# Application of GIS technologies in the decision-making process of utilization at the local scale of manure produced in small households of the Republic of Moldova

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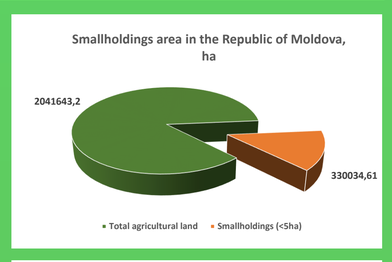
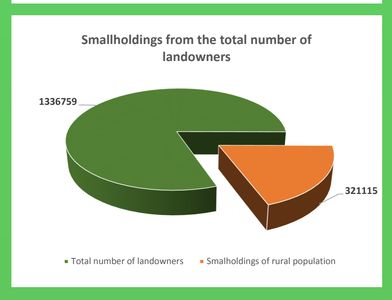
## INTRODUCTION

At present, modern space technologies only begin to be integrated into Moldovan agriculture. It is obvious that they are more accessible to large agricultural companies, while smallholdings do not currently have technological support from them. Meanwhile, these technologies are able to provide very good support to small households (<5 ha), which today, according to cadastral data for 2018, make up 321115 persons (or 24% of the total number of landowners) and own 330034.61 ha (or 16.2% of agricultural land).

Present research is focused on one of the main problems that exist in smallholdings of the Republic of Moldova – animal wastes or manure. According to the official data, in smallholdings of the population, there are about 88.6% of cattle, 54.7 of swine, 96.9 of sheep and goats, 97.1% of horses. The collection, storage and use of produced manure for fertilizing are not done in most of the cases. Usually, the manure is left near the roads, rivers, in the ravines etc. that conducts to pollution of soil and water.




## MATERIALS AND METHODS

The research was carried out at Grinauti commune, Rascani district in the Nothern part of the Republic of Moldova. Selection of sites suitable for manure application as fertilizer was done basing at eight factors relevant to the purpose of the research and taking into consideration country legislation regarding the use of manure, zones of protection etc. In cases of lack of some regulations it was used European legislation or bibliographic recommendations.

Generation of decision models is usually made by integrating factors relevant to the study. 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). In our research, we used the most common prescriptive models: the Boolean logic model and the Weighted Linear Combination (WLC).

The Boolean model is performed by multiplying the criteria represented in binary form (O'Sullivan D., Unwin D.J., 2010):


***Figure 1. Research area of Grinauti village, Rascani district***

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

where:
$S_i$ - represents index of suitability for spatial unit i;
$Cr_i^j$ - the value of criterion j for space unit i;
n - number of criteria.

WLC is also known as Simple Additive Weighting Combination and consists in summation of weighted criteria (Eastman J. R. 1999)

$$S_i = \sum_{j=1}^{n} w^j * Cr_i^j$$

where:
$S_i$ represents suitability index for spatial unit $i$;
$w_i^j$ represents the weight of $j$ criterion ($Cr_i^j$) applied to all units ($i$);
n - number of criteria.

## RESULTS AND DISCUSSIONS

**Manure generation in the Grinauti commune, Rascani district.** On the territory of Grinauti commune there were no livestock farms at the time of our research. All animals were maintained in smallholdings. The data on livestock and poultry in Grinauti commune were provided by the commune' Town hall. The annual amount of manure produced in the commune was calculated by use of Rusu Al., et. al. method (2012) using average values for each species (*Table 1*).

***Table 1. Average amount of manure accumulated annually in the Grinauti village, Rascani district***

| Species | Number of animals | The amount of manure accumulated in one year, tonnes | | |
|---|---|---|---|---|
| | | from 1 animal | from all animals | share of total volume,% |
| Cattle | 252 | 7,9 | 1991 | 56,9 |
| Sheep and goats | 702 | 0,5 | 351 | 10,0 |
| Swine | 320 | 1,8 | 576 | 16,5 |
| Horse | 36 | 5,1 | 184 | 5,2 |
| Poultry | 8000 | 0,05 | 400 | 11,4 |
| **Total** | | | **3501** | |

The quality of manure varies according to the species, the nature of fodder, the method of maintenance and the age of the animals. Using the average values of the manure composition for each species, we calculated the amount of nutrients produced each year as manure in Grinauti commune (*Table 2*).

***Table 2. Quality of manure accumulated annually in the Grinauti village, Rascani district***

| Species | Content of main elements in annual quantity of manure, kg | | | | NPK, kg |
|---|---|---|---|---|---|
| | Organic matter | Total N | Total $P_2O_5$ | Total $K_2O$ | |
| Cattle | 342000 | 11000 | 9000 | 21000 | 40000 |
| Sheep and goats | 95000 | 3000 | 2000 | 5000 | 10000 |
| Swine | 105000 | 5000 | 4000 | 4000 | 13000 |
| Horse | 31000 | 1000 | 1000 | 2000 | 4000 |
| Poultry | 104000 | 6000 | 10000 | 5000 | 20000 |
| **Total** | **677000** | **26000** | **25000** | **36000** | **87000** |

According to the questionnaire and the observations made during the field research, most of the produced manure is dumped into unauthorized landfills (ravines) located around the village, "burned in the pit", or used for winter heating in the form of "tizic". Only about a quarter of the surveyed population uses manure, especially from poultry, for soil fertilization. During the field trips we found a single field where was stored the manure for fermentation and further soil fertilization, but these quantities are insignificant compared to its annual amount. Thus, according to our calculations, 677 thousand kg of organic matter, 26 thousand kg of nitrogen, 25 thousand kg of phosphorus, 36 thousand kg of potassium annually are lost.

**Generation of the Boolean model:**

The input data in the decision model were generated taking into account the following eight factors: land use, proximity to localities and sheepfolds, proximity to access roads (asphalt or countryside road), proximity to springs and wells, proximity to water areas (lakes, rivers, wetlands), soil quality represented by "bonitet", slope inclination and phosphorus content in the soil. These factors have been selected as decision criteria because they can be represented graphically and at the same time are measurable parameters, which allows their grading in the context of the researched problem.

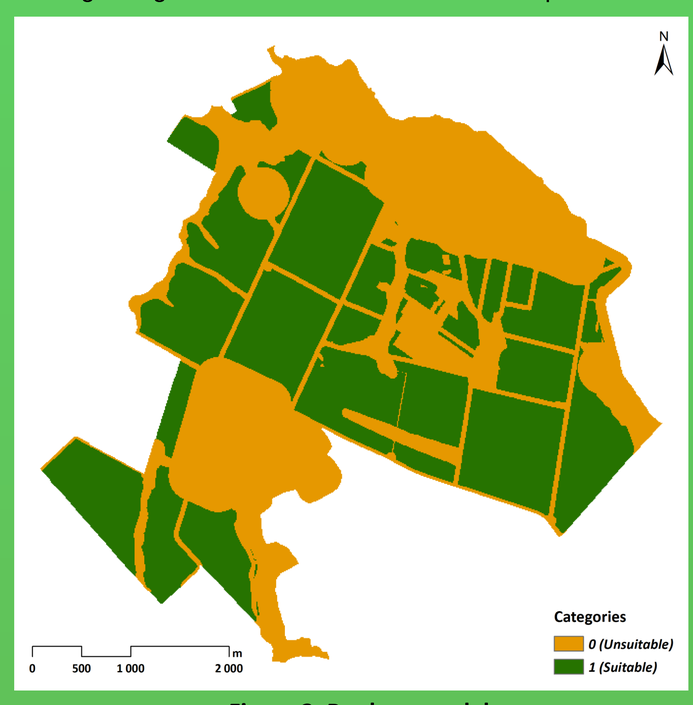



**Figure 2. Boolean model**

**Generation of the WLC model:**

For the WLC model, data has been standardized so that soils with lower "bonitet" have a higher priority; the amount of mobile phosphorus in soils was represented in six groups, with priority being given to land with lower phosphorus content; data on slopes has been standardized so that smaller slopes have higher priority; places closer to the road have a higher priority; land at a greater distance from extravilan fountains and arranged springs has higher priority; the land closer to the localities and the sheepfolds have higher priority; higher priority is given to land far from aquatic objects. The land use factor data set is the same as in the Boolean model.

$$Cr_i' = \frac{Cr_i}{Cr_{max}} \qquad Cr_i' = 1 - \frac{Cr_i}{Cr_{max}}$$

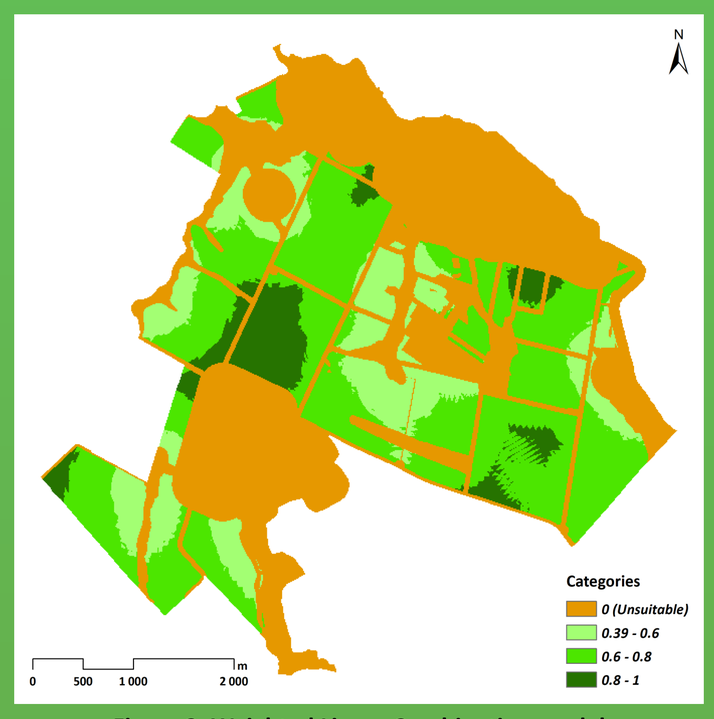



**Figure 3. Weighted Linear Combination model**

## CONCLUSIONS

Two spatial decision models based on multi-criteria data analysis were built to achieve the research goal: the Boolean model and the Weighted Linear Combination model (WLC). According to our results, about 77.89% of the arable land of Grinauti commune is favorable for application of manure as fertilizer. Because the WLC model contains the Boolean model, the generated favorable area is the same in both cases.

The main advantage of the WLC model is that the values of the favorability index can be compared to each other, which makes it possible to make decisions in the presence of more alternatives. Among the advantages of the Boolean model, we can mention the simplicity of generating and interpreting the results of the decision models.

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