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NUMERICAL MAPS OF THE AGROCLIMATE OF POLAND

Mapy Numeryczne Agroklimatu Polski

ABSTRACT: The computerized Agroclimate Model of Poland is a component of the Integrated Spatial Information System for Agricultural Production in Poland built at the Institute of Soil Science and Plant Cultivation (IUNG) in Puławy. One of its versions is used for generating data for climatic map construction. It has three components: a Digital Terrain Model (DTM) of Poland, the algorithms for calculating elements of agroclimate and the output tables with results. Numerical maps might be produced directly from the output tables connected by the one-to-one relation to the DTM, or from polygon covers created by interpolation of the DTM. The model can compute mean values of the basic climatic features, but the algorithms may also be used jointly and other, e.g. economic, information may be added. The methods developed can find application in decision support systems to generate information for a variety of users: farmers and agricultural advisors, landscape architects, civil engineers, regional planners, foresters, ecologists, agricultural scientists etc.

keywords: ***słowa kluczowe***
agroclimate – *agroklimat*, numerical map – *mapy numeryczne*

INTRODUCTION

Agroclimatic maps of Poland have been made with the aid of traditional cartographic methods for quite a long time now and a number of valuable atlases have been published (10). In other countries a number of various numerical climatic maps, both raster and vector, have been created in recent years with the aid of different modelling techniques (2, 3, 7, 11, 12).

The modelling of climate is not a new concept (1, 17). Such models take advantage of the fact that climate has definite location that can be described by geographic co-ordinates. Development of climatic models can be traced back to as early as the 19th century, but, due to excessive computational requirements, their practical implementation was non-existent until just a few decades ago. The growing performance of machine calculating techniques has changed this situation entirely. The advancement of new user-friendly computer modelling tools provided the means for constructing models of climate, simplifying the process of mathematical description of spatial and cyclic variation of climatic elements. GIS technology made possible near-automatic or even fully-automatic creation of climatic maps from such models. And last but not least, the maps can now be delivered over the Internet to the most distant customers in seconds.

THE AGROCLIMATE MODEL OF POLAND

The first attempts at describing the elements of climate as the function of geographic co-ordinates, as well as the idea of using harmonic analysis for presenting the yearly cycle, were made over one hundred years ago (6). The essential innovation introduced here is the integration of both methods (Fourier's coefficients as the function of geographic co-ordinates) in the description of spatial distribution of climatic elements (4, 5). The algorithms link the yearly cycle of meteorological elements with their spatial image (quantified with the aid of methods of multiple regression). They describe basic climatic features in any point in Poland. The mean values and variability (probability, risk etc.) of such elements of agroclimate as temperature, precipitation, sunshine duration, relative humidity and potential evapotranspiration may be determined in the model for an arbitrary point and period. In the Agroclimate Model the concept of computing the values of the elements of agroclimate in the basic time unit of one day was used. Values for any longer period can be easily calculated (sometimes by simple addition) and various thematic maps can be derived by combining the algorithms in meaningful ways. For instance, the process of developing the algorithms for calculating phenological periods of selected crops from temperature and photoperiod algorithms could be done just by re-writing the computer program.

The algorithms of the Agroclimate Model were implemented in a computer program (Fig. 1). The data that need to be entered into this computerised model of agroclimate are latitude, longitude and height above sea level of a given point (selected with a mouse click) and the time period in days. For the purpose of presenting spatial variability of agroclimatic features, a version of the Model for map construction was built. It uses the idea that a map can be composed of a number of points. The map model may therefore be regarded as a multiplication of the point model as far as the climatic algorithms are concerned. In the Agroclimate Model for map construction (Fig. 2) a digital terrain model (DMT) is used in the form of a point cover (13). The points are regularly spread over the area of Poland, covering it with the resolution of 2 km by 2 km and are operated on by the algorithms in sequence to make different calculations (temperature, precipitation, sunshine duration etc.). The attributes the points in the cover have, beside geographic co-ordinates, are regional correction values for temperature, humidity, precipitation and evapotranspiration (regions after 8). The attributes constitute the data of the model. The programs in the Model for climatic map construction can compute the mean values and probabilities of the main elements of agroclimate in periods (such as calendar year, months, or any arbitrary

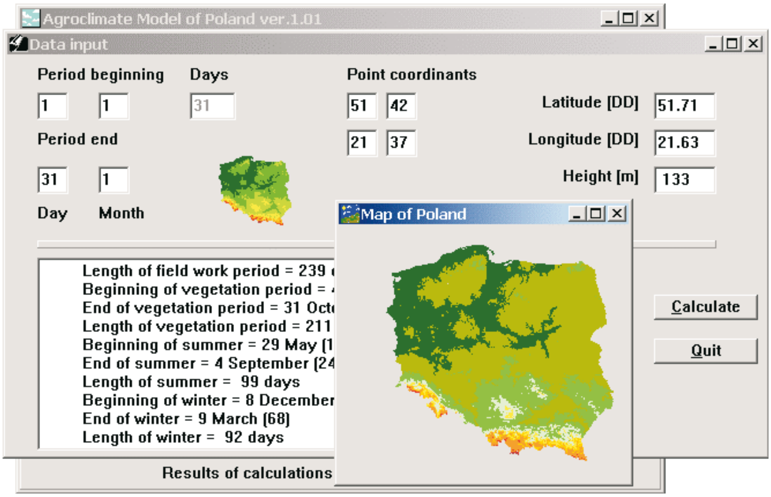

Fig. 1. The Agroclimate Model of Poland for point information as a computer program
Model agroklimatu Polski dla danych punktowych jako program komputerowy

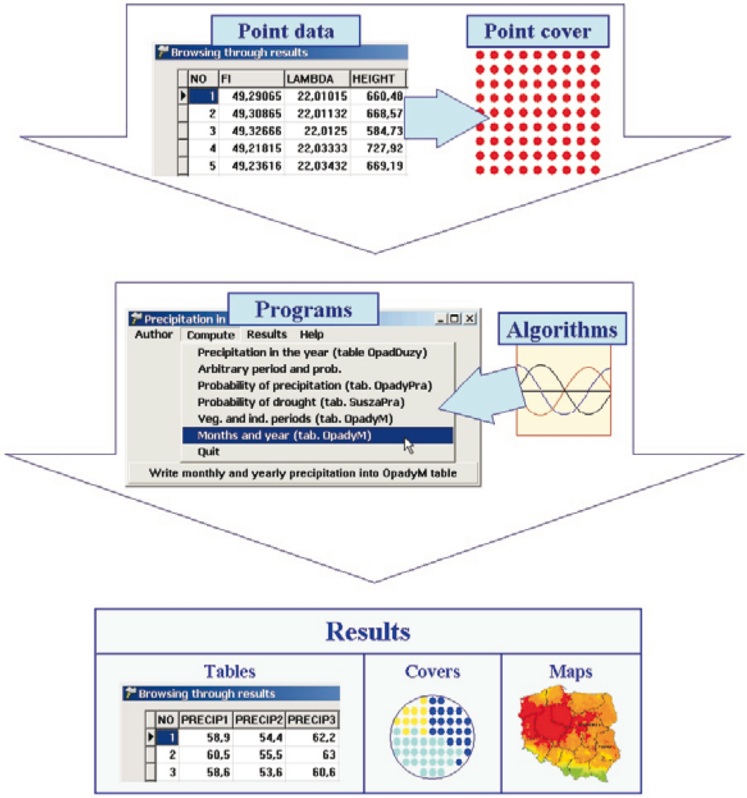

Fig. 2. The Agroclimate Model of Poland for map construction
Model agroklimatu Polski do konstukcji map

period entered by the user). The algorithms for different elements of agroclimate may be combined, e.g. the temperature algorithm together with the algorithms of other elements of agroclimate make it possible to compute the values of these other elements in the periods determined by temperature (such as vegetation period, growing period, winter and summer). The results are in a tabular form and can be related to the points in the point cover by a one-to-one relation, and as attributes to the spatial data they can be used to create maps. In this way the output is not only in the form of tables, but also in the form of covers and maps (Fig. 2).

NUMERICAL MAP CREATION

Two different methods of map creation have been tried: either directly from the point cover or from polygon covers interpolated from the point data. The procedure of creating maps directly from the point cover was found to be especially satisfactory for maps of small scale (i.e. 1:4000000), however, for larger point maps denser DTMs can be used. The "look" of a point map is different from what cartographers are used to and perhaps, to accept this new type of numerical map, it might require making concessions. Numerical maps that resemble hand-made ones, and especially large maps, may be produced from polygon covers created by interpolation of the point cover. However, they are generally more arduous to make than point maps as polygon covers from interpolation often require some manual preparation by splining and generalisation before they can be used for map creation.

The model does not produce maps fully automatically (although it is technically possible, especially with point maps), and some human effort is necessary to achieve the acceptable aesthetic level required by the art of cartography. With point maps cross-calculation between different tables is also possible and this is a forte of this kind of maps.

The maps of the following elements of agroclimate averaged in periods (calendar year, months, etc.) have already been made, based on the results from the model:
- air temperature,
- sums of precipitation and probability of precipitation,
- potential evapotranspiration,
- air humidity at noon,
- number of hours of sunshine duration,
- number of days of snow cover of specified depth, this algorithm developed by Kozyra (9).

Other maps (with no direct relationship to periods) include:
- elements of plant phenology (recommended dates of maize sowing, the mean date of maize ripening, probability of maize ripening),
- climatic index of hop yields,
- potato yield loss as influenced by precipitation deficiency,
- climatic valuation of selected staple crops, etc.

OTHER IMPLEMENTATIONS OF THE AGROCLIMATE MODEL

The Agroclimate Model can not only compute the mean values of an element of climate but also determine the resultant action of a number of pre-selected elements. Moreover, other information (e.g. soil characteristics, economic and socio-economic data etc.) can be superimposed on the climatic one to create complex analyses in which agroclimate is one of the variables (15). Along these lines a method to generate maps of cost-effectiveness of potato irrigation in Poland was developed (14). Similarly, a method for generating numerical maps of profit probability for maize production in Poland was developed (15). With these methods regions most suitable for cultivation of various agricultural crops can be determined with reference to the criteria most proper for the purpose of the analysis. These methods, along with others developed during the research on the model, may find application in decision support systems for presenting information to a variety of users: farmers and agricultural advisors, landscape architects, civil engineers, regional planners, foresters, ecologists, agricultural scientists etc. An example of the end product of the model is the Agroclimate Atlas of Poland (available on CD) which contains over one hundred climatic maps (Fig. 3). An example of a thematic map based on the data derived from a combination of a few different algorithms is shown in Fig. 4. The computer program "The Agroclimate

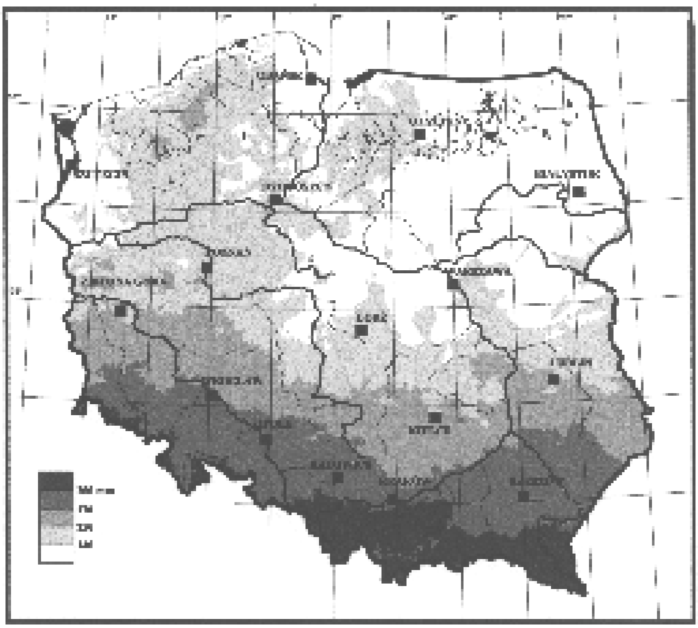

Fig. 3. One of the agroclimatic maps from the Agroclimate Atlas of Poland
(a map of the sum of precipitation exceeded with the probability of 1%)
Jedna z map agroklimatycznych z Atlasu Agroklimatu Polski
(mapa sum opadów przewyższanych z prawdopodobieństwem 1%)

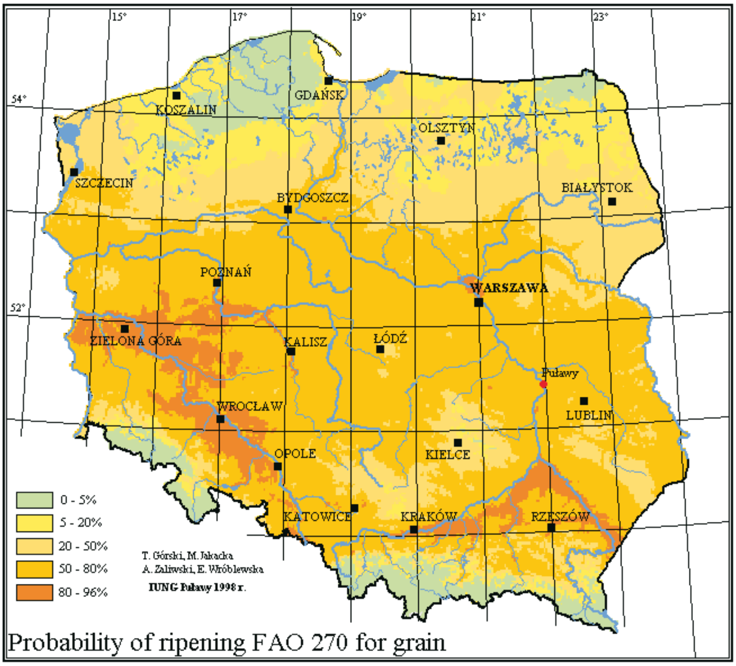

Fig. 4. One of the thematic maps from the Agroclimate Model of Poland
(a map of probability of ripening of the FAO 270 maize for grain)
Jedna z map klimatycznych z Modelu agroklimatu Polski
(mapa prawdopodobieństwa dojrzewania kukurydzy FAO 270 na ziarno)

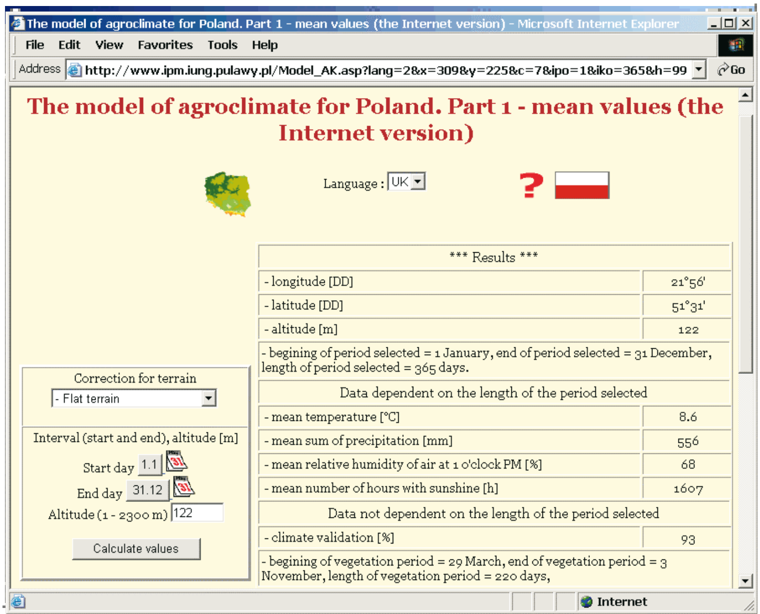

Fig. 5. One of the Web pages of the Internet version of the Agroclimate Model of Poland
Jedna ze stron www internetowej wersji Modelu agroklimatu Polski

Model" (Fig. 1) for calculating elements of agroclimate in a point is also available. An Internet version of the model for point data has now been made available as well (Fig. 5). It has currently five modules: mean values of agroclimate elements, probability of precipitation, precipitation exceeded (precipitation in the period as calculated on the basis of a given probability), climatic index of hop yield and potato yield loss as influenced by precipitation deficiency (16). In the Internet version all the user needs to do is to indicate a point in the map, enter the period and choose the terrain properties. The elevation of the point can also be entered if a more accurate value is known; otherwise the value specified by the model is used. After pressing a button in the browser the calculation procedures on the server are set in motion and the results are sent back to the browser.

CONCLUSIONS

1. Agroclimatic maps based on the results from the Agroclimate Model may show any arbitrary period, even as short as one day.
2. The maps produced from data provided by the model are made in an incomparably shorter time than manually. Undertaking tasks previously avoided because of the time and effort required is now made much easier.
3. By coupling the Agroclimate Model with other databases, or using data generated by other models, it can be adapted relatively easily to generate data for making thematic maps needed for different purposes.

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MAPY NUMERYCZNE AGROKLIMATU POLSKI

Streszczenie

Komputerowy model agroklimatu Polski jest jednym z modułów Zintegrowanego systemu informacji o rolniczej przestrzeni produkcyjnej Polski zbudowanego w Instytucie Uprawy Nawożenia i Gleboznawstwa. Jedna z jego wersji jest przeznaczona do generowania danych do konstrukcji map klimatycznych. Posiada on trzy komponenty: Cyfrowy Model Terenu dla Polski, algorytmy obliczeniowe elementów agroklimatu i tabele z wynikami obliczeń. Mapy numeryczne mogą być wykonywane bezpośrednio z danych zawartych w tabelach, połączonych relacją z Modelem Terenu, lub z warstw poligonowych powstałych przez interpolację Modelu Terenu. W Modelu Agroklimatu można obliczać nie tylko średnie wartości podstawowych charakterystyk klimatycznych ale również łączyć algorytmy a także dodawać inne dane, np. ekonomiczne. Opracowane metody mogą znaleźć zastosowanie w systemach wspomagania decyzji do generowania informacji przeznaczonej dla różnych użytkowników: rolników, doradców rolniczych, architektów krajobrazu, planistów, leśników, ekologów, instytutów i uczelni rolniczych itd.

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