with 15 devices.

Each device records measurements with 6 minutes frequency (10 measurements per hour). Altogether 24 hours' measurement from the whole experimental area results in 41 280 digits.

3. System environment and the idea of technical solution

For the sake of experience and hardware possessed by further users it was decided that the application should be produced basing on Intel's systems. Similar circumstances (and for example relatively cheap licence) were the reason for choosing systemic environment (MS Windows) as well as consistently relational database system MS Access and packed Surfer (Golden Software) used for map visualisation. Both of the last tools co–operate well in the selected MS Windows environment. Other options of the system production were judged as inadequate to the task's size, at least at this stage. Respects of data safety (measurement of meteorological factors is unique) were the cause for the system to contain double data archives (the archive of source files coming from the measurement devices and the archive of database files).

Information about the experimental area is available in the system as stratified vector maps as well as in the attribute form in a relational model. The logical data arrangement from Surfer's procedures was used here; the base for creating maps is grid of co–ordinates (x, y) of assigned density. Grid nodes have one attribute: usually it is a point's height (if a grid projects area configuration), but it could be any other digital quantity, for example precipitation magnitude over a given area. Grid nodes and some of their attributes have been imported into the database (see the database scheme). It has been assumed that the areas between nodes (size 10 per 10 metres in reality: that is the size of a single measurement station) have the same attributes as the nearest node. In this way such problems as: finding whether a particular point belongs to a given area, calculating terrain slope and aspect, determining buffer zones etc. could be solved.

The tests carried out at the experimental area proved high compatibility of parameters calculated in the database with real quantities corresponding with them (Figure 4). For example the average mistake between terrain aspect calculated in the database and real aspect at 20 certain points at the experimental area is 4.3 degrees.

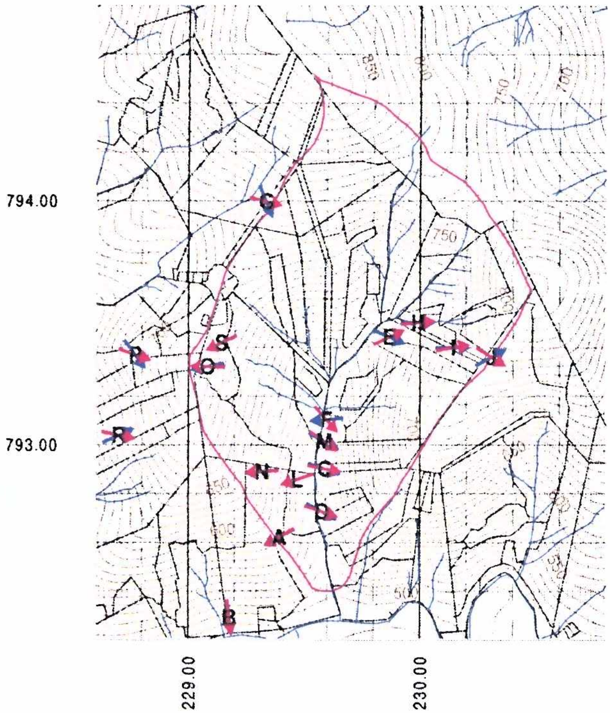

Figure 4. *System credibility test: on the map there are shown points, where terrain phisiography characteristic was made and samples for laboratory researchl were taken. Red arrow shows aspect calculated in database, black is the real aspect of the place*

4. System's functions

The present version of the system allows realisation of most of the assumed functions. The most important of them are:

- Importation of research results carried out at the experimental area. Files are prepared by electronical devices or come from digitalisation of measurements carried out at mechanical devices (results are recorded on paper tape as a continuous graph).
- Data verification by users: ability to mark "unsure" measurements (they are not taken into consideration during data analysis) and to reconstruct missing measurements basing on data coming from the nearest stations or on functions of typical changeability of given quantity.
- Data arrangement according to user's recommendations.
- Data selection by time (day, week, month etc.).
- Visualisation of selected measurement rounds on a graph (Figure 6).
- Statistic estimations for chosen measurement round (total, average, minimum, maximum etc.).

- Collecting full information about a given point of experimental area (data about tree stand, geographical conditions and information from the nearest measurement station) (Figure 5).
- Area selection by tree stand, soil and geographical conditions criteria (Figure 7).
- Estimation of physiographic parameters of experimental area.
- Selection and exportation of data into tool programs used for mathematical models creation.

Thanks to POTOK system certain time–consuming computations and terrain analyses are automated, and the results received are often more precise than these obtained with the use of previous methods. It concerns especially the problem of selecting areas fulfilling complex criteria of geological structure and tree stands, as well as estimation of physiographic parameters.

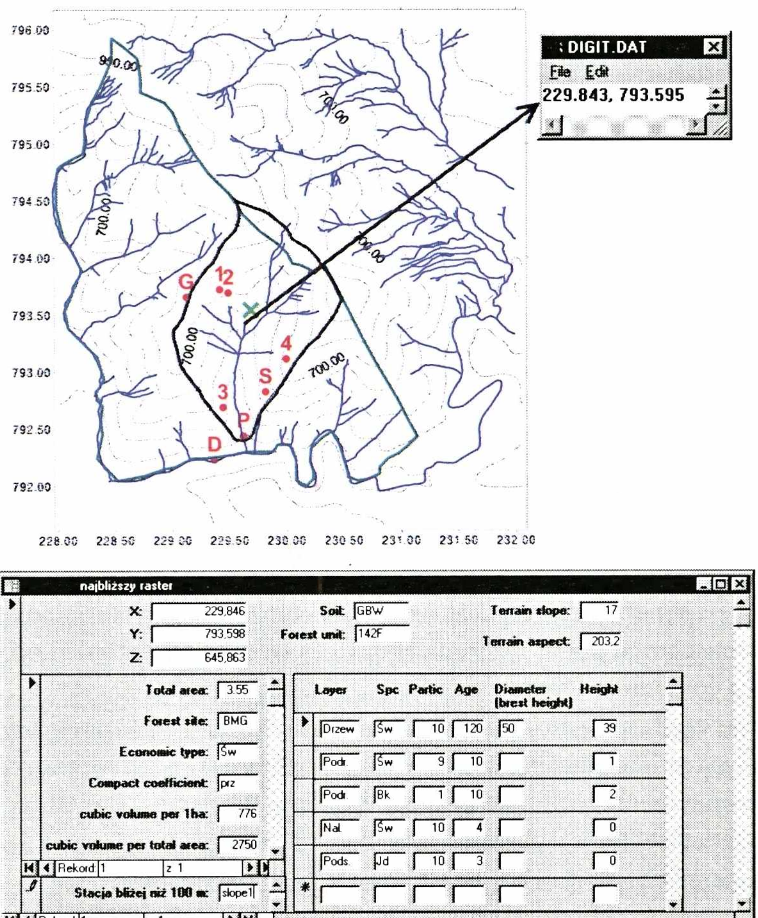

***Figure 5.** Example of balance sheet about a particular point from experimental area selected by user: selection can be proceeded by writing down co–ordinates or (much simpler) by clicking it on a digital map*

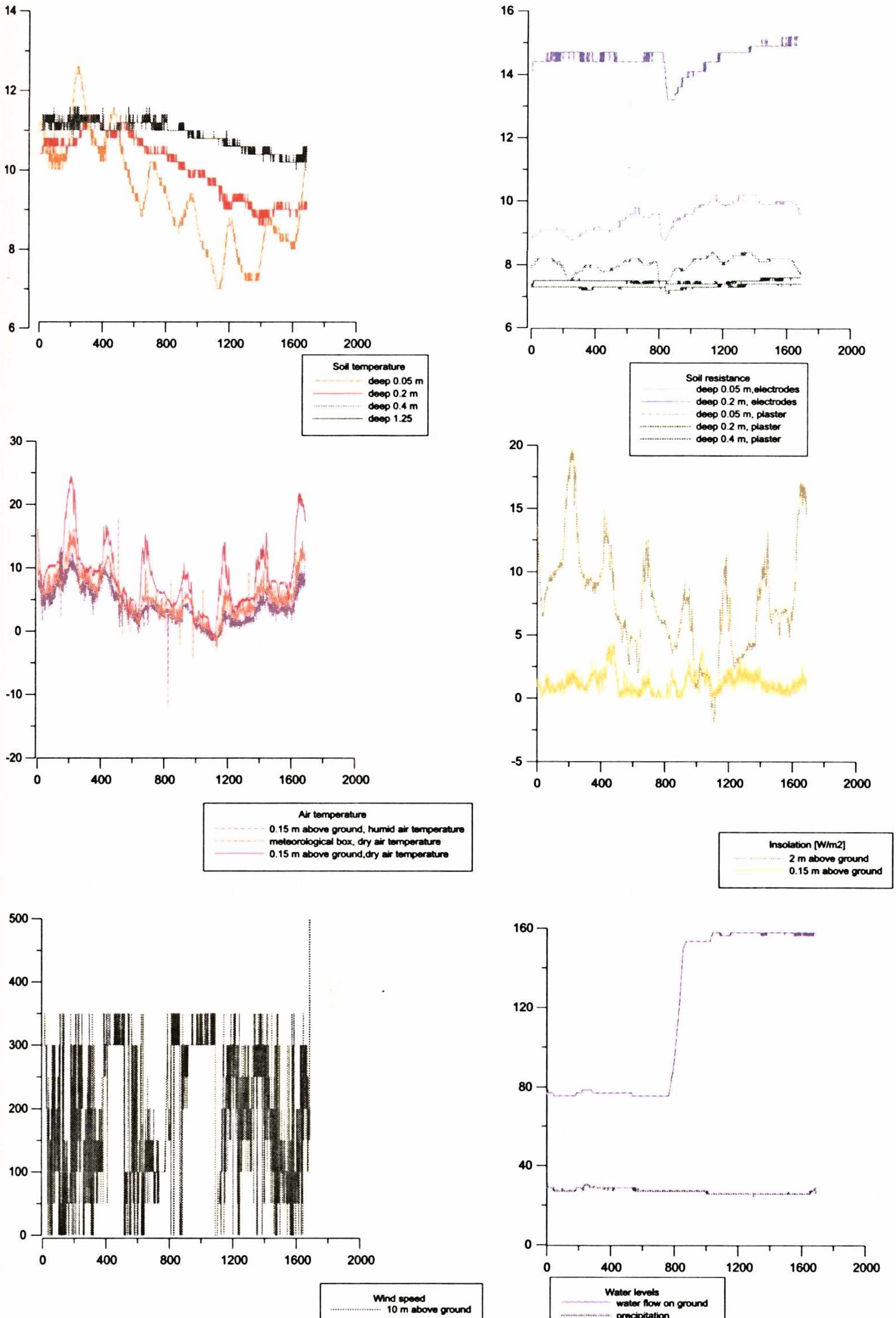

Figure 6. *Example of interactively created graphs. User specifies station and measurement period. Each graph represents another type of device*

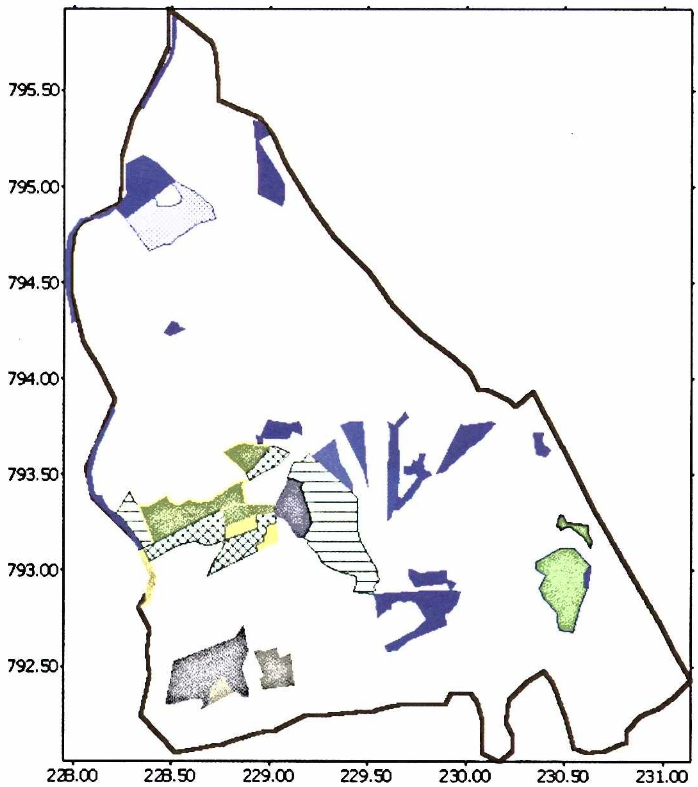

Figure 7. *Area selection based on tree stand criteria. This interactively created map presents areas where there are 10 to 70 % Beeches [Fagus silvatica] in tree stand of age greater than 20 years. Borders on the map are the experimental area borders*

5. Application of the system and its further development

System POTOK is successfully used to accumulate data gained by research project "Test of water balance in Spruce [*Picea Abies*] forests of Istebna" lead by the Institute of Forest Engineering, Agricultural Academy in Cracow. At the moment (August 99) the database includes results of measurements from eight electronical stations working ceaselessly since January 1998.

This system was a great help for researchers during preparation of annual report at the end of 1998. Data about physiography of the experimental area produced by POTOK system was used for research, which resulted in a few Master's theses defended at the Forestry Faculty in Cracow. The system is planned to be used during research carried out at the Agricultural Academy in Cracow (especially research on relations between atmosphere water balance index and different forest's habitats production) and PhD dissertation concerning research on water balance in selected, special forest zones like road's shoulder.

From the technical point of view, a new version of the system, respecting multi–access design type client–server, is anticipated.

References

[1] A. Czarniecka, *Geografical Information System — choosen ecosystem's components projection with database and digital vector maps use*, MSc thesis, Computer Science Institute at Mining and Metallurgy Uniwersity in Cracow, Cracow 1998

[2] J.Suliński (ed.), *Test of water balance in Spruce [Picea Abies] forests of Istebna.First annual report*, Institute of Forest Engineering Agricultural Academy in Cracow, Cracow 1997