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SYSTEM OF ECOLOGICAL FORECASTING (SEF): USERS' MANUAL

INTRODUCTION

The system of ecological forecasting (SEF) created at the All-Union Research Institute for Systems Studies (VNIISI) in Moscow, is designed for analyzing and forecasting changes in local environmental conditions, which may result from human activities within a region, natural calamities, or global changes. The basic portion of the system is an integrated model of environmental adjustment. Access to the model is achieved through an interactive procedure designed to meet the requirements of users with different backgrounds in ecology and programming. All programs are written in FORTRAN 77. The model has been successfully applied for projecting the outcomes of various policy options in forestry and regional development.

1. OVERVIEW OF THE MODEL

The model deals with environmentally homogeneous areas (regions) not less than 10,000 km^2 in size. The specification of the equations included in the model is based on the historic evolution of paragenetic sets of lands. The model consists of 3 submodels (sectors), devoted to the adjustment of different sets of environmental parameters: the biotic sector, the water sector, and pollution sector.

The biotic sector covers the reproduction of vegetation (biomass), as well as changes in the amount of dead biomass and soil fertility.* The model distinguishes 3 types of lands:

- lands not used for agricultural purposes;
- lands used for agricultural purposes; and
- wetlands

and a variety of vegetation types, such as tundra, taiga, different kinds of forests, etc. The model also accounts for possible shifts from one type of vegetation to another as a result of changes in environmental conditions.

The biotic parameters of the model are responsible to exogenous disturbances (policy measures, natural calamities, global changes as well as inputs from other sectors of the model). The following options may be included in the user-defined scenario:

- changes in temperature trend
- changes in precipitation trend
- changes in the amount of pollutants and fertilizers
- changes in irrigation
- changes in the amount of biomass caused by fires on lands not used for agricultural purposes
- new forest plantations on lands not used for agricultural purposes
- new shelter belts

The water sector of the model covers surface-water flows, ground-water flows (upper and deeper layers), and water reservoirs. The output of this sector includes the density of erosion furrows, the rates of ground-water flows, soil salinity, and other hydrological parameters.**

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*The reader will find a more detailed description of this sector in Kroutko et al. (1982a,b).

**The model does not give the rates of surface-water flows, since this is largely a spatial problem, which cannot be resolved by means of a structural model.

The inputs to this sector include:

- user specified changes in drainage intensity and in the amount of land, covered with reservoir (lakes, ponds, etc.)
- user specified changes in the ground-water stock (amount of water pumped for irrigation purposes)
- user specified changes in the amount of land used for agricultural purposes; water delays in irrigation
- climatic changes (global, specified by the user)
- other changes in ecological parameters of the region, which are outputs from the biotic and pollution sectors of the model

The pollution sector is, in a sense, a superstructure designed for the detailed analysis of one of the major anthropogenic factors, i.e., pollution. The pollutants which are included in the model fall into the following categories:

- sulfur oxides
- nitrogen oxides
- nitrogen, phosphorous, and organic combinations

The latter are actually fertilizers, but as they are dampened in water, they are pollutants and we have therefore included them in the pollution sector.

The type of chemical transformation of the pollutants depends upon the environment, therefore the pollution of air, soil, and water are treated separately (this is also true for different types of lands). The transformation of fertilizers which form durable combinations with soil components are not considered, though the model accounts for the improvement of soil due to fertilization.

The pollution submodels assumes two kinds of control:

- changes in pollution rates by type of environment (air, water, soil)
- changes in the rates of chemical transformation of the pollutants, which are a result of changes in water flow and depend on the current state of the ecosystems (which is an output from the other submodels)

The three submodels mentioned above form an integrated model of local environmental development. The system also includes a number of service modules, which will be discussed below. Here we shall only mention the initialization module which automatically sets the values of the environmental parameters corresponding to an aggregated (mostly verbal) description of the region specified by the user.

The approach is based on the assumption that the quantitative characteristics of the region closely correlate to a limited number of aggregated regional characteristics such as climatic zone, type of topography, type of lithology, so that the disaggregated values may be defined with a reasonable degree of accuracy on the basis of the verbal characteristics of the environment specified by the user. However, this approach implies a rather high degree of aggregation. All the user specified characteristics should relate to the region as a whole, i.e., represent average values. Similarly to inputs, the outputs of the model refer only to the general trend of regional development. The results, however, are by no means trivial. Computer experiments have shown that the model successfully copes with the effects of: soil deterioration, forest degradation caused by acid rains, various changes in the composition of soil and water as a result of agricultural development, and changes in potential production of various crops, resulting from climate changes.

2. GENERAL DESCRIPTION OF THE SYSTEM

We hope that the user will find the system easy and convenient to work with. It was designed to satisfy the requirements of the users with little or no background in programming and computers. Input mistakes (if traced by the system) are ignored. The most frequent display is a list of options; the user has only to specify the option number which does not usually require much effort.

Other advantages of the system include the following:

- interactive access to the model
- the specification of the region can be saved for future use
- the specification of scenarios can be saved and restored in case the user wishes to make alterations
- information on the current state of the system is available upon the request of the user
- the results may be presented in plotted or tabular form

3. MODELLING STAGES

A user may test an unlimited number of different policies or scenarios in the course of a session. However, his moves on each policy or scenario version involve six steps as follows:

1. specify region
2. adjust the model to regional data
3. specify scenario
4. set time interval; run the model
5. observe output
6. choose next stage

The session always starts with stage 1, although the sequence of stages as they may be encountered in the course of the interaction is not necessarily numerical (see Figure 1).

Before discussing each stage of the modelling session in greater detail, we shall make a few technical remarks:

- in response to the prompt:

  ANY ALTERATIONS? (yes = 1; no = 2)

  type 1 for "yes", and 2 for "no"
- when you specify the value of a certain variable, make certain that it is measured in the units indicated in the prompt
- when a list of options is displayed, the user is expected to input the number
- in case an input mistake should occur, the system will repeat its question and ignore the previous input

An example of an interactive session is presented in Appendix 3.

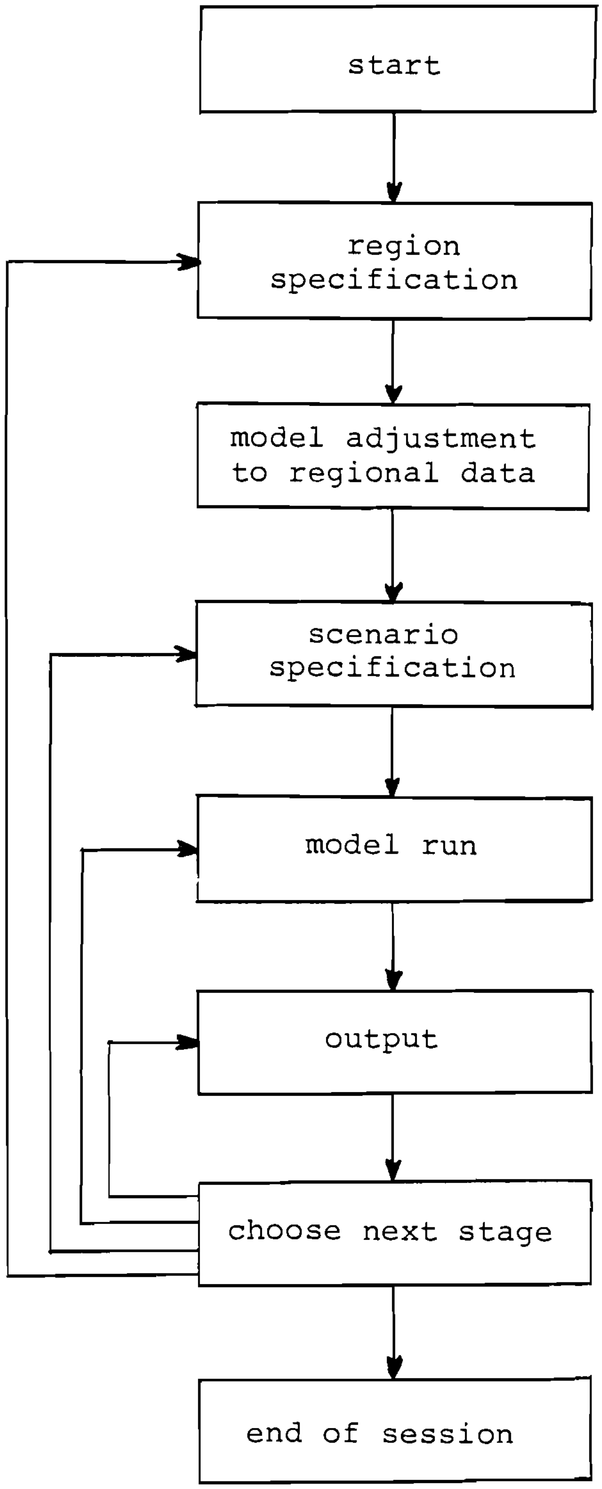

Figure 1. Session stages.

3.1 How to Start the Session

To run the model type SEF on your terminal. The session opens with the following message:

YOU ARE WELCOME TO
THE SYSTEM OF ECOLOGICAL FORECASTING

You will have to wait for a few seconds—the time needed to install the task and initialize the system.

3.2 Specify Region

The stage opens with a heading

SPECIFY REGION

The user will be requested to specify the ecological characteristics of the region that he has chosen to work with. The input values should be long-term averages rather than current parameters. If the user is interested in the behavior of the system under some unusual circumstances he should specify all the external disturbances at the stage of scenario specification.

There are several ways in which the user may specify the region. These are listed in the first display of this stage:

<u>Modes of specification</u>

1. optional
2. automatic
3. select standard region
4. return to previous region
5. pass on to next stage

Options 1-4 are closed in the sense that after the user has reached the end of any path (rooted in these options) the system returns the initial display so that if any alterations are necessary the user may go through the procedure again.

3.2.1 Option 1: Optional Specification

The user is requested to specify detailed regional characteristics by answering to systems prompts.

The whole procedure is divided into several substages, each of which ends with a question:

Any alterations? (yes = 1, no = 2)

If the answer is "yes", the user is offered a chance to make input corrections within the current portion of the list.

The full list of specifications is as follows:

<u>Hydrological and geological</u>

- filtration from transit rivers (mm/km^2) (water infiltrated into ground-water horizon (within the boundaries of major transit rivers)/total area)
- maximum of monthly surface water flow rates/annual rate of surface water flow (%)
- depth of first ground-water plane (m)
- depth of second ground-water plane (m)
- depth of first aquiclude (m)
- depth of second aquiclude (m)
- depth of second water-bearing horizon roof
- depth of permafrost (m) (in case there is no permafrost, input 150)
- total dissectment (km/km^2)
- dissectment by transit rivers (km/km^2)
- maximum cut (m)
- average cut (m)
- % of total area, covered with lakes
- average surface slope (tangens)
- average width of river valleys
- downward infiltration of ground-water (%)
- infiltration of ground-water, second layer, into rivers (%)
- ground-water salinity (grams/liter)
- deep ground-water salinity (grams/liter)

Any alterations? (yes = 1, no = 2)

Second substage. The user is expected to specify the biotic parameters by three types of lands:

Biomass, average (tons per hectacre):

1 - lands not used for agricultural purposes

2 - lands used for agricultural purposes

3 - wetlands

Mortmass, average (tons per hectare):

1 - lands not used for agricultural purposes

2 - lands used for agricultural purposes

3 - wetlands

Soil Index

1 - lands not used for agricultural purposes

2 - lands used for agricultural purposes

3 - wetlands

The soil index is a measure of soil fertility. The lowest value of the index is 0, the highest is 20. The following approximate estimates may prove helpful: podzols - 4; grey forest soil - 9; siliceous soils - 9; brown, savanna soil - 12/15; black soil - 18/19.

Soil salinity (%)

1 - lands not used for agricultural purposes

2 - lands used for agricultural purposes

Step 3 opens with a message:

> "Attention! The values of the specified parameters should be consistent with the altitude of the area in question."

The user is requested to input average annual values accounting for the climatic differences in mountain areas and plains.

- precipitation (mm)
- temperature (centigrade)
- wind velocity (m/sec.)
- difference in temperature for valleys and uplands (centigrade)

Substage 4. The user has to specify the prevailing type of lithology:

1 - sand
2 - loamy sand
3 - loam
4 - clay
5 - marl
6 - compact sedimentary rocks
7 - intrusive and metamorphic rocks
8 - shingle beds
9 - karst rocks

This terminates the optional procedure and the system returns to the initial list. The user may either pass on to the next stage or change the specifications.

3.2.2 Option 2: Automatic Specification

This mode does not require as much input information as the previous one. The user should answer only 6 questions (in contrast to 38 in case of optional mode). All the necessary data will be automatically reconstructed by the system on the basis of verbal description. The first two lists deal with the types of geographical belts and prevailing type of vegetation:

<u>type of geographical belt</u>:

1 - arctic
2 - temperate
3 - temperate belt of central sector
4 - subtropical
5 - tropical
6 - equatorial
input option number -

<u>type of vegetation</u>:

1 - arctic lichen tundra
2 - moss - lichen tundra
3 - low bush tundra
4 - subtundra
input option number -

The content of the second list depends upon the response of the user to the previous one. The above list appears in case of option 1 of the first list(arctic). Option 2 (temperate belt) would be followed by

<u>type of vegetation</u>:

5 - taiga
6 - mixed forest
7 - broad leaf forest
8 - meadow steppe
9 - steppe
10 - dry steppe
11 - subdesert
12 - desert

Option 3 (central part of temperate belt) would be followed by

<u>type of vegetation</u>:

13 - taiga
14 - southern taiga
15 - mixed forest
16 - steppe
17 - dry steppe
18 - subdesert

Option 4 (subtropical) leads to

<u>type of vegetation</u>:

19 - subtropical desert
20 - subtropical steppe
21 - subtropical prairie
22 - subtropical sclerophyllous forest
23 - sclerophyllous forest, sparse growth of trees
24 - subtropical monsoon forest

Option 5 (tropical) -

<u>type of vegetation</u>:

25 - tropical subdesert
26 - tropical desert
27 - tropical savanna

28 - tropical monsoon forest
29 - tropical forest

and finally, option 6 (equatorial) -

<u>type of vegetation</u>:

30 - subequatorial savanna
31 - subequatorial monsoon forest
32 - equatorial forest

The second list terminates this sequence and the user is requested to specify the type of topology:

<u>type of topology</u>:

1 - low land
2 - plains
3 - upland
4 - low mountains
5 - plateau
6 - mountains, medium height
7 - table-land

The next list contains different types of lithology and is equivalent to the relevant list of the optional mode:

<u>type of lithology</u>:

1 - sand
2 - loamy sand
3 - loam
4 - clay
5 - marl
6 - compact sedimentary rocks
7 - intrusive and metamorphic rocks
8 - shingle beds
9 - karst rocks

The following list contains various intensities of marshiness for different types of hydrological land structure. High level of marshiness of typical for aquiclude - 0.5-2 meters deep; medium for 2.5-3.5 meters deep; low for 3.5-5 meters deep.

The display is:

<u>marshiness resulting from shallow aquiclude</u>:

1 - is absent
2 - strong
3 - medium
4 - weak

This terminates the automatic specification mode.

3.2.3 Option 3: Select Standard Region

No additional information is required of the user who has chosen to work with a standard region. The specification of the region in this case is as follows:

type of geographical belt - 2 - temperate
type of vegetation - 7 - broad leaf forest
type of relief - 2 - plains
type of lithology - 2 - loamy sand
marshiness - 1 - is absent
filtration from transit rivers - 0 - is absent

Having entered this information in the system displays the previous (initial) list of options and prompts the user to continue the interaction.

3.2.4 Option 4: Return to Previous Region

In case the user has chosen to work with the previous region the system restores the specification of the region as it was immediately after the last region specification procedure. This mode of specification, however, may be chosen only in case the previous region was actually specified by the user.

3.2.5 Option 5: Pass on to Next Stage

In response to option 5 the screen displays the following message:

INPUT COMPLETED

THE MODEL IS BEING ADJUSTED TO REGIONAL DATA

This indicates that the specification of the region is completed and the control was transmitted to the next stage - model adjustment to regional data, which is performed automatically.

3.3 Model Adjustment

Model adjustment does not require the participation of the user. Once the procedure is over, the screen displays the following message:

MODEL ADJUSTMENT COMPLETED

Input proportion of lands used for agricultural purposes (%)-

and waits for an answer. Having received it, the system passes control to the next stage. If the answer is inconsistent with the previously defined characteristics, the session is terminated. To change the answer the user will have to initiate the model once again.

3.4 Specify Scenario

This stage starts with a prompt:

SPECIFY SCENARIO

0 - continue

1 - return to previous scenario

2 - show system state

3 - temperature trend

4 - precipitation trend

5 - pollution and fertilization rates

6 - irrigation regime

7 - drainage intensity

8 - fires on lands not used for agricultural purposes

9 - artificial destruction of biomass

10 - increase or decrease of lands used for agricultural purposes

11 - new plantations on lands not used for agricultural purposes

12 - new shelter belts on lands used for agricultural purposes

13 - changes in the amount of wood caused by lumbering

It is assumed that the policy/scenario options will remain unchanged over the next simulation period. Any policy change may be introduced only after this period is over. A user may define as many successive policies of regional development as he wishes, provided that he does not surpass the upper limit of total simulation time, which is 200 years.

It should be noted that the model does not extend the effects of previous policy decisions to the successive periods so that in case the user wishes to trace them, he should formulate his policy options respectively.

We shall illustrate the procedure of scenario formulation with the following example, devoted to the evolution of a forest over the period of 25 years, assuming that 10 years after the beginning of this period there is a forest fire.

Having defined the region we go on to specify the scenario, that includes a set of policy variables and changes due to natural causes. The first time period will be 9 years. After the run is over we shall reformulate the scenario to include the effect of a forest fire. The second time period would last only 1 year since forest fires do not usually happen 2 years in a row. Then we shall have the scenario again, leaving out the forest fire option to trace the effects of the initial policy decisions over the following 15 years.

The interactive procedure at the stage of scenario specification is very similar to that of region specification. The system prompts the user with a list of 14 options, of which all but the zero option are closed.

It should be noted that option 13 refers only to forest areas.

3.4.1 Option 0: Continue Modeling

If the user has specified option 0, the system responds with

set time interval (max number of years - *)

which indicates that the control passes to the next (fourth) stage. The scenario, which was selected at stage 3 is stored in a file for possible future uses.

3.4.2 Option 1: Return to Previous Scenario

This option tells the system to restore the previous scenario. While it does so, the screen displays the list of scenario options and the answer of the user. As soon as the previous scenario is restored, the system will display the list anew, prompting the user to indicate his option. This procedure enables the user to formulate new scenarios by altering the previous ones.

3.4.3 Option 2: Show Systems State

In response to option 2 the system displays a table, which includes the current value of all the major variables, referring to the 3 types of lands, water, and climate. The units of the variables are indicated in the brackets:

SYSTEM STATE

```
CLIMATE:     T= 26.216/o/     R= 866.61/mm/
--------------------------------------                  !! LAKES (%) = 0.00
LAND TYPE !NONAGRCL.! AGRICUL.!WETLANDS.!!
 DV (%)   ! 92.7114 ! 0.      !  2.2886 !!             ------------------
 HFV      !  100.69 !  100.19 !  107.27 !!               Flow parameters:
 CLV      !   0.976 !  0.     !   1.360 !!             FL (mm)         =199.975
 CPDL     ! 1.00000 ! 1.00000 ! 1.00000 !!             CFWV(1) (%)     = 46.006
 SPWV(mm) !  0.1315 ! 0.1411  !   0.013 !!             CFWV(2) (%)     = 37.676
 DWNV(mm) !  0.0062 ! 0.1690  !  0.0553 !!             CFWV(3) (%)     = 16.318
 FIS      !  0.     ! 0.      !  0.0001 !!             RMDV (%)        = 15.547
 KV       !       1 !       2 !       1 !!             HGW (m)         =  7.398
 S (tn/h) !   19.76 !   0.    !    8.41 !!             HP1 (m)         = 20.000
 GH(tn/h) !   0.    !   0.    !   0.    !!             HGWD (m)        = 41.398
 SM(tn/h) !   0.006 !  0.     !   0.065 !!             HWPD (m)        = 51.000
 SLTV (%) !  0.1295 ! 0.1798  !  0.3765 !!             HPF (m)         =150.000
 SV       !  16.077 !  6.711  !   4.702 !!             HEX (m)         = 50.000
=======================================!!
    DN(km/km2)=  2.2766   DNF(km/km2)=  1.0305
 RCSV(g/l)=   0.4276  SW1V(g/l)=  0.3770   SW2V(g/l)=  1.3611

 Do you want to save the parameters of system state?(yes=1/no=2) -
```

Do you want to save SYSTEMS STATE? (yes = 1, no = 2)

A list of full names of the variables is in Appendix 1. In case a user wants to save the parameters of the current state of the system, the system will store them in the "state.d" file. After the system has received the answer, the list of scenario options will be displayed.

3.4.4 Option 3: Temperature Trend

The system displays the following prompt:

Rate of temperature change (in degrees centigrade per year)

The user is expected to input the annual rate or temperature change within a region. The temperature trends, specified by the user will maintain over the previously specified period.

3.4.5 Option 4: Precipitation Trend

The system displays the following phrase:

Rate of precipitation change (mm/year)

The user should input the annual rate of precipitation change that will maintain over the previously specified time period.

3.4.6 Option 5: Pollution and Fertilization Rates

The system displays the following list:

POLLUTION AND FERTILIZATION
Pollutants (tons per hectare):

1 - SOx
2 - NOx
3 - CxHy
4 - Pb
5 - Hg
6 - Cd
7 - nitrogen fertilizers
8 - phosphorous fertilizers

9 - muck

10 - exit

Input option number -

Options 1-9 will return the system to the same list. To return to the list of scenario options indicate option 10. If any number from the range 1-6 was chosen, the user will have to specify the distribution of the relevant pollutant between different types of environment by answering to prompts:

- on lands not used for agricultural purposes
- on lands used for agricultural purposes
- air pollution
- water pollution

Options 7 and 8 of the previous list will require answers only to the first two questions of the above list; option 9 will require answering prompts 1, 2, and 4.

Having specified the distribution of pollutants and fertilizers the user should indicate option 10. This is followed by another prompt:

Thermal pollution (in degrees centigrade)

Thermal pollution, as it is assumed here, is the annual increment of average annual temperature due to thermal wastes. This value has to be indicated only once. If the user chooses to alter the rate of thermal pollution, he should indicate the anticipated deviation of the previously defined trend.

3.4.7 Option 6: Irrigation Regime

The user is requested to specify the sources and the intensity of watering in the region

<u>sources of water used for irrigation purposes</u>:

- -ground-water (mm)
- -deep ground-water (mm)
- -artesian water (mm)
- -rivers and lakes (mm)
- -transit rivers (mm)

Water delay on lands used for agricultural purposes:

1 - significant

2 - moderate

3 - is absent

Input option number -

The user is expected to specify water delay only once at the beginning of the session. If later he chooses to consider any changes in the water delay, he should specify the deviation from the previous value.

3.4.8 Option 7: Drainage Intensity

The following text is displayed

Drainage:

1 - intensive

2 - moderate

3 - insignificant

4 - is absent

Input option number -

Increase of area covered with lakes in result of hydrotechnical works -

3.4.9 Option 8: Fires on Lands Not Used for Agricultural Purposes

The system will request the user to specify the damage done by fires by displaying the following prompt:

Damage done by fires:

1 - significant

2 - medium

3 - small

Input option number -

It should be kept in mind that if forest fires are included in the scenario, the system automatically runs the model over a 1-year period and passes the control to the fifth stage.

3.4. 10 Option 9: Artificial destruction of biomass

The display is:

Destruction of biomass by vehicle compaction -
Pasturage is

0 - absent
1 - weak
2 - moderate
3 - intensive
4 - very intensive

Input option number -

3.4.11 Option 10: Increase or decrease of the Amount of Lands Used for Agricultural Purposes

The user is requested to specify the annual increase or decrease of the area of agricultural lands as % of the previous year, total:

Change in the amount of lands used for agricultural purposes

increase -
decrease -

3.4.12 Option 11: New Plantations on Lands Not Used for Agricultural Purposes

The display is:

New plantations on lands not used for agricultural purposes, % of total area -

3.4.13 Option 12: New Shelter Belts

As was already mentioned, this option relates only to the regions where forests occupy a significant part of the area.

The user is requested to answer to the following prompt:

New shelter belts (% of total area) -

3.5 Set Time Interval; Run the Model

This stage opens with the following request:

Set time interval (maximum number of years - *) -

where the asterisk stands for the number of years left before the simulation time expires. The total length of simulation period should not exceed 200 years.

After the system has received an answer it displays the following message:

Model run

When the run is over, the system passes on to the next stage.

3.6 Output Modes

The fifth stage opens with a list of output modes:

<u>Output modes</u>:

1 - standard output
2 - optional output
3 - continue

(However, if the total number of years that have passed since the beginning of the simulation period is less than 5, this stage is skipped and the control automatically passes to the next stage.)

3.6.1 Standard Output

Option 1 is followed by the display of sets of the major variables, included in the model.

The first list is as follows:

<u>Biotic parameters</u>:

1 - soil - vegetation
2 - soil productivity - soil index - dampness
3 - soil - fertilizers

Water parameters:

4 - total flow

5 - surface dissectment

6 - ground-water flow

7 - deep ground-water flow

Salinity parameters:

8 - soil - ground-water

9 - ground-waters - river waters

10 - pollution parameters

Input option number-

If option 10 were chosen, then the second list would be displayed,

```
   POLLUTION PARAMETERS/BY TYPE
OF ENVIRONMENTAL COMPONENT & POLLUTANT

Pollution of
1  -  plants/ with toxic metals
2  -  soil/ with toxic metals
3  -  air
4  -  surface waters/ with metals
5  -  surface waters/ with hydrocarbons/
      nitrogen and phosphorus
6  -  ground-waters/ with  metals
7  -  ground-waters/ with hydrocarbons/nitrogen and phosphorus
8  -  deep ground-waters/with metals
9  -  deep ground-waters/ with hydrocarbons/nitrogen and phosphorus

10 - return to previous list

    Input option number -
```

Option 10 of the second list indicates return to the previous list. Options 1 and 3 of the first list and 1-2 of the second require additional information, which is prompted by the following display:

Type of land:

1 - lands not used for agricultural purposes

2 - lands used for agricultural purposes

3 - wetlands

After the system has received the required information, a list of output forms is displayed. It should be noted that options 2 and 4-9 from the first list do not require any additional information on the type of scaling for plotted output.

3.6.2 Optional Output

Option 2 implies that the user should specify the numbers of the output variables on his terminal. The prompt is

Input variable number -

The list of variables is included in Appendix 2. The prompt is repeated four times, since the number of output variables cannot exceed 4. In case the number is less than 4, the user should input 0 to indicate that the list is exhausted. After this the system will display a list of output forms.

3.7 Output Forms

At this stage the user is requested to specify the form of output for the selected variables. The display is:

Output forms:

1 - tabular
2 - plotted
    Input option number -

Option 1 is followed by a table of output values. An example of such a table can be found in Appendix 3. In case the user specified option 2, he will be requested to specify the type of scaling procedure. The display is:

Scaling modes:

1 - automatic, single scale for all variables
2 - automatic, separate scale for every variable
3 - manual, single scale for all variables
4 - manual, separate scale for every variable
    Input option number -

Option 1: The system initializes a procedure for defining the minimum (Y min) and the maximum (Y max) values among all the values of the output variables (this may be done only in case the output variables are measured in the same units). These values then serve as the upper and the lower boundary of the plotted output along the Y axis.

Option 2: The system defines the minimum (y^i min) and the maximum (y^i max) values for each of the output variables (where i is the index of the output variable). All the output curves are then scaled separately to fit into the same box.

Option 3: The minimum (Y min) and the maximum (Y max) among all the values of the output variable are specified by the user in response to a prompt

Marginal values of variables

In case some values of an output variable exceed (or are less than) the upper (or lower) limit defined by the user, the system cuts off the protruding part of the curve to make it fit into the box.

Option 4: The user is requested to specify the Y^i min and Y^i max values for each of the output variables (i = index of the output variable) by answering to a sequence of prompts

MIN of 1 variable -
MAX of 1 variable -
MIN of 2 variables -
MAX of 2 variables -
MIN of 3 variables -
MAX of 3 variables -
MIN of 4 variables -
MAX of 4 variables -

In case the values of any variable should exceed the specified limits, the protruding part of the curve is cut off in the same way as in option 3 above.

In case the values of any variable should exceed the specified limits, the protruding part of the curve is cut off in the same way as in option 3 above.

3.8 Choose Next Stage

When the user has reached this last stage he is offered the following list of options to choose from:

Session continuation options:

0 - terminate session
1 - define region
2 - define scenario
3 - continue modelling
4 - output results
5 - show current system state
Input option number -

Option 0 terminates the session. The results, i.e., parameters of the systems state, tables and/or plots, will be stored in files "state.d", "figure.d", table.d", respectively.

Options 1-4 transfer control to the current stage of the simulation procedure. In case option 5 is specified, the system will display parameters of current systems state.

REFERENCES

Kroutko, V.N., S.A. Pegov, and B.M. Khomyakov (1982a) *The Evaluation of the Quality of Environmental Components.* Preprint. Moscow: The All-Union Institute for Systems Studies (VNIISI) (in Russian).

Kroutko, V.N., S.A. Pegov, and B.M. Khomyakov (1982b) *A Dynamic Model of Environmental Development.* Preprint. Moscow: The All-Union Institute for Systems Studies (VNIISI).

APPENDIX 1

DESCRIPTION OF VARIABLES USED IN SYSTEM

The description of variables uses the following notation

1. The units of measurement are indicated in brackets after the full name of the variable.
2. Index 'i' appearing in the name of certain variables should be interpreted as follows:
   - i=1 - lands not used for agricultural purposes;
   - i=2 - lands used for agricultural purposes;
   - i=3 - wetlands.
3. Index 'j' indicates different kinds of pollutants and fertilisers:
   - j=1 - sulfur compositions;
   - j=2 - nitrogen compositions;
   - j=3 - hydrocarbons,
   - j=4 - compositions of Pb;
   - j=5 - compositions of Hg;
   - j=6 - compositions of Cd,
   - j=7 - nitrogen fertilizers;
   - j=8 - phosphorus fertilizers;
   - j=9 - organic fertilizers;
   - j=10:15 - reserved indexes.

Biotic parameters.

B(i) - biomass (tons per hectare).
BM(i) - dead biomass (tons per hectare).
CLV(i) - climate index.
CPOL(i) - pollution index.
D(i) - proportion of the i-th type of lands in the total area (lakes not included) (%).
DV(i) - proportion of the i-th type of lands in the total area (lakes included) (%).

DWNV(i) - wind erosion rate(mm/year).
FIS(i) - increment of soil quality index due to fertilisation.
GH(i) - soil productivity (tons per hectare).
HFF(i) - humidity.
HFV(i) - humidity for i-th type of lands.
KV - vegetation type:
KV=1 - grass;
KV=2 - forest-steppe;
KV=3 - forest;
KV=4 - moss-lichen.
SLTV(i) - soil salinity (%).
SPWV(i) - rate of surface errosion by type of land (mm/year) .
SV(i) - soil index.

Drainage parameters.

CFWV(1) - proportion of surface drainage in total drainage (%).
CFWV(2) - proportion of drainage from upper ground layer in total drainage (%).
CFWV(3) - proportion of drainage from lower ground layer in total drainage (%).
DN - total dissectment (km/km2).
DNR - dissectment with rivers (km/km2).
FL - total drainage rate (mm/year).
FL1 - surface drainage rate (mm/year).
FL2 - rate of drainage from upper ground layer (mm/year).
FL3 - rate of drainage from lower ground layer (mm/year).
FL1+FL2 - sum of FL1 and FL2 (mm/year).
FL12+FL3 - sum of FL1,FL2 and FL3 (mm/year).
HEX - maximum cut (m).
HGW - depth of 1-st ground water plane (m).
HGWD - depth of 2-nd ground water plane (m).
HP1 - depth of 1-st aquiclude with the influence of permafrost (m).
HPF - depth of permafrost plane (m).
HWP - depth of 1-st aquiclude (m).
HWPD - depth of 2-nd aquiclude (m).
RMDV - effective surface drainage (%).
SW1V - water salinity, 1-st ground-water plane (g/l).
SW2V - water salinity, 2-nd ground-water plane (g/l).
RCSV - river water salinity (g/l).

Parameters of pollutants and fertilizers (tons per hectare).

PLA(j) - atmospheric pollution.
PLDW(j) - water pollution, 2-nd ground-water plane.
PLGM(j) - ground pollution, between 1-st and 2-nd water planes.
PLGW(j) - water pollution, 1-st ground-water plane.
PLP(j,i) - vegetation pollution.
PLS(j,i) - soil pollution (mobile compositions).
PLSG(j,i) - soil pollution (connected compositions).
PLWT(j) - surface water pollution .

APPENDIX 2

SEF OUTPUT VARIABLE NUMBERS

1 DN	2 DNR	3 B(1)
4 B(2)	5 B(3)	6 CFWV(1)
7 CFWV(2)	8 CFWV(3)	9 CPOL(1)
10 CPOL(2)	11 CPOL(3)	12 FL
13 GH(1)	14 GH(2)	15 GH(3)
16 HGW	17 HGWD	18 HWP
19 HWPD	20 HFF(1)	21 HFF(2)
22 HFF(3)	23 RCSV	24 SW1V
25 SW2V	26 SLTV(1)	27 SLTV(2)
28 SLTV(3)	29 SV(1)	30 SV(2)
31 SV(3)	32 PLA(1)	33 PLA(2)
34 PLA(3)	35 PLA(4)	36 PLA(5)
37 PLA(6)	38 PLA(7)	39 PLA(8)
40 PLA(9)	41 PLA(10)	42 PLA(11)
43 PLA(12)	44 PLA(13)	45 PLA(14)
46 PLA(15)	47 PLDW(1)	48 PLDW(2)
49 PLDW(3)	50 PLDW(4)	51 PLDW(5)
52 PLDW(6)	53 PLDW(7)	54 PLDW(8)
55 PLDW(9)	56 PLDW(10)	57 PLDW(11)
58 PLDW(12)	59 PLDW(13)	60 PLDW(14)
61 PLDW(15)	62 PLGW(1)	63 PLGW(2)
64 PLGW(3)	65 PLGW(4)	66 PLGW(5)
67 PLGW(6)	68 PLGW(7)	69 PLGW(8)
70 PLGW(9)	71 PLGW(10)	72 PLGW(11)
73 PLGW(12)	74 PLGW(13)	75 PLGW(14)
76 PLGW(15)	77 PLP(1,1)	78 PLP(2,1)
79 PLP(3,1)	80 PLP(4,1)	81 PLP(5,1)
82 PLP(6,1)	83 PLP(7,1)	84 PLP(8,1)
85 PLP(9,1)	86 PLP(10,1)	87 PLp(11,1)

88 PLP(12,1)	89 PLP(13,1)	90 PLP(14,1)
91 PLP(15,1)	92 PLP(1,2)	93 PLP(2,2)
94 PLP(3,2)	95 PLP(4,2)	96 PLP(5,2)
97 PLP(6,2)	98 PLP(7,2)	99 PLP(8,2)
100 PLP(9,2)	101 PLP(10,2)	102 PLP(11,2)
103 PLP(12,2)	104 PLP(13,2)	105 PLP(14,2)
106 PLP(15,2)	107 PLP(1,3)	108 PLP(2,3)
109 PLP(3,3)	110 PLP(4,3)	111 PLP(5,3)
112 PLP(6,3)	113 PLP(7,3)	114 PLP(8,3)
115 PLP(9,3)	116 PLP(10,3)	117 PLP(11,3)
118 PLP(12,3)	119 PLP(13,3)	120 PLP(14,3)
121 PLP(15,3)	122 PLS(1,1)	123 PLS(2,1)
124 PLS(3,1)	125 PLS(4,1)	126 PLS(5,1)
127 PLS(6,1)	128 PLS(7,1)	129 PLS(8,1)
130 PLS(9,1)	131 PLS(10,1)	132 PLS(11,1)
133 PLS(12,1)	134 PLS(13,1)	135 PLS(14,1)
136 PLS(15,1)	137 PLS(1,2)	138 PLS(2,2)
139 PLS(3,2)	140 PLS(4,2)	141 PLS(5,2)
142 PLS(6,2)	143 PLS(7,2)	144 PLS(8,2)
145 PLS(9,2)	146 PLS(10,2)	147 PLS(11,2)
148 PLS(12,2)	149 PLS(13,2)	150 PLS(14,2)
151 PLS(15,2)	152 PLS(1,3)	153 PLS(2,3)
154 PLS(3,3)	155 PLS(4,3)	156 PLS(5,3)
157 PLS(6,3)	158 PLS(7,3)	159 PLS(8,3)
160 PLS(9,3)	161 PLS(10,3)	162 PLS(11,3)
163 PLS(12,3)	164 PLS(13,3)	165 PLS(14,3)
166 PLS(15,3)	167 PLWT(1)	168 PLWT(2)
169 PLWT(3)	170 PLWT(4)	171 PLWT(5)
172 PLWT(6)	173 PLWT(7)	174 PLWT(8)
175 PLWT(9)	176 PLWT(10)	177 PLWT(11)
178 PLWT(12)	179 PLWT(13)	180 PLWT(14)
181 PLWT(15)	182 FL1	183 FL2
184 FL1+FL2	185 FL12+FL3	.

APPENDIX 3

This appendix includes the example of the session with the SEF devoted to analysis of the scenario "Consequences of lumbering in temperate belt".

Y O U   A R E   W E L C O M E
T O
T H E   S Y S T E M   O F   E C O L O G I C A L   F O R E C A S T I N

D E F I N E   R E G I O N

SPECIFY REGION

Modes of specification

1 - optional
2 - automatic
3 - select standard region
4 - return to previous region
5 - pass on to next stage

Input option number - 1

TYPE OF GEOGRAPHICAL BELT

1 - arctic
2 - temperate
3 - temperate belt of central sector
4 - subtropical
5 - tropical
6 - equatorial

Input option number - 2

PREVAILING TYPE OF VEGETATION
5 - taiga
6 - mixed forest
7 - broad leaf forest
8 - meadow steppe
9 - steppe
10 - dry steppe
11 - subdesert
12 - desert

Input option number - 7

TYPE OF TOPOLOGY

1 - low land
2 - plains
3 - upland
4 - low mountains
5 - plateau
6 - mountains,medium height
7 - table-land

Input option number - 3

TYPE OF LITHOLOGY

1 - sand
2 - loamy sand
3 - loam
4 - clay
5 - marl
6 - compact sedimentary rocks
7 - intrusive and metamorphic rocks
8 - shingle beds
9 - karst rocks

Input option number - 3

MARSHINESS RESULTING FROM SHALLOW AQUICLUDE

1 - is absent
2 - strong
3 - medium
4 - weak

Input option number - 1

Filtration from transit rivers (mm/km2) - 0.

SPECIFY REGION

Modes of specification

1 - optional
2 - automatic
3 - select standard region
4 - return to previous region
5 - pass on to next stage

Input option number - 5

INPUT COMPLETED

THE MODEL IS BEING ADJUSTED TO REGIONAL DATA

MODEL ADJUSTMENT COMPLETED

Input proportion of lands used for agricultural purposes(%) - 0.

D E F I N E   S C E N A R I O

0 - CONTINUE
1 - RETURN TO PREVIOUS SCENARIO
2 - SHOW SYSTEM STATE
3 - temperature trend
4 - precipitation trend
5 - pollution and fertilisation rates
6 - irrigation regime
7 - drainage intensity
8 - fires on lands not used for agricultural purposes
9 - artificial destruction of biomass
10 - increase or decrease of lands used for agricultural purposes
11 - new plantations on lands not used for agricultural purposes
12 - new shelter belts on lands used for agricultural purposes
13 - changes in the amount of wood caused by lumbering

Input option number - 10

```
Wood cutting (% of forest area) - 10.

Is it selective (young trees)? (yes-1/no-2) -  2

0  - CONTINUE
1  - RETURN TO PREVIOUS SCENARIO
2  - SHOW SYSTEM STATE
3  - temperature trend
4  - precipitation trend
5  - pollution and fertilisation rates
6  - irrigation regime
7  - drainage intensity
8  - fires on lands not used for agricultural purposes
9  - artificial destruction of biomass
10 - increase or decrease of lands used for agricultural purposes
11 - new plantations on lands not used for agricultural purposes
12 - new shelter belts on lands used for agricultural purposes
13 - changes in the amount of wood caused by lumbering

    Input option number -  0

Input duration of simulation period(maximum 100 years) -  20


 M O D E L   R U N

   SESSION CONTINUATION OPTIONS

0 - terminate session
1 - define region
2 - define scenario
3 - continue modelling
4 - observe output
5 - show current system state

    Input option number -  4

   OUTPUT MODES

1 - Standard output
2 - Optional output
3 - Continue

   Input option number  -  1

   S T A N D A R D   O U T P U T

   BIOTIC PARAMETERS
1  - soil - vegetation
2  - soil productivity - soil index - dampness
3  - soil - fertilizers
```

WATER PARAMETERS
4 - total flow
5 - surface dissectment
6 - ground-water flow
7 - deep ground-water flow

SALINITY PARAMETERS
8 - soil - ground-waters
9 - ground-waters - river waters

10 - POLLUTION PARAMETERS

Input option number - 1

TYPE OF LAND

1 - lands not used for agricultural purposes
2 - lands used for agricultural purposes
3 - wetlands

Input option number - 1

OUTPUT FORMS

1 - tabular
2 - plotted

Input option number - 1

time	w(1)	SV(1)	SLTV(1)
1.0	0.300402e+03	0.931984e+01	0.699361e-01
2.0	0.283619e+03	0.906139e+01	0.695612e-01
3.0	0.263196e+03	0.899191e+01	0.695974e-01
4.0	0.244721e+03	0.896659e+01	0.696563e-01
5.0	0.227626e+03	0.890292e+01	0.698166e-01
6.0	0.210697e+03	0.909562e+01	0.701347e-01
7.0	0.196659e+03	0.872652e+01	0.699591e-01
8.0	0.187176e+03	0.856626e+01	0.700270e-01
9.0	0.175551e+03	0.849321e+01	0.702446e-01
10.0	0.166772e+03	0.815425e+01	0.702176e-01
11.0	0.158562e+03	0.783174e+01	0.701012e-01
12.0	0.150662e+03	0.758462e+01	0.700741e-01
13.0	0.142294e+03	0.752452e+01	0.702906e-01
14.0	0.135570e+03	0.722640e+01	0.701569e-01
15.0	0.129166e+03	0.697905e+01	0.699822e-01
16.0	0.123662e+03	0.671621e+01	0.696626e-01
17.0	0.117246e+03	0.662001e+01	0.696623e-01
18.0	0.111614e+03	0.643661e+01	0.695577e-01
19.0	0.106696e+03	0.630962e+01	0.693941e-01
20.0	0.100669e+03	0.630155e+01	0.695493e-01

end

```
Do you want to print the table ?(Yes-1/No-2) - 2


   OUTPUT MODES

 1 - Standard output
 2 - Optional output
 3 - Continue

   Input option number  - 1


   S T A N D A R D   O U T P U T

   BIOTIC PARAMETERS
 1  - soil - vegetation
 2  - soil productivity - soil index - dampness
 3  - soil - fertilizers

   WATER PARAMETERS
 4  - total flow
 5  - surfase dissectment
 6  - ground-water flow
 7  - deep ground-water flow

   SALINITY PARAMETERS
 8  - soil - ground-waters
 9  - ground-waters - river waters

 10 - POLLUTION PARAMETERS

    Input option number - 1


   TYPE OF LAND

 1 - lands not used for agricultural purposes
 2 - lands used for agricultural purposes
 3 - wetlands

    Input option number - 1

              OUTPUT FORMS

 1 - tabular
 2 - plotted

    Input option number - 2
```

```
     SCALING MODES

  1 - automatic/single scale for all variables
  2 - automatic/separate scale for every variable
  3 - manual/single scale for all variables
  4 - manual/separate scale for every variable

     Input option number - 2

                          1 - E(1)                    2 - SV(1)
                          3 - SLTV(1)
  1.  300.          22--------------------------------------3--------------------
  2.  9.32          !122               !2        3333 !      3 3      !
  3.  0.7003e-01    !  1222222222222 2                 3!        3     !
                    !    1             !3 2       3      33     3    3    !
                    ------11---------3-22223--------3333------3--------------
                    !       11      3      32222    !              3 !
                    !         11    !  3 33       2 !               3!
                    3           113!   3          22!                !
                    !             111              2                 3
  1.  204.          -------------3---111-----------22------------------------
  2.  7.81          !3            3  !   111        !  2222          !
  3.  0.698e-01     !            3   !      111     !      222       !3
                    ! 3         3    !         1111!         22      !
                    --------33-------------------11111-------22---3---------
                    !  33333         !             !   1111       22  33333
                    !                !             !       111111!22      33
                    !                !             !             11122222  3
                    !                !             !             !      112223
  1.  101.          -----------------------------------------------------------23
  2.  6.32
  3.  0.694e-01   1.0             5.8             10.5            15.3
Do you want to save the plot ?(Yes-1/No-2) - 2


     OUTPUT MODES

  1 - Standard output
  2 - Optional output
  3 - Continue

     Input option number  - 3

     SESSION CONTINUATION OPTIONS

  0 - terminate session
  1 - define region
  2 - define scenario
  3 - continue modelling
  4 - observe output
  5 - show current system state

     Input option number - 0

      T H E   S E S S I O N   I S   O V E R


                G O O D   B Y E !

      THE RESULTS ARE STORED IN  FILES:
      state.d, figure.d, table.d
```