Raport Badawczy

Research Report

RB/29/2002

Environmental Aspects of Elaborated Computer Systems of Regional and Country Development

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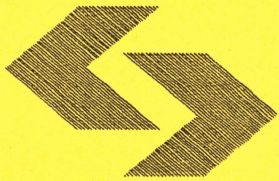

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Warszawa 2002

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Introduction

In recent years the problem of transition towards ecologicaly sustainable economic development has gained real importance due to both resource limitations and the need of environmental protection. In order to solve the problem one should take into consideration (i) availability of technologies enabling utilization of both renewable and nonrenewable energy sources, leading to reduction of air pollution, (ii) availability of financial means required to introduce these technologies, (iii) air quality control techniques that take into account location of pollution sources, regional dispersion/deposition of air pollutants and costs of technologies for air pollution abatement.

In the paper two of the computer systems elaborated at Sytsems Research Institute are presented concentrating on the environment protection aspects: KARO - Computer System for The Analysis of Energy Sector Expansion its Impact on Atmospheric Pollution, and REGION - Computer System for Complex Analysis of Regional Development.

1. Computer System KARO

1.1 General remarks

In recent years the problem of transition towards ecologicaly sustainable economic development has gained real importance due to both resource limitations and the need of environmental protection. In order to solve the problem one should take into consideration (i) availability of technologies enabling utilization of both renewable and nonrenewable energy sources, leading to reduction of air pollution, (ii) availability of financial means required to introduce these technologies, (iii) air quality control techniques that take into

account location of pollution sources, regional dispersion/deposition of air pollutants and costs of technologies for air pollution abatement.

The elaborated computer system KARO deals with the above aspects. Main functions of the system are: (i) to evaluate the consequences of selected expansion scenarios for the energy demand and energy supply sectors, (ii) tho verify the potential of national economy to meet the assumed expansion scenario, (iii) to suggest the optimal strategy for the location of new investments and technologies minimizing the negative impact of the economic expansion on the environment.

The computer system KARO consists of two main parts: (i) the model of national economy including the energy sector, and (ii) the model of air pollutiom dispersion and evaluation of environmental impacts. The main functional blocks of the system are as follows: budget, energy demand, energy supply, new investments amd graphical presentatiom of results. The main goal of the system is to answer the followimg questions: (i) what should be the scenario of energy sector expansion that would lead to reduction of energy consumption as well as abatement of environmental pollution, (ii) what are the means necessary to realize the assumed scenario, (iii) what are the economic conditions under which those means are available, (iv) are the the required technologies of of energy production available (including renewable technologies), (v) what is the optimal location of new investments in the energy sector (in terms of minimization of environmental pollutiom), (vi) what is the spacial pattern of environmental impact (sulfur oxides concentration and total sulfur deposition) resulting from the considered expansion scenario.

The final outputs of the model for the assumed expansion scenario are: (i) predicted emission levels of 6 main pollutans for both existing and newly built power stations and heat generatig plants consdered as point sources - visualised as time functions or, regionaly agregated, on administrative map of Poland, (ii) annualy (seasonly) averaged spatial distribution patterns of polluting factors from heat and power stations under condideration (eventually including the low level emission from household sector and transboundary flows) - presented in the form of concentration/dposition maps in regional and/or country scale.

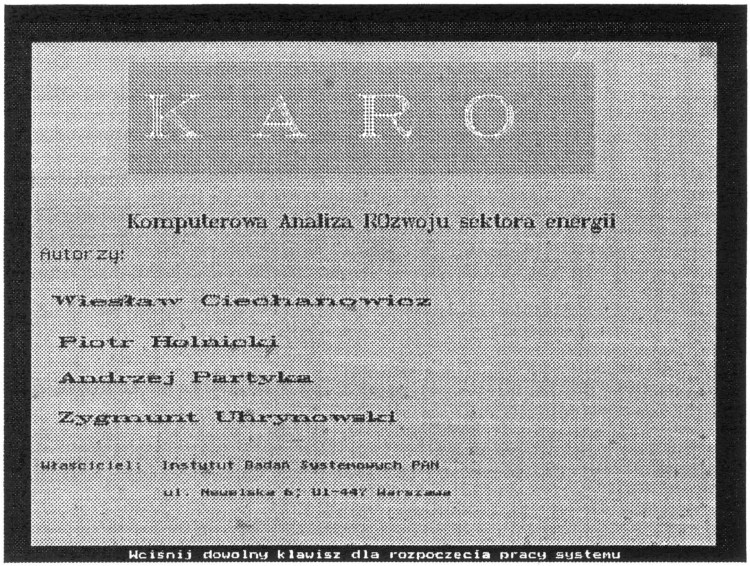


Fig. 1.1. The title panel of the KARO computer Sytem

1.2. Selected numerical results

The system has been applied for analysis of economic and environmental consequences of selected expansion scenarios of energy demand and energy supply sectors in Poland. The set of the main emission sources consists of 70 major power and heating plants. The simulation was performed within the period 1993 -- 2030. It is assumed that potential for energy conservation in industry is 10 – 20 % of conventional technology case, depending on the branch of industry. Moreover, it is assumed that the unit heat demand in residential buildings will respectively decrease within the period of simulation.

The following scenarios of energy sector expansion were considered:

Scenario 1. No technological changes are introduced in the energy system,

Scenario 2.Major technological modernization in residential sector is applied: (i) building isolation technologies leading to reduction of the unit heat demand, (ii) central solar heating plants with seasonal storage, assisted by an electric, gas or oil driven heat pump,

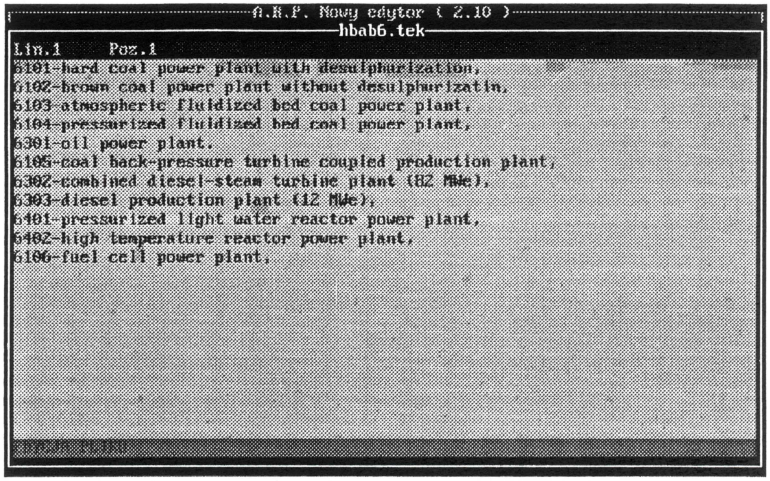


Fig 1.2. The assumed set (a) of conventional and unconventional technologies for energy production sector

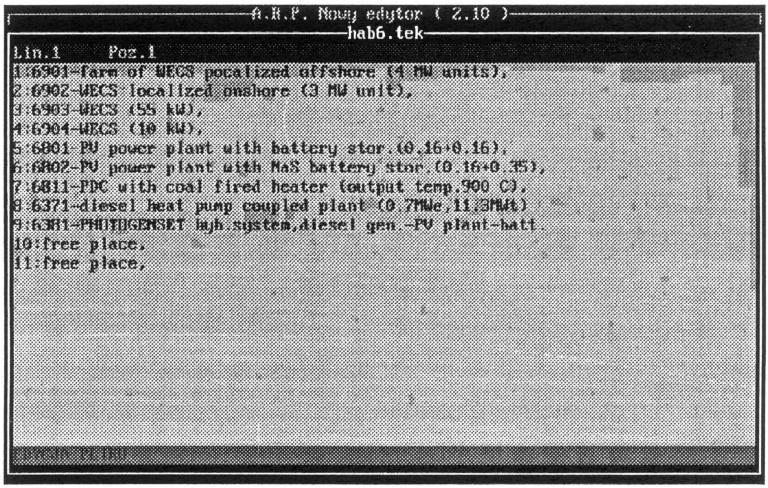


Fig 1.3. The assumed set (b) of conventional and unconventional technologies for energy production sector

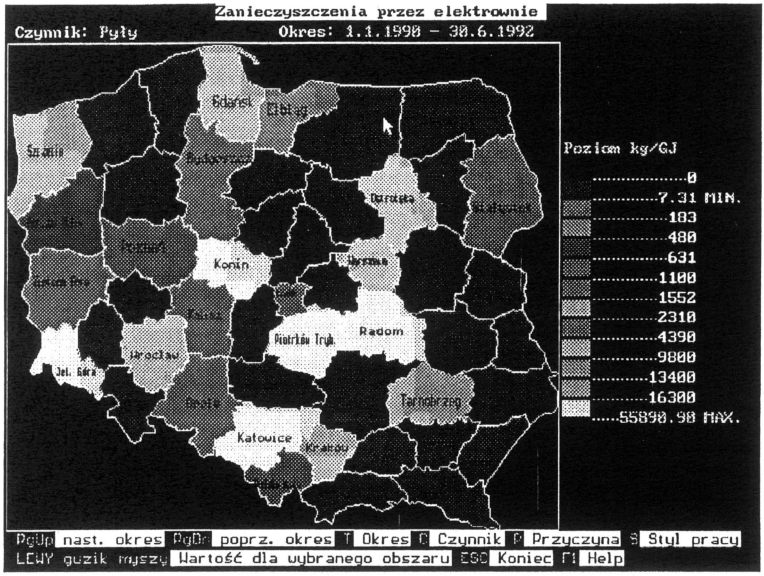


Fig. 1.4 Emission levels in the country regions predicted in a chosen time period - for one of the scenarios proposed

Scenario 3. As in Scenario 2, plus energy conservation technologies in all the branches of industry,

Scenario 4. As in Scenario 3, plus the following unconventional technologies: (i) offshore located wind generator farms, (ii) short rotation forestry culture for wood production, utilized next as energy carrier, (iii) chemical conversion of wood to liquid fuels.

In Fig 1.2 and 1.3 the sets of conventional and unconventional technologies for a residential sector has been shown. Similar sets of conventional and unconventional technologies for energy production sector have also been assumed. In the Fig. 1.4 there are shown emission levels predicted for one of the scenarios proposed - for particular regions of Poland,

In Fig. 1.5 the initial distribution of SO_2concentration for the year 1993 due to residential sector and local industry emissions is presented. The impact of transboundary concentration inflow is shown in Fig. 1.6. Figure 1.7 presents the total SO_2 concentration map, including energy sector emissions for the initial year 1993. Location of the main point emission sources (power and heating plants) is indicated. Environmental impact of one of the

energy expansion scenario for the year 2030 is presented in Fig. 1.8. General decrease of concentration observed is a result of energy conservation policy and emission reduction by utilizing "clean" technologies (compare Fig. 7).

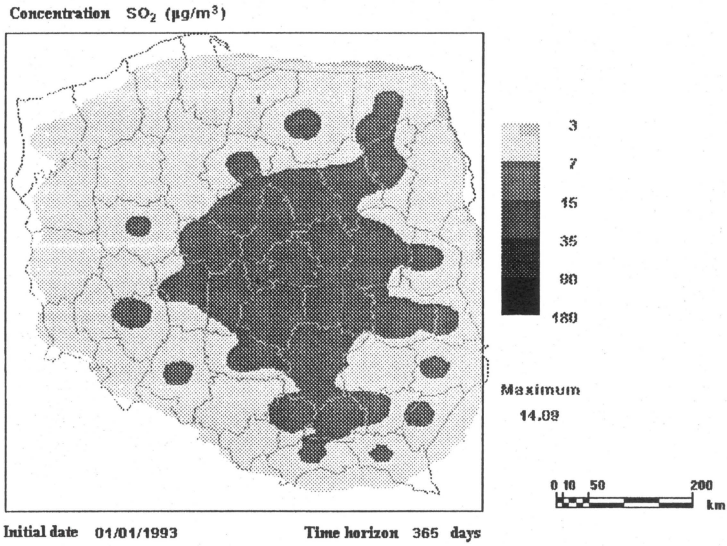


Fig. 1.5 Influence of local industry and the residential sector

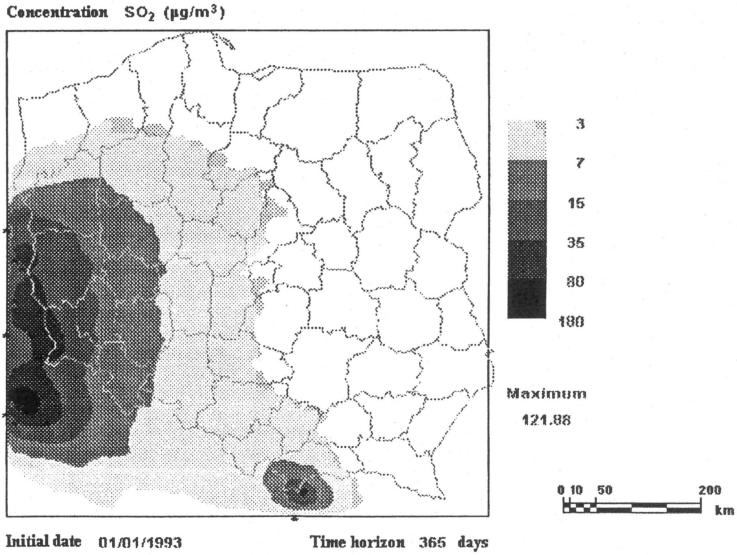


Fig.1.6. Influence of the transboundary SO_2 inflow

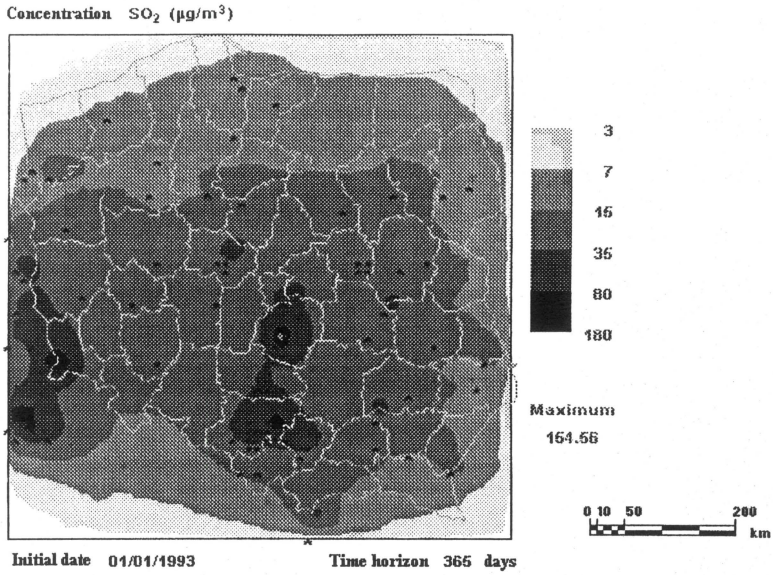


Fig. 1.7 Total year-averaged SO_2 concentration map

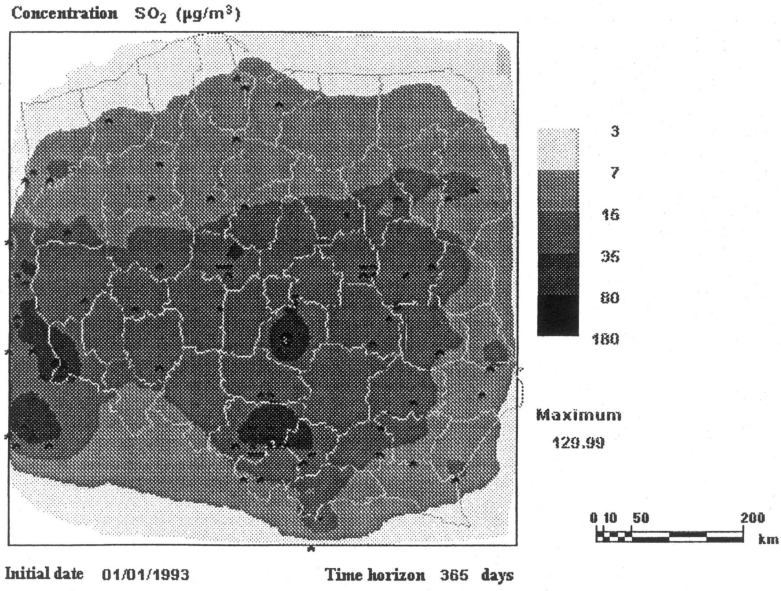


Fig. 1.8. Environmental effect of energy conservation scenario about the year 2030

2. The Structure and Characteristics of the Computer System REGION

2.1 General remarks

The computer system REGION developed at System's Research Institute was elaborated as an aid for decision makers in solving the following problems:
in the scale of regions (in the sense of voivodship) or country
1. testing assumed scenarios of sustainable region expansion development,
2. determining conditions for the use of chosen unconventional technologies of renewable and unrenewable energy sources,
as well as:
3. supplying documentary evidence to enable possible ecoconversion of the Polish debts for the suitable region development,
in the scale of communes:
4. looking for the best (most profitable) variants of development strategy, having in mind the following aspects:
   - increasing the commune share in the generation of the Gross Domestic Product,
   - decreasing the number of unemployed,
   - decreasing the emission of destructive substances to the air,

as well as to estimate:
   - the financial consequences of implementation of proposed expansion strategies.

The structure of the system

The REGION computer system consists of many cross-linked modules. The modules itself have the hierarchical, multiple-level structure. The first level consists of the basic modules:

- selection of an administration level. i.e. a given region (commune, county or voivodship)
- demographic forecast for the voivodship, to which the selected region belongs
- analysis of the activities in selected economy sectors: agriculture, industry, water management
- analysis of the activities in selected branches of services: trade, transport, housing, municipal services, education, culture, health, sports.
- assessment of the individual incomes, consumption and savings resulting in the demand for new houses in the region
- analysis of the house building in the region, as one of the factors of the development
- assessment of the incomes and expenditures of the communes
- assessment of the demand for the energy carriers by the industrial and services sectors
- assessment of the environmental pollution on the commune level
- and the second level consists of the modules:
- data input, selection, aggregation and preliminary processing, when necessary
- calculation procedures for the selected data set
- analysis of the output data with the selection of the best solution

The analysis of sustainable development consists:

in agriculture module:

- ♦ farm restructuring
- ♦ new farm specialization in production
- ♦ soil irrigation

in industry module:

- ♦ assessment of the financial condition of the firms active in the commune
- ♦ level of unemployment in the commune

The analysis of renewable energy sources utilisation consists:

in agriculture module:

- biomass cultivation for energy production

in water management module:

- installation of small hydro power plants

in housing module:

- installation of solar heating systems

in energy supply module:

- installation of wind powered electrical plants

The analysis of environmental protection consists of:

- atmosphere pollution from the global point of view – emission of greenhouse gases
- atmosphere pollution from the local point of view – emission of sulphur and nitrogen dioxides, causing acid rains.

The expansion goals, for the separate production and service activity types, are determined. They are subgoals of the main expansion goal involving the sustainable region expansion, which include the environment protection as well as utilization of renewable energy sources. For the assumed subgoals of separate activities the computer system enables to assign the expansion consequences in the form of expansion constrains and the required production means.

Function realized by separate modules can be accessed by the help of screen menus. For the user convenience they create multilevel hierarchical structure. Apart from the overall description, each module has it own description being the first position of menu. By choice the given menu position initiate the execution of programs, which realize the defined functions, or to pass menu lower position. Fig. 2.1 illustrates the main menu of REGION computer system where the enlighten bar is placed on the production sectors item. The structure of this sector is described in the lower screen window and the corresponding submenu is presented on Fig. 2.2. Selecting the agriculture sector item and pressing Enter gives rise to the main menu of this sector presented on Fig. 2.3. As it can be seen from this picture, the agriculture sector comprises two subsectors: vegetal production and animal production. The fourth level system menu regarding the vegetal production is showed on Fig. 2.4.

COMPUTER SYSTEM FOR COMPLEX ANALYSIS OF REGION DEVELOPMENT

INCLUDING PROBLEMS OF
ENERGY, AGRICULTURE, WATER MANAGEMENT,
ENVIRONMENT PROTECTION AND
SUSTAINABLE DEVELOPMENT OF RURAL AREAS

REGION

SYSTEMS RESEARCH INSTITUTE
POLISH ACADEMY OF SCIENCES

2000

Fig. 2.1 Title panel of the REGION computer system

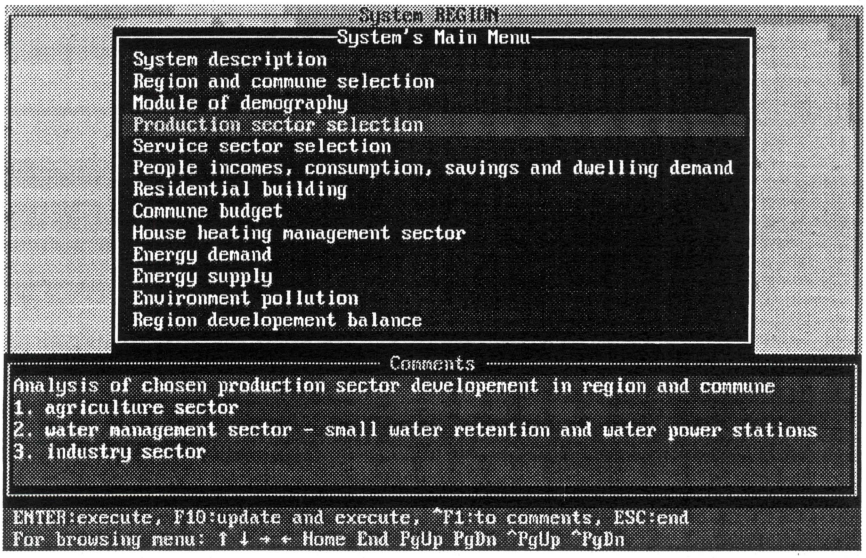


Fig. 2.2 The main menu of the REGION computer system

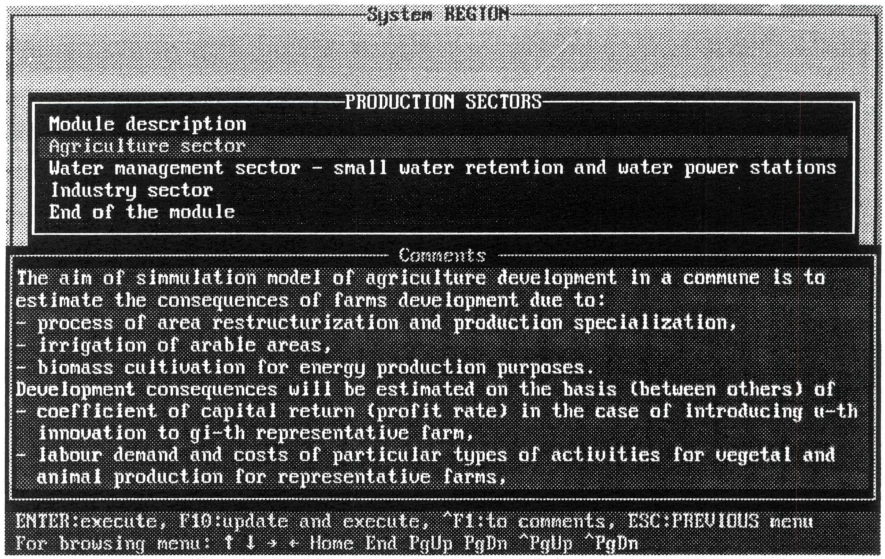


Fig. 2.3 The menu of the production sectors module

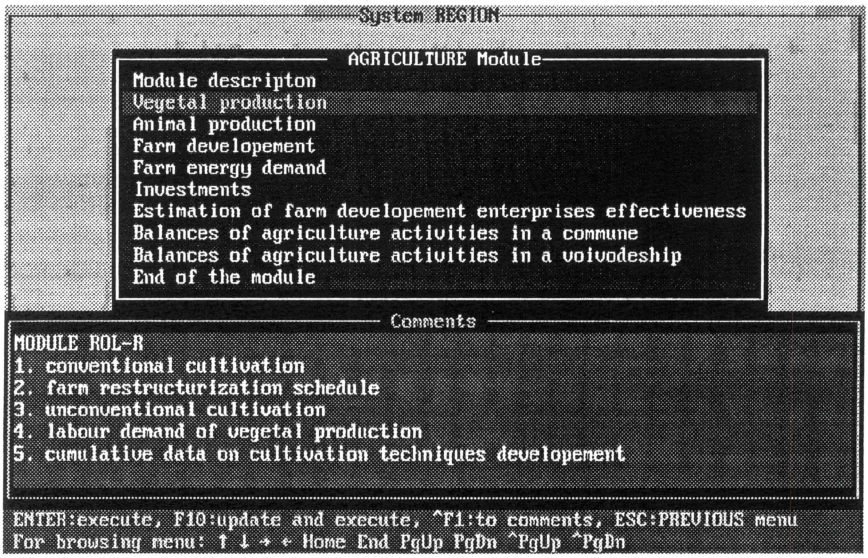


Fig.2.4 The main menu of the agriculture module

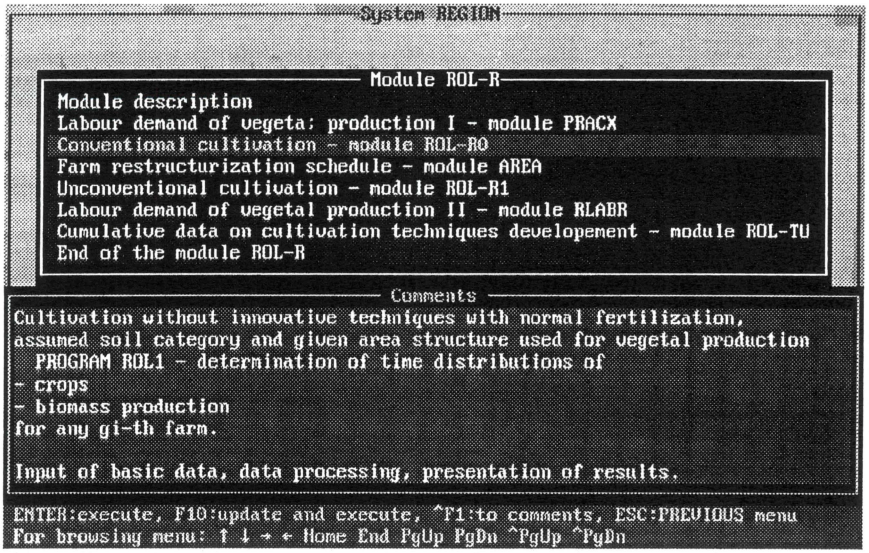


Fig. 2.5 The menu of the vegetal production module

2.2 Forecasting of sulfur oxides transboundary inflow

The sulfur dioxides due to the acid rains can contribute among others to destruction of biomass plantation. The knowledge of the transboundary pollution flow of sulfur dioxides could be helpful for the control of the pollution impact on the environment, as well as for the biomass plantation localization.

General problem description

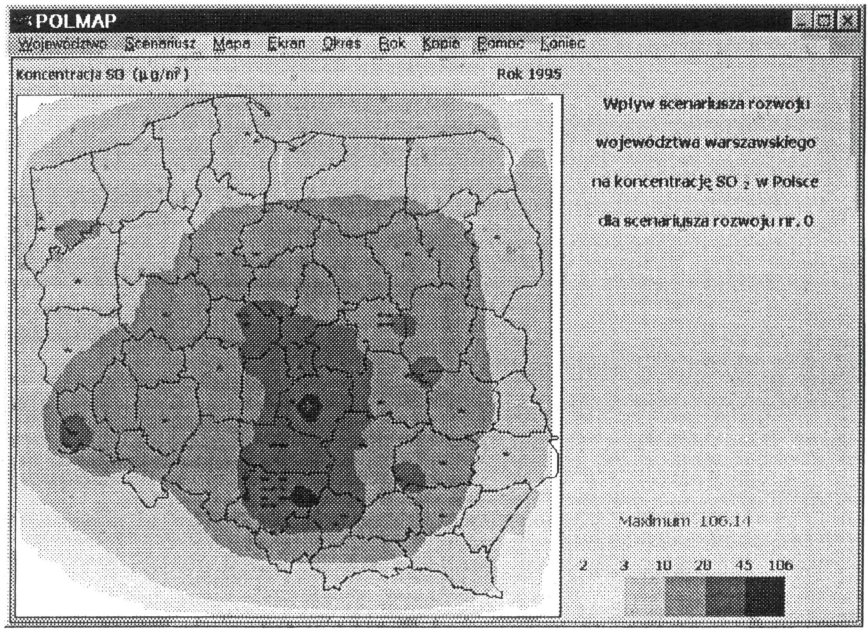
The total emission of sulfur oxides and nitrogen oxides in Poland is one of the biggest in Europe. High level of air pollution has a great impact on the environment (e.g. soil, forests, water, agriculture crops etc.) and affects people's health not only in Poland but also in neighboring countries due to transboundary pollution flows. On the other hand, emissions from major power plants in other East European countries (East Germany, Czech Republic) affect significantly South-West regions of Poland.

The simulation of sulfur oxides forecasting is realized in two stages. The first involve the assessment of the sulfur dioxide emission by all hydrocarbon fuel consumers for separate

regions of the country. Residential sector is considered as the set of voivodship-averaged, aggregated area sources. Also, the influence of the neighboring regions (countries) due to transboundary pollution inflow is taken into consideration.

Then these information are utilized by environmental pollution module. Model of this module calculates year-averaged (or season- averaged) spatial distributions of polluting factor (concentration/deposition) per unit emission, for power installations under consideration. The input data set consists of structural characteristics of the area (geometry, topography, aerodynamical roughness), meteorological data (wind field, precipitation, mixing height, atmospheric stability conditions). For a given expansion scenario, the matrices are multiplied by the respective (for each source) emission intensity and superimposed to form the resulting pollution field. It is presented in a form of isoline concentration/deposition maps by the graphical output block.

Fig. 2.6 Impact of a development scenario of Warsaw region on sulphur-dioxide concentration in Poland



Bibliography

1. W.Ciechanowicz, Z. Uhrynowski, Some problems in the simulation of the sustainable development of rural type regions in Poland. 1st Polish – Swedish Working Meeting On Establishing International Collaboration in the Field of Bioenergy Production and Utilization,Warsaw, Jun 19, 2000.

2. W.Ciechanowicz, Z. Uhrynowski, The Structure and Main Features of the Computer System REGION. 1st Polish – Swedish Working Meeting On Establishing International Collaboration in the Field of Bioenergy Production and Utilization,Warsaw, Jun 19, 2000.

3. W.Ciechanowicz, P. Holnicki, M. Inkielman, A. Kałuszko, A. Partyka, J. Sikorski, L. Słomiński, Z. Uhrynowski, S. Zadrożny (Systems Research Institute Polish Academy of Sciences), A. Ciołkosz, K. D¹browska-Zielińska (Institute of Geodesy and Cartography, Remote Sensing and Spatial Information Centre), „Problems of economy, energy, water management and environment in the simulation of the sustainable development of regions with the majority of rural areas" Materiały konferencji International Meeting „IIASA Days in Ukraine", Kijów, marzec 18-19,1999 r.,

4. W. Ciechanowicz, Suggested frames of a workshop on „Biomass and Fuel Cells: Alternatives for Environment Protection and Rural Development", 1st Polish – Swedish Working Meeting On Establishing International Collaboration in the Field of Bioenergy Production and Utilization,Warsaw, Jun 19, 2000.

5. W.Ciechanowicz Bioenergy as a factor of the sustainable rural area development in Poland, IIASA, 2001

6. W.Ciechanowicz, Z. Uhrynowski, A computer system for Poland's sustainable development analysis, encompassing problems of environmental protection, agriculture, energy, and water management. Research project description. 1st Polish – Swedish Working Meeting On Establishing International Collaboration in the Field of Bioenergy Production and Utilization,Warsaw, Jun 19, 2000.

7. W.Ciechanowicz, A. Partyka, Z. Uhrynowski, System komputerowy do kompleksowej analizy wykorzystania bioenergii na obszarach wiejskich, Warszawa 2000.

8. W.Ciechanowicz, A. Partyka, Z. Uhrynowski, Problemy intensywnej uprawy biomasy w modelu symulacji rozwoju rolnictwa w regionie rolniczym, Warszawa 2000.

9. W. Ciechanowicz, „Bioenergia jako Czynnik Rozwoju Obszarów Wiejskich, Międzynarodowe Warsztaty Szkoleniowo – Naukowe „Bioenergia na Rzecz Rozwoju Wsi" Warszawa, 26 - 29 września 2001.

10. Z. Uhrynowski, System Komputerowy do Wariantowej Analizy Rozwoju Regionu, Międzynarodowe Warsztaty Szkoleniowo – Naukowe „Bioenergia na Rzecz Rozwoju Wsi" Warszawa, 26 - 29 września 2001.

11. W.Ciechanowicz, Z. Uhrynowski, Biomasa – metanol - ogniwa paliwowe: Założenia, uwarunkowania i koncepcja programu rozwoju wsi i ochrony środowiska", IBS PAN, Warszawa 2001.