

GIS-MODELLING OF LAND USE OPTIMISATION STRUCTURE ON RADIOACTIVITY POLLUTED TERRITORIES

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Abstract

The version of land use optimisation of the polluted agricultural territories of Ukraine is offered. The project includes the design of the ecological permissible rotation and implementation of the efficient countermeasures directed to the minimisation of internal human doze. The project is realised with using GIS-technology and method of unified soil coding.

1. Methods and data

The problem of rehabilitation of the radioactive polluted territories of Ukraine and returning these territories to product of traditional kinds of plant and animal farming is the actual problem of minimisation Chornobyl's accident's consequences. This problem requires the complex decisions. Under unstable economic condition in agriculture of Ukraine, the rehabilitation of the radioactive polluted territories should be carried out with using of the most economically decisions. The applied measures should be directed to reduce human doze as much as possible. The concept of rehabilitation of polluted agrolandscapes is directed to organize the ecologically stable agricultural production — production of the ecological and normative clear products, regardless of ownership.

The farming on the radioactive polluted territories with different levels of soil contamination can be keeping by changing of agriculture's system or its separate elements: crop rotations' systems, methods of tillage, application of fertilizers, agricultural technologies, structure of the cultivated areas. The farmers on these territories may change farm's organization and specialization. The conditions of pollution - the density of contamination, pollutant's kind, distribution of polluted fields - determine the cultivated area structure. The agricultural crops are essentially differing on radionuclides' accumulation in a crop. The harvest can be used as feed, fodder, and seedcorn.

At organization of crop rotations it is necessary to take into account factors: composition of the crops, their allocation in the land use structure, organization of territory and farming, biological features of crops, necessity of spatial isolation of separate crops [1].

It is necessary to create the best conditions for increase of soil's fertility by planning of crop rotation. It will be engage the stable economic growth. The following parameters:

humus balance, expenses for restoration of soil's fertility, total product cost with the account of soil quality, crop rotation's allocation are use for an estimation of the land use level [2].

The planning of land use structure on the radioactive polluted agricultural territories supported by using geographical information system (GIS). The object of GIS-modelling is digital model of land use structure. We offer to use GIS for planning ecologically healthy crop rotation's structure to the minimisation of human doze. The algorithm of planning of variants of optimum localization of the farm's fields takes into account the results of GIS-modelling: an assessment of product contamination, planning of optimum countermeasures, estimation of economic and ecological efficiency of applied measures.

For execution of this task there were created:

1. Digital model of researched territory — digital maps of land use, soil, ownership, crop rotation's structure.
2. The database of the ecological and economic parameters for designing the different variants of crop rotation s' structure optimisation and estimation of the economic and radioecological efficiencies.
3. The working models are realised:
 - The creation of a integrated cartographical coverage for GIS-modelling [3],
 - The classification of territory by product contamination [3],
 - The agroecological grouping of fields by degree of soil contamination and soil parameters [5],
 - Planning of optimum counter-measures [4].
 - The estimation of doze efficiency [4].

The optimum project of crops' location on fields was made with taking account of soil and product contamination, soil's type and soil texture by method of an agroecological fields grouping [5].

2. The basic principles of geoinformation modelling

The geoinformation technology of modelling of the various scenarios of land use is requires:

- The actual and reliable information about researched territory (basic topographical maps, plans of farm's land use, statistical materials, economical and ecological data),
- Compliance of the principles: accordance of the geographical localization of ecological parameters with the spatial scales of the determined task; integration of all parameters within of the homogeneous territorial unit.

The realization of idea of local homogeneous sites selection requires the procedure of a partition of territory by various features: type of the soil, land use structure, agrochemical

and radiological monitoring data and (or) other features necessary for information maintenance for the determined model. After the partition of territory, all information should be assembled in united coverage (layer consisting of local homogeneous units) in correspondence with the requirements of used GIS. This layer is necessary for continuity and completeness cover of all researched territory by selected parameters. The construction of such layer represents geometrical crossing of basis maps with simultaneous integration their data by GIS.

3. The scenarios of land use organization

The planning of scenarios of rehabilitation of the radioactive polluted territories with the methodology of geoinformation technologies includes development and realization of the following tasks:

1. Modelling of dynamic of the farm radioecological situation (product and soil contamination) and classification of farm's territory by radioecological parameters.
2. Scenarios of optimum field's location of farm's crop rotation — scenarios of organizational counter-measures for improvement of an ecological and economic situation of the farm.
3. Scenarios of additional counter-measures for increase the soil's fertility and farm's productivity.
4. Assessments of economic and ecological efficiency.

The modelling is the consecutive process. It is necessary to execute it step by step. Briefly we shall describe the offered steps.

1. *The modelling of dynamic of radioecological situation* and the farmland's classification is based on the procedure of identification of radionuclides transfer factors from soil into plants for different products and types of soils. The estimated index (the suitability of soil for using) is calculated by modelling data for different products and soil types [3]. Firstly the product level contamination is predicted using spatial data - transfer factors for different soil types and soil contamination. Then the classification of territory by three parameters: the product level contamination, soil contamination, value of transfer factor is made. These data are used for constructing the thematic map of suitability territory for agricultural production.
2. *The scenario of allocation fields' optimum* at farm's crop rotation is based on usage the agroecological principle of territory organization. This principle provides agroecological grouping of soils by genetic and agroproduced attributes with data about the degree of soil contamination [5]. The agroecological groups are combining the soils, which are keep the most productivity for the same biological cultures. For each group and subgroup the type of land use directed to decrease of radioactive product contamination is defined.

The ten land's groups by soil conditions are formed for agriculture territory of Ukrainian Polissya [5]. These groups are divided into subgroups by contamination rate and type of land use. The density of soil contamination essentially weights on type of land use. The gradations of soil contamination density are: up to 5, 5-10, 10-15, more 15 (Ci/km²). Dynamic crop rotation for farm's fields with different soil contamination is offered. For each

field the individual crop rotation (as a general rule with 4-5 crops) is constructed. It allows controlling the flow of radionuclides from soil to plant. For each soil's group are offered both static, and dynamic crop rotation, the usage of typical and special agricultural technologies, and the recommendations of counter-measures implementation. The criteria's of arable land to grassland reorganization by agroecological potential are created. For each class of soils the following characteristics are given: number of soil's group, type of soil, intensity of contamination, structure of crop rotation, agricultural engineering.

3. *The scenarios of the additional agromeliorative measures* use investigated parameters (spatial input data) for different types of soil, soil texture, agrochemical parameters. Criteria for planning of the counter-measure are: the content of mobile potassium in soil, soil acidity, and the density of soil contamination by ^{137}Cs or ^{90}Sr and calculated level of product contamination. Together with organized countermeasures agromeliorative measures are offered for reduction of product contamination level and human doze. The choice of the most effective measures is made on the principle of the greatest reduction by human doze.

The basic criteria of efficiency of the applied counter-measures are:

- Reduction factor of radionuclides concentration in products — Radiological efficiency.
- Prevented collective doze load as a result of applied countermeasures — Doze efficiency.
- Cost of the prevented collective doze unit— Economic efficiency.

The radiological efficiency is supervised during modelling the counter-measures application at farm, and the economic efficiency is estimated only after product realization.

4. Realization of scenarios and results

The spatial modelling of the scenarios of land use organization by agroecological principal was realized for separate farms of the polluted territories (Chernigov, Zhitomir and Kiev areas). The modelling was carried out using:

- geoinformation system - MapInfo and ARC/INFO.
- Digital cartographical material (soil map, land use map, topographic map, map of agrochemical and radioecological observation network.
- Unified data base of ecological and economic parameters.
- Soil database with unified coding of soil types.

During realization of procedure were created: the digital reference book with the unified soil code for farm, the digital reference book of agroecological soil groups for farm, the classifier of land use scenarios, the classifier of the scenarios of crop rotation structure.

The spatial modelling procedure of the agroecological principle of land use organization includes the following steps:

1. Definition of agroecological groups for investigated farm's soils. The result of this step is the cartographic layer with information about agroecological soils groups by fields.

2. Formation of soil contamination classes by farm's fields.
3. Integration by step 1 and 2 data. The formation of land use organization scenario with using the classifier of land use scenarios.
4. Planning of crop rotation structure using of the results of step 3.

The output data is the information about agroecological groups and subgroups of soil of farm's fields with per year crop rotation structure as thematic maps of the scenario of farm's territory argpecological organisation.

The example of farm's territory agroecological organization using GIS-technology is given for the Redkovka farm in Chernigov region (Figure).

Thus, the procedure of choice of land use optimum structure as one of variants of rehabilitation of territory — organizational with addition agromeliorative measures for reduction of product contamination and human doze, is offered.

The algorithm of modelling of the scenarios is submitted as the computer-aided GIS-procedure, which uses the unified organization of thematic and cartographical information, and also soil data.

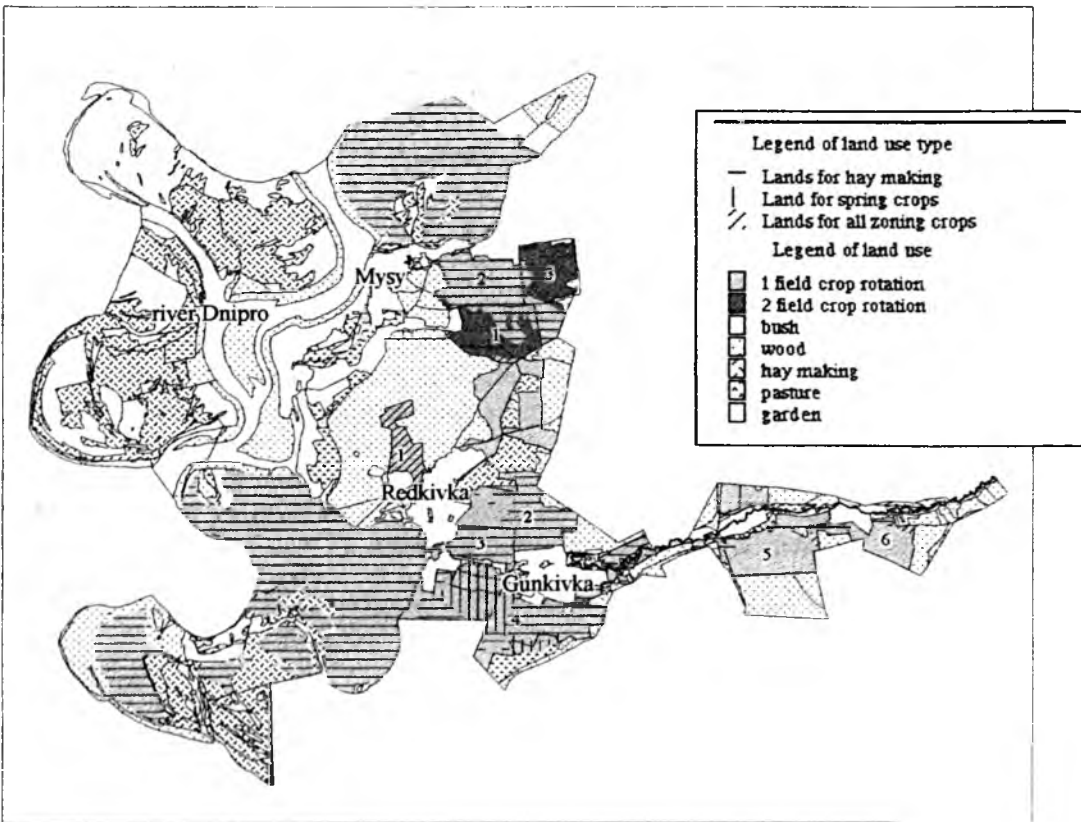


Figure — The supported of farm's land use organization

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