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Evaluation of land parcels with drainage systems for its renovation

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ABSTRACT

Calculation of complex evaluation of land drainage plots (ME criteria) is carried out on the base of Saaty pairwise comparison method [2, 14-20]. In the case this method involves pairwise comparisons of 4 criteria (TC, EC, SC and ECC) to create a ratio matrix. It takes as an input the pairwise comparisons and procedures the relative weights as output. Specifically, the weights are determined by normalizing the eigenvector associated with the maximum eigenvalue of the ratio matrix.

Complex evaluation of land drainage plots is carried out for two special cases:

1) in case of ecological criterion is more important;

2) in case of economical criterion is more important.

The use of method of multi-criteria assessment for definition the index of multiple evaluations allows creating integrated description of current state of the drainage areas.

Contents

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1. Introduction

The data published by FAO in December 2010 had shown that the food price index in the world has reached the highest value for last 20 years (215 points) [1]. Moreover, existing growth of the population demands doubling of food production in nearest 25 years and there are all preconditions for the beginning new crisis, and first of all, it will be expressed in increase of the food prices in the world market [1]. Thereupon it increases efficiency of investments into food production. Tendencies in climate changes are those, that climatic conditions in the North-West of Russian Federation will become more favourable.

Therefore the problem about renovation and returning drainage lands with the drainage systems in an unsatisfactory condition (they demand repair) into agricultural food productions is actual. This problem demands the balanced ecological-economic decision. As on the one hand abandoned drainage lands have adverse influence on ecological conditions and the renovation will allow improving it. And on the other hand it is necessary to provide correct functioning of drainage system that ecological conditions did not worsen. In the present work we report the decision of the problem. The method for choice of agricultural land parcel with drainage system for reconstruction on the basis of modelling in Geographical Information Systems (GIS) environment is presented.

2. Literature review

GIS are important tools for spatial planning. Spatial planning involves decision-making techniques that are associated with techniques such as Multi Decision Criteria Analysis and Multi Criteria Evaluation. Combining GIS with those techniques creates a powerful tool for spatial planning [2]. Another category of decision-making techniques utilised in spatial planning is based on the application of fuzzy set theory [3]. The combination of GIS with fuzzy set theory and deterministic models is known as GIS Fuzzy Modelling (GISFM). During the last few years, several applications of this approach for spatial planning have been attempted. In particular, GISFM was used for land suitability assessment in the process of agricultural experimentation [4]. Common problems of using of fuzzy algorithms to support spatial planning had been discussed in [5].

Many elements of sustainable land use management planning have uncertainties on the one hand and geo-located characteristics on the other hand. Uncertainty is inherent in processes of the planning, which involve data and model uncertainty. It originates from the features of objects (variability, instability, etc) and also from the way of obtaining data (measurement accuracy, processing error, quality of data source, etc). GISFM is a useful approach for dealing with uncertainty and imprecision. Here common GISFM approach is illustrated on the base of development of two fuzzy algorithms: one algorithm - for creation of complex criterion on the base of partial criteria, and another algorithm - for evaluation of data quality.

GISFM approach was adopted for solution of the problem of investments allocation into worse agricultural land parcel with drainage system that requires renovation. GISFM was applied for complex evaluation of land drainage systems located in the suburbs of Saint-Petersburg agricultural area. The missing data about loads on water bodies (rivers in region) by agriculture waste products from land drainage system is calculated and mapped automatically by the use of the ecological model and software developed by authors. Complex evaluations of land drainage parcel are carried out by fuzzy model with the use of four criteria (technological, economical, ecological and social) for two special tasks: 1) ecological criterion is more important and 2) economical criterion is more significant. The results show the opportunity of parcel ranging by criterion of fund efficiency. All results were provided by measure of trust, which was created by GISFM.

3. The goal of the work

Assess land parcel with drainage system on four criteria (ecological, economic, social and technological) and using GIS and fuzzy set theory and choose the one more land parcel suitable for renovation.

4. Material and methods

It is necessary to solve the problems of allocation of investment between drainage land parcels that need renovations in the design of transformation of land drainage systems. In other words, each land drainage system can contain some elements that need to be improved, and funds for their transformation and rehabilitation are limited in most cases. Thus, it is necessary to solve the following problem: how to allocate the available investment between these parts. Figure 1 has shown a structure of GISFM adopted for complex evaluation of land drainage systems.

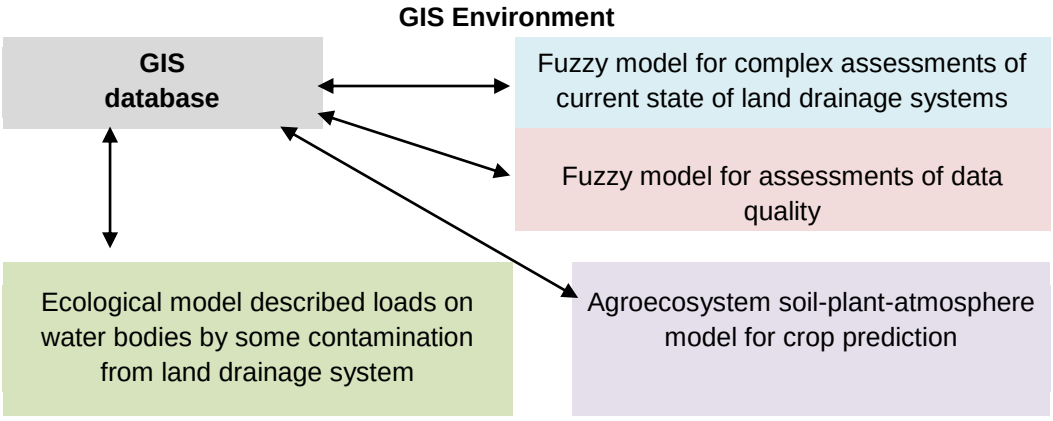

Figure. 1: Structure of GISFM adopted for complex evaluation of land drainage systems

Combination of fuzzy modelling and GIS technology with process-oriented (or object-oriented) models and expert systems creates a new opportunity for decision making. Methodological basis of complex evaluation of land drainage parcels is the section of fuzzy set theory devoted to multi-criteria evaluation and choice of alternatives [5]. Coefficients of relative significance of criteria are determined by the pairwise comparison method, which was developed by Saaty [2].

In the process of planning to renovate a drainage system, it is necessary to assess the current state of each land drainage plot and evaluations of land drainage systems for allocation of investment. In connection with this, the problem can be defined as requiring the following:

- to collect data sets;
- to estimate a measure of mistrust for gis database [6];
- to obtain missing data about loads on water bodies (rivers in region) by some contamination from land drainage system;
- to obtain data about possible crop production on the land parcels, which will renovated;
- to carry out complex evaluation of land drainage systems for special cases when ecological criterion is more important;
- to make similar analysis for other cases in which economical criterion is more important.

All these steps have been illustrated for a drainage system near Saint-Petersburg, Russia.

The missing data about loads on water bodies (rivers in region) by some contamination (products of agriculture) from land drainage system is calculated and mapped automatically by the use model is based on the regional recommendations [7]. This guideline has the relevant legal status that ensures a legal basis for usage by local administration of the results of the model application. The model is intended for calculation of the amount and concentration of pollutants transported into water objects from agricultural plots through drainage systems. The model contains sub-models for nitrogen (NH4, NO3, NO2) and phosphorus (P). A whole load (L) from agriculture parcel with drainage systems per year for any contamination is follow:

$$L = F(p, l, s, d\ sq), \tag{1}$$

p - precipitation per year (with probability 10, 50 and 95 percents); l - type of land use (arable land or not); s - soil texture; d - type of drainage system (which determines a proportion between a drainage and surface runoff); sq - area of agriculture plot.

We used argoecosystem soil-plant-atmosphere model AGROTOOL to obtain data about possible crop production on the land parcels [8].

5. Results and discussion

Application of GISFM was utilised for complex evaluation of land drainage systems located in the suburbs of Saint-Petersburg agricultural area. GIS database was created with the use of the county plat maps, data of land surveys, cadastre documents, etc. After creation of GIS database for drainage system a measure of mistrust for all attributes has been set on the base of expert opinion, using appropriate fuzzy model. The integrated measure of mistrust has been defined by the fuzzy operation named Fuzzy Algebraic Product [9].

Above-mentioned ecological model and AGROTOOL - a crop simulation model were coupled with GIS using software developed by authors (figure 2). Land drainage parcels are introduced as alternatives and the four criteria for evaluation of the parcels are defined as follows (all criteria are estimated by membership function for fuzzy set "the best land drainage plots for investment"):

Economic criterion (EC): defines the economic efficiency of the use of fund for renovation. Thus, EC =1 if the economic efficiency is high; EC = 0 if it is not.

Technological criterion (TC): defines the labour-intensiveness of the renovation. TC =1 if labour-intensiveness is normal; TC = 0 if labour-intensiveness is greater.

Ecological criterion (ECC): defines the ecological effect of renovation. ECC =1 if the ecological situation has improved greatly; ECC = 0 if it has not improved very much.

Social criterion (SC): defines as the human reaction. SC =1 if the human reaction is very strong; and SC = 0 if it is not.

Index of multiple evaluations (ME): defines the composite effect of the economic, technological, ecological and social factors. ME =1 if land drainage parcel is the best for investment; ME = 0 if it is the worst.

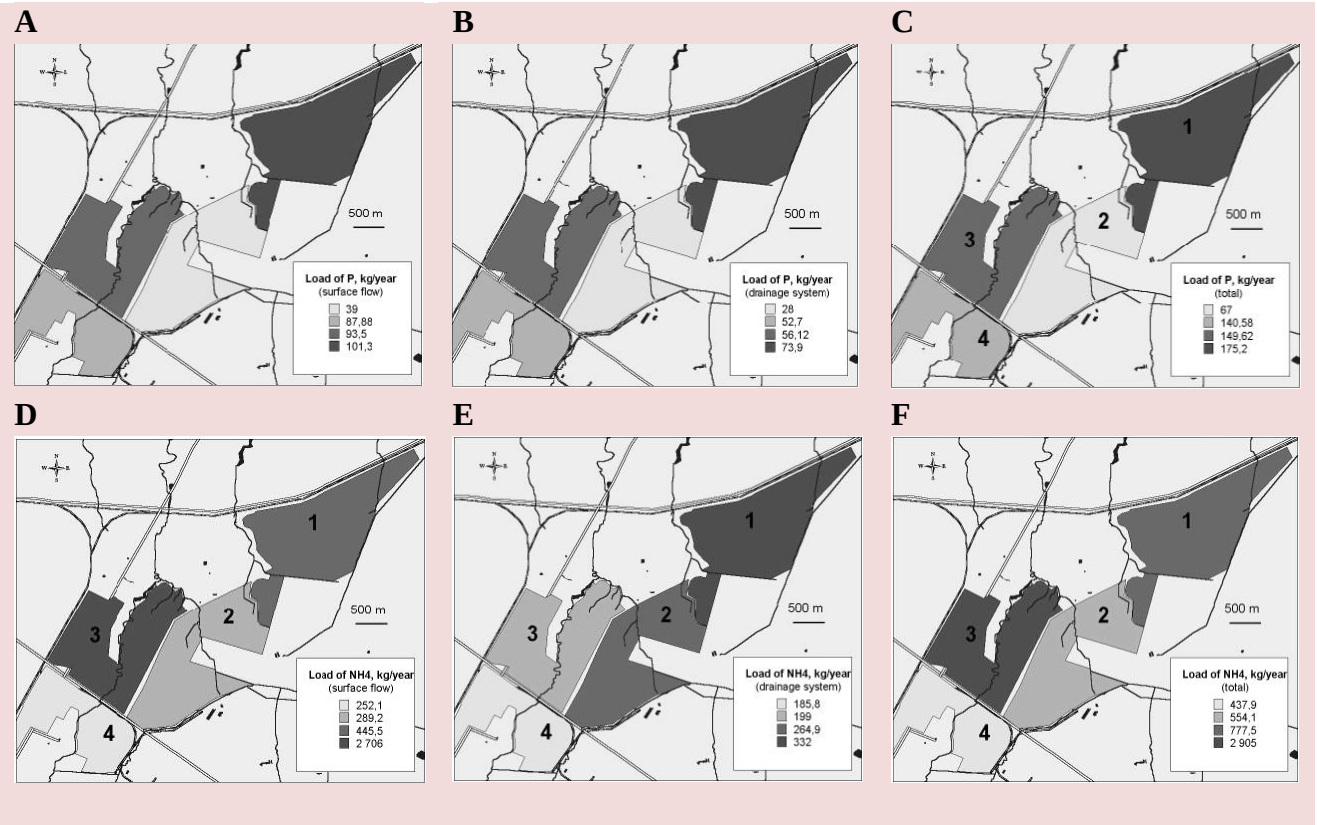

Figure 2: Loads (kg/year) on water bodies (rivers in region) by contamination from land drainage system: A, B - load of P, C - total load of P; D, E - load of NH4; F - total load of NH4

Experts evaluate particular values for all criteria. In this case study, the economic and technological criteria are described by a stepwise linear function [5, 10-13]. A social criterion is evaluated using linguistic values. The approach is based on the observation that experts usually use linguistic constructs for the evaluation of ecological and social situations. A five-point membership scale ranging from Absence to Very High values has been

assigned. The expert's job is to evaluate each land drainage plot and then choose the most suitable linguistic value to describe the evaluation of the ecological or social effects of the renovation. Ecological criterion is evaluated using linguistic constructs and results of modelling.

Calculation of complex evaluation of land drainage plots (ME criteria) is carried out on the base of Saaty pairwise comparison method [2, 14-18]. In the case this method involves pairwise comparisons of 4 criteria (TC, EC, SC and ECC) to create a ratio matrix. It takes as an input the pairwise comparisons and procedures the relative weights as output. Specifically, the weights are determined by normalising the eigenvector associated with the maximum eigenvalue of the ratio matrix. Complex evaluation of land drainage plots is carried out for two special cases: 1) ecological criterion is more important and 2) economical criterion is more important. The use of method of multi-criteria assessment for definition the index of multiple evaluations allows creating integrated description of current state of the drainage areas.

6. Conclusions

GIS Fuzzy Modelling (GISFM) is a new approach based on interfacing fuzzy and crisp modelling with GIS. It is an appropriate methodology to support location choice and land suitability assessment, as demonstrated by example of practical implementation to the problem of investment allocation into worse part of the land drainage systems located in the Saint-Petersburg suburbs. The result has demonstrated the advantages of GISFM. In particular, fuzzy models are modelling constructs featuring two main properties firstly, they can operate at the level of linguistic terms (fuzzy sets); and secondly, they represent and process uncertainty. Using GISFM, it possible to describe both subjective (knowledge-driven) and deterministic (data-driven) information. Also GISFM is an effective tool for evaluation of the quality of attribute database. In particular, it has been show as all results are provided by measure of mistrust, which was created by GISFM.

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Оценка земельного участка с дренажными системами для их восстановления

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ИНФОРМАЦИЯ О СТАТЬЕ	**История**	**Ключевые слова**
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АННОТАЦИЯ

Расчет комплексной оценки земельных участков с дренажными системами (ME критериям) осуществляется на базе Saaty метода сравнения попарно [2, 14-20]. В данном случае этот метод включает парные сравнения по 4 критериям (TC, EC, SC и ECC) для создания отношения в виде матрицы. Он принимает в качестве ввода парные сравнения и относительные веса в качестве вывода. В частности, веса определяются путем нормализации собственного вектора, связанного с максимальным собственным значением коэффициента матрицы.

Комплексную оценку земельных участков с дренажными системам проводят в двух частных случаях:

1) экологический критерий является более важным;

2) экономический критерий является более важным;

Использование метода оценки по множеству критериев для определения индекса множественной оценки позволяет создавать интегрированное описание текущего состояния водосборных площадей.

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