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SITE SELECTION FOR MANURE STORAGE FACILITIES USING GIS TECHNOLOGIES

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Abstract

Selection of potential suitable sites for the construction of manure storage facilities was made by use of Multi-Criteria Data Analysis in the GIS environment. From the wide variety of prescriptive models of multi-criteria data analyses, we selected and used in the research the decision model based on Boolean logic. In order to choose suitable locations for the construction of the manure storage facilities the decision model based on the Boolean logic was built taking into account 6 factors: slope; proximity to access roads; proximity to wells and springs; proximity to villages and sheepfolds; proximity to water bodies; land use. As a result of studying Moldovan legislation and bibliographic data, selection criteria were established for each factor that ensures the correct ecological, sanitary and aesthetic location of the manure storage facilities. As a result of the combination of the mentioned factors, the potential sites for the construction of the manure storage facilities with an area of 337400 m^2 or 33.74 ha were identified. The potential interest present 7 areas with an area greater than 1.8 ha.

Key words*: Boolean logic model, GIS, manure, site selection.*

INTRODUCTION

The problem of the use of manure in the Republic of Moldova is a priority both from the environmental and human health point of view. Actually most animals and birds are maintained in smallholdings of rural population. According to the statistical data for the period of 2013-2017 about 425-743 thousand tons of manure is formed in the Republic of Moldova yearly (Statistical Yearbook of the Republic of Moldova, 2018). At the same time only 29-55% of the manure was used as soil fertilizer. The rest of manure is usually discarded into unauthorized places. This illegal action leads to the nitrate pollution of the main drinking water sources and creates great health problems of rural population. The best way to minimize the impact of manure on the environment is to use it as soil fertilizer. Manure is an excellent source of nutrients for crops and it provides organic matter that plays enormous role in restoration of soil fertility. Collecting the manure in a locality requires building manure storage facilities where it will be stored and fermented accordingly to the ecological requirements.

The purpose of the research is to adapt and implement modern methods at selection of suitable locations for manure storage facilities using Geographic Information Systems (GIS) technologies. The location should be selected basing on the ecological and sanitary requirements, as well as the aesthetic point of view.

To achieve the purpose of the research, a decision model was built on the basis of the Multicriteria Data Analysis in the GIS environment. Generation of decision models was made by integrating relevant study factors. The result of the integration is a complex index, which represents the gradual suitability of the possible multitudes of alternatives. Such analyses are known as Multicriterial Data Analysis (Eastman J.R., 1999).

The research was carried out with the financial support of Academy of Sciences of Moldova under the project for young researchers Nr. 35/IND "Selection of suitable sites for manure application using Geographical Information Systems (GIS) technologies. Case study of Grinauti village, Riscani district", project leader PhD Ciolacu Tatiana.

MATERIALS AND METHODS

The research was carried out in the northern part of the Republic of Moldova, Rascani district, Grinauti commune (Figure 1).

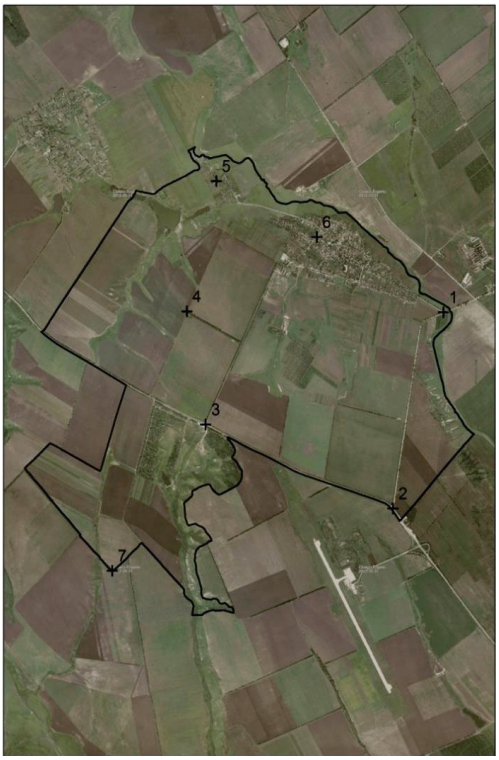

Figure 1. Research area of Grinauti commune, Rascani district

Initial data were collected from the next available sources:

Slopes layer was obtained through the built-in Slope tool in ArcGIS based on the Digital Elevation Model. The Digital Elevation Model (Figure 3) was generated using the Topo to Raster tool of ArcGIS based on the topographic map 1: 25000 available on the Land and Cadaster Agency website (Figure 2).

Proximity to access roads. Roads have been digitized from orthophoto images.

Proximity to wells and springs. The data regarding spatial location of wells and springs were taken with GPS.

Proximity to villages and sheepfolds. The data about location of villages and sheepfolds were extracted from the land use map. Land use, hydrographic network, road network were digitized from the ortofoto image available on the web portal of the Land and Cadaster Agency.

Land use. Data regarding land use were digitized from the orthophoto image available on the Land and Cadaster Agency web portal.

There is a wide variety of prescriptive models for multi-criteria analyses. In this paper a decision model based on Boolean logic was built. The Boolean model is performed by multiplying the criteria represented in binary form (O'Sullivan D., Unwin D.J., 2010):

$$S_i = \prod_{j=1}^{n} Cr_i^j$$

where:

Si represents index of suitability for spatial unit i;

Cr_i^j - value of criterion j for space unit i;

n - number of criteria.

Each pixel of a criterion in a Boolean model is considered "zero" if there cannot be installed manure storage facility, and "one" if installation is possible. By multiplying raster data composed of pixels with a value of "one" or "zero" as the result we obtain a raster of suitability where each pixel can have only "zero" or one "values".

Construction of decision models was performed using raster data because data of this type does not require topology validation after data combining. A raster data layer is a set of quadrants of the same size called pixels or cells, each pixel having a numeric value representing a real world feature. An object represented in a raster layer is made up of at least one pixel.

The following factors were used to construct decision models: slope; land use; proximity to villages and sheepfolds; proximity to the access roads (asphalt road, country road); proximity to springs and wells; proximity to water bodies (lakes, rivers); The factors were represented in the form of raster thematic layers.

RESULTS AND DISCUSSIONS

As a result of studying Moldovan legislation and bibliographic data, the selection criteria were established for each factor that ensures the correct ecological, sanitary and aesthetic

location of the manure storage facilities (Ciolacu T. et al., 2018).

Slopes. Lands with a slope greater than 5° were considered unsuitable (Figure 4).

Proximity to access roads. Areas located at a distance less than 100 m from roads were considered unsuitable. By use of built-in instruments Buffers, Multiple Ring Buffer, and Clip we obtained buffer zones of 100 m from all the roads from aesthetic reasons (Figure 5).

Proximity to wells and springs. Areas at a distance more than 50 m from fountains and springs were considered acceptable. By use of built-in tools Buffers, Multiple Ring Buffers, and Clip we obtained buffer zones of 50 m from unsuitable areas for the construction of manure storage facilities (Figure 6).

Proximity to villages and sheepfolds. Based on the experience of other states, it was decided to use a 250 m buffer zone from all the villages and sheepfolds from the studied area (Basnet B.B. et al., 2001). Another argument for using a buffer zone for localities was the reduction of the polluting impact on aquifers near the locality. During the field researches, it was noticed that the lands near the sheepfolds were in a deplorable state because of manure accumulations, which made us apply here the same restriction as for the localities. Thus buffer zones of 250 m from unsuitable areas were built (Figure 7).

Proximity to water bodies. According to the RM Law Regarding Protection Areas for Rivers and Lakes no. 440-XIII 1995, art. 7, the width of riparian water protection strips should be not less than 100 m for large rivers, not less than 50 m for medium rivers and at least 20 m for small rivers (Ungureanu et. al., 2006). Thus, the land at a distance of less than 100 m from Raut river and 25 m from the rest of the small rivers from the territory was considered unsuitable for our purposes.

In the case of lakes was used 50 m buffer zone (Figure 8). Due to the fact that there was a wet area on the territory of the commune, it was decided to apply here the same restrictions as for the small rivers.

Land use. Pastures and the territory of the former farm were considered suitable for our purpose (Figure 9).

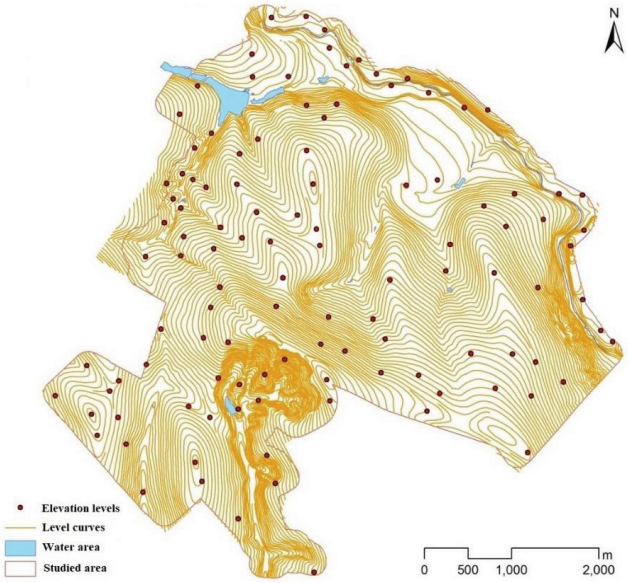

Figure 2. Topographic map of Grinauti commune, Rascani district

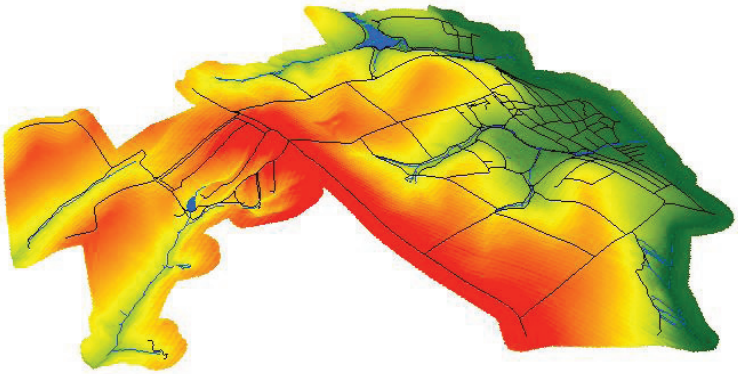

Figure 3. Digital Elevation Model of Grinauti commune, Rascani district

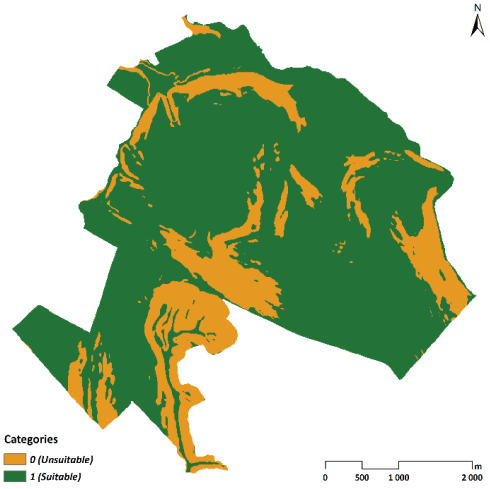

Figure 4. Slopes

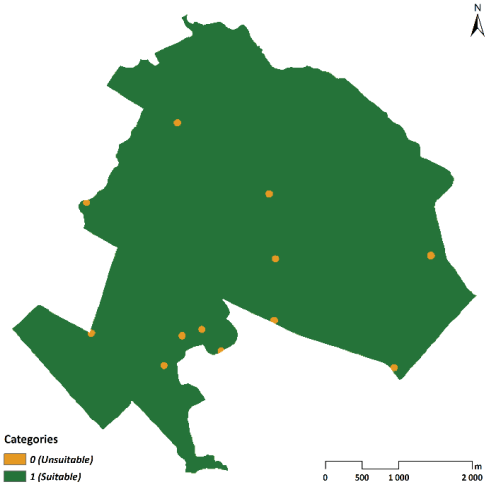

Figure 6. Proximity to wells and springs

Figure 5. Proximity to access roads

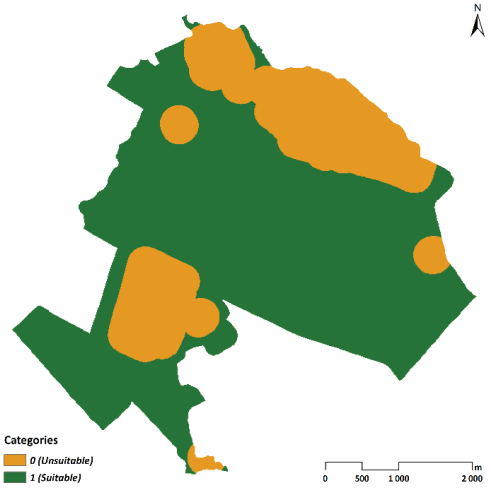

Figure 7. Proximity to villages and sheepfolds

Figure 8. Proximity to water bodies

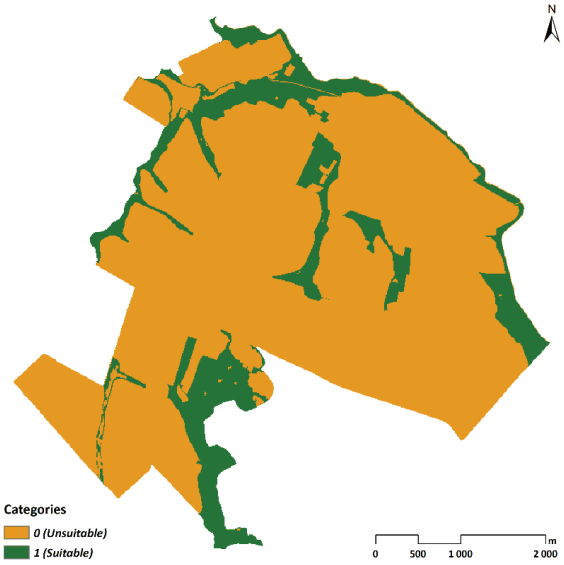

Figure 9. Land use in Grinauti commune, Rascani district

Each of the above mentioned criteria was prepared to be combined in the Boolean model. Thus, the input data was reclassified in binary form according to the parameters described above.

As a result of the combination of the factors we obtained the results presented in Figure 10.

The potential sites suitable for the construction of manure storage facilities were identified with the total area of 337400 m^2 or 33.74 ha.

The potential interest present 7 plots with an area greater than 1.8 ha.

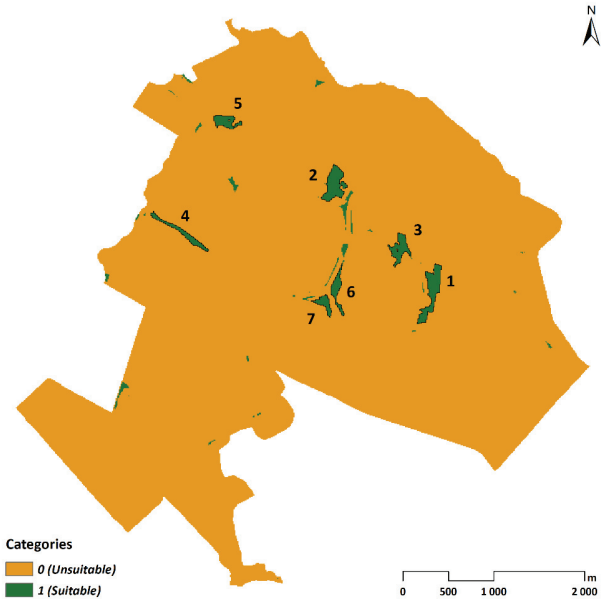

Figure 10. Boolean decision model determining suitable locations for construction of manure storage facilities

CONCLUSIONS

Application of Multicriteria Data Analysis in site selection of manure storage facilities was performed through the construction of Boolean decision model. We took into account six factors, that will ensure correct from ecological point of view, location of the facilities: slope; proximity to access roads; proximity to wells and springs; proximity to villages and sheepfolds; proximity to water bodies; land use. On the base of the constructed Boolean model, we identified seven sites, greater than 1.8 ha, suitable for the construction of the manure storage facilities.

Storing manure in authorized places such as manure storage facilities will minimize its environmental and human health impact in the studied community. Introduction of the manure into the soil as a fertilizer will increase soil organic matter content, will contribute to soil structure restoration and will diminish negative humus balance in soils.

ACKNOWLEDGEMENTS

This research work was carried out with the financial support of Academy of Sciences of Moldova under the project for young researchers Nr. 35/IND "Selection of suitable sites for manure application using Geographical Information Systems (GIS) technologies. Case study of Grinauti village, Riscani district".

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