IRSTI 36.33.35

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DIFFERENTIATED EVALUATION OF THE CONTRIBUTION OF OIL AND GAS PRODUCTION COMPLEX OF MANGISTAU REGION TO ANTHROPOGENIC IMPACTS ON THE RELIEF

The article presents the results of one of the stages of solving a complex theoretical problem in the field of integrated environmental assessment of the territory – the search for methods solving the inverse problem. The essence of the inverse problem is to determine the contribution of an individual industry or individual entity to the anthropogenic transformation of the natural environment in the presence of an available expert assessment of the ecological situation in the region that maps the levels of total impact of all enterprises and all sectors of the regional economy on the ecological situation.

The solution of the inverse problem is of great practical importance for objectifying the «polluter pays» principle, the instrument of which is the system of payments for emissions to the environment. However, the widespread practice of transferring waste on contractual terms to specialized companies for their export and processing negates this principle in the field of waste management. An independent assessment of the ecological situation in the region, based on monitoring data, determines the total impact of all enterprises in all sectors of the regional economy and also does not allow assessing the contribution of individual industries or individual enterprises to total pollution.

The work was carried out within the framework of the grant financing project of the Ministry of Education and Science of the Republic of Kazakhstan No. 0589 / GF-4 «Development of a method for objectifying expert estimates of the contribution of individual pollution sources to the overall ecological situation of the territory». At the first stage of the research in this direction, a method for generalized solution of the inverse problem was developed and the results of the evaluation of the contribution of the oil and gas producing complex of the Mangystau region to anthropogenic transformation of the ecological situation in the region were obtained.

In the proposed article, the second method for solving the inverse problem, which allows to differentially differentiate the implementation of the polluter pays principle, is described in the example of the assessment of the role of OGPC in the anthropogenic transformation of the relief. Since only one of the components of the natural environment is considered, the solution obtained will be private. To obtain an integrated assessment, it will be necessary to carry out similar studies for the remaining components of the natural environment and combine them in an integrated (total) solution, taking into account the role of each component in the formation of the environmental situation. Differentiation is performed on the basis of receiving the construction of a grid model in which the areas of contours of each level of anthropogenic impact within a block are summed and assigned to the center of the block, providing the mapping of cartographic information to quantitative information.

A particular solution of the inverse problem of a private integrated environmental assessment is found as the difference of the partial objective functions reflecting the average (weighted average) estimates of the anthropogenic impact on the components of the natural environment as a whole for each block of the grid model and for the sum of the areas of all zones with OGPC in blocks with their presence. Loads to the levels of transformation in private target functions take into account the level of complexity of carrying out environmental measures for each component of the natural environment, their justification is given in the legend of the evaluation maps. After calculating the target functions for the total area of all blocks and the areas of the contours of different levels of impact of the OGPC, total ballots are obtained, and after dividing by area area or area of the OGPC zones – differentiated estimates of anthropogenic disturbance of the Mangystau region territory in each block and in parts of blocks with OGPC .

The results of calculations showed that the OGPC .creates an additional load on the relief in the range from 0 to 60.46%, while the method of generalized estimation of the contribution of the OGPC . as a whole in the region gave a value of 16.73%. Thus, the method of differentiated estimation makes it possible to identify areas where the anthropogenic impact of OGPC . is less than that of other sources, and an analysis of the range of changes in the integral solution in zones with OGPC can serve as the basis for objectifying the differentiated implementation of the polluter pays principle.

Key words: Mangystau Region, Oil and Gas Production, Level of Anthropogenic disturbance of relief, Objective Function.

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Маңғыстау облысының мұнай-газ өндіруші кешенін рельефке антропогендік әсерін сараптамалық бағалау

Мақалада мәселені кері шешу әдістерін іздеу – кешенді экологиялық бағалау саласындағы кешенді теориялық мәселелерді шешу кезеңдерінің бірі ұсынылған. Кері мәселенің мәнісі бір саланың үлесін немесе аймақтың кешенді экологиялық жағдайын сараптамалық бағалауы бар табиғи ортаға антропогендік бұзылысын, әсерін жалпы барлық кәсіпорындар әсерінен және экологиялық жағдай туралы облыстық экономиканың барлық секторларының деңгейлерін көрсететін картаны пайдаланып бір нысанды анықтау болып табылады. Кері шешім әдісі «ластаушы төлейді» принципін объективизациялауда қолданбалы мәні зор, қоршаған ортаға эмиссия үшін төлемдер жүйесі маңызды құрал. Алайда, оларды жою және қайта өңдеу үшін арнайы компанияларға келісім-шарт негізінде қалдықтарды аудару қарапайым тәжірибе қалдықтарды басқару саласындағы осы принцип жоқ. Мониторинг деректері бойынша облыстың экологиялық жағдайын тәуелсіз бағалау облыс экономикасының барлық саласының, барлық мекемесінің үлесін бағалауға, сонымен қатар жекеленген саланың кешенін бағалауға немесе жекеленген мекеменің ластану үлесін бағалауға мүмкіндік бермейді.

Жұмыс Қазақстан Республикасы Білім және ғылым министрлігінің жобасы гранттық қаржыландыру аясында №0589 / GF-4-ақ жүргізілді «жалпы экологиялық жағдай аумағында ластану жеке көздерін үлесін сараптамалық бағалау обьективтілігі әдісін дамыту». Осы саладағы зерттеулердің бірінші кезеңінде біз кері міндеттері әдісі өңделіп, және аймақтағы экологиялық жағдайға антропогендік бұзылысына Маңғыстау облысы мұнай-газ кешенінің бағалау нәтижелері алынған.

Бұл мақалада жер бедеріне мұнайгаз өндіруші кешенінің антропогендік бұзылысын бағалау маңызын мысал тұрғысында алып, «ластаушы төлейді» қағидатын географиялық сараланған іске асыруға мүмкіндік беретін кері мәселе шешімінің екінші әдісі баяндалған. Табиғи ортаның бір ғана құрылымын қарастыруына байланысты, алынған нәтиже жеке болып есептеледі. Интегралды бағалау үшін табиғи ортаның басқа құрылымына талдамалық зерттеу және экологиялық жағдайды қалыптастыруда әрбір компоненті рөлін ескере отырып, ажырамас (жалпы) шешімімен олардың интеграциясын талап етеді. Саралау торлық модельді құру негізінде сандық картографиялық ақпаратқа ауыстырыла отырып, блок орталығына жазылып, антропогендік әсер деңгейінің аудан контуры блок аймағында есептеледі.

Жеке кешенді экологиялық бағалау кері шешімі олардың қатысуымен блоктарға мұнайгаз өндіруші кешеннің барлық аймақтарын сомасы әрбір блок тор үлгі үшін тұтастай қоршаған ортаның компоненттеріне антропогендік орташа (орташа алынған) бағалауды көрсететін ішінара объективті функциялардағы айырмашылық болып табылады.

Жеке мақсатты атқарымда бұзылыс деңгейінің жүктемелері әрбір табиғи ортаның компоненттері бойынша табиғатты қорғау іс шарасын жүргізудегі олардың негізі бағалау картасының шартты белгілерінде көрсетілген. Барлық блоктар ауданы және мұнай газ өндіруші кешеннің әсерінің түрлі деңгейіндегі контур ауданы бойынша мақсатты атқарым есебінен кейін ауданның балдық есебі алынған, ал әрбір блокта мұнайгаз өндіруші кешенмен әрбір блокта Маңғыстау облыс территориясының рельефіне антропогендік бұзылысын сараптамалық бағалау мұнай газ өндіруші кешеннің аудан аймағына немесе аймақтың аудан деңгейіне бөлінгеннен кейін анықталады.

Есептеу нәтижелері мұнай газ өндіруші кешеннің 0-ден 60,46% диапозонында рельефке қосымша жүктеме туғызатындығын, бұл жалпылама әдіс мұнай газ өндіруші кешенін бағалауда жалпы облыс бойынша 16,73% өлшемін көрсетті. Сондықтан сараптамалық бағалау әдісі облысты анықтауға мүмкіндік беріп, мұнай газ өндіруші кешен бойынша антропогендік әсері қай жерде басқа ластану көздерінен аз екендігін көрсетеді, ал интегралды шешім өзгерісін талдау мұнай газ өндіруші кешен аймағында «ластаушы төлейді» принципін сараптамалық жүзеге асыруда маңызды.

Түйін сөздер: Маңғыстау облысы, мұнай газ өндіруші кешен, рельефке антропогендік бұзылыс әсері, жеке мақсатты атқарым, территорияны кешенді экологиялық бағалаудың кері міндеті.

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Дифференцированная оценка вклада нефтегазодобывающего комплекса Мангистауской области в антропогенное воздействие на рельеф

В статье представлены результаты одного из этапов решения сложной теоретической проблемы в сфере комплексной экологической оценки территории – поиск методов решения обратной задачи. Суть обратной задачи состоит в определении вклада отдельной отрасли или отдельного объекта в антропогенную трансформацию природной среды при наличии имеющейся экспертной оценки экологической ситуации региона, картографически отражающей уровни суммарного воздействия всех предприятий и всех отраслей экономики региона на экологическую ситуацию.

Решение обратной задачи имеет большое прикладное значение для объективизации принципа «загрязнитель платит», инструментом которого является система платежей за эмиссии в окружающую среду. Однако распространенная практика передачи отходов на договорных началах специализированным компаниям по их вывозу и переработке сводит на нет этот принцип в сфере управления отходами. Независимая оценка экологической ситуации региона по данным мониторинга определяет суммарное воздействие всех предприятий всех отраслей экономики региона и также не позволяет оценить вклад отдельных отраслей или отдельных предприятий в суммарное загрязнение.

Работа выполнена в рамках грантового финансирования Министерства образования и науки РК №0589/ГФ-4 «Разработка метода объективизации экспертных оценок вклада отдельных источников загрязнения в общую экологическую ситуацию территории». На первом этапе исследований по этому направлению был разработан метод обобщенного решения обратной задачи и получены результаты оценки вклада нефтегазодобывающей комплекса (НГДК) Мангистауской области в антропогенную трансформацию экологической ситуации региона.

В предлагаемой статье на примере оценки роли НГДК в антропогенной трансформации рельефа изложен второй метод решения обратной задачи, позволяющий территориально дифференцировать реализацию принципа «загрязнитель платит». Поскольку рассматривается только одна из составляющих природной среды, полученное решение будет частным. Для получения интегральной оценки потребуется выполнение аналогичных исследований для остальных составляющих природной среды и объединение их в интегральном (суммарном) решении с учетом роли каждой составляющей в формировании экологической ситуации. Дифференциация выполняется на основе приема построения сеточной модели, в которой площади контуров каждого уровня антропогенного воздействия в пределах блока суммируются и приписываются к центру блока, обеспечивая перевод картографической информации в количественную.

Частное решение обратной задачи частной комплексной экологической оценки находится как разность частных целевых функций, отражающих усредненные (средневзвешенные) оценки антропогенного воздействия на компоненты природной среды в целом по каждому блоку сеточной модели и для суммы площадей всех зон с наличием НГДК в блоках с их наличием. Нагрузки на уровни трансформации в частных целевых функциях учитывают уровень сложности проведения природоохранных мероприятий по каждому компоненту природной среды, их обоснование приведено в легендах оценочных карт. После расчетов целевых функций по полным площадям всех блоков и площадям контуров разных уровней воздействия НГДК, получены суммарные баллоплощади, а после деления на площадь области или площадь зон с НГДК – дифференцированные оценки антропогенной нарушенности рельефа территории Мангистауской области в каждом блоке и в частях блоков с НГДК.

Результаты расчетов показали, что НГДК создает дополнительную нагрузку на рельеф в диапазоне от 0 до 60,46% при том, что метод обобщенный оценки вклада НГДК в целом по области дал величину 16,73%. Таким образом, метод дифференцированной оценки позволяет выделять области, где антропогенное воздействие НГДК меньше воздействий других источников, а анализ диапазона изменений интегрального решения в зонах с НГДК может служить основанием объективизации дифференцированной реализации принципа «загрязнитель платит».

Ключевые слова: Мангистауская область, нефтегазодобывающий комплекс, степень антропогенной нарушенности рельефа, частные целевые функции, обратная задача комплексной экологической оценки территории.

Introduction

The region is located in the southwest of the Republic of Kazakhstan in the desert zone and includes the peninsula Mangyshlak, the Ustyurt plateau, the Buzachi peninsula, the Dead Kuluk and Kaidak sores and is characterized by continental dry desert climate, strong storms and winds. In most of the territory of the Mangystau region, east and south-east winds prevail in winter, in the west – west and north-west. The average annual wind speed is 3-7 m / s, the maximum reaches 10-26 m / s, winds of a hurricane character with a speed of more than 15 m / s are observed on the coast in winter.

Most of the territory of the region is occupied by wormwood-solonchak desert with areas of shrubby vegetation on brown soils: the surface is partially covered with solonchaks, takyr-like solonetzes and sands with extremely rare vegetation. Thus, the climatic conditions of the Mangystau region predetermine the development of deflation and sorption processes, the formation of a scarce soil and vegetation cover with a low ability to mitigate the effects of anthropogenic impacts.

At the heart of the region's economy is the oil and gas sector, whose production accounts for more than 90 percent of the total industrial output in the region, which explains the attitude towards the oil gas producing complex as the main source of anthropogenic disturbance of the natural environment components, since the oil and gas extraction industry is traditionally considered one of the most environmentally dangerous industries..

The natural conditions of the regions in combination with the anthropogenic load determine their ecological situation. The ecological state of the territories is assessed by the results of a different type of monitoring of the components of the natural environment. The technical means of monitoring reflect the influence of many sources of anthropogenic impact on the state of the air, soil, vegetation, relief, surface and groundwater through a number of measured parameters. These parameters are the basis for the construction of complex (by all components) or partial (for individual components) environmental assessments of the natural environment.

The complexity of the task of constructing complex and private environmental assessments led to the lack of generally accepted methods for solving it. However, for an objective implementation of the polluter pays principle, an independent assessment of the contribution of individual sources to these integrated or private environmental assessments is also needed, i. It is necessary to find a way to solve the inverse problem of a complex (or private) environmental assessment.

The solution to this problem is the aim of the grant project performed by the authors, which is funded by the Ministry of Education and Science of the Republic of Kazakhstan №0589/GF-4 «Development of the method of objectification of expert assessments of contribution of specific sources of pollution to general environmental situation of the territory». Within the framework of the project, a number of works have been completed, some of which have already been published (Pavlichenko 2015 :133).

. They consider examples of the solution of the inverse problem by the method of generalized assessment to determine the contribution of the activities of the OGPC Mangystau region to anthropogenic modifications of the most important components of the natural environment and the actual data for their confirmation.

The aim of this paper is to describe the methodology and results of solving a particular inverse problem of integrated environmental assessment in a second way, a method of differentiated estimation, to determine the role of OGPC in anthropogenic transformation of relief in Mangystau region

Material and Research Methods

The ecological state of the territories is assessed by the results of a different type of monitoring of the components of the natural environment. The technical means of monitoring reflect the influence of many sources of anthropogenic impact on the state of the air, soil, vegetation, relief, surface and groundwater through a number of measured parameters. These parameters are the basis for the construction of complex (by all components) or partial (for individual components) environmental assessments of the natural environment. The complexity of the task of constructing complex and private environmental assessments led to the lack of generally accepted methods for solving it. However, for an objective implementation of the polluter pays principle, an independent assessment of the contribution of individual sources to these integrated or private environmental assessments is also needed, i. It is necessary to find a way to solve the inverse problem of a complex (or private) environmental assessment. In this case, a comprehensive environmental assessment is considered in accordance with R. Pantle (Pantle R.1979:215) who called it an objective function. The published articles (Pavlichenko 2016: 58, Pavlichenko 2016: 198, Yespolayeva A.R 2016:13) detail the method for solving the inverse problem of integrated environmental assessment based on the use of ready-made maps of expert private environmental assessments of anthropogenic transformation of the components of the natural environment in order to obtain generalized estimates

The difference between the differential approach and the generalized approach is that for generalized estimations using GIS-technologies, the sums of areas of equal levels of anthropogenic transformation of the components of the natural environment within the whole region and in zones with the development of the oil gas producing complex were determined, and in the method of differentiated estimates, these operations are performed in Limits of the grid model blocks for the map (fig.1).

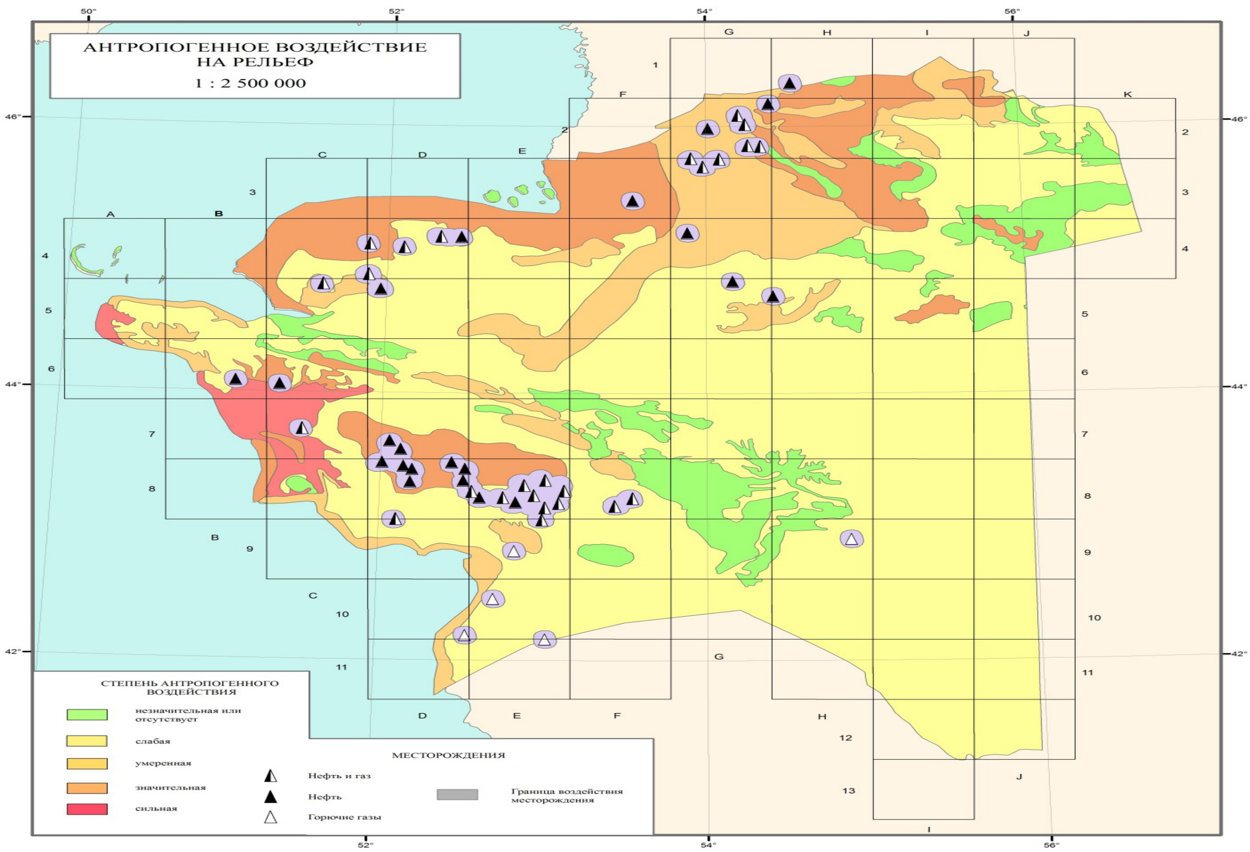

Figure 1 – Grid model of the map of anthropogenic impact on the relief
The original map was published in the (Atlas :2011)

Since the map used as the initial data is an expert generalization of the geographical maps of the relief of the Mangystau region and an inventory map of anthropogenic sources of impact, an analysis of the objectivity of the construction of the evaluation map was carried out in Pavlichenko 2015:133) This analysis showed a high degree of its objectivity, due to the consideration of the natural conditions of the territory, studied according to the data of expeditionary research and space exploration data, as well as the completeness and diversity of the anthropogenic factors transformation of the relief. However, the resulting map, on which the grid model is constructed, contains only 5 levels of anthropogenic impact acting as factors of the multiple linear regression equation, which, in accordance with the recommendations of R.Pantle, is taken as a kind of objective function determining the value of integrated environmental assessment. The problem arises of justifying the sufficiency of these 5 levels in order to achieve sufficient accuracy of further constructions on their basis.

Here the work (Gmoshinsky 1977:64) is devoted to a popular presentation of the ideas of engineering ecology. It is shown that if ecology is considered from the standpoint of the general theory of systems and quantitative information theory (Jeffers 1981:213), one can obtain a very simple formula (1) for calculating a sufficient number of parameters n (environmental factors in the objective function equation) for the desired accuracy of the estimate:

$$\Delta = \frac{1}{l^n}, \qquad (1)$$

where, l – is level of quantization of assessment scales used in assessment of environmental factors (number of divisions of assessment scale).

It follows from formula (1) that, even with the coarsest evaluation scale with a quantization level of 2 (ie, for an expert evaluation based on the «yes» and «no»), sufficient accuracy (errors do not exceed 4%) can be achieved with 5 counted Parameters (□ = 1/25 = 0.03125, or 3.1%). Thus, the number of analyzed parameters n (the exponent in the denominator of the formula), rather than the quantization level of the scales l (the number of divisions in our measuring «ruler») exerts a greater influence on the accuracy (ie, actually on the objectivity) of the expert estimates.

Thus, the initial map, which is the basis for the construction of the grid model, satisfies the necessary conditions of objectivity and accuracy. We now turn to the presentation of the method of solving the inverse problem of a complex ecological assessment for a particular (for relief). (Bevers 1999:249, Boumans 2002:529)

The method of private (for one of the components of the natural environment) differentiated solution of the inverse problem of integrated ecological assessment of territories provides for the initial use of a map published in the Atlas of Mangystau region with a ready integrated environmental assessment that takes into account the influence of all sources of impact on the relief and is implemented by two methods.

Method 1 is aimed at obtaining concrete factual data in a form adapted for use in objective functions and justifying the sufficient objectivity of these objective functions. To convert the initial cartographic (dispersed) information into quantitative (concentrated) for particular target functions, the grid model and GIS technologies are used (the joint use of ArcGIS and QGIS DESKTOP.

The grid model as a whole is a superposition of a grid of elementary blocks (an obligatory condition for translating dispersed cartographic information into quantitative, point, is the equality of all blocks whose centers are points to which all the information on the block is attached) with characteristic boundaries (sea shore, Settlements, etc.) on all maps serving as sources of source information. For a more accurate alignment, the set of maps of the actual geoecological material and the contours of the grid model should be reduced to a single scale – this is the main condition for constructing a grid model, Most often a set of necessary parameters have to be recruited from different maps. Further blocks are numbered or they are assigned an alphanumeric code.

The grid model database for the possibility of its processing by numerical methods must be a matrix of initial data in which the block numbers are successively written for each row of the grid model in the first column of the matrix of the original data. Thus, the grid of blocks on the grid model «unfolds» into one column of the matrix of the original data. The following columns are filled with the coded value of the characteristics selected for analysis (area, length, number of icons, etc.).

As a result of transforming the cartographic information on the grid model, a matrix of quantitative information is obtained in which the columns are areas of each of the 5 levels of anthropogenic impact for each component of the environment across the entire Mangystau region as a whole and zones with the presence of OGPC, but now this is the sum of the areas of the contours within each block of the grid model – a system of square blocks, into which is broken entire territory of the region.

Thus, we obtained an algorithm for obtaining quantitative information on the basis of the grid model of cartographic information (Araujo 2007:743, Pavlichenko 2017: 210, Armand 1992:208).

The second method coincides in the form of the construction of solutions with method 2 in the method of generalized estimation, but in this case all these constructions are performed according to the area of each block of the grid model. This method makes it possible to differentiate the anthropogenic impact on each component of the natural environment, and then in blocks with the presence of OGPC, thus ensuring the differentiation of the role of OGPC over the territory. Since the difference between the differentiated approach and the generalized approach is only on the scale of the assessment (within a single block or across the entire region), type of objective functions will differ only in the recording of the signs by the membership of the objective function parameters to the whole territory or to the block located at the intersection of the i-th line and j column, it is possible to use the equations obtained in [3] for the objective functions over the relief, assigning them the icons of belonging to the block ij. As a result, we obtain equation (2) for a particular objective function of the total area of each block and (3) for a particular objective function of the area of blocks with OGPC:

$$POF_{ijrel} = f_{ijrel1} + 3 \cdot f_{ijrel2} + +5 \cdot f_{ijrel3} + 7 \cdot f_{ijrel4} + 9 \cdot f_{ijrel5}, \quad (2)$$

$$POF_{ijrelOGPC} = f_{ijrel1OGPC} + 3 \cdot f_{ijrel2OGPC} + +5 \cdot f_{ijkrel3OGPC} + 7 \cdot f_{ijrel4OGPC} + 9 \cdot f_{ijrel5OGPC}, \quad (3)$$

Where f_{ijrelk} –function of a certain (k-th) level of anthropogenic disturbance of the relief (rel), which is calculated by dividing the value of the total area of polygons of a certain anthropogenic transformation level for this component as a whole in block ij by the area of this block; $f_{ijrelkOGPC}$– analog of $f_{ijрелk}$ in blocks with the presence of OGPC.

The weight loads of each parameter of the objective function are determined under the condition that five levels of influence on the individual components of the natural environment are consistent with the traditional one in expert assessments with a ten-point scale. In the case of a linear scale, there will be 2 points for each of the 5 levels, with an increase in the level of the transformation corresponding to an increase in the scoring.

This statement is justified from the standpoint of the complexity and cost of carrying out environmental protection measures, in particular measures for reclamation of the territory. As the cost of environmental measures increases in proportion to the degree of anthropogenic disturbance (ie, the reduction of the ability of natural systems to self-repair), a private environmental assessment of the contribution to each zone is established in accordance with a weighting factor proportional to the level of transformation in the scoring scale. In this case, the lower and upper boundaries of 5 levels (parameters of the objective function) are scores:

- For low-level transformation – 2÷4;
- For moderate levels of transformation – 4÷6;
- For significant transformation – 6÷8,
- For strong transformation level – 8÷10.

Taking the average values of the contribution of the OGPC into the anthropogenic transformation of the relief, the mean values between the values of the value classes were obtained, respectively, for the coefficients 1, 3, 5, 7 and 9, respectively.

The role of OGPCij in the transformation of each constituent of the natural environment in each ij-block of the grid model of the Mangystau region is determined by subtracting the value of the POF fijrel obtained from the calculations of equation (2) from the value of the POF fijrel OGPC calculated from equation (3), leading to form that reflects the calculation of the function in each block. Taking the average values of the contribution of the OGPC into the anthropogenic transformation of the relief, the mean values between the values of the value classes were obtained, respectively, for the coefficients 1, 3, 5, 7 and 9, respectively.

The role of OGPCij in the transformation of each constituent of the natural environment in each ij-block of the grid model of the Mangystau region is determined by subtracting the value of the POF fijrel obtained from the calculations of equation (2) from the value of the POF fijrel OGPC calculated from equation (3), leading to form that reflects the calculation of the function in each block (4):

$$PSIP_{ijRel} = POF_{ijrelOGPC} - POF_{ijrel} \quad (2)$$

The resulting value in points POFijrel can be translated to a percentage multiplying by 10, as full scale of 10 points is taken for 10%. This value is additional (since the total impact of all the main factors in accordance with the legends to the evaluation maps is reflected in the POF fiirel and POFirel and OGPC), the contribution of OGPC ij to the anthropogenic transformation of the relief in each ij-block of the grid model.

As a result, we obtain a system of equations for obtaining a differentiated assessment of the contribution of the OGPC to the anthropogenic transformation of the relief.

Table 1 – Selection of the results of calculations of particular objective functions and a particular solution of the inverse problem of an integrated environmental assessment for differentiation of the OGPC territory in the Mangystau region

Designation of blocks	For the full blocks in the territory of the region						For blocks with the presence of OGPC						$PSIP_{ijrel}$
	f_{ijrel1}	f_{ijrel2}	f_{ijrel3}	f_{ijrel4}	f_{ijrel5}	$POF_{ijRELл}$	$f_{ijrelOGPC1}$	$f_{ijrelOGPC2}$	$f_{ijrelOGPC3}$	$f_{ijrelOGPC4}$	$f_{ijprelOGPC5}$	$POF_{ijrelOGPC}$	
1-G	0,000	0,000	0,999	0,001	0,000	5,001							-5,001
1-H	0,131	0,000	0,106	0,763	0,000	6,001	0,000	0,274	0,268	0,457	0,000	5,366	-0,635
2-F	0,000	0,000	0,368	0,632	0,000	6,264							-6,264
2-G	0,005	0,000	0,793	0,202	0,000	5,383	0,000	0,000	0,000	0,866	0,134	7,267	1,884
2-H	0,070	0,000	0,293	0,637	0,000	5,992	0,000	0,175	0,144	0,681	0,000	6,012	0,021
2-I	0,059	0,427	0,430	0,084	0,000	4,077							-4,077
2-J	0,158	0,697	0,105	0,040	0,000	3,054							-3,054
2-K	0,410	0,590	0,000	0,000	0,000	2,181							-2,181
3-C	0,000	0,000	0,000	1,000	0,000	7,000	0,000	0,284	0,187	0,528	0,000	5,488	-1,512
3-D	0,000	0,000	0,000	1,000	0,000	7,000	0,000	0,293	0,245	0,462	0,000	5,339	-1,661
3-E	0,169	0,000	0,000	0,831	0,000	5,988							-5,988
3-F	0,000	0,000	0,028	0,972	0,000	6,944							-6,944
3-G	0,000	0,000	0,953	0,047	0,000	5,094	0,007	0,000	0,260	0,511	0,221	6,879	1,785
3-H	0,099	0,000	0,429	0,472	0,000	5,550							-5,550
3-K	0,402	0,598	0,000	0,000	0,000	2,197							-2,197
4-A	1,000	0,000	0,000	0,000	0,000	1,000							-1,000
4-B	0,000	0,000	0,000	1,000	0,000	7,000							-7,000
4-C	0,000	0,275	0,024	0,702	0,000	5,854	0,000	0,531	0,469	0,000	0,000	3,937	-1,917
4-D	0,000	0,726	0,016	0,258	0,000	4,065							-4,065
4-E	0,000	0,490	0,087	0,423	0,000	4,866							-4,866
4-F	0,000	0,286	0,356	0,358	0,000	5,144							-5,144
4-G	0,000	0,300	0,694	0,006	0,000	4,413	0,000	0,000	1,000	0,000	0,000	5,000	0,587
4-H	0,107	0,410	0,476	0,007	0,000	3,764							-3,764
4-I	0,246	0,606	0,013	0,135	0,000	3,072							-3,072
4-J	0,413	0,421	0,000	0,166	0,000	2,840							-2,840
4-K	0,000	1,000	0,000	0,000	0,000	3,000							-3,000
5-A	0,002	0,273	0,263	0,000	0,462	6,293							-6,293
5-B	0,015	0,692	0,260	0,033	0,000	3,621	0,000	0,000	0,154	0,150	0,696	8,084	4,463

Results and Discussion

In accordance with the algorithm described in the methodological section, a matrix of initial data was obtained, consisting of 10 columns corresponding to 5 levels of anthropogenic impact on the relief (5 columns for the total area of blocks and 5 columns for zones with OGPC), and 90 lines corresponding to 90 blocks per Grid model (see Figure 1). In view of the awkwardness of the table, it is not given in the article, however, part of the table (Table 1) with calculations of particular objective functions by equations (2) and (3) and the particular solution of the inverse problem by equation (4) is given for the visualization of calculations.

As can be seen from Table 1, due to the fact that blocks with the presence of OGEC are much smaller than in the territory of the region as a whole (24 out of 90), many blocks with negative values of the particular solution of the inverse problem appear in the column of the values of $PSIP_{ijrel}$. Thus, even without the construction of isolines, it is possible to judge the zones of intensive manifestation of the influence of OGPC.

Let us now analyze the advantages of the method of differentiated estimation, which requires much more time for its implementation at the stage of obtaining quantitative information on the cartographic material, in comparison with the method of generalized estimation. First, we try to justify the physical meaning of the results of solving the inverse problem.

As follows from equation (4.3), the particular solution of the inverse problem of the $PSIP_{jrel}$ is constructed as the difference of the particular objective functions characterizing the level of anthropogenic impact on the relief in blocks with the presence of zones with OGPC and in blocks throughout the region as a whole. In this case, in the part of the territory where OGPC is absent, the value of $PSIP_{ijrel}$ will be determined by the influence of all the factors of impact on the relief taken into account in the evaluation map, but with a minus sign, since the $POF_{ijrelOGPC}$ in these blocks is equal to 0.

Judging from the recording of equations (2) and (3), the maximum values for them (equal to 9) will be achieved in the case when the entire area of the block or the contours of the OGPC manifestation is only one color corresponding to the maximum exposure level (k = 5). This is explained by the fact that f5ijrel is obtained by dividing the sum of the fifth-level contours in the block (in this case it is the whole block) by the area of the block, i.e. As a result, we get 1. And since for the fifth level the weight coefficient is 9, multiplying 1 by 9, we get 9. Similar arguments can be repeated for f5ijrelOGPC. Here, as in the case of a generalized solution, it should be remembered that fkijrelOGPC is calculated only within the zones with the presence of OGPC, and not within the entire block area. Thus, $PSIP_{ijREL} = 0$ will mean that the effect POF_{ij} rel Reg considered completely, i.e. This is the upper limit of the full compliance with the principle of polluter pays. Consequently, a negative value of the $PSIP_{rel}$, which is in the range from 0 to the $POF_{ijrel\ Reg}$ with a minus sign, means that there is no additional contribution from the OGPC to the anthropogenic disturbance of the relief, i.e. This is the area of fair action of the polluter pays principle:

$$-POF_{ijrel} \leq PSIP_{ijrel} < 0 \tag{5}$$

And only in the case of positive values of $PSIP_{ijrel}$, the effect of this principle is violated, because They proved to be higher than the accounted effects of all operating factors, including OGPC. This is already an area of possible violation of the principle polluter pays:

$$PSIP_{ijrel} \geq 0 \tag{6}$$

Since the values of the $PSP_{jrelReg}$ are higher than the average for all blocks, they are also encountered in the absence of OGPC, in order to demonstrate the work of inequalities (5) and (6) in Table 2, a sample of such blocks and all blocks with OGPC is presented.

For convenience of perception in the last column of Table 2, blocks with absence of OGPC are marked in yellow, indicating that there are cases of a high level of anthropogenic transformation of the relief by the effects of other sources of impact listed in the legends of the inventory and evaluation maps. This is the case of «the impact of only other sources of influence.»

In blocks with the presence of OGPC, the range of action of inequality (5) is singled out in a separate color – the case «the influence of other sources of influence exceeds the impact of the OGPC.» As can be seen from Table 2 of these blocks, only 5 of the 24 blocks with the presence of OGPC. The remaining 19 blocks fall within the scope of inequality 6, where «the effect of the OGPC exceeds the block average», i.e. The area of possible violation of the principle polluter pays. Thus, a differentiated assessment made it possible to obtain qualitatively new information on the role of OGPC in the anthropogenic transformation of the relief.

Table 2 – Differentiated assessment of the contribution of OGPC to anthropogenic disturbance of the relief

Designation of blocks	POF_{jrel}	$POF_{jijrel\ OGPC}$	$PSIP_{ijrel}$	The differentiated assessment of the level of impact of OGPC on anthropogenic disturbance of the relief
5-A	5,204		-5,204	Influence of only other sources
6-A	4,949		-4,949	Influence of only other sources
4-B	7		-7	Influence of only other sources
5-B	3,681	5	1,319	The impact of OGPC exceeds the block average
6-B	4,817	6,426	1,609	The impact of OGPC exceeds the block average
7-B	8,746		-8,746	Influence of only other sources
8-B	6,85		-6,85	Influence of only other sources
3-C	7	6,735	-0,265	The impact of other sources of impact exceeds of OGPC
4-C	5,854	5,867	0,013	The impact of OGPC exceeds the block average
6-C	4,921	7,494	2,573	The impact of OGPC exceeds the block average
7-C	6,626	8,929	2,302	The impact of OGPC exceeds the block average
8-C	5,133	5,33	0,197	The impact of OGPC exceeds the block average
9-C	4,074		-4,074	Influence of only other sources
3-D	7	6,118	-0,882	The impact of other sources of impact exceeds of OGPC
4-D	4,065		-4,065	Influence of only other sources
7-D	4,949	5,412	0,463	The impact of OGPC exceeds the block average
8-D	4,731	8,627	3,897	The impact of OGPC exceeds the block average
9-D	3,523	3,973	0,45	The impact of OGPC exceeds the block average
10-D	4,227	3	-1,227	The impact of other sources of impact exceeds of OGPC
11-D	3,957		-3,957	Influence of only other sources
3-E	5,988		-5,988	Influence of only other sources
4-E	4,706		-4,706	Influence of only other sources
8-E	4,974	6,55	1,576	The impact of OGPC exceeds the block average
10-E	3,113	3,189	0,076	The impact of OGPC exceeds the block average
11-E	3	3	0	The impact of OGPC exceeds the block average
2-F	6,264		-6,264	Influence of only other sources
3-F	6,944	7	0,056	The impact of OGPC exceeds the block average
4-F	5,064	3	-2,064	The impact of other sources of impact exceeds of OGPC
1-G	5,001		-5,001	Influence of only other sources
2-G	5,297	7,505	2,208	The impact of OGPC exceeds the block average
3-G	5,094	7	1,906	The impact of OGPC exceeds the block average
4-G	4,413	6,109	1,696	The impact of OGPC exceeds the block average
5-G	3,318	3,224	-0,095	The impact of other sources of impact exceeds of OGPC
9-G	2,01	8,056	6,046	The impact of OGPC exceeds the block average
1-H	6,001	7	0,999	The impact of OGPC exceeds the block average
2-H	5,992	5,497	-0,495	The impact of other sources of impact exceeds of OGPC
3-H	5,55		-5,55	Influence of only other sources
1-I	6,034		-6,034	Influence of only other sources

Thus, in the generalized assessment model, we obtained averaged anthropogenic impact on the relief over the whole region or all areas with OGPC, and a particular solution of the inverse problem is the average estimate of the excess of the role of OGPC in the zones with their presence. As a result, all zones with OGPC were «guilty» in additional impact on the relief by 16.73%, and it should be recalled that we are talking only about the zones with the OGPC, no conclusions could be drawn about extending this influence to the neighboring territories.

Unlike from the model of the generalized assessment, the model of differentiated evaluation showed that in four blocks out of 24 the anthropogenic disturbance of the relief as a result of the influence of other factors turned out to be higher than from the impact of the OGPC. And difference in the positive values of the particular solution of the inverse problem in magnitude can form the basis for establishing differentiated payments for emissions into the environment.

Conclusion

The method of differentiated evaluation for its implementation requires much more time at the stage of obtaining quantitative information on the cartographic material in comparison with the method of generalized estimation, but it has a number of undoubted advantages. Thus, in the generalized estimation model for the particular solution of the inverse problem, we obtained an average estimate of the excess of the role of OGPC in anthropogenic impact on the components of the natural environment. As a result, all zones with OGPC were «guilty» in additional impact on the components of the natural environment. The method of differentiated estimation allows us to identify areas where the anthropogenic impact of OGPC is less than that of other sources, and an analysis of the range of changes in the integral solution in zones with OGPC can serve as the basis for objectifying the differentiated implementation of the principle by polluter pays. The maximum values of particular objective functions can not exceed a value equal to 9. This is explained by the essence of their members (particular from dividing the sum of the areas of contours of the same color in the block by the area of this block), as well as the values of their weight coefficients. In this case, the function of the 5th level of anthropogenic disturbance will be equal to 1, which, when multiplied by the weight coefficient for the fifth level, equal to 9, will give 9. Here, as in the case of a generalized solution, it should be remembered that fkijrelOGPC is calculated only within the zones with the presence of OGPC, and not within the entire block area. Thus PSIPijrel = 0 will mean that the effect POF_{ijrel} considered completely, i.e. This is the upper limit of the full compliance with the polluter pays principle.

Therefore, a negative value of the $PSIP_{jrel}$, which is in the range from 0 to the POF_{ijrel} with a minus sign, will mean that there is no additional contribution from the OGPC to the anthropogenic disturbance of the constituent of the natural environment, i.e. This is the area of fair action of the polluter pays principle.

And only in the case of positive values of the $PSIP_{ijNECp}$, the operation of this principle is violated, because They proved to be higher than the accounted effects of all operating factors, including OGPC. This is already an area of possible violation of the polluter pays principle:

Elevated in comparison with the average for all blocks, the values of the PSP_{ijrel} are also encountered in the absence of OGPC, i.e. There are cases of a high level of anthropogenic transformation of the relief under the influence of other sources listed in the legends of the inventory and evaluation maps. This is the case of «the impact of only other sources of influence.»

Thus, a differentiated assessment made it possible to obtain qualitatively new information about the role of OGPC in the anthropogenic transformation of the relief.

In contrast to the model of generalized assessment of relief, the model of differentiated estimation showed that in four blocks out of 24 the anthropogenic disturbance of the relief as a result of the influence of other factors turned out to be higher than from the impact of OGPC.

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