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Study Of Natural Formation And Anthropogenic Change In Soils For Sustainable Land-Use.

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ABSTRACT

In this work, we have presented an approach to rational territorial organization of the environment with the aim of harmonizing natural, economic and socio-demographic processes. Successive stages of the action for the development of basin nature management projects are proposed by us. Design technology rational land use is implemented for one of the small river basin. The work showed the principal possibility of solving the problems of nature use, as demonstrated by the example of a specific project for environmental management of catchment of a small river.

Keywords: Land use, rural areas, agrolandscape, ecological arrangement, GIS-technologies.

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INTRODUCTION

The decrease of the supplies of soil resources and the deterioration of their quality – is a global problem, settlement of which becomes the barest necessity for humanity, because of absence of any alternative. The destruction of soils under the influence of water and wind erosions leads to the losses, which cannot be supplied by soil formation process in an economically acceptable period. Geoplanning of rural areas and development of indicators of the optimal solutions for sustainable land management practices and agriculture THEY represent the most effective approach to resolving the current problems of restoration of natural resources and ecological safety of the environment **[**30, 33, 4, 6, 12, 1**].**

The key efficiency indicator for the land management practices is the ratio of soil regeneration processes and soil destruction processes due to erosion. The direct identification of soil formation rates and soil erosion rates proved its inapplicability (due to erosion, the soils in an agrolandscape have velocities other than those in the conditions of a natural soil formation; and the soil formation rates in the natural conditions are often one order lower than those that can be monitored using erosion control). The prevailing approach to the soil resources requires change of ultimate accounting of their values [28]. These tasks are successfully solved using the concept of soil chronosequences [8, 3]. A new perspective in reviewing the problem (by total properties in aggregate in relation to the members of evolution chronological series, rather than by individual soil properties) will allow determining the space-time state of the land cover.

Assessment of the soil formation velocity plays a crucial role in both natural conditions when a sufficient amount of plant matter comes into soil and in agroecosystems where the deficiency of plant matter [9, 21, 22, 20] is often observed.

On the basis of the regional database, mathematical models were developed which adequately describe the nonlinear processes of zonal soils [23]. It should be noted that the important application of the models obtained is their ability to determine the threshold of resistance of soil to loss of the main resource evaluation properties (thickness of the humus horizon and humus content in it). Soil development is a long-term and relatively slow process.

The total data available in the modern scientific and educational literature (published within the last three decades of the 20th century) contain the results of field observations of soils of different ages in various regions of Eastern Europe, showing that the average annual rate of humus layer formation under the action of natural factors in the equal density (if we accept it 1.25 t m^{-3}) is 1.65–2.0 t ha^{-1} [9, 23]. It is important to note that the idea of the duration of soil use as a resource depends largely on the evaluation of soil erosion rates [10]. The main natural laws of the distribution of the arable lands destructed by erosion correlate well with geomorphological, climatic, soil conditions and with the peculiarities of agricultural use. But sometimes there is not direct correspondence between the degree of destruction of arable lands and the intensity of erosion, which is important in soil conservation projection. The highest intensity of water erosion is on the border of the wooded steppe zone and a north subzone of the steppe, in some districts of reaches 15–22 t ha^{-1} in a year. Within the last 30 years, the total erosional feature of the topsoil in the Belgorod region (2713.4 thou ha) has increased by 6% due to the intensification of the erosion process and can be approximately 60% [27]. The assessment of average annual soil losses due to erosion showed that at their vast variety for this region they remain within the limits of 11–12 t ha^{-1}. Rhythmic variations of intensity of the erosion process due to change of aerohydrothermal conditions in the subdivisions of Holocene horizons of the landscapes with size $n \cdot 10^2$ years can be considered as evolution component of pedogenesis [13, 26].

Since the early 19th century, the anthropogenic impact on the catchments has been increased in the twofold population growth, and in the second half of the 19th century, the peak was registered in the ploughing of lands as well as the minimum in the forest coverage for the whole historical period [25]. Along with increasing the intensity of agriculture, the problem was the abandonment of agricultural land in Russian Federation in the late 20th century [18].

The effects of the high erosion rate and formation of the dense ravine-gully network were the increase in the thickness of the deluvial sediments in the basins of the small rivers and the silting of their channels. The results of long-term studies of the agrogenic evolution of automorphic Chernozem in the Central Russian upland [7, 17, et al.], as well as a comparison virgin, cultivated, and old-arable soils showed that with the long processing of soils there was a significant transformation on soil profile morphology, organic carbon and physico-chemical properties.

Macromorphological indices attest to the enhanced development of humification processes and leaching of carbonates and soluble salts in the soils cultivated during the several centuries. The reproduction of soil organic matter and its quality, which is responsible for the agrophysical properties of a plough horizon [5, 16, 29, 35], is central to soil fertility management for sustainable agriculture. In the course of agrogenic evolution, progressive changes in the morphology of soils are not accompanied by the improvement of soil aggregation at lower levels [21].

The loss of organic carbon (Corg) in continually ploughed land is 51%, while in modern-day ploughed land it amounts to 39% [20]. In addition to the general content of Corg, soil degradation also manifests itself in the labile and light fractions of Corg, the biomass of microorganisms and their respiration [32, 15]. In addition, in the geochemical cycle the toxic elements should be in focus soil monitoring of agricultural land [14, 35, 38].

Approach to geoplanning of rural areas showed its effectiveness when using the concept of basin nature use and technological opportunities of geoinformational designing and remote sensing. Already implemented of scientific and technical transfer to basin arrangement of rural areas with the help of geoplanning in one of the Russian regions (Belgorod oblast) is provided (for 62 basins of small rivers) [25]. Ways for optimization of the land structure for sustainable land management are implemented in practice, which allowed increasing of areas of those, which provide environmental stability of the territory. Our research was aimed at further development of the algorithm of design solutions by the example of the basins of one of the small rivers of the region.

MATERIALS AND METHODS

The earlier basin and administrative approach to rationalization of the nature management was implemented [19, 25, 27] with the addition of these developments a new approach to representation of large natural reserves [37]. For the type design of basins there was instrument “Iso Cluster” in ArcGIS used. In the course of analysis of the design results obtained it is established that the for the purpose of geoplanning the rural area the up-to-date maps of the land are necessary, for the purpose of which there were large-scale electronic maps and identification of land use by satellite imagery. Quantification of areas of arable land and forest plantations for basin organization of nature management and the geoplanning of the rural area was carried out in GIS on the basis of vector digital maps [11, 36].

Information about the structure of the land was updated on the basis of high resolution satellite images. The Field Calculator tool in the attribute table for each river basin allowed calculating the land use for each river basin. While analysing position-dynamic structure (PDS) of landscapes (according [31]) GIS is used for automated detachment of small watersheds in river basin on the base of analysis of digital elevation model (DEM) and hydrologic modelling [2]. Complex ArcGIS 10.1 and ArcHydro applications were used at composing the PDS scheme of the river basin. This allows us to identify morphometric peculiarities of the river basin and perform a range of analytical procedures.

RESULTS AND DISCUSSION

The experience of the soil conservation arrangement of the agrolandscapes of the erosion dangerous territories shows the particular importance of a scientific basis of the basic normative indices – the permissible erosion losses of soil and the norms of reproduction of quantity and quality of soil resources. Three main groups of methods, discovering soil erosion tolerance values (T-level) can be distinguished according to the differences in correlating the erosion soil losses with the rate of forming the humus horizon. It is essential to note; that principles of T-level grounding don't accord to present-day level of knowledge. There is urgent need to begin modelling of resource-forming processes in soil and develop algorithms of long-term soil resources management instead of method of expert estimation. The variation of the regional (landscape) levels of the soil fertility, exceeding the interzonal differences (in the connection with the soil types, great groups etc.), the aspiration for the adaptation of the projected soil conservation systems of agriculture to the local landscape conditions cause the need in the correlating level of discretization of the estimations of the soil loss tolerance and the erosion yield.

Under the conditions of modem intensive agriculture, it is difficult to value the speeds of humus horizon formation, which is connected with the considerable dynamics of agricultural systems, activation of erosions and other reasons. It is obvious that this question cannot be solved out of touch with the peculiarities of reproduction of organic substance. In the Chernozem zone, where the problem of humus state's regulation is discussed as the provision of sufficient (not managed with the special means) level of the part of humus in the soil for preservation of favourable water-physical, technological and phytosanitary qualities of soil, estimation of cultural pedogenic process transits more into the sphere of quantities, but into the sphere of qualities' estimation of soil resources, mainly in bounds of cultivate horizon.

The condition of preservation (at least, for the nearest perspective) of slightly and much part of moderately eroded soils' bonitet can be reached by optimization; of factors of management to the values that could provide the simple reproduction of soil resource.

Sustainable environmental management at the municipal level involves not only the full use of natural resources, but also support of their restoration. The main natural resources (mineral, water, soil, and biological resources) have a spatial confinement in a landscape in various combinations. This is the basis for search for the best environmental management options when designing natural economic systems.

The general scheme of resources restoration management, including restoration of soils, reflects the necessity to have an exclusion block as well as regulatory block with the functions of resources restoration, where environment-forming, ecological and attractive actions are carried out (Figure 1).

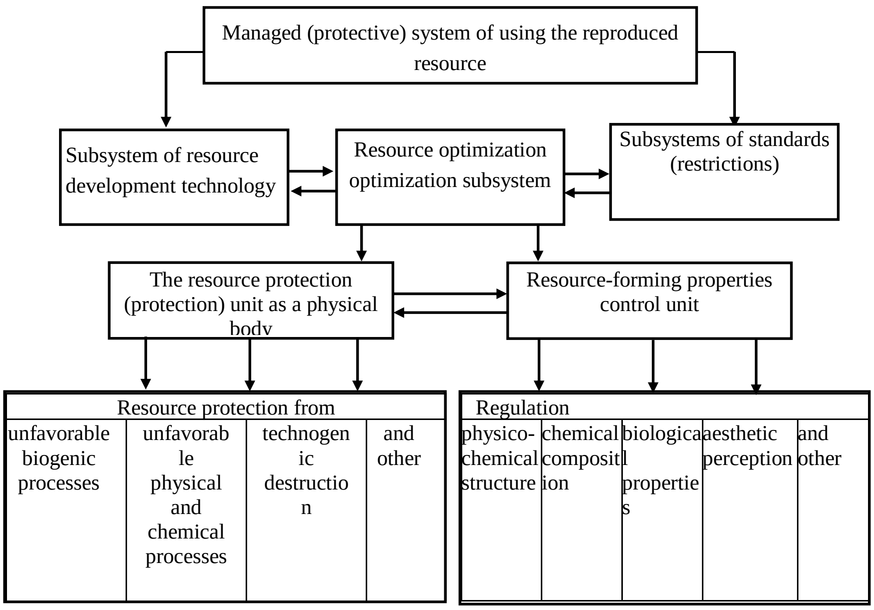

Figure 1: Schema of a managed system for using a reproducible resource

A controlled system for restored resource management shall include a subsystem for the consumer product production technology along with an optimisation subsystem (regulatory and management subsystem). The optimisation subsystem provides the line of “Objective Function – Critical Indicators – Optimisation Function”. Here the block of resource protection as a physical body is required to preserve the external features (sizes), for example, for soil – to save the thickness of humus horizon, for forest – the total volume of wood, etc. The other block is more sensitive for most of issues - regulation of resource-forming properties: for soil - fertility, for water – quality thereof etc.

The comparison of normatives with the estimations of erosion intensity allows basing the complex of measures, which have anti-erosion, anti-deflation and soil conservation orientation. But more often it is necessary to transit to more radical arrangement of agrolandscape's structure. Such a problem appears in the projection of agricultural systems, based on the contour-improvement arrangement's principles. These systems, solving the main problem – the regulation of runoff on slope and erosion losses, create the basis for strengthening of ecological orientation in agriculture. On some stages of projection this is – taking microzonal conditions into account and increasing in productivity because of the full realization of soil-climatic force and possibility of descend in technogenical loads, this is the making of ecological diversity in agrolandscape etc. The close relationship of soil and plant cover [24] determines the need to optimize the ratio of the areas of the ecological fund of land and for economic needs. The new territorial structure of agrolandscape must be organizing basis for the transition from soil-water conservational arrangement of the territory to the landscape-ecological agriculture, which occupies the whole agricultural districts. It should consist of not only naturally-economic massifs, connected with landscape units of corresponding classes, but also of protected territory, buffer zones, radial ecotone system. Boundaries of antierosional (contour) organization's regulations on the arable lands must be joined with the other lands and the line elements in agrolandscape (forests, pastures, hay lands, flood plain meadow, and gullies). The transition to the new type of agriculture – landscape contour-improvement – is not only perfection of territorial organization of the land use, but also making of basis for full use of mechanisms of landscape's self-regulation in functioning of naturally-economic systems.

The sustainable territorial arrangement of the environment requires choosing the unit of spatial arrangement where natural, economical, and socio-demographic processes can be harmonised. This can ensure integration of agricultural community around economic stabilisation basing on sustainable use of natural resources.

The geoplanning involves regulation of territory use, formation and maintenance of comprehensive environment with the purpose to ensure well-balanced development of the region and improve the quality of life. We offer to consider geoplanning both as a synthetic structural scientific approach and a systematic process of sustainable social territorial arrangement, as well as a management technology.

Selection of basin structures, as hierarchic totality of spatial relations determined by water flow, pumps, and dissolved materials, to be a basis for the system predetermines the appearance of certain advantages in organisation and control of environmentally-focused natural resource management. Ordered and relevant information on the basin arrangement of the territory is of fundamental importance for environmental management, especially when planning the development of production facilities associated with the use of considerable amounts of water resources.

Successive stages of action for the development of basin nature management projects have been identified:

GIS-mapping of landscape structures and modern ecological and economic situation;
diagnostics of the ecological-economic balance of lands and the degree of their natural protection;
ecological arrangement of lands from water bodies and rivers by fixing landscape-justified boundaries of coastal and water protection zones;
landscape mapping of types of arable land by gradation of slopes with determination of priority working areas for the biologization of agriculture;
optimization of the structure of agricultural land: the rationale of territories for cultural pastures with multicomponent grass mixtures, for haying, vegetable growing, forest melioration, establishment of bee-parks, land cultivation and implementation of conservation programs for disturbed and unproductive land;
substantiation of decisions on development of the sphere of recreation and tourism;
territorial allocation of new functional zones – specially protected natural areas, equipped springs, entomological micro-reserves, etc.;
justification of the environmental monitoring system;
assessment of the effectiveness of basin nature management projects.

The small river for the demonstration project (Manjoha) has a length of 8 km and a basin area of 7,260 hectares. The share of agricultural land is 74.4% of the total area, including arable land – 73%. The total forest cover of the territory is small for the forest-steppe and is 13%.

The concept of ecological and economic balance of the territory helps to improve the ratio of two major groups of lands: commercially used and unaffected or slightly affected by human activities (environmental land reserves that perform crucial ecological and biospheric functions). This concept was used in the Project (Figure 2). Functional zones in the basin allow implementing actual special programmes and projects for a specific of a river catchment were justified in the Project of a basin-based organization of nature management (Table).

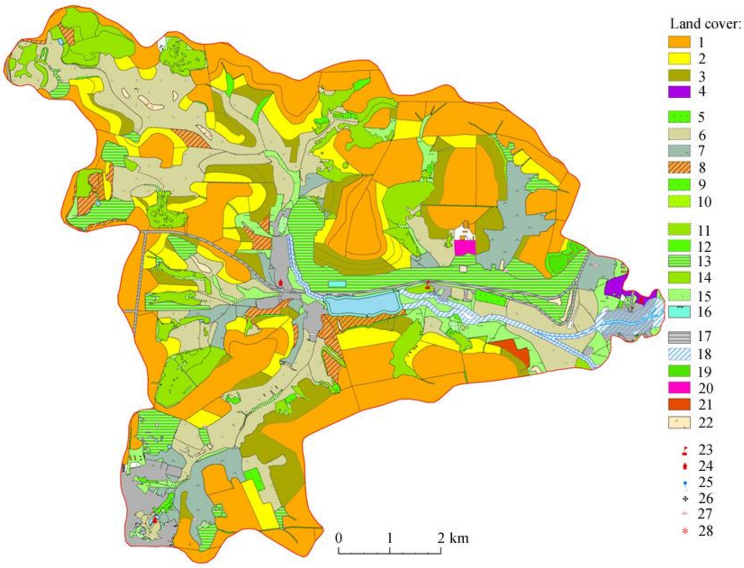

Figure 2: The results of designing a basin-based organization of nature management for one of the small river basin.

Land cover: 1 – field crop rotation; 2 – grain-grass crop rotation; 3 – soil-crop rotation; 4 – vegetable growing; 5 – gardens; 6 – grassland; 7 – pasture; 8 – bee parks; 9 – forest strips; 10 – flooded spillways; 11 – forest; 12 – shrubs; 13 – continuous afforestation; 14 – under self-growth of forest; 15 – natural vegetation; 16 – recreation areas; 17 – protection zones along motorways; 18 – water protection zones; 19 – natural reserves; 20 – land reclamation; 21 – conservation of land; 22 – rock outcrops; 23 – ancestral homesteads; 24 – family farms; 25 – springs; 26 – churches; 27 – monuments of archaeology; 28 – hunting reserves (bridges). on the territory of

Table: The most significant changes in land use for the small river basin

Structure of the land fund	Squares, ha		Balance: +/-	
	actual	after implementation	ha	%*
Farmland	5401	5042	–359	–7
Arable land, including:	3950 (73%)	3278 (65%)	–672	–17
with gradient, degrees				
0-3	2379	2094	–285	–12
3-5	961	867	–94	–10
5-7	390	275	–115	–29

more than 7	212	10	–202	–95
Pastures	1100	376	–724	–66
Hayfields	351	1208	+857	+244
Vegetable growing	8	21	+13	+163
Recreational areas	0,6	23	+22,4	+3733
Protected areas	5	104	+99	+1980
Woodiness	936	1254	+364	+40
Bee-parks	0	145	+145	–
Under ponds and lakes	0	47	+47	–
Conservation of lands	0	15	+15	–
Reclamation of lands	0	12	+12	–
Gardens	0	11	+11	–
Water discharge spillage	0	11	+11	–

* The dash means that new land use types appeared on the project for the first time.

The highest erosion hazard is found within the territory of basin in the arable land at the slopes over than 3°, which is 40%. Therefore, the reduction of arable area from 73 to 65% within the total area of agricultural land is justified as it helps to reduce the area of arable land on slopes by over 5 by more than 5° per 10%. With purpose to biologise the arable land, several technological groups of land were defined by gradation of slopes (3, 5 и 7°). This made it possible to distribute crop rotation with various proportions of perennial grasses and to propose priority actions for erosion control (minimum tillage, strip cropping, meadow formation for emergency discharge into hydrographic network, and use of silt filters). The project of land reserves structure improvement allowed establishing territories for multicomponent cultivated grasslands, haying, and vegetable farming (within the framework of the Family Farms programme). New functional areas were also established: promising areas for family farms, protected natural valleys, areas for entomophile’s trees and shrubs planting nearby beekeeping areas, small entomological reserved woods and hunting areas, wild fowl reserves, which will help in pest control, and exclusion zones for cultural heritage sites.

As a result, the destabilising areas were reduced from 4817 to 3618 hectares that is, by 25%, and the areas of environmental reserves increased from 2443 to 3642 hectares, that is, by 33%. So the following values of environmental parameters can be achieved: the ratio of relative tension of environmental and economic land condition decreased from 1.98 (below optimal not more than 10%) to 1.30 (optimal), the coefficient of natural protection of the territory increased from 0.39 (critical) to 0.60 (relatively favorable).

CONCLUSIONS

In order to increase the resistivity of agricultural landscapes to the effect of human activities it is required to develop feasible areas for improvement of environmental protective land arrangement with mandatory addition of natural and semi-natural biocenoses to agricultural lands. Achievement of balance of the land reserves in the conditions of a sloped landscape is only possible when the use of land will become integrated part of soil protection arrangement over the entire water-shed area. As the basic space arrangement unit, it is proposed to use a basin of a smaller river, rather than economic and technological units that are not linked to the landscape morphology. The territorial arrangement shall be performed simultaneously within the entire area of the basin, which will make it possible to reduce the cost of implementation thereof in each farm and increase its efficiency. In order to use lands in the best way and preserve their quality, agreements shall be made between the economic entities located within the certain river basins.

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