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SGEM
THE BASIN APPROACH TO THE ANTHROPOGENIC IMPACT
ASSESSMENT IN OIL-PRODUCING REGION

Prof. Oleg Yermolaev

Bulat Usmanov
Kazan (Volga Region) Federal University, Kazan, Russia

ABSTRACT

Basin approach used to estimate impact of oil and gas industry on the environment and
develop solutions for natural resources optimization on the study territory. The main
objective was to find effective methods of analyzing spatial and temporal patterns of
geosystems functioning under strong anthropogenic pressure. The complexity of natural
systems and the need to integrate large number of factors required the use of modern
methods of geoinformatics, information technology, mathematical and cartographic
modeling. 713 watersheds of 2-3 orders allocated in the region of JSC "Tatneft" for the
purpose of spatial analysis. Weighted scores method with extensive involvement of GIS
spatial analysis used for an integrated anthropogenic disturbance assessment within the
elementary basins. As a result, "Map of cumulative anthropogenic impact" and "Integral
environmental assessment map" were built. "Map of cumulative anthropogenic impact"
allows through the selected parameters to identify the impacts caused by agricultural
activity and "Integral environmental assessment map" – oil and gas industry impact on
the environment. A technique for quantifying of different sectors of the economy
contribution to human impact on the certain components of the landscape realized by
the example of forest vegetation. Methods of forest separating fragmentation by road
network (transport) and linear facilities of the oil industry study allowed evaluating of
their contribution to overall level of human impact.

Keywords: Basin approach, anthropogenic impact, integrated assessment, spatial
analysis, geographic information systems.

INTRODUCTION

The activities of the oil and gas industry inevitably have a negative impact on the
environment and often leads to changes in natural systems, disruption of their
functioning and sustainability mechanisms. An integrated approach to the environment
components properties study and comparison with the existing technogenic impact is
the most correct to evaluate the potential impacts of oil and gas industry on the
environment and develop solutions to optimize nature in the study area [1]. Geosystem
approach is the best way to provide integrity; it allows selecting a representative
conjugate series of territorial units for spatial analysis of the environmental impact by
economic activities. In these units, a regular uniformity of the physical parameters of
environment is observed and systemic linkages between natural components are taken
into account [2].

The selection of operational-territorial units (OTU) has fundamental importance in
practical problems solving in the field of environmental protection, especially on the
stage of its present state evaluation. All environmental assessments and management
policies of oil companies in the field of ecology are based on these units and their selection is a separate problem, that largely determines the quality and cost of the work in the environmental field [3]. However, there is an obvious contradiction between geosystems and administrative-territorial approach at the stage of selecting OTU, largely due to the information support operations and binding of the enterprise to a particular item of the administrative-territorial division.

Currently, there are several approaches to the choice of the unit: the administrative-territorial division, sample characteristics, geometrical regular grid, landscape and river basin approach.

We’ll focus on the ideology of a river basin approach. This variant of territorial division is most useful in the humid plains of the Earth temperate belt, where the main role in relief formation is played by the permanent and temporary water flows [4].

The founder of the basin approach R. Horton (1948) proposed a river basins analysis system, including the definition of order, structure of river network and its role in basin and riverbed erosion development [5].

Basin approach is also the main for conjugate geochemical landscapes allocation, because in watershed basin natural matter and energy movement processes logically develops and determine elements migration.

An important feature of these territorial units is the fact that they represent geosystem formation with all its features and natural boundaries and also meet the requirements of representativeness to the maximum extent. One of the requirements for spatial assessments – data should be analyzed on the basis of the smallest territorial units and avoid larger arbitrary OTU, except when they relate to the studied data [6]. The relatively small size of elementary basins allows to present study area fractionally, slight variation in size avoids visual dominance of any areas in spatial assessment. Another important point is the ease of their borders selection and the possibility of reasonable transition to different size when generalization level is changes.

Of course, basin approach for all its obvious advantages is not deprived lacks. Thus, its use in the arid landscape zones, in bedded, wetland and lacustrine relief conditions, with continuous development of permafrost rocks can be problematic, as well as in the case of upland type broad watersheds [7]. Despite this, river basin approach use is the most reasonable in spatial assessments of economic activity impact on the environment. Environment state conditions forecasting and environmental protection measures development [8], [9].

**BASIN APPROACH APPLICATION TECHNIQUE**

This approach has been implemented to create a specialized environmental protection Geographic Information System (GIS) in the region of Joint-Stock Company (JSC) “Tatneft”.

Technological impact in the region of JSC “Tatneft” caused not only by oil industry [10]. Large number of major industrial enterprises, intensive agricultural use of the territory, dense transport infrastructure is also largely determines the anthropogenic impact on region environment. In such circumstances, integrated approach in environmental impact assessment is necessary [1]. This allows to determine impact level and particular industry sector contribution to the overall technogenic pressure on the study area.

For the purpose of spatial analysis 713 watersheds of 2-3 orders with unique ID created by Straler-Filosofov classification. Each OTU is evaluated on various parameters.

The most common technique for estimated indexes integration is numerical score. Their simple summation usually used for generalized assessment that not sufficiently substantiated due to significant differences in the importance of individual parameters and various contributions in geosystems disturbance [11]. This approach often leads to incorrect conclusions. Integration can be performed more accurately when final assessment is calculated as sum of weighted scores for individual components [12]. Preliminary all values must be normalized for ease of handling to range from 0 to 1, where 0 corresponds to the minimum score, and 1 - max.

Weighting coefficients for an objective evaluation of each indicator contribution were calculated. They are determined by allocating one of the indicators, which, according to experts, changes most “synchronously” with the required integral evaluation. This indicator is called the general (Xgen). According to this index “synchronicity” change all other particular scores along with the required integral evaluation is estimated. Usage of usual pair correlation to evaluate “synchronicity” is undesirable because initial indicators are expressed in scores, i.e. not absolute but ordinal. Therefore, we used the Sperman rank correlation coefficient. Then, among the resulting pair correlation coefficients maximum one was selected and by dividing the rest pair correlation coefficients by maximum weighting index for individual indicators was obtained.

Further sum of the weighted scores calculated for each basin and ranked from 1 to 5 at the final stage of landscapes disturbance evaluation for the convenience of subsequent analysis. The most disturbed basin geosystems match 1 point, the least - 5 points.

To collect information from various OTU containing data about the state of components of the environment and anthropogenic impacts and to translate the results of the integrated analysis on the basins, regular grid with a step of 250 m used.

As a result, the evaluation maps were constructed – “Map of cumulative anthropogenic impact” (Fig. 1) and “Integral environmental assessment map” (Fig. 2).

**RESULTS**

**Map of cumulative anthropogenic impact** – one of the basic maps, which is required for a comprehensive estimation of the territory. It was based on the borders of OTU, the relevant to the drainage basin.

At weighted scores calculation, as noted above, the choice of the general indicator (Xgen) is essential, and we selected total vegetation area (forests and meadows) in the basin geosystems. Vegetation cover largely determines the comfort of environmental conditions for human life, plays the role of ecological frame of territory, defining diversity of ecosystems and their resistance to external impacts.

The following indicators were taken as particular: the cultivated area (% of basin area), gully dissection density (km/km²), eroded soil area (% of basin area), road network density (km/km²), settlements area (% of basin area), forest and meadow communities disturbance category (scores), forest cover reduction index (% of basin area) for the period from 1800.
9 particular indicators used in calculation of cumulative pressure on basin ecosystems. As seen from their list, they represent almost all aspects of the economic impact on the landscapes: transport, timber industry, urban and agro-industrial complexes. In addition, vegetation disturbance was taken into account in the assessment.

Using the technique of weighted scores requires caution in choosing not only general, but also the entire system of particular indicators. Temptation of mechanistic account of the greatest possible range of parameters can lead to large errors and incorrect conclusions in spatial analysis.

The strength and direction of linkages between the impact factors (Xi) and environment favorability indicator (Xgen) are shown in Table 1.

Table 1. Correlation coefficients between the general indicator (Xgen) and impact factors (Xi)

<table>
<thead>
<tr>
<th>X1 cultivated area</th>
<th>X2 settlements area</th>
<th>X3 eroded soil area</th>
<th>X4 gully dissection density</th>
<th>X5 road network density</th>
<th>X6 forest disturbance</th>
<th>X7 meadow disturbance</th>
<th>X8 forest cover reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.95</td>
<td>-0.22</td>
<td>-0.13</td>
<td>-0.09</td>
<td>-0.11</td>
<td>0.78</td>
<td>-0.12</td>
<td>0.16</td>
</tr>
</tbody>
</table>

The results of the spatial analysis of the environmental situation in the region by the method of weighted scores presented on "Map of cumulative anthropogenic impact" (Fig. 1). For degree of anthropogenic impact the following relations obtained: very strong – 207 basins, strong – 273, average – 157, moderate – 57 basins and weak – 19 basins.

Thus, in the study region more than two thirds of basin ecosystems are influenced by strong and very strong anthropogenic impacts.

**Integral environmental assessment map.** To solve this problem the above-described method of weighted scores and GIS spatial analysis technology used. The difference is that pair correlation coefficients between Xi and Xgen calculated in more accurate way: in absolute values, instead in scores. In integral estimation a large range of environment components indicators included. They are expressed by different sum of scores and represented as geographic information layers.

All indicators used in the evaluation were divided into two groups. The first – "processor" [13] group includes indicators describing anthropogenic influences. By combining them, you can single out share of the impact of one or another economic complex on the environment. "Processor" group indicators, subsequently were taken as Xgen, included 12 types of impacts (total specific anthropogenic impact, taking into account linear, point and area sources of environmental pollution and the volumes of produced hydrocarbon, the proportion of land occupied by oil and gas facilities, etc.). "Indicator" group formed by indicators reflecting consequences of anthropogenic impacts on the environment. It consisted of 14 indicators (complex index of air pollution; chloride contamination of ground and surface water, degree of river water pollution, overall incidence of the population, etc.). The use of geo-information approach and the weighted scores technique (Table 2) allowed to create assessment.
maps on individual components and the final integral map (Fig. 2). Analysis of the maps showed that areas with moderate and high degree of disturbance prevail in study region.

Table 2. Correlation coefficients between Xgen ("processor" group), and the individual components of the environment ("indicator" group)

<table>
<thead>
<tr>
<th>Environment components (impact indicators)</th>
<th>Summary anthropogenic impact</th>
<th>Impact by oil and gas industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwaters</td>
<td>0.24</td>
<td>0.63</td>
</tr>
<tr>
<td>Surface waters</td>
<td>0.12</td>
<td>0.72</td>
</tr>
<tr>
<td>Soils</td>
<td>0.05</td>
<td>0.00</td>
</tr>
<tr>
<td>Air</td>
<td>0.12</td>
<td>0.09</td>
</tr>
<tr>
<td>Vegetation</td>
<td>0.27</td>
<td>0.62</td>
</tr>
<tr>
<td>Fauna</td>
<td>0.16</td>
<td>0.10</td>
</tr>
<tr>
<td>Man</td>
<td>0.16</td>
<td>0.27</td>
</tr>
<tr>
<td>Landscapes</td>
<td>0.31</td>
<td>0.04</td>
</tr>
</tbody>
</table>

In the center of map a kind of core with strongly disturbed basins formed, related to the eastern part of Almetyevsky, western – Aznakaevsky and southern – Sarmanovsky municipal districts where major oil extraction conducted. Weak and moderate level of disturbance is typical to wooded undisturbed basins of Nurlatsky, Cheremshansky, Zainsky, Leninogorsky, Aktanyshsky and Elabuzovsky municipal districts.

Overlaying of "Map of cumulative anthropogenic impact" and "Integral environmental assessment map" gives in general a good convergence of boundaries with similar categories of human impact and disturbance of the environment. Differences between final maps are due for usage of much broader spectrum of anthropogenic impact types, as well as taking into account its intensity on "Integral environmental assessment map". Comparison of resulting synthetic maps and list of estimated indicators shows that first map allows highlighting the impact caused mainly by agricultural activities, and second – the oil and gas industry impact on environment.

As we can see above, most frequently, in the analysis of the factors determining the environmental condition of the territory, the indicators of state of certain components of environment are used. At the same time it is extremely important not only component-wise grouping of environmental indicators, but also division of anthropogenic impacts characteristics on the groups characterizing various sectors of the economy to determine their quantitative contribution to the overall effect. For this purpose, we evaluated the "separating" fragmentation of forest vegetation (on the contribution of various sectors of the economy) as a form of human impact within the boundaries of the basin geosystems. It is assumed that an increase of forests fragmentation degree decreases their resistance to human impacts, also violated ecosystem connection and biodiversity. Vegetation pattern is perhaps the most physiognomic geocomponent and also indicator of landscape pattern [14].

To assess the contribution to forests fragmentation, we used electronic layers of forests contours, road networks (transport sector), linear objects of the oil industry (oil pipelines, water) and watershed boundaries as OTU. As a result, data that qualitatively characterize the forest fragmentation were obtained: the average contour area, the fractional index, degree of differentiation contours size, which allows estimating of anthropogenic impact.

In spatial analysis of the environmental impact of oil and gas complex in landscaped zones of the Earth with well-developed drainage system (for Russia is the temperate zone of humid plains), the basin principle of ecological state evaluation is most expedient. It is this approach and the use of modern GIS technologies in the evaluation of anthropogenic disturbance allows quantifying the multiple aspects of human impact and of environmental components state. Used technique based on a river basin approach allows spatial analysis of human impact in the region of intense oil production as on individual components as well as on environment in general. In addition, the basin approach is effective in determining of contribution of various sectors of the economy on the state of individual geocomponents of environment.

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REFERENCES


THE CETĂȚENI GEOMORPHOSITE (ARGEȘ, ROMANIA). GEOMORPHO-CULTURAL ASSESSMENT AND TOURISM VALORIZATION

Dr. Mădălina Nicoleta Frinculeasa

Dr. Alexandru Istrate

Department of Geography, Faculty of Humanities, University Valahia of Târgoviște, Romania

ABSTRACT

The natural reserve from Cetățeni (Cetățeni Gorges or Cetățeni karstic microrelief) is located in the extreme south of the Leaota Mountains, on the left side of the Dâmbovița River, in the Cetățeni village. The spectacular physiognomy of this relief with sharp peaks, columns and rock pedestals are mainly the result of the selective erosion of the conglomerates. Natural conditions have favored the development of an interesting flora of numerous endemic and therophilic elements specific to the South. Situated between the Coman and Chiliiț creeks, it is enriched by its cultural-historical significance revealed through archaeological research (evidence of habitation dating from the beginning of the Bronze Age, a Geto-Dacian settlement, Proto-Bulgarian habitation, Romanian medieval fortress and settlement). Cetățeni is an important touristic location in the Dâmbovița Valley, however, the main attraction is the new Cetățuia Negru Vodă Orthodox Church (built near "Schitul lui Negru Voda" - hermitage carved into the rock dating from the 15th century), recently integrated into the landscape and cultural spectrum of the area. In this context, the aim of this paper is to provide a geomorpho-cultural assessment of the Cetățeni geosite, emphasizing the cultural-historical elements, which have become complementary parts of the valorization of this landscape and spiritual resource in its entirety. This new rezoning of the geosite also imposes different parameters in the development of protection and valorization strategies because, under the pressure of natural and anthropic factors easily noticeable in the study area, ignoring them can lead to the disappearance or destruction of a source of genuine cultural and scientific touristic potential.

Keywords: geomorphosite, touristic potential, geomorpho-cultural assessment, Cetățeni

INTRODUCTION

The complex tourist valorization has imposed during the last few decades a new approach of the elements of attractiveness of a region. Therefore, in the scholarly literature, new concepts and notions have appeared, defining ways of evaluation and implicitly of promotion of some natural and cultural resources, crucial to a certain area. The geomorphosite is defined as "a part of a land area considered particularly important for understanding the evolution of the Earth, of the climate and of life" [6].