LANDSCAPE-DYNAMICAL SCENARIOS SIMULATION AND MAPPING IN GEOGRAPHIC INFORMATION SYSTEMS

Gregory A.Isachenko , Andrey I.Reznikov
Laboratory of Landscape Research and Ecological Mapping ,
Saint-Petersburg University
Institute of Geography
V.O., Sredniy pr.,41
199004 St.Petersburg RUSSIA

Abstract

Landscape-dynamical scenario (LDS) is a method of long-term landscape dynamics simulation (prediction) which is based on assumption: the territory for the designated future period will not be subjected to impacts on landscapes except given by the scenario. Every scenario is based on algorithm: landscape - present state - impact - future state. LDS simulation is possible providing knowledge of present processes in landscapes: their intensity, rate, manifestation in different landscape elements. It is also need taking into account the long-term consequences of the most probable human impacts owing to existing mode of environmental management in the region. The optimal period for LDS simulation are from 10 to 50 years. The main principle of scenarios mapping is based on the differentiation of long-term consequences of any human (or natural) impact in conformity with types of landscapes. As regards mapping it means the correlation of predicted future states and landscape boundaries. The fragment of LDS map of a test plot (southern tayga, North-West of Russia) is presented.

The paper also discuss the concepts of Ladoga Region GIS for landscape dynamics simulation and monitoring, creating at the Laboratory of Landscape Research and Ecological Mapping, St.Petersburg University.

1 Introduction

Geographic information systems for environmental management, taking into account what is termed long-term processes in landscapes, are non-developed now. The Laboratory of Landscape Research and Ecological Mapping (St.Petersburg University) is at the beginning of creating the Ladoga Region GIS for landscape dynamics simulation and monitoring.

In this paper we would like to discuss the conceptual basics of the system to be created, notably regarding the problem of scenarios simulation and mapping. The GIS is projected with the purpose of using data concerning landscapes' changes in middle- and long-term time scale (decades and hundreds of years). Main idea of designed GIS: the conclusions about future states of landscapes due to human impacts are based on the analysis of present states of the related landscapes, subjected to similar impacts in the past. The projected GIS is intended for organization of data, received by different methods of researches in the form, suitable for reconstruction, forecasting and simulation of landscape-dynamical scenarios.

Ladoga Region is a territory around the largest and deepest lake in Europe - Ladoga lake; area about 35,000 km^2 ; the population is more than 5,500,000 people (including Saint-Petersburg). The border of the region is considered in major extension to correspond to the landscape regions boundaries. Western border of the territory coincides with Ladoga lake and Gulf of Finland watershed, and north-western border (along a frontier between Russia and Finland) is close to watershed between Ladoga and Saima lakes.

Ladoga Region includes more than 50 small river catchment areas and 6 near-Ladoga areas of the transit rivers basins. On the other hand, the territory is subdivided in 18 landscape regions. Every landscape region is considered as the individual area in which the geological structure, climate and vegetation zone (subzone) are homogenous.

More than 30 towns and urban settlments are situated in Ladoga Region at the present time. The rural population is located very unevenly: some landscape regions have no settlements with more than 1,000 people. Last 20-30 years intensive human impact on landscapes has resulted in a sharp worsening of the environmental situation. Main ecological problems are connected with: industry, urbanisation, water pollutions and lakes' eutrophication, uncontrolled forest felling, densely distributed large stock-breeding farms, recreational press.

The studied territory (Ladoga Region) is considered in the GIS as a combination of the landscapes of a different rank. Any landscape in turn is examined as a system being in alternating states of a different duration: from diurnal states up to long-term ones (duration of tens and hundreds yr).

The evidence concerning long-term landscape dynamics are gained while using diffrerent methods of studies: field researches (temporary interpretation of spatial structures, detailed forest valuation on index plots, ecological-floristic composition analysis, periodic observations on the test plots of Ladoga Region Landscape-ecological Field Station); remote sensing analysis, palaeogeographic data interpretation, historical and archival investigations.

2 Structure of the GIS projected

Designed GIS functionally will be consist of database management system, system of simulation as unit model with memory and interface with a external mapping system. The output forms are presented in text format or as files in format of used mapping system.

The principal subjects used in the GIS are site, state and impact. Site (location) of landscape is considered as a combination of parameters (elements) whose time of change is always more than the time of simulation (forecast) that the first is ranged from hundreds to thousands years. Site parameters are usually not modified by human impacts. State of landscape is defined as combination of parameters whose time of change is comparable with the period of simulation, that is not more than 100-150 years. State parameters can be modified by human impacts. Impact on landscape is considered as event caused by external (natural or anthropogenic) factors and causing comparatively ra- pid change of landscape state.

For the GIS realization the following databases are created.

"Test plots". Contains formalized descriptions of studied landscapes including parameters of their locations and states as well as evidence of palaeogeographical, dendrochronological, historical and other researches. On the basis of these data a classification of the landscapes and their present and previous states are made; character and age of impacts are identified.

"Site - state". It is made on the ground of the previous database and contains for each type of landscape site the list of its possible states (observable and restored) and probability of each of them.

"State - state". Contains for each type of landscape site a square matrix, showing opportunity of transitions from one state to another, and also the information on impacts, caused these transitions, and time of landscapes' change. The database is made automatically from two previous databases, then it is supplemented manually on the basis of expert evaluations and other data sources.

"Impact - state". For each type of landscape and every state contains the list of possible impacts and probable landscapes' changes as a result of these impacts, with valuation of changes' probability. Consequent choosing by sites and states of landscapes would make the "trajectory" of landscape dynamics in the space of its states.

3 Landscape-dynamical scenarios simulation and mapping

Specific peculiarity of the GIS created is a data output in the form of scenarios maps. Landscape-dynamical scenario (LDS) is based on assumption: the territory for the designated future period will not be subjected to impacts on landscapes except given by the scenario. Every scenario is based on algorithm: landscape - present conditions (state) - impact - future state. Realization of such algorithmes is possible in tabulated, matrix, graph form. However the most effective and informative way of scenario presentation is mapping.

Probability of information containing in algorhithmes depends on quantity and quality of knowledge accumulated in the databases with using above-mentioned research methods. Scenarios simulation is possible providing knowledge of present processes in landscapes: their intensity, rate, manifestation in different landscape elements (relief, climate, vegetation, soils etc.). What is more it is need taking into account the long-term consequences of the most probable human impacts owing to existing mode (system) of environmental management in the region. Reasoning from the state of our knowledge at the moment, we can consider the most reliable results of LDS simulation being for period from 10 to 50 years.

By way of example of LDS for Ladoga Region landscapes we can mention: total bog drainage with water level lowering for 1 m in 20 years; clear cutting of all ripe stands (+10 years) ; crown fire (+10 years, Figure 1); ploughing up and cultivation of all lacustrine clayey terraces covered with forest (+50 years).

LDS map is a most complicated and original type of landscape-dynamical maps, which are created on the common pattern (grid) of landscape units. Scenario is a result of simulation; it can be also considered as a synthesis of all previous stages of mapping (map of impacts, map of present processes in landscapes) with addition of new information. As distinct from above-mentioned kinds of maps showing past and present facts and objects, LDS maps have hypothetical character.

The main principle of scenarios mapping is based on the differentiation of long-term consequences of any human (or natural) impact in conformity with types of landscapes. As regards mapping it means the conformity (correlation) of predicted future states and landscape (site) boundaries (Figure 1).

The methodical complexity of landscape-dynamical scenarios simulation in the first place is connected with the problem of impacts superposition. While simulating dynamics of certain landscape due to given impacts, it is need to appreciate the "deviations" (owing to impacts of preceeding period) from main dynamical tendency. Presenting in this paper map fragment (Figure 1) contains contours where consequences of given impact (crown fire) are superposed on results of old forest fire (a part of contours designated "Sg").

Other problem in LDS modelling is necessity to take into consideration the lateral (horizontal) interrelations (torrents) between neighbouring landscapes: surface flow, spreading of plants and animals, transition of solid material etc. It is known that certain long-term processes (such as bogging) can slowly "move" the borders of landscape sites. At present, in the absence of reasonable knowledge concerning spatial influence of one landscape on another, we use to accept invariability of landscape sites "framework" for the period of simulation.

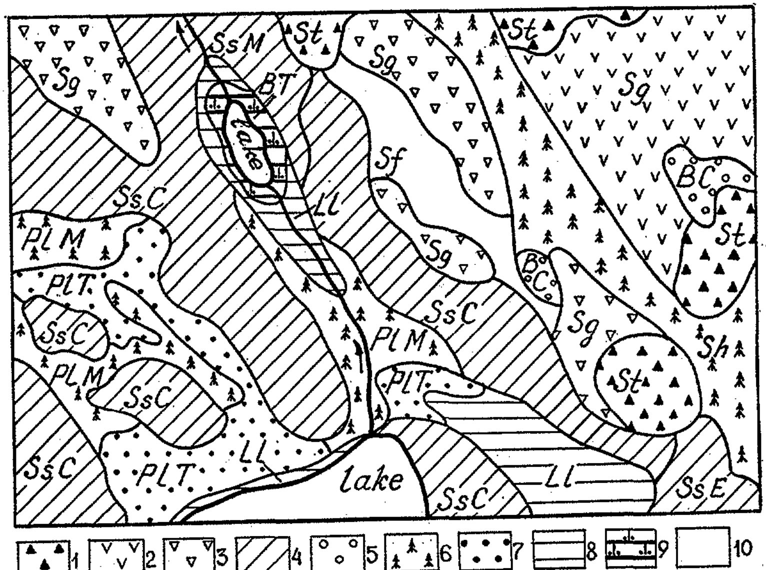

Figure 1: Landscape-dynamical scenario: crown fire and termination of all human impacts (+10 years); test-plot in North-West of Ladoga Region. Original scale 1: 5 000. Types of local landscapes and their present state (in square brackets): St - tops of granite ridges (selga) [open pine forest and rocky communities]; Sg - gently near-top slopes of selga [pine woods with green mosses, pine woods with heath after old fires]; Ss - slopes of selga [SsC - pine grassy woods, SsE - spruce grassy woods, SsM - birch and aspen grassy woods]; Sf - footsteps on selga [spruce bilberry woods]; Sh - inner depressions [small-leaved grassy woods]; Pl - limnetic clayey terraces [PlM - alder and birch wet grassy groves (regenerating forest); PlT - meadows]; Ll - bogged clayey terraces [willow-shrub]; B - peat-bogs [BC - pine and birch sphagnous forests; BT - sedge and sphagnous floating-bog].

Predicted states and processes after 10 years: The landscapes subjected to fire: 1 - burn; pine and birch regeneration, post-pirogenic moss cover forming, downfall of old pines, rocks' weathering increase; 2 - burn; pine regeneration, predominance of heath (the sites where fire was 20 years ago); 3 - burn; pine regeneration, predominance of heath, downfall of old pines; 4- burn, asp and birch regeneration, predominance of herbaceous, downfall of old trees, soil enrichment; 5 - peat-bog; birch and pine regeneration, predominance of willow-shrub. The landscapes which are not subjected to fire: 6 - small-leaved grassy and bilberry woods with stronger position of spruce; 7 - first stage of forest regeneration (birch, asp, alder) after cessation of haying; 8 - willow-shrub; predominance of sedge, water-logging with peat build-up; 9 - slow lake's overgrowing by floating bog; 10 - spruce woods, relative stabilization (the state will not change).

4 Conclusions

It is easily to verify that even for small territory in tayga zone the number of possible landscape-dynamical scenarios comes to tens. Their mapping by traditional manual way is impossible. Therefore the future steps on the way of LDS simulation will be connected with possiblilities of GIS technologies.

The approach given in this paper seems to offer important advantages over the traditional geographic forecasting (prediction). The possibility of reasonably fast output of scenarios (with the availability of adequate databases) in answer to information of designed impacts allows to "be ready" to respond to maximum of possible environmental situations in near future. It requires looking over different LDS and selection of optimal variant.

Aforeside features are favourable for the LDS computer maps applications by decision-makers in the field of land use, natural management and landscape design. In this connection it should be stressed that any scenario map is only the top of "icebrg" of a large databases containing special information about processes and their parameters in different elements of landscape.

References

[1] Isachenko, Gr.A. & A.I.Reznikov, 1994. Natural and antropogenic dynamics of landscapes: information system of simulation for Ladoga Region. EGIS/MARI'94 Conference Proceedings, Vol.1, pp. 661-667, EGIS Foundation, Utrecht/Amsterdam.