GEOGRAPHIC INFORMATION SYSTEM FOR LAND CAPABILITY EVALUATION AND MAPPING SUPPORTING EROSION PREVENTIVE LANDUSE

Eng. Vihra Stoinova
Prof. Dr. Svetla Rousseva
Assoc. Prof. Dr. Ilia Malinov
Institute of Soil Science, Agrotechnologies, and Plant Protection (ISSAPP) "Nikola Pushkarov", **Bulgaria**

ABSTRACT *- Soil is a valuable non-renewable natural resource that should be used in accordance with its natural potential. Sustainable management of soil resources combines maintainance of a high productivity with environmental protection. Landuse planning in accordance with the suitability of land for effective erosion preventive landuse, depending on a number of limitation factors and threats, should be a fundamental principle of soil and water conservation. The report will present the elements of a geographic information system for assessment and mapping of the limitation factors and land categorization according to its capability for effective erosion prevention use.the approach used is a prerequsite for integrated sustainable management of soil and water at catchment scale.*

Keywords: *soil, erosion, land capability evaluation, mapping*

INTRODUCTION

Soil is limited, practically irreplaceable and non-renewable natural resource with a number of key functions for the nature and society, the most important of which are related to food and biomass production, as well as storage, filtering and transformation of matter and energy. Deterioration of the soil functions as a result of pollution and a number of physical and chemical processes of natural and anthropogenic origin define eight major soil degradation processes. Soil erosion is one of the most serious global threats impacting the agricultural and forest lands, as well as urban areas. Sustainable management of soil resources has no alternative in the globalized world. Combining maintenance of high productivity with protection of the natural environment, it means land use planning in accordance with the suitability of land for effective erosion control land use, depending on the series of limiting factors and threats.

Nowadays, specialized journals and internet sites publish more and more often materials that highlight the need for a thorough and comprehensive assessment of the suitability of the land and provide new guidelines and methods to achieve it [3], [5], [10], [11]. Integration of Bulgaria into European structures imposes a change in the agrarian policy of the country, the established market relations, the new agricultural structures, etc., and require the use of appropriate methods of agricultural lands capability evaluation for effective erosion control and use at different scales.

Considering that our country lags behind in the field of land environmental assessment and the need of new scientific and applied concepts in land capability categorisation for erosion prevention use we aim to develop practically oriented models in GIS format for different scales and users at national, municipal and local levels, based on the GIS technology and the available data sets of soil, topography and climatic conditions. The development of such environmental land capability evaluation and categorization of the country's territory is the goal of this work.

MATERIAL AND METHODS

In view of the great diversity of the soil cover of Bulgaria, especially in terms of the rooting depth, the stoniness, and the great differences in altitude – indicators requiring greater clarification of the criteria of the land capability classes, we selected the 8-grades classification for the aims of this project This classification is similar to that developed by USDA [6] and the Long-term erosion control Programme in Bulgaria [9]. This is the best way of taking into consideration the specific topographic, soil and climatic conditions of the country while the GIS methods enable better

processing of the huge amount of information hold by the database developed so far. This classification is focusing on the requirements for soil protection from erosion (Fig. 1).

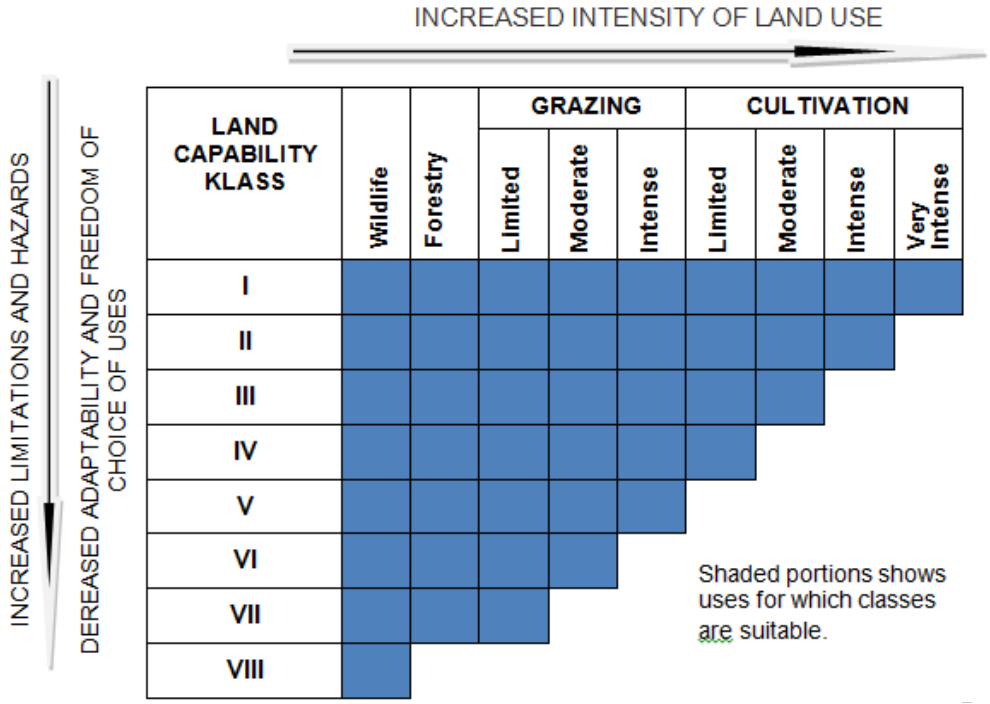


Fig. 1. The relationship between Land capability classification classes and and the intensity with which each class (adapted from Davidson [1]).

The system has three levels of categorization of land use (Fig.2):

- Land Capability **classes** - gives an indication of the overall extent of restrictions on land use;
- Land Capability **sublasses** - indicate the type of restrictions which exist in the class and
- Land Capability **units (blocks)** - cartographic units with similar soil types require the same type of management and the conservation suitable for growing the same crop species with similar potential yields, i.e. account the capability of land for cultivation of different crops.

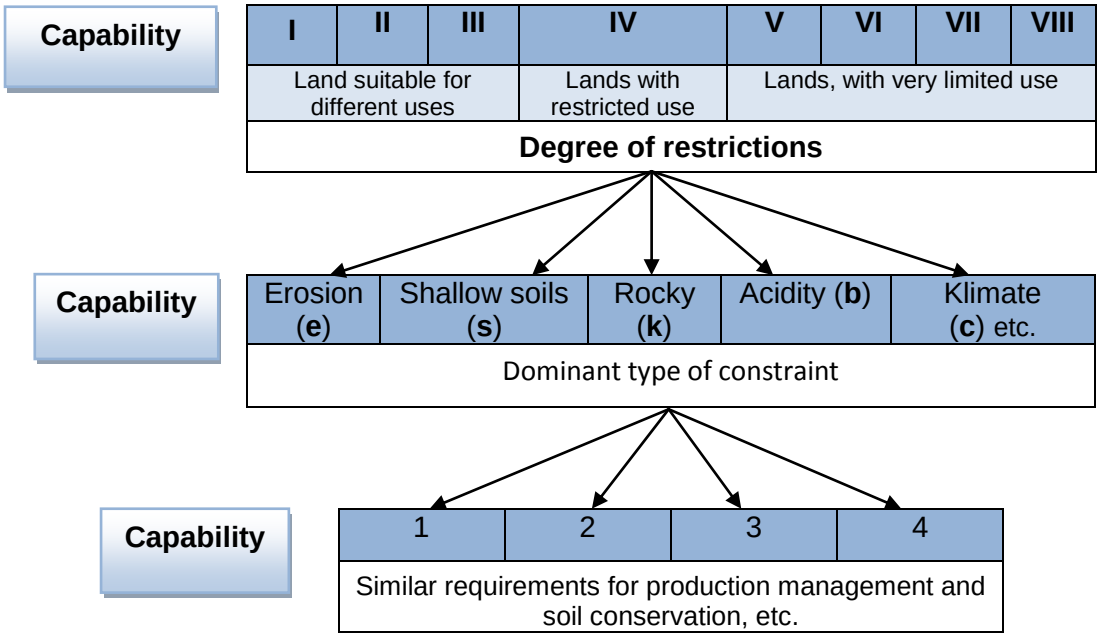


Fig. 2. Levels of the land Capability Classification System for efficient and economic use of erosion control (Adapted from NWASCO [8])

In the process of building the GIS, different maps (topographic, soil and climatic) were digitized and superimposed to obtain Map of Land Capability evaluation of land use and erosion control (Fig.3). The characteristics of the earth (e.g., slope, type of soil, the risk of erosion) were used to determine the quality of the lands. This project proves that the application of GIS as a tool can give quick and effective results on Land Capability evaluation.

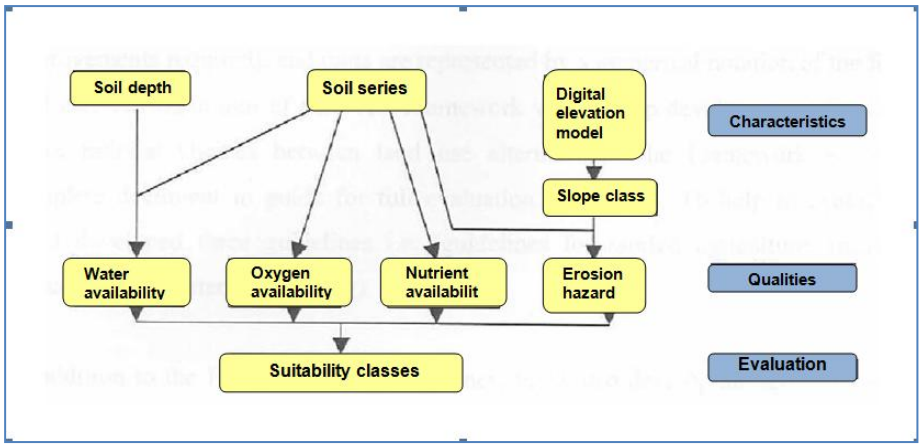


Fig. 3. Stages and types of the data in GIS to map land capability classes for erosion preventive use

Depending on the degree of restrictions on land use, the lands capability classes are divided into 3 main groups: 1) Land suitable for different uses – including classes I, II and III; 2) Lands with restricted use – including class IV, and 3) Lands with very limited use – including classes V, VI, VII and VIII.

Diagnostic indicators for the initial determination of land classes both scales of categorization are the soil susceptibility to erosion (soil erodibility), the soil profile depth and the slope gradient, while the methods of data evaluation, i.e. approaches for defining the classes can be identified as classification and quantitative (Fig.4 and Fig.5). Developed GIS layers of the main factors of sheet water and wind erosion [2], [7] enable not only development with more details and improvement of the classification approach for land capability evaluation proposed by Onchev [8] but also the use of quantitative methods in which relationships between variables are defined by using an equation, which results determine the capability class. For this reason, the small-scale land capability evaluation for the entire country's territory was done using both methods – the classification and the quantitative one and the results were compared and analyzed.

K factor /t ha h/ha Mj mm/	Soil profile depth/ cm /	<1	1-3	3-6	6-12	>12
<0,02	>50	I	II	III	IV	IV
	50-30	II	II	III	IV	IV
	<30	III	III	IV	IV	VI
0,02-0,04	>50	I	II	III	IV	IV
	50-30	II	II	III	IV	VI
	<30	III	III	IV	IV	VII
>0.04	>50	I	II	III	IV	VI
	50-30	II	II	IV	IV	VII
	<30	III	IV	IV	VI	VII

Group slope gradient in degrees

Fig. 4. Classification method – illustrates the relationship between the susceptibility of soils to erosion, the soil profile depth and the slope gradient.

Soil profile depth / cm /	1	2	3	4	5	6	7	8	9
<30	III	III	IV	IV	IV	IV	VI	VII	VII
50-30	II	II	III	III	IV	IV	IV	VI	VII
>50	I	II	II	III	III	IV	IV	IV	VI

Class of potential erosion risk

Fig. 5. Quantitative method II – illustrates the relationship between the classes of potential erosion risk and the soil profile depth.

Results from a comparative study show that the quantitative method II is more accurate compared to the quantitative method I (Fig. 6). This is because the quantitative method II is more detailed as it uses nine classes of potential erosion risk and the smaller ranges better define the classes of land capability. Thus, either classification method or the quantitative method II variant can be used with GIS depending on the type and the level of processing of the input information.

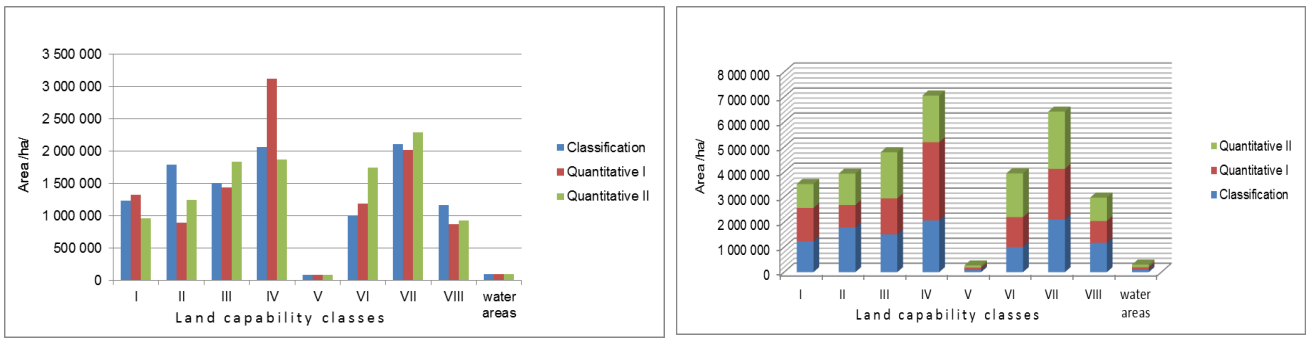


Fig.6. Land capability classes at different quantitative methods

RESULTS AND DISCUSSION

To obtain the final map of the land capability for effective economic and erosion preventive land use, and application for administrative regions, municipalities and catchments, the GIS consists of 6 or 7 layers (levels of information) depending on the method of classification used.

1. **Distribution of soils in Bulgaria according to the soil profile depth and restricting land use factors.** This first level of the GIS system was build up on the basis of the soil map. The soil are classified into 3 groups depending on the soil profile depth. There are grouped and specified 21 limiting factors (Fig. 7).

2. **Distribution of Bulgarian territory according to the soil erodibility classes.** To obtain the second level of the GIS system, the map of soil erodibility in Bulgaria in digital form was used where initial 6 soil erodibility classes are grouped in 3 classes (Fig. 8).

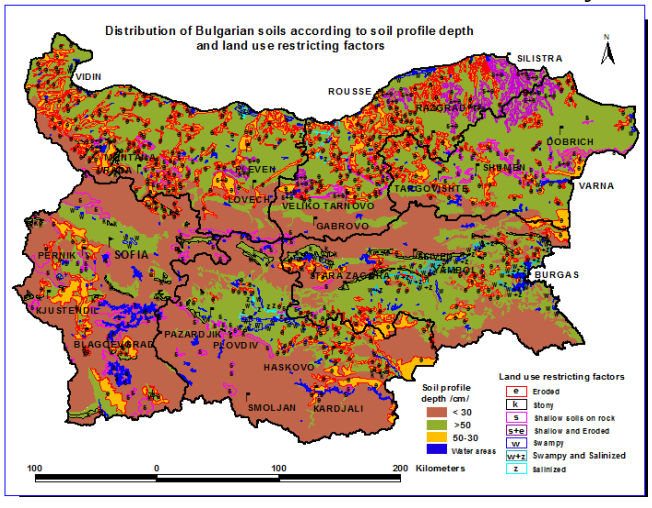


Fig. 7. Map of Bulgarian soils according to the soil profile depth and the land use restricting factors

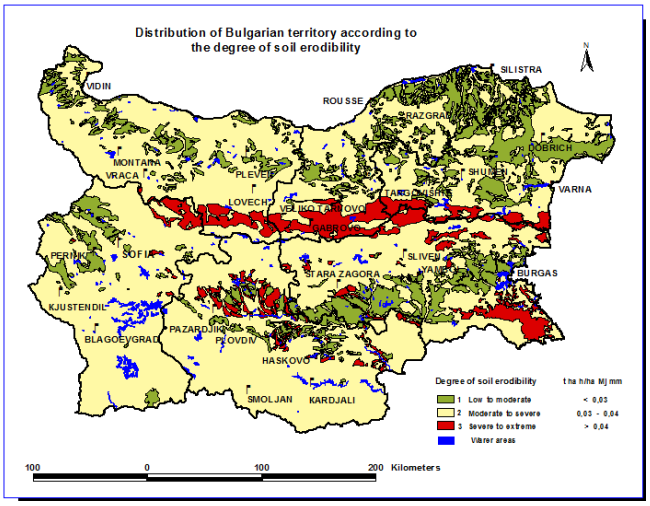


Fig. 8. Map of erodibility of Bulgarian soils

3. **Distribution of the territory of Bulgaria according to the slope gradient groups.** This third level of the GIS system is based on DEM 50. The slopes are grouped in 5 groups of gradients and the lands of altitude above 1 200 m, being considered not suitable for agricultural use, are separated (Fig. 9).

4. The levels 2 and 3 of the GIS system are developed when land capability is evaluated following the classification method. When the quantitative method is used, these levels are substituted by the **map of the potential soil erosion risk** (Fig. 10).

These levels of information are sufficient to identify the classes of land capability for effective economic and erosion prevention use and to define the limiting land use factors, i.e. classes and subclasses of lands capability. Here are the limits of the opportunities of the small-scale mapping of land capability for efficient economic and erosion prevention use, which is done for the entire country's territory (Fig.11).

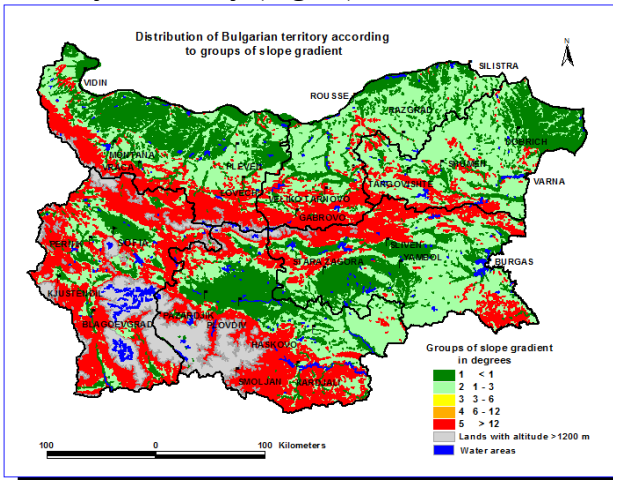


Fig. 9. Map of slope gradient groups of Bulgaria

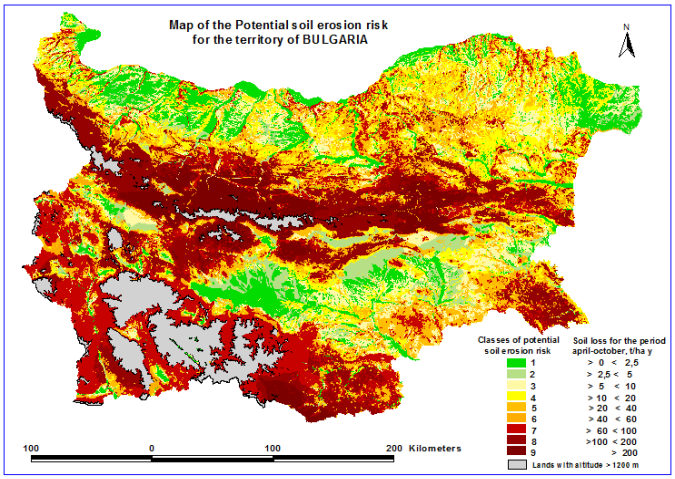


Fig. 10. Levels of the potential soil erosion risk

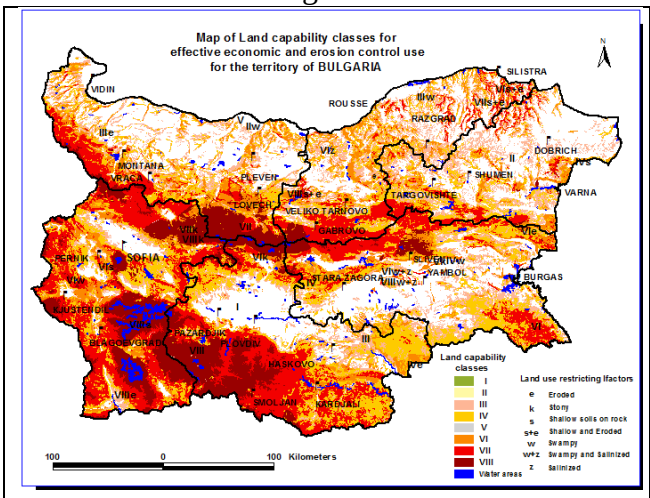


Fig. 11. Map of land capability classes for effective erosion control use in Bulgaria

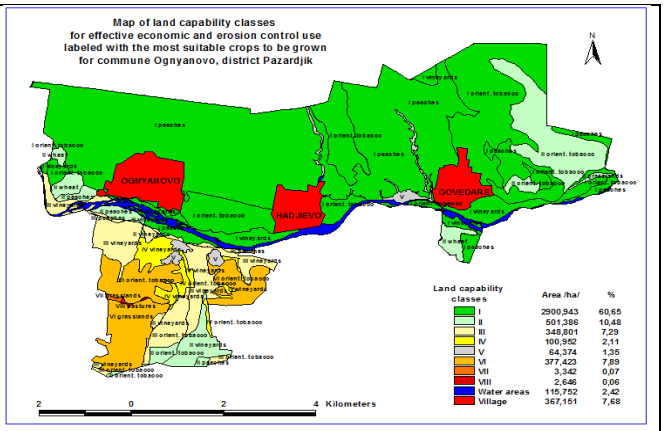


Fig. 12. Map of land capability classes labeled with the most suitable crops to be growing

5. The next level is the unit of land capability for economic and erosion preventive use. This is the third level in the capability assessment of land use. Here it is illustrated at a scale of 1:10 000 for the area of commune Ognyanovo, consisting of three villages of Pazardzhik municipality. Units are areas of the same class and subclass of land use and require similar measures for soil management and conservation have similar potential performance and are suitable for growing crops of one and the same group. The determined and recorded land capability units are comparable across districts, municipalities or catchments because as one legend with 22 most widely used crops is applied for the entire country. To illustrate this third level of land capability evaluation, land suitability classes are calculated using the software product of Georgiev [4] and the resulting tables are attached to the large-scale digital soil maps at a scale of 1:10 000 (Fig.12).

6. Follows the level of **the layer of the administrative units – regions, districts, municipalities**. The system enables choice of map of land capability classes for a single region, district or municipality. It enables also a choice of a single capability class or type of limitation in the selected administrative unit (Fig.13).

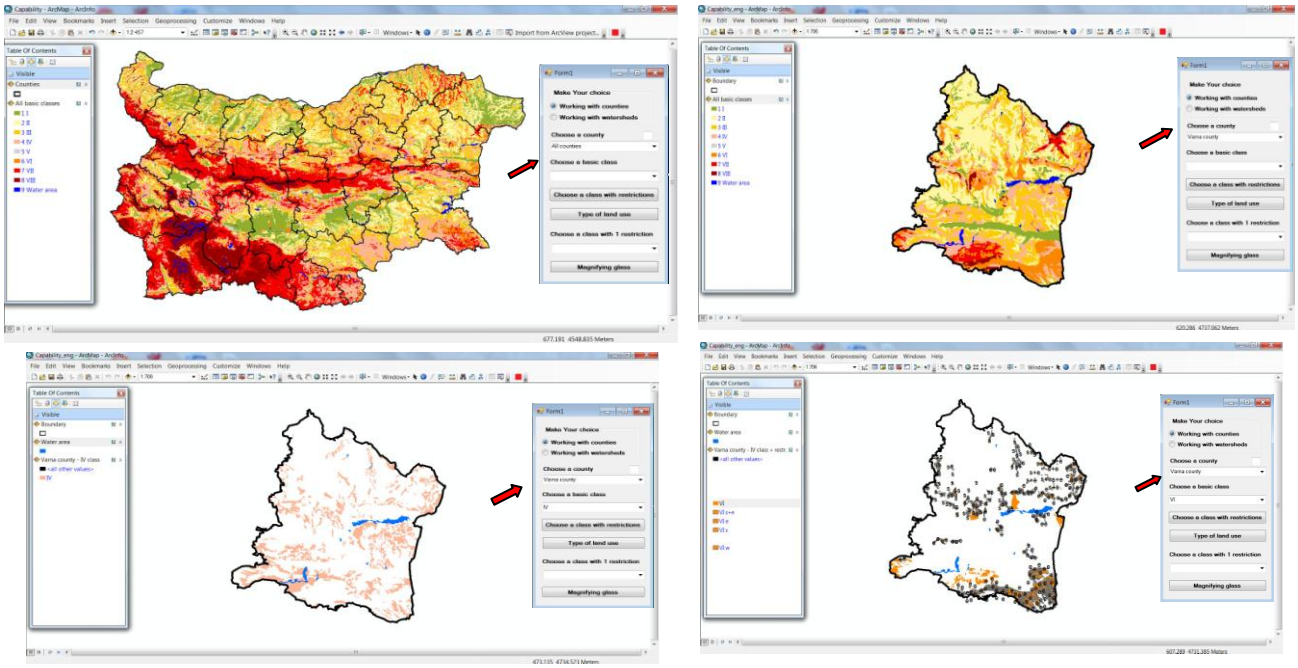


Fig. 13. Map of land capability classes and the layer of the administrative districts

7. Follows the level of the **catchment basins**. The small-scale categorization uses 21 catchments of the main rivers in Bulgaria, while the large scale uses the catchments provided by the four basin directorates of the country – Danube, Black Sea, East and West Aegean. The program elenables a choice to work with a particular chatchment, a separate capability class or a type of restriction within the selected object. (Fig.14).

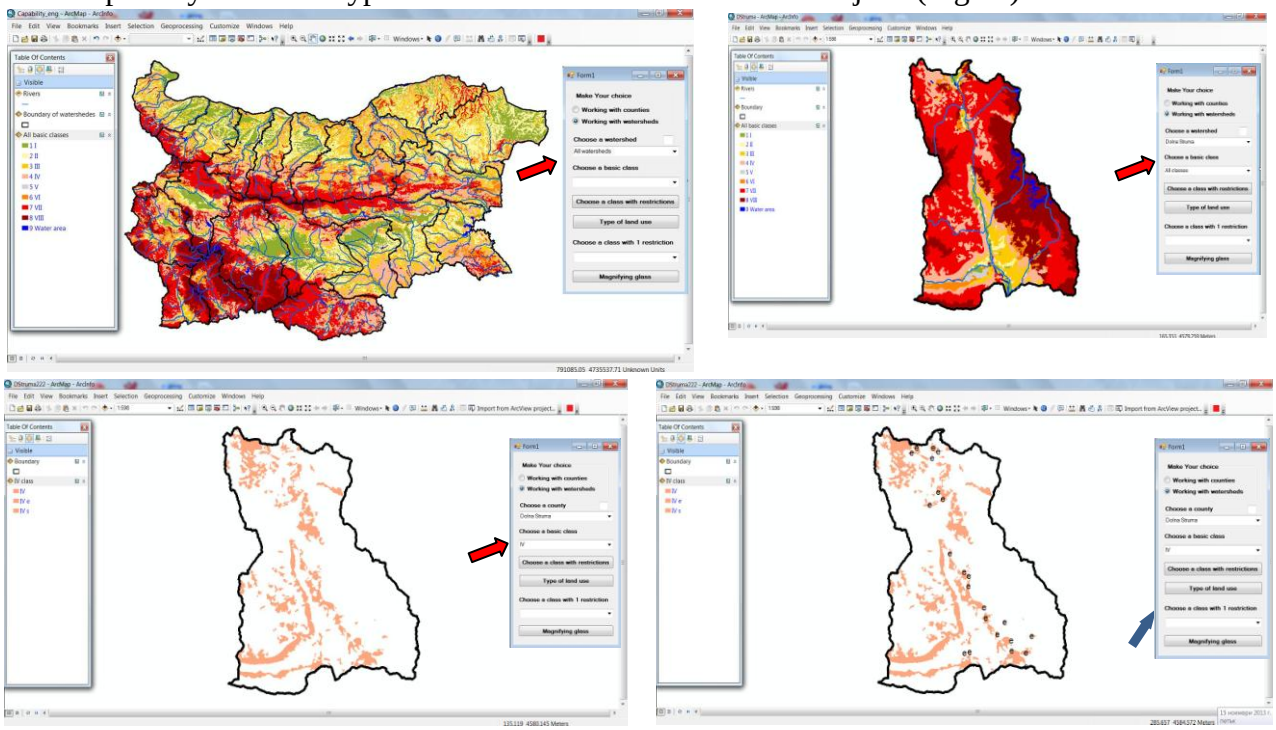


Fig.14. Map of land capability classes and the layer of the catchment areas

8. The last level is **the permanent land cover**. This level works with different legends depending on the scale of land capability categorization and the type of information used:
    - GIS database of CORINE 2006 – information used for small-scale categorization;
    - Land partitioning plans or physical blocks – information from aerial photographs 2006 and 2010 for large-scale categorization.

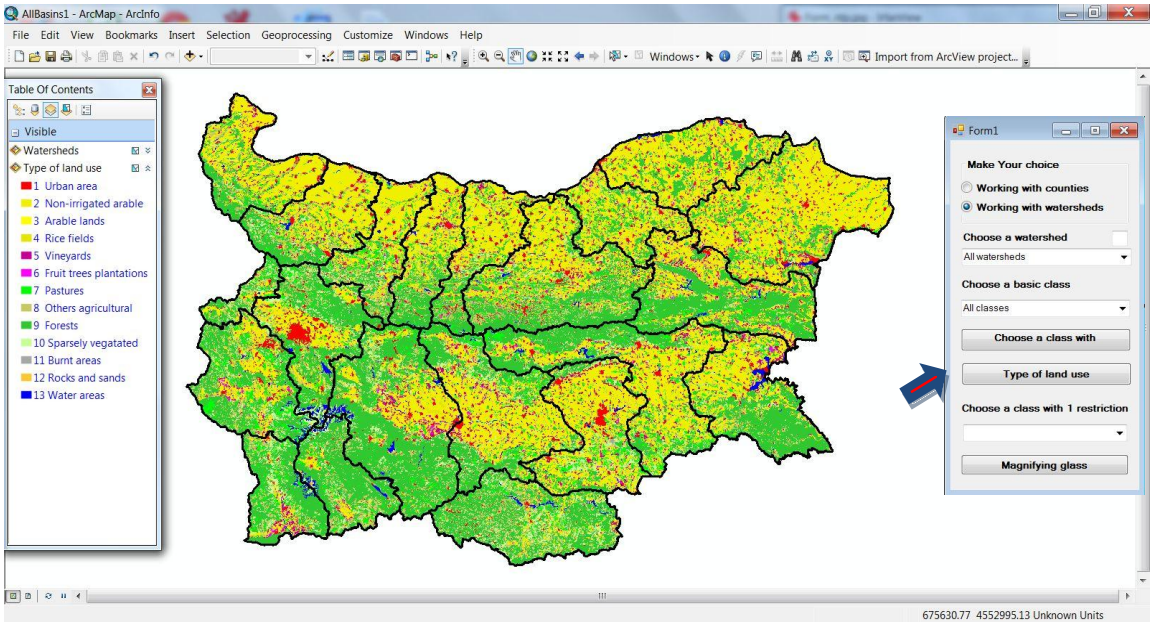
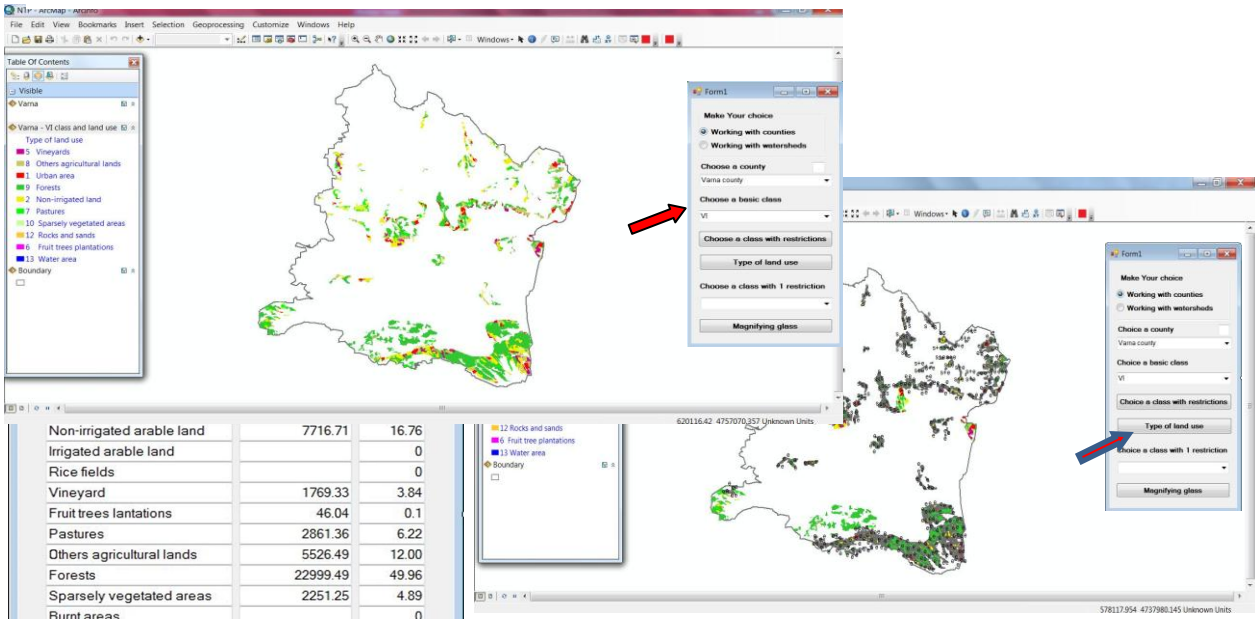


Fig.15. Legend used for small-scale categorization

The program has a tabular output in area and percentage distribution of land according to the class of the permanent land cover in the selected region, municipality or catchment (Fig.16).



Non-irrigated arable land	7716.71	16.76
Irrigated arable land		0
Rice fields		0
Vineyard	1769.33	3.84
Fruit trees lantations	46.04	0.1
Pastures	2861.36	6.22
Others agricultural lands	5526.49	12.00
Forests	22999.49	49.96
Sparsely vegetated areas	2251.25	4.89
Burnt areas		0
Rocks and sands	105.56	0.23
Water area	7.1	0.02
Total	46038.14	100.00

Fig. 16. Legend used for large-scale categorization and example of a tabular output of the system for land capability evaluation

When working at level **units** of the Land Capability evaluation for effective erosion preventive use there is an opportunity of two types of map and tabular output menu (using 2 buttons - "**Classes with the best suited crop**" and "**Choice of crop**", Fig. 19) depending on the type of problem to solve:

- Which are the most suitable crops for cultivation and effective erosion control according to the land capability classes in particular study area (Фиг.17), or
- Which lands are suitable from a point of view of environment protection and erosion prevention for growing certain types of crops (eg, vineyards, tobacco, etc.) in the study area (Fig.18).

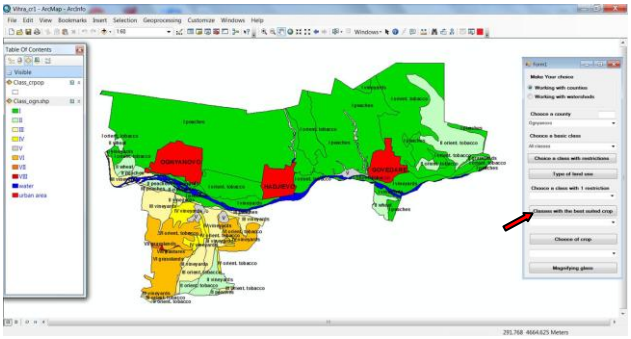


Fig. 17. Example of an output of the system determining the most suitable crop according to the land capability class

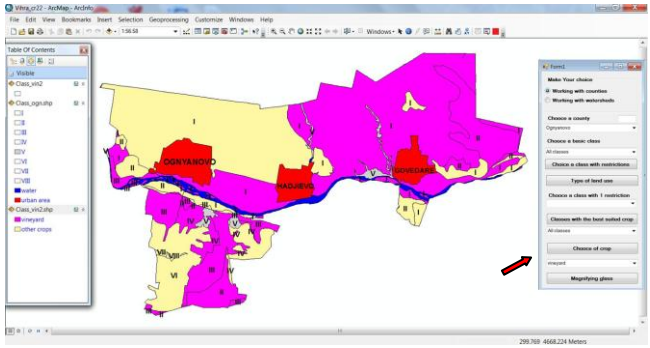


Fig. 18. Example of an output of the system determining the most suitable land for growing particular crop according to the land capability class

ArcMap10 was used to obtain a well organized GIS database for land capability classes. Two models of the user interface with buttons for two categorisation scales, namely M 1:100 000(Fig.19 a) and M 1: 10 000 (Fig. 19 b), were developed using the programming language VB.net. This way, the third evaluation level is reached – Land Capability Units.

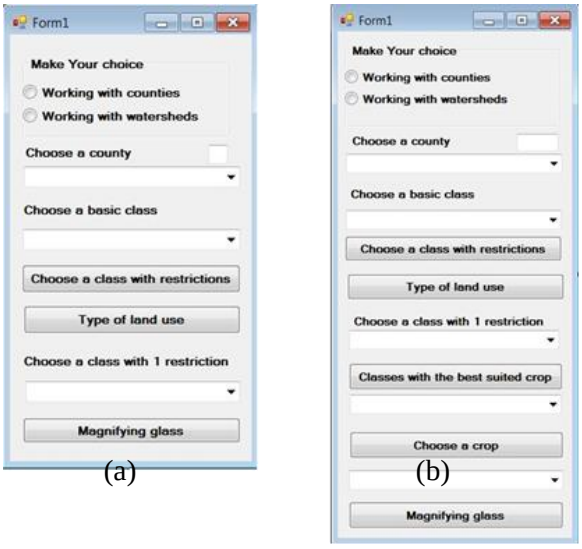


Fig. 19. User interface for two categorisation scales, namely M 1:100 000 (a) and M 1: 10 000 (b)

CONCLUSIONS

Practically oriented models (GIS format) have been developed using the GIS technologies and databases of collected soil, relief and climatic conditions in two scales where the classes, subclasses and units on land capability are available in area and percentage distribution, depending on the permanent land use. These can be viewed and analyzed by districts, municipalities, localities or catchments, and thus to serve users at national, municipal and local levels. They can also be used for scientific analyzes and interpretations.

The results of the developed system can be useful at three levels :

- National – for quality and quantity inventory of agricultural land, planning and nationwide zoning of various agricultural activities for improving the agricultural policy;
- Municipal – for design, production specialization, successful adoption of various funds, satisfying the public requirements, etc.;
- Local – will answer the specific needs of the farmers, tenants, agricultural manufacturing industry, traders of agricultural production, etc.

REFERENCES

[1] Davidson, D. The Evaluation of Land Resources. Longman. Chapters 7 & 8, 1992.

[2] Dzhodzhov H., Stefanova V., Rousseva S., Malinov I., Kroumov V. Development and implementation of mathematical model for soil wind erosion assessments. Contract № 3449/2003 with Ministry of Environment and Waters. Final report. 2004**.**

[3] Fahdil Ahady, Hazaina Harisno, Nilo Legowoc. Land Suitability Map Development for Central Java and Daerah Istimewa Yogyakarta Provinces Based on WebGIS. International Conference on Advances Science and Contemporary Engineering (ICASCE). 2012.

[4] Georgiev B. Computer model for assessment and categorization of the agricultural land in Bulgaria. Version 3.0. MSSRPR, Agrareconomics, Sofia, 1992.

[5] Gool, D., Tille, P. and Moore, G. Land evaluation standards for land resource mapping. Assessing land qualities and determining land capability in south-western Australia. 2005.

[6] Klingebiel, A. A., P. H. Montgomery. – Land capability classification. USDA, Agr. Handbook, 2005.

[7] Nikolov I., Rousseva S., Stefanova V. Consultancy Company on specifying and improving the water erosion assessment model. Project 00043507 „Capacity Building for Sustainable Land Management in Bulgaria" Contact No 2006-072-POG. Report http://www.unccd-slm.org/files/1-Water_erosion_model_EN.pdf 2007.

[8] NWASCO. Our Land Resources. National Water and Soil Conservation Organisation, Wellington, New Zealand. 1979.

[9] Onchev, N., H. Konke And M. E. Baumgardner. A key for estimating land use capability for soil conservation. Trudi mejdunarodnova kongressa pochvovedov, t.XI, Moskva, 1974.

[10] Santun R.P. Sitorus, 2010. Land Capability Classification for Land Evaluation: A Review, ISSN 1907-0799. Jurnal Sumber Daya Lahan Vol. 4 No. 2, December, 2010.

[11] Wright I A, R V Birnie, A Malcolm, W Towers and M McKeen. The Potential Use of the Land Capability for Agriculture Classification for Determining Support to Disadvantaged Areas of Scotland. Macaulay Institute Craigiebuckler Aberdeen AB15 8QH. 2006.