ASSESSMENT OF AGRICULTURAL SUITABILITY POTENTIAL LAND IN BĂLŢATA BASIN

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Resumé *L`évaluation du potentiel de l'aptitude des terres est une étape importante dans la définition des limites écologiques de la planification territoriale. Nous parlons de la recherche dans la façon dont certains types d'utilisation des terres influencées sur la productivité. Cette étude évalue l'aptitude des terres dans le bassin Bălţata sur la base d'une expertise des indicateurs de favorabilité: la pente et de la terre à l'aide, la texture du sol, teneur en matière organique des substances, l'épaisseur de la couche d'humus. Une carte d'aptitude des terres à des fins agricoles a été élaborée sur la base de la modélisation. Les résultats de la recherche montrent que la plupart de la surface du bassin est propice à l'agriculture, mais certains ajustements aux conditions locales morphologiques sont nécessaires. Près des trois quarts de la région a une bonne aptitude des terres et équitable, alors que 14,7% de la région est modérée et la moyenne. 10% de la surface du bassin ne sont pas propices à l'agriculture. Il s'agit notamment de zones dégradées, les zones habitées, et des bassins hydrographiques.*

Cuvinte-cheie: utilizarea terenurilor, pretabilitatea agricolă, bazinul r. Bălţata.

1. Introduction

Evaluation of the land suitability potential, especially under conditions of limited land resources is an important step in assessing environmental status and planning. The purpose of the evaluation of the soil pretability is the prediction of the soil natural potential with the aim to maintain a certain way of use for a long time period without worsening the soil quality. In conditions of temperate continental climate with dry and hot summers, soil and water resources conservation practices are carried out on the level of basin, as the basins represent integrated units. Each basin land unit, delimitated according to its properties, has its own potential and limits of use. The land units can be evaluated according to their qualitative characteristics (FAO, 1990). The analysis of the contribution of different parameters was assessed according to different land favorability parameters. Agricultural land suitability index is a parameter which values are grouped into six categories of suitability: very good, good, moderate, medium and low. This classification was made by superimposing different layers with the respective share using the Geographic Information System (GIS).

2. Study area

As a subject was selected the Băltata basin, located at east of Chisinau, at Northern latitude 46°58'41" and 47°06'46" and Eastern longitude 28°51'42" and 29°13'17", with a total area of 166,94 km^2. Agricultural activity in this area is focused on cereal crop production and viticulture. The dominant soils are cernoziom, carbonate soils and low humid typical with average thickness (25-50 cm) on sandy and clay rocks. In the medium and lower waterstream of the river meadow the substrate is represented by limestone and on the slopes by pebble. Interfluve gravels consisting of sand, comprise the old terraces of river Dniester. The average altitude within the basin is 123 m and varies from 17,6 m to 220,8 m. The average monthly temperatures range from -3°C in January to 21°C in July. Average annual precipitation ranges from 500 mm in the eastern basin to 550 mm in the west. Basin is characterized by a high share of degraded land. Thus, 30,9% of land is eroded and the area occupied by landslides shares 6,3%. During a long period, detailed measurements were made at 24 hydrological and meteorological stations. The data resulted in subsequent studies that can serve as sources of information in assessing the correlation level of different geographical landscape components. Taking into consideration the mentioned above this river was selected as the pilot region for the assessment of agricultural land suitability.

3. Datasets

In conducting this study there were used 2004Landsat satellite images, Google 2008Earth images, topographic maps 1: 50 000; soil map 1: 200 000; Geological map 1: 200 000 and the data collected in the field. The data process was done using ArcGIS 9.3 and ERDAS IMAGINE 8.7 software. The basin boundaries were drawn based on topographic maps. In the field, there were collected data on the geological composition (wells and geological sections), soils (profiles), land use (identification of the type of vegetation, type of crop, the degree of land degradation, etc.). The information on land use were obtained through satellite imagery processing and using the Land Cadastre on village level for 2008.

4. The factors taken into account while the assessment of suitability and the research methodology

The steps undertaken for the development of land suitability maps represent a result of the decisions regarding land that need to be improved and the way how to improve them. Therefore, the assessment of land suitability takes into account the physical particularities, socio-economic limits and possibilities of the territory. In general, they are limited to the natural potential of land for agriculture.

The joint effect of physical parameters determines the suitability degree and also facilitates the hierarchization of lands into different classes of development. In addition, the land suitability assessment process depends very much on the predominant conditions such as degree of anthropogenic influence on land. It is in this context, that the suitability analyses, carried out in this research, should be approached as the identification of priorities for the development of agriculture. This is why there are carried out interdisciplinary researches (field trips, facts, old maps and satellite images) in order to determine the suitability of land use and to identify the regions to be used for agricultural purposes. The following parameters are relevant for the soil suitability analyses: (I) land use / categories of land, (II) soil type, (III) content of organic matter in soil, (IV) humus layer and (V) slope (S. Bandyopadhyay, and others, 2009). The assessment of physical parameters is completed by the information on usage restrictions for agricultural purposes. The notion of limit is derived from the land quality. For example, if the slope has considerable values, there are restrictions about the soil erosion severity and, on contrary, higher organic matter content shows a "better health" of soil. All the mentioned physical parameters were used to identify areas suitable for agriculture. The multifactor analysis of the suitability indicator was performed by unifying these parameters in a GIS environment.

On the basis of the data obtained by processing satellite images and topographic maps (scale 1: 50,000) and soil map (scale 1: 200,000) there were developed a set of thematic maps: land use map (I) soil map (II), the map soil organic matter content (III) depth map (thickness) of soil (IV) and slopes map (V).

For the development of the digital database and for the data analysis, the ArcGIS software was used. Thematic maps have been transferred into digital format, in vector format and then drawn. All the polygons from the thematic maps were given specific values of favorability. Initially each polygon of the final thematic layer was viewed qualitatively in one of the following categories: (I) good, (II) fair, (III) moderate, (IV) average and (V) poor. These values were assigned based on the importance of land for agriculture. Subsequently these values were introduced in each thematic layer, resulting from its features. A database was made for each layer and all of them were integrated and analyzed by weighted aggregation method, using function ArcToolbox / Analisys Tools / Overlay / Union (ESRI 1988, 1989). Using this method all these values were summed, the final polygons are representing the sum of the different layers, accrding to their suitability. The formula used for the assessment of the suitability potential for agricultural purposes was calculated by using ArcToolbox / Data Management Tools / Fields / Fields/ Calculated:

$$\mathbf{IPAT = 0{,}2\,(UT)_{\mathit{i=1\text{-}6}} + 0{,}2\,(TS)_{\mathit{i=1\text{-}5}} + 0{,}1\,(P)_{\mathit{k=1\text{-}6}} + 0{,}25\,(CO)_{\mathit{l=1\text{-}4}} + 0{,}25\,(A)_{\mathit{m=1\text{-}4}}}$$

Where, the IPAT is - agricultural land suitability index, UT - land use (grades 1-6), ST - soil type, considered as specific texture, degree of erosion, etc.. (classes 1-5), P - slope (grades 1-6), CO - soil organic carbon (grades 1-4) and A is the depth factor (thickness) of soil (grades 1-4). Indices *i*, *j*, *k*, *l* and *m* denote subclasses, based on the degree of importance in the formation of land suitability.

The next step is the integration of spatial layers, which is done with the formula of ArcGIS module, based on logical analysis and assigned values. The initial information on the parameters that influence the land suitability is in a descriptive form and shows the qualitative indicators that influence significant the agriculture. In order to come to efficient conclusions by carrying out calculations and other math operations with a subsequent analysis in GIS, the descriptive information was converted in suitability indices of the agricultural land or rating. The influence of variables on land suitability was classified in the following order: organic carbon content, soil depth, soil texture, land use and slope. Given the importance of these indicators regarding the land suitability for different classes, the polygons were given certain values, as sensitivity among the other classes in the same thematic layer. Integration of various land suitability influencing factors was carried out on this stage. Higher values indicate that the factor has a major impact on agriculture. Different classes of each thematic map were grouped in one of the categories and the corresponding values were indicated according to the relative favorability or unfavorability of the land suitable for agriculture. Finally the demarcation of land suitable for agricultural production according to the potential was carried out.

4.1. Land use

For the development of the thematic map "Land use" there was used Landsat satellite imagery, Google Earth images of 2001 and 2008. The satellite images were classified using maximum probability methods. There were defined several classes, which, subsequently using ERDAS software, were grouped into six categories of land: urban land, farmland, orchards, vineyards, pastures, forests and water bodies.

According to the use of land, arable land areas have been classified in the category of good suitability. Normally, they could receive the maximum value (very good suitability), but much of these lands are situated on the slopes, which contribute to activation of erosion processes. The pastures and fallow lands, which currently are not used, are allocated with the category average suitability land. The perennial plantations have a low suitability because mostly they are located on the slopes. Even if forests fall into the category of land suitable for agriculture, due to environmental and legal reasons, were placed in the category of those with low suitability, as they can't be used in agricultural purposes. Water and human settlements get null value that excludes them from the final map.

4.2. Soil Map

While development of the soil map there was used soil map with scale 1:200 000, corrected during the field trips. On the basis of the soil map of the study region, the soil depth profiles for each defined area were developed. During field trips the interpretation units of soil maps and classes were correlated and interpreted data from the map 1:200 000 were transferred to the final soil map. Overall five soil types (series) have been identified and mapped.

Based on genetic characteristics of the soil (texture, susceptibility to erosion and physical-chemical reaction), morphological features of land (slope, drainage) and ecological factors (those agro-climatic) which restrict the land use, the classification of soil suitability was developed. The soils of 3rd type are thick, clayey, sandy loam and clay loam, slightly eroded or not eroded. They are represented by levigated chernozem and typical weak humified chernozem, with the richest organic carbon content (1,51 to 2,63%). They meet the interfluve areas. These areas were classified as with high favorability. Type 1 soils have a sandy loam and clay loam structure and have the same properties as the type 3, but they differ in thickness (lower) of the humus layer (50 cm or less) and a lower organic carbon content (0,51 to 1,50%). They were grouped into the category of those with good suitability. Type 5 soils includes alluvial soils and vertic chernozems, with thick humus layer (50-100 cm), non eroded surface, clay and sandy loam with poor and medium drainage.

Type 2 soils are clayey and clay loam with small thickness (25 cm), medium eroded and with a moderate organic matter content (1,58-2,04%). They were also classified as land with medium suitability. Type 4 soil have a sand-clay structure, small thickness, with moderate inclined slopes affected by erosion and relatively low organic carbon content. In this category the chernozems affected by landslides and all the residential areas are included. They have a low agricultural suitability.

4.3. Slope

For the delimitation of the slopes the land numerical model developed on the basis of land contours, extracted from the topographic map scale 1:50000 was used.

From morphometrical point of view, the study area is a hilly plain, with transition landscapes to plateau areas with sharp slopes. Slope value varies from 0 to 31°, with an average value of 31°. According to the slope value, the study area has been divided into six classes. Classes 1 (0-1°) and 2 (1-3°) are rated as very good and good respectively, due to nearly plain relief and optimal penetration rate. Land these classes are more common in the east and north of the basin and are currently used as farmland. Classes 3 (3-5°) and 4 (5-10°) are classified as moderate and middle, due to rugged landscape with maximum partial infiltration, they are good for agriculture. Class 5 (10-15°) with relatively high amount of flow is attributed to the category poor. Class 6 (>15°) include unsuitable or very weak land, due to the presence of sleep slopes and big surface of flow. The land is rough on the right side of the river. These soils have low soil fertility and currently are occupied by forest plantations and vineyards.

It should be added that often within the basin the morphological particularities of land location are not followed. According to some authors (V. Surd, 2005) the arable land must be located predominantly on slopes with gradients up to 5 degrees, vineyard land - on the slope of 10-30°, land tree - 15-40°, hay - 0-5°, pastures - 5-40°, buildings and roads - 0-40° (depending on the lithology), forest lands have no such limits.

4.4. Organic matter

Role of soil organic matter is very important. They are the best source of principal soil nutrients. Quantity of humus in the soil was determined based on soil map. The obtained value was multiplied to a conversion factor to obtain the percentage of humus in the soil. Soil humus content changes according to the soil type and the management of land resources (degree of erosion, land use etc.). Humus contain content in soil shows its state and suitability for agriculture. The average quantity of organic carbon in soil within the basin is 1,4% and the maximum – 2,63%.

4.5. Soil thickness.

Soil thickness is an important physical parameter. It determines the grow of the plant root system, the available water and air volume that may contain the soil. Shallow soils and rocky substrate restricted root system growth. The soil thickness changes depending on the clay minerals type. Measurement of the soil effective thickness has been made both basing of the soil map and on profiles. To determine the thickness of the soil the profiles of each type of soil were studied basing on the cartographic materials, relevant bibliography and the field trips.

Soil thickness changes depending on soil type. It also depends on the specific landscape and morphology of native rock. More inclined slopes, as, for example, those near the settlements Sagaidac, Valley Village and Cimişeni, have a thin humus horizon. The texture (especially the granular-metric size), mineralogical composition and degree of rock substrate weathering are also important factors influencing soil thickness. For agriculture the soils of medium thickness that combine the high content of organic humus with optimal conditions of aeration have the best suitability (excellent and good). Soils with high and low thickness, respectively, receive low and average values.

5. Results and discussion

After the classification, all the thematic layers were overlaid in ArcGIS using weighted aggregation method (weighted aggregation method). By grouping layers and polygons the areas of suitability for agriculture were delineated: very good, good, moderate, medium and low.

Areas with high suitability for agriculture represent 51,8% of the basin (Figure 1). In these areas there are favorable soil conditions (typical and carbonate chernozem) and slope has low values - below 5°. These areas are represented by arable land, which is normally recommended in such situations.

Sectors with good suitability are represented by meadows and some slopes areas on with the angle up to 10°. They occupy 23,5% of the basin and are used as grasslands (meadow areas), forests and arable land. The last type of use is contraindicated and it is recommended that these slopes be turned into arable land meadows, orchards and / or plantation forestry.

The land with moderate suitability value for agriculture includes slopes with the angle 5-10°, sometimes 10 to 15° with the carbonate and typical chernozem. These areas represent 7,4% of the total area. They have an insular distribution, being recorded in more compact areas in north of the village Cimişeni and west of the Cruzeşti village. These lands, according to the exposition, are recommended to be used as pastures or perennial plantings.

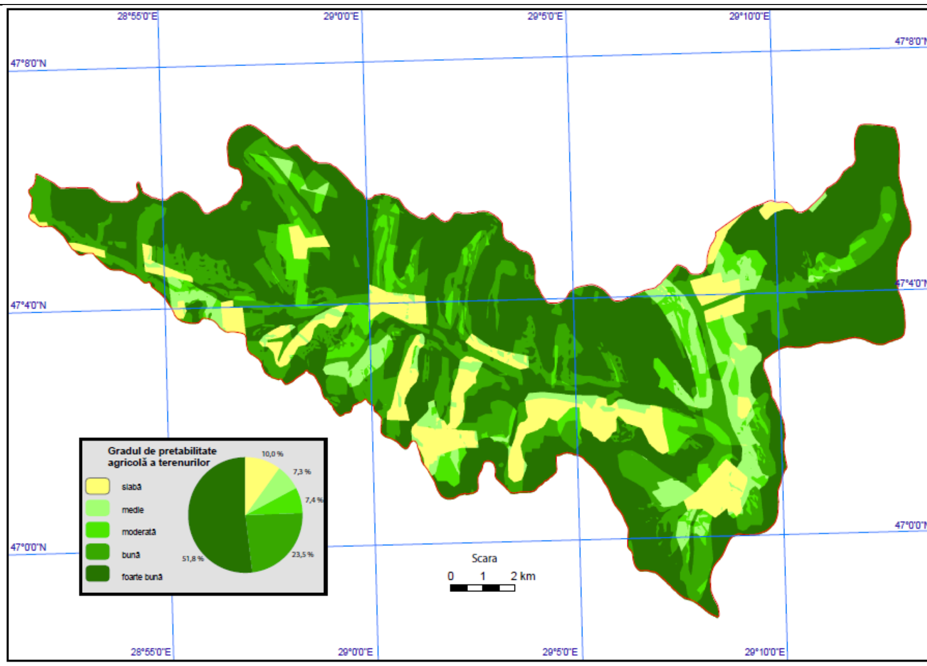

Figure 1. Agricultural suitability of land

The areas with average suitability values (7,3%) are found on the slopes of the lower watercourse between the localities Bălăbăneşti and Cimişeni where slope value reaches 15°. These fields have different uses, but forest plantations predominate, some sectors are covered with bushes and orchards, which are recommended in such conditions.

Land with low levels of agricultural suitability includes areas occupied by towns, ponds and wooded areas affected by landslides. These fields are represented by a meadow plane relief (in case of localities) or slopes with angle 15-31°.

6. Conclusions

Modeling based on GIS map was developed for agricultural land suitability. The study shows that most of the river basin planning is suitable for agriculture, but some sectors require adaptation to local conditions of morphological relief. About ¾ of the region is characterized by high and good agricultural suitability. Moderate and average suitability is characteristic for 14,7% of the basin. Non suitable land for agriculture accounts cca. 10% of the basin and includes buildings, water bodies and areas affected by landslides.

Research shows that 7,4% of the land is not used as requires the basin geomorphology and soil. For a sustainable use of land and for obtaining optimal agricultural productivity it is necessary to develop action plans based on potential values of land suitability and water availability. Land conservation measures must be accepted as an indispensable part of sustainable development plan. Action plans and their implementation should include crop rotations with leguminous crops. These measures are required in areas with high, good and moderate suitability, but in terms of the presence of available water resources for irrigation. Land with an average potential can be used as a pastures or for the rotation system. Forest-pastoral and forest systems can be used on the low agricultural suitability land.

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