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Agroecological potential and geographic information systems (GIS) mapping in the region of Stara Zagora, Bulgaria (Part II). Assessment and suitability of agricultural lands

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Abstract

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The research is based on the processed soil, climatic and agroecological data presented in Part I, as in the present study (Part II) an evaluation of the agronomic potential of the lands of the villages of Edrevo and Panicherevo, region Stara Zagora was carried out. The suitability of the lands for the cultivation of main agricultural crops has been determined. The field ratings by crops and the average agronomic score were calculated, which also determines the final land evaluation classification (categorization and grouping) under non-irrigation conditions. The final land evaluation classification is also harmonized with FAO recommendations. Land evaluation data is added to the developed geographic information system (part I) and is spatially visualized in the form of maps showing the suitability of agricultural lands for different crops growing.

Keywords: geographic information systems (GIS); agro-ecological potential; land evaluation; climate; soils

Introduction

Soil fertility is the ability of the soil to provide plants with all the necessary conditions for their growth and development. One of the scientific methods for determining soil fertility is through the quality assessment and categorization of agricultural lands (Krasteva et all, 2020). The land evaluation is a comparative assessment of agricultural lands based on their characteristics and/or qualities and shows their suitability for growing one or a group of crops at a given level of agricultural technology. A main factor for the sustainable development of agriculture is the use of scientific approaches and innovations for managing natural resources, as well as the use of achievements in various fields e.g. Geographic Information Systems (GIS). They are a product of modern technological achievements and their ultimate goal is to make management decisions based on the collection, processing, analysis, modeling and mapping of all types of data. GIS are the modern platform for work in the field of environment, land cover and resource management, in general.

Therefore, the objective of the research is: to make a geospatial interpretation of the data on the agronomic suitability of the agricultural lands in the two studied areas, to indicate the most suitable agricultural crops for cultivation, and visualize the results in the form of maps.

Materials and Methods

The following soil types have been established in the lands of the villages of Edrevo and Panicherevo, Stara Zagora region (part I):

Cinnamonic forest soils – according to the classification of Teocharov et al. (2019) are classified as follows: 5th class, 1st subclass, group/type A. Cinnamonic forest soils, subtype 3. Shallow (Leptic); Leptic Cambisols, WRBSR, 2014 and 6th class, 2nd group/type Pseudopodzolic soils; Planosols, WRBSR, 2014;

Alluvial and Deluvial soils including Alluvial-meadow, Deluvial-meadow and Alluvial-deluvial meadow, classified as follows: 3rd class, 1st group/type Alluvial soils and 2nd group/type Deluvial soils, subtypes Eutric and Dystric; Fluvisols, WRBSR, (2014);

Rendzinas (Humous-carbonate) – 1st class, 3rd group/type Humous-carbonate soils; Rendzic Leptosls, WRBSR (2014).

In order to facilitate the analysis of the data in the present study, we have created a single legend of the soil types for the two studied lands. Table 1 presents averaged physico-chemical data for the individual soil types, through which the quality assessment of agricultural lands was carried out.

Except the soil characteristics, the climatic conditions, accounted for by correction of the climatic coefficients from 0.00 to 1.00 also takes part in the land evaluation.

The land evaluation by crops was carried out through the following algorithms in "Methodology for work on the cadaster of agricultural lands in the NRB" (Petrov et al., 1988) and according to the equation compiled by Georgiev (2006).

The primary soil, subsoil, climate and agroecological data for the characteristics are from the soil and soil evaluation archives of ISSAPP „N. Poushkarov, and the climatic ones are from the officially published Climate Reference Books (Koleva & Peneva, 1990; Kyuchukova, 1979; 1983), summarized in Part I of the publication.

Table 1. Averaged analytical data of the soil types in the lands of the villages of Edrevo and Panicherevo, the region Stara Zagora

№	Soil differences	< 0,01 mm in plowed horizon (%)	< 0,01 mm in area under plowed horizon (%)	Humus horizon depth (cm)	Soil profile depth (cm)	Texture Coefficient	pH /KCl/	Humus %
1	Strongly leached to weakly podzolized Cinnamonic forest soils, uneroded and slightly eroded	25	35	25	200	2,7	4,02	0,8
2	Strongly leached to weakly podzolized Cinnamonic forest soils, slightly and moderately eroded	28	44	28	130	1,7	4,30	1,1
3	Undeveloped and shallow Cinnamonic forest soils, slightly and moderately eroded, slightly stony	16	16	26	26	1,0	4,5	0,6
4	Undeveloped and shallow Cinnamonic forest soils, slightly and moderately eroded	23	23	21	21	1,0	4,3	1,2
5	Undeveloped and shallow Cinnamonic forest soils, moderately to heavily eroded, heavily stony	36	36	21	21	1,0	5,30	3,4
6	Alluvial, weakly powerful	2	23	26	220	1,0	5,10	1,1
7	Alluvial – meadow, weakly powerful	33	36	28	180	1,0	4,8	1,1
8	Alluvial – meadow, powerful	49	53	43	180	1,0	4,70	1,6
9	Alluvial – deluvial, weakly powerful, slightly stony	15	17	20	130	1,0	4,80	0,7
10	Alluvial – deluvial, moderately powerful, slightly stony	27	26	29	135	1,0	5,0	1,5
11	Deluvial, weakly powerful, slightly stony	17	18	15	120	1,0	4,6	0,8
12	Deluvial, moderately powerful	31	38	26	120	1,0	6,10	1,3
13	Deluvial-meadow, moderately powerful, slightly swampy	37	41	35	165	1,0	4,20	1,0
14	Humus-carbonate soils (Rendzini), shallow, moderately and heavily eroded	41	41	20	20	1,0	7,10	2,6

The correction coefficient for the climate in the Georgiev's formula is determined according to the existing „Maps of agro-climatic regions and suitability coefficients for the most important crops in Bulgaria" – fund of ISSAPP „Nikola Poushkarov".

ArcGIS Desktop 10.8 software was used for the geospatial interpretation of the data.

Results and Discussion

Based on the specific analytical data and following the practical progress of the agricultural land evaluation, provided for in the methodology adopted in our country (Petrov et al., 1988), a land evaluation of the lands/fields/areas from the agricultural fund in the villages of Edrevo and Panicherevo, Stara Zagora region, has been carried out. The Average Agronomic Rating (AAR) of the lands were calculated, which also determines the final land evaluation classification (categorization and grouping) under non-irrigated conditions. The final land evaluation classification is also harmonized with the recommendations of the FAO (FAO, 1976) (Table 2). The results were added to the already developed geographic information system (part I) and visually interpreted in the form of maps.

According to the land evaluation, 577.14 ha of the total area of the two lands (5678.19 ha) belong to the so-called „good lands" or these are lands of the 3rd and 4th categories. As the 3rd category (Average Agronomic Rating (AAR) 70–80) – 70.48 ha are classified the Alluvial-meadow soils, powerful from the land of the village of Edrevo. Of the 4th category (AAR 60–70) 506.66 ha of the total area of the two lands are classified the soil types of Alluvial and Alluvial-meadow soils, weakly powerful and Alluvial-deluvial and Deluvial soils, moderately powerful.

A total of 1376.39 ha belong to the rating group of the „average good lands" or the 5th and 6th categories, of which 363.07 ha belong to the 5th category (AAR 50-60 points). These are the Alluvial-deluvial and Deluvial soils, weakly powerful and Deluvial-meadow soils, moderately powerful. Of the 6th category (40–50 points) are classified the Strongly leached to weakly podzolized Cinnamonic forest soils, non-eroded and slightly and slightly to moderately eroded with an area of 1013.32 ha.

The underdeveloped and shallow Cinnamonic forest soils with different degrees of erosion and the Humus-Carbonate soils (Rendzini) with a total area of 726.57 ha are the so-called „unsuitable lands" of the 9th (10–20 points) and 10th (0-10 points) categories (Table 2, Figure 1).

Land evaluation category gives an idea of the productive qualities of land. The final land classification of the assessed areas, according to the Bulgarian methodology, is also harmonized with the FAO recommendations (Table 2). The results are visualized in Figure 1 and Figure 2. According to the harmonization made, the agricultural lands from the two villages belong to classes S2, S3 and N2. With the largest area of 1259.32 ha are the lands of class S3 which charac-

Table 2. Average agronomic rating, land category and grouping by FAO suitability classes of agricultural lands in the lands of the villages of Edrevo and Panicherevo, Stara Zagora region

№	Soil differences	Average agronomic ratings	Land category	Class FAO
1	Strongly leached to weakly podzolized Cinnamonic forest soils, uneroded and slightly eroded	46	6	S3
2	Strongly leached to weakly podzolized Cinnamonic forest soils, slightly and moderately eroded	47	6	S3
3	Undeveloped and shallow Cinnamonic forest soils, slightly and moderately eroded, slightly stony	13	9	N2
4	Undeveloped and shallow Cinnamonic forest soils, slightly and moderately eroded	14	9	N2
5	Undeveloped and shallow Cinnamonic forest soils, moderately to heavily eroded, heavily stony	6	10	N2
6	Alluvial, weakly powerful	66	4	S2
7	Alluvial – meadow, weakly powerful	69	4	S2
8	Alluvial – meadow, powerful	73	3	S2
9	Alluvial – deluvial, weakly powerful, slightly stony	51	5	S2
10	Alluvial – deluvial, moderately powerful, slightly stony	61	4	S2
11	Deluvial, weakly powerful, slightly stony	51	5	S2
12	Deluvial, moderately powerful	67	4	S2
13	Deluvial-meadow, moderately powerful, slightly swampy	58	5	S2
14	Humus-carbonate soils (Rendzini), shallow, moderately and heavily eroded	12	9	N2

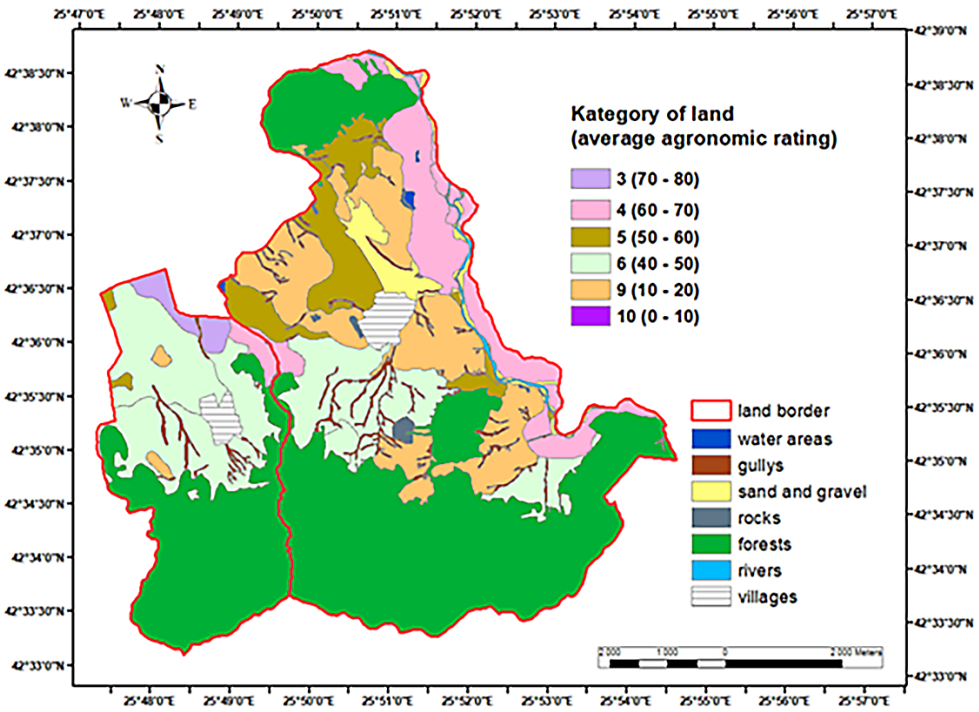

Fig. 1. Category of the agricultural lands (average agronomic rating) from the lands of Edrevo and Panicherevo villages, Stara Zagora region

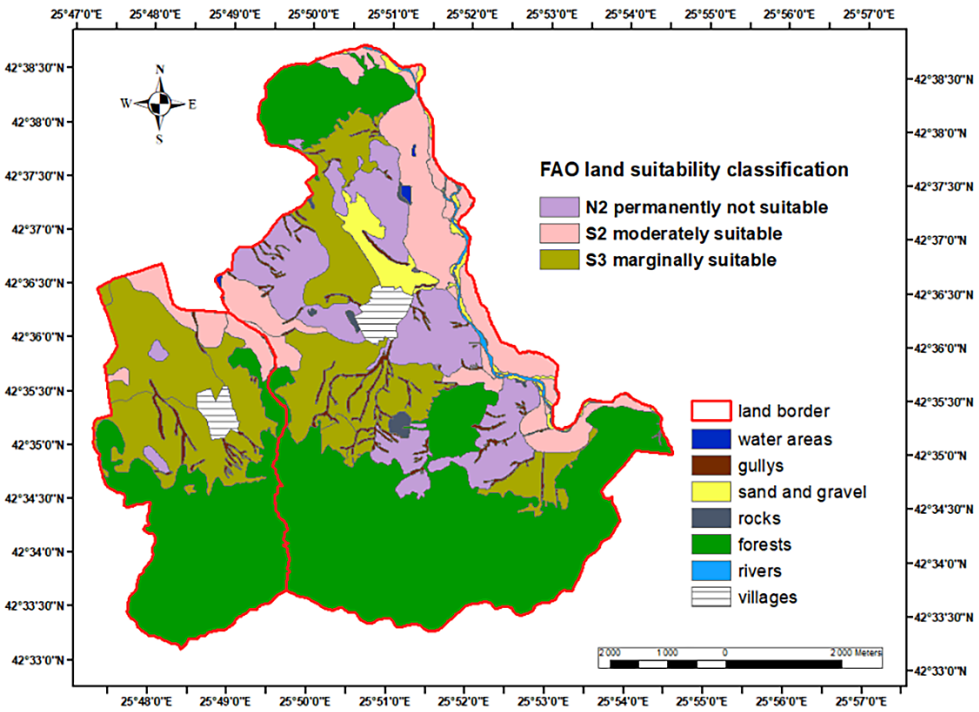

Fig. 2. Suitability classes of agricultural lands from Edrevo and Panicherevo villages, Stara Zagora region, according to the FAO classification

Table 3. Field ratings (FR) of the agricultural lands in the areas of the villages of Edrevo and Panecherevo, the region of Stara Zagora according to the requirements of individual crops

№	Soil differences	Field Ratings (FR)															
		Wheat	Corn	Sunflower	Sugar Beet	Oriental tabacco	Broadleaf tabacco	Potatoes	Vineyards	Apples	Pears	Plums	Peaches	Cherries	Alfalfa	Pastures and meadows	Tomatoes
1	Strongly leached to weakly podzolized Cinnamonic forest soils, uneroded and slightly eroded	50	30	24	34	61	34	25	36	47	47	68	40	48	43	69	37
2	Strongly leached to weakly podzolized Cinnamonic forest soils, slightly and moderately eroded	53	34	29	38	48	43	23	43	55	57	72	46	49	44	59	40
3	Undeveloped and shallow Cinnamonic forest soils, slightly and moderately eroded, slightly stony	25	0	0	0	40	0	11	0	0	0	0	0	0	0	31	0
4	Undeveloped and shallow Cinnamonic forest soils, slightly and moderately eroded	30	0	0	0	30	0	15	0	0	0	0	0	0	0	34	0
5	Undeveloped and shallow Cinnamonic forest soils, moderately to heavily eroded, heavily stony	7	0	0	0	20	0	3	0	0	0	0	0	0	0	28	0
6	Alluvial, weakly powerful	80	58	46	58	47	71	31	54	65	62	70	68	74	64	70	69
7	Alluvial – meadow, weakly powerful	84	61	49	65	46	75	29	52	71	68	73	70	79	69	71	70
8	Alluvial – meadow, powerful	92	69	55	71	35	82	28	51	75	72	82	65	74	72	74	75
9	Alluvial – deluvial, weakly powerful, slightly stony	54	38	30	40	70	38	22	48	59	56	64	58	57	48	62	52
10	Alluvial – deluvial, moderately powerful, slightly stony	72	52	41	52	47	64	28	54	65	62	70	68	74	58	70	62
11	Deluvial, weakly powerful, slightly stony	54	38	30	40	70	38	22	48	59	56	64	58	57	48	62	52
12	Deluvial, moderately powerful	80	58	44	64	60	70	24	53	68	65	70	65	83	70	71	69
13	Deluvial-meadow, moderately powerful, slightly swampy	70	52	42	58	50	61	27	0	69	66	88	58	64	61	70	58
14	Humus-carbonate soils (Rendzini), shallow, moderately and heavily eroded	23	0	0	0	33	0	8	0	0	0	0	0	0	0	32	0

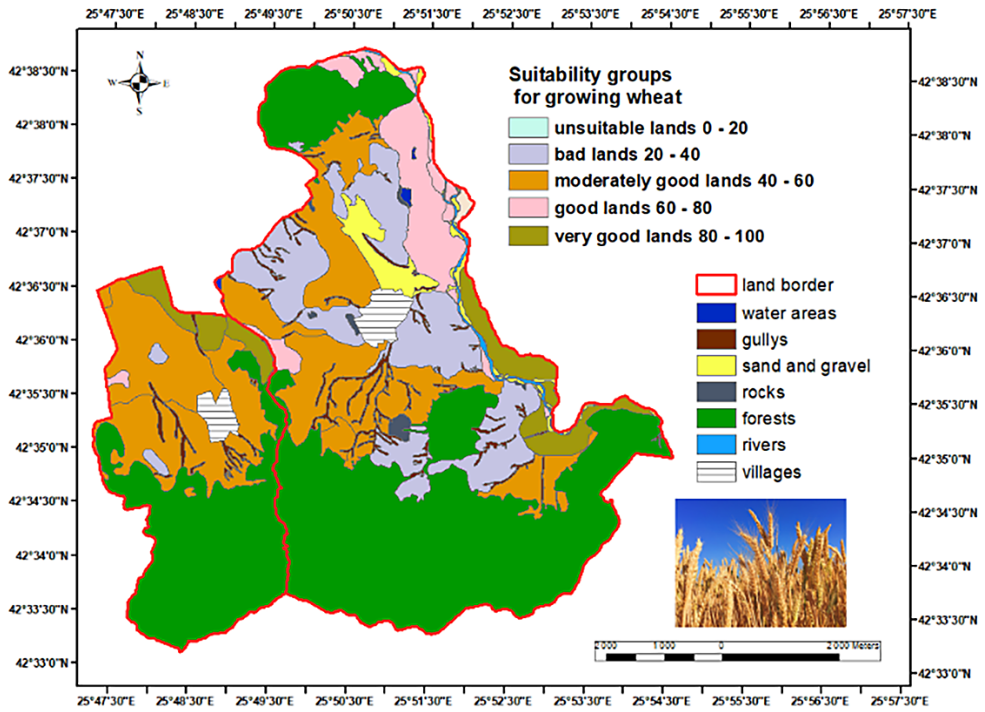

Fig. 3. Suitability of agricultural lands from Edrevo and Panicherevo villages, region Stara Zagora for growing wheat

terizes „marginally suitable lands“. These are the lands with more than 3 moderately expressed agro-ecological restrictions, and/or up to 1 strict agro-ecological restriction, which can be corrected with relatively low inputs and moderately specific production technologies. In the Bulgarian land classification, they correspond to lands with an average agronomic rating of 35 to 50 field ratings or the 6th and part of the 7th category (Table 2, Figure 2).

The lands of class S2 „moderately suitable lands“ have an area of 692.81 ha. These are lands with more than 4 insignificant and/or slight agro-ecological restrictions and/or no more than 3 moderately expressed agro-ecological restrictions. In the Bulgarian land evaluation classification, they correspond to lands with an average agronomic rating of 50 to 75 field ratings or the 5th, 6th and part of the 3rd category (Table 2, Figure 2).

Currently and potentially unsuitable lands (permanently not suitable) class N2 occupy 726.57 ha and include lands with average agronomic rating below 20 field ratings, with 1 or more very strict agro-ecological restrictions, the correction of which is economically unprofitable or impossible at the existing level of agriculture. These are the 9th and 10th categories of land from the Bulgarian land evaluation classification (Table 2, Figure 2).

The average agronomic rating (AAR) is the result of the values of the field ratings obtained for unified crops, the same for the territory of the entire country: cereals, technical crops, fruit, fodder crops, vegetables and vineyards. For the studied lands, the land evaluation for a large number of crops is zero (have a value of 0), which is the result of unfavorable soil conditions. These are the Undeveloped and Shallow Cinnamonic Forest soils, as well as the Humus-Carbonate soils (Rendzini), where the limiting factor is the very small capacity of the soil profile. The results of the evaluations (field agronomic ratings) of land suitability in relation to the requirements of individual crops are shown in the Table 3.

As a result of the land evaluation and categorization, in relation to the requirements of the agricultural crops, included in the methodological requirements, it was found that of the cereal crops, in the studied lands, the most favorable conditions exist for growing wheat, 235.6 ha are „very good lands”; 358.57 ha are „good lands“; 1357.96 ha are „moderately good lands“ and 725.16 ha are „bad lands“ (Table 3, Figure 3). The most suitable for wheat cultivation („very good“ and „good“ lands) are the majority of the Alluvial, Deluvial, Alluvial-meadow and Deluvial-meadow soils.

The best conditions of the technical crops, are for oriental and large-leaf tobacco. Regarding oriental tobacco, the “good lands” (60-80 field ratings (points)) are 913, 74 ha. – part of the Alluvial-deluvial and Deluvial soils and the

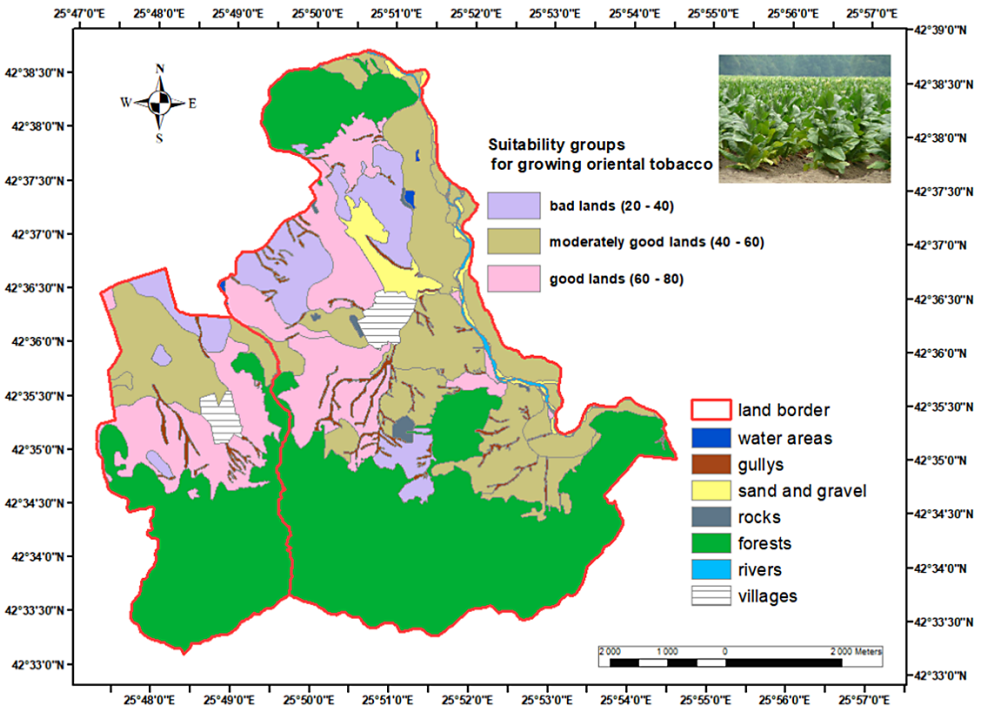

Fig. 4. Suitability of agricultural lands from the villages of Edrevo and Panicherevo, Stara Zagora region, for growing oriental tobacco

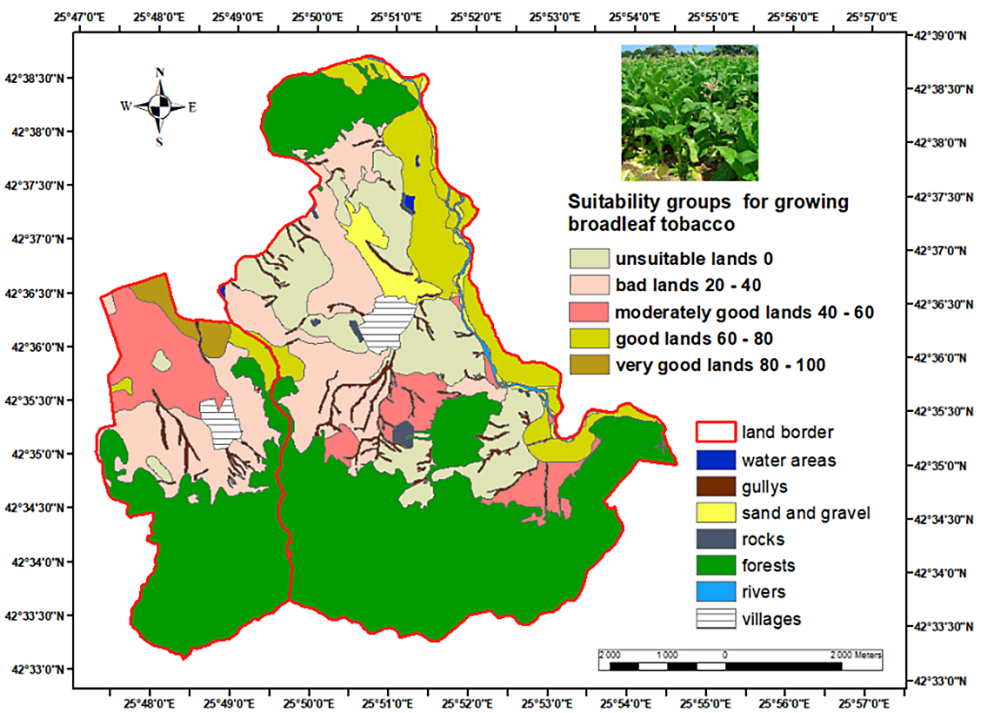

Fig. 5. Suitability of agricultural lands from the villages of Edrevo and Panicherevo, Stara Zagora region for growing large leaf tobacco

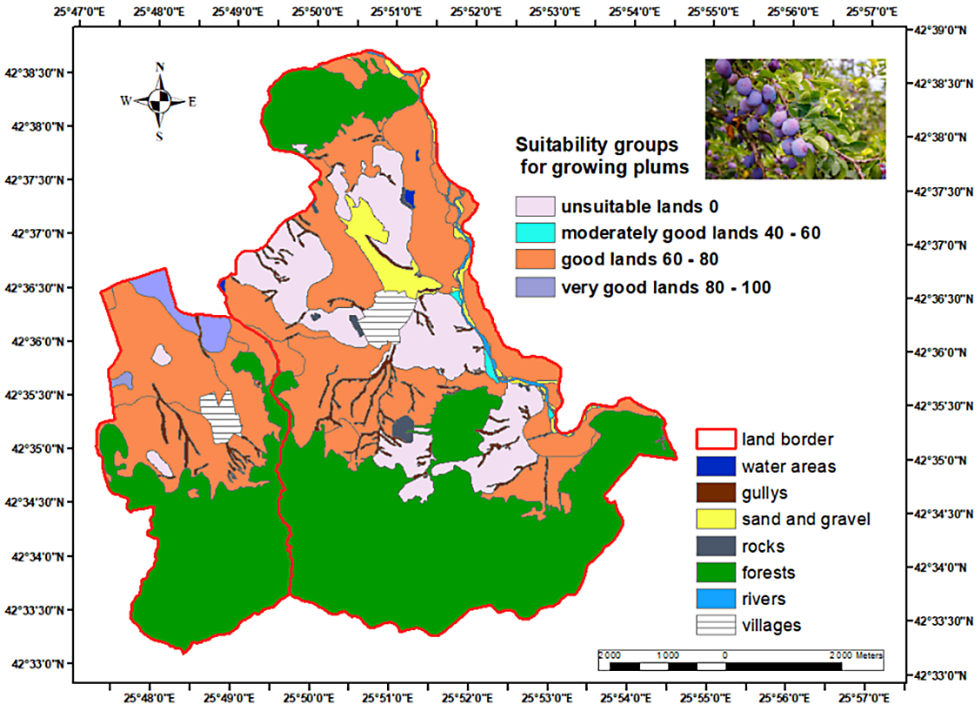

Fig. 6. Suitability of agricultural lands from the villages of Edrevo and Panicherevo, Stara Zagora region, for growing plums

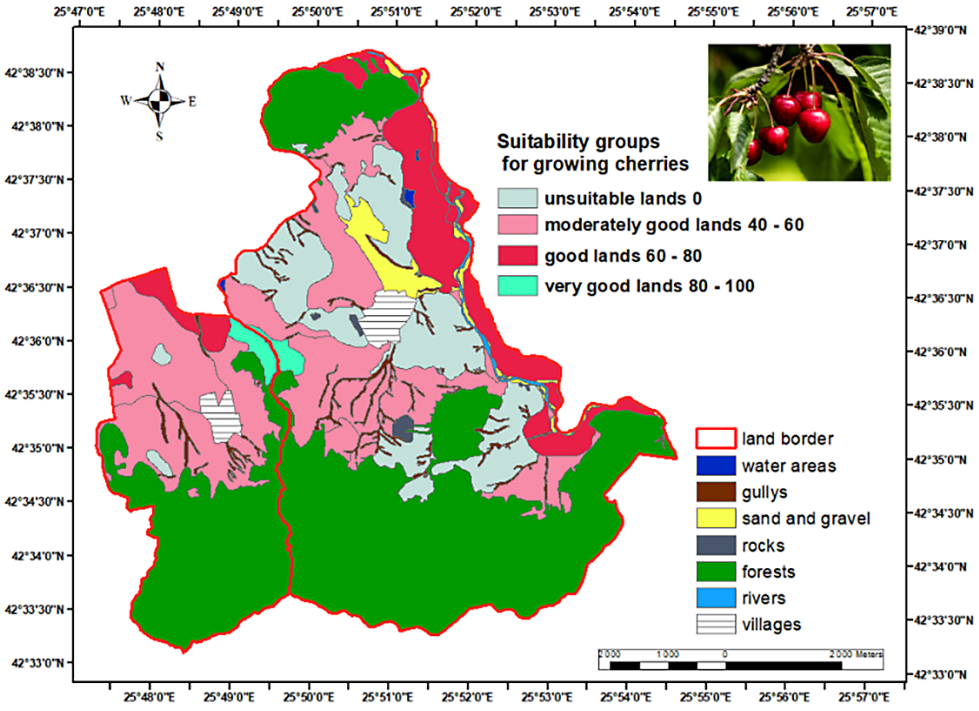

Fig. 7. Suitability of agricultural lands from the villages of Edrevo and Panicherevo, Stara Zagora region, for growing cherries

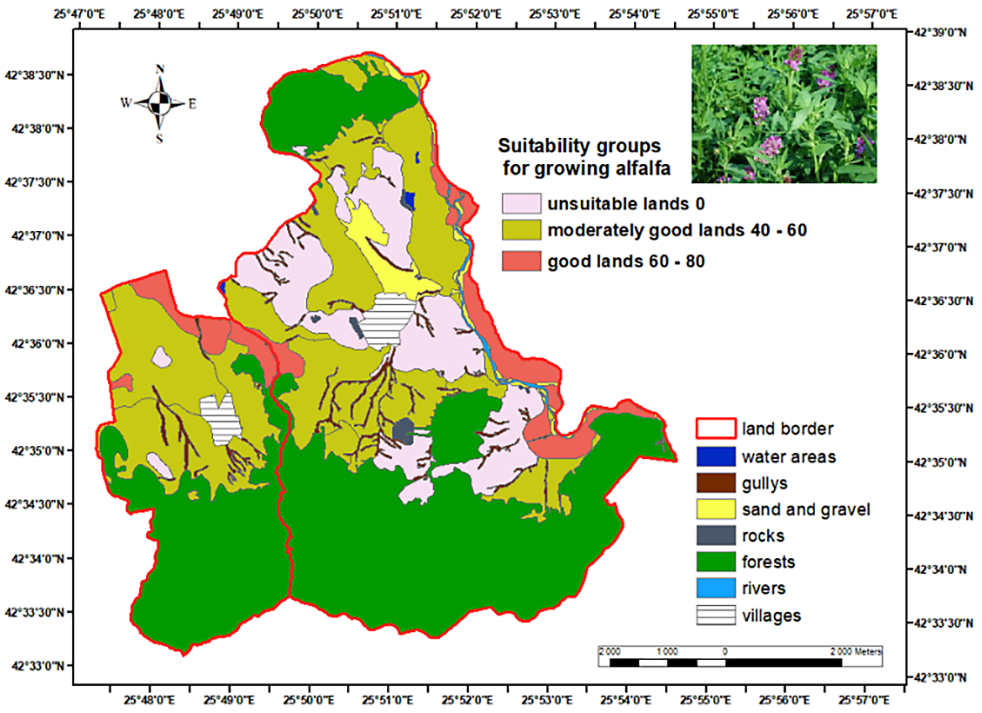

Fig. 8. Suitability of agricultural lands from the villages of Edrevo and Panicherevo, Stara Zagora region, for growing alfalfa

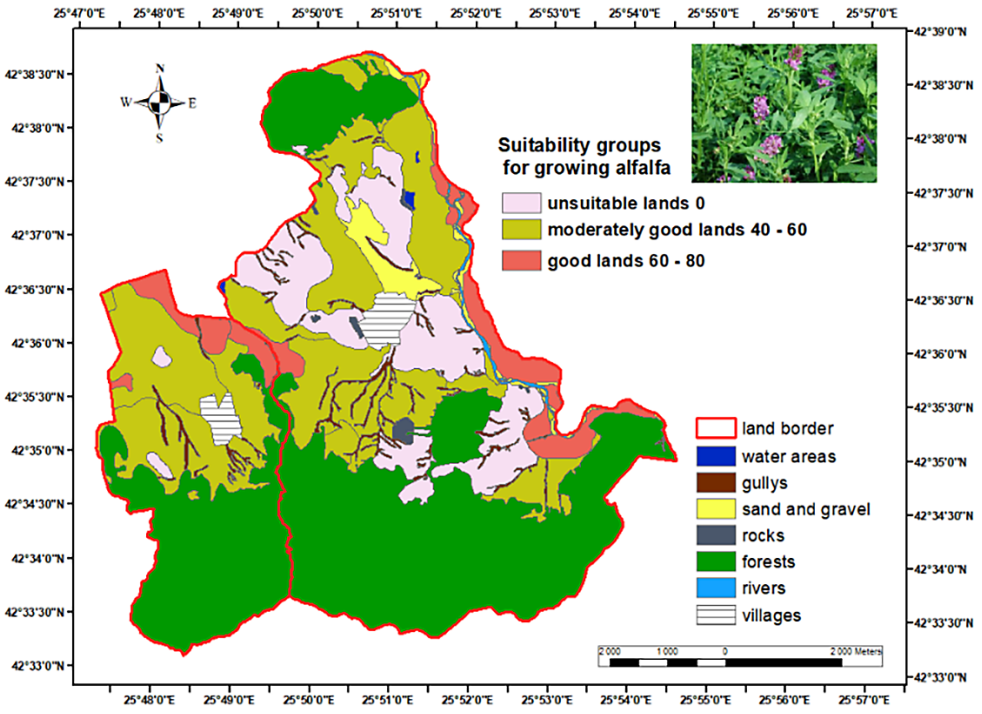

Fig. 9. Suitability of agricultural lands from the lands of the villages of Edrevo and Panicherevo, Stara Zagora region, for growing pastures and meadows

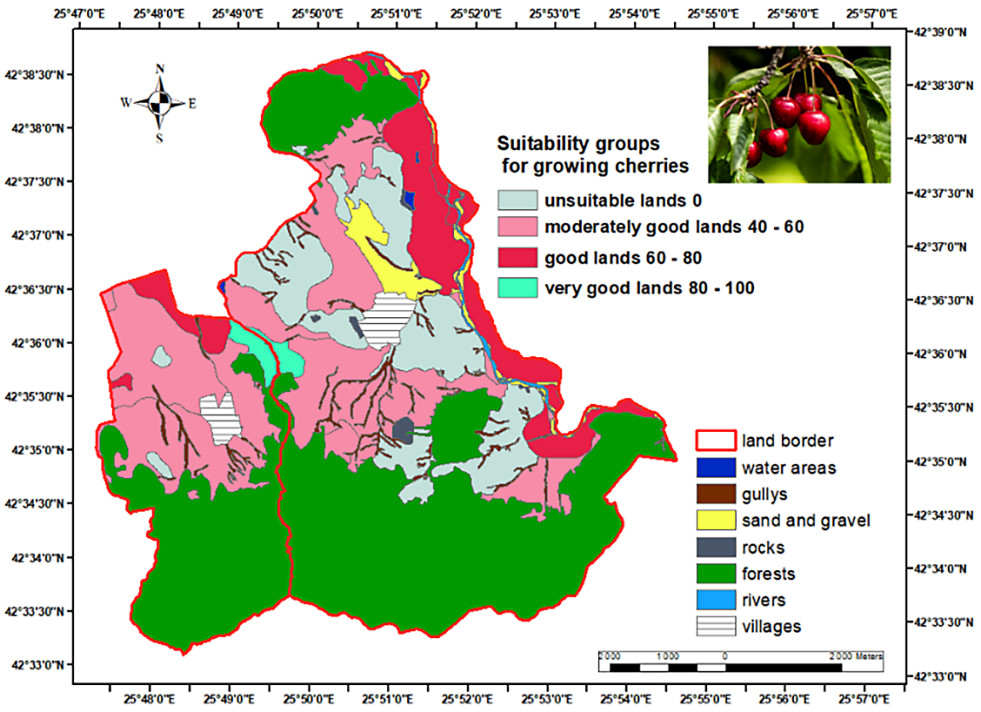

Fig. 10. Suitability of agricultural lands from the villages of Edrevo and Panicherevo, Stara Zagora region, for growing tomatoes

Strongly leached to slightly Podzolized Cinnamonic Forest soils. On the average basis the "good lands" (40–60 points) have the largest area, 1311.83 ha. Only 453.12 ha are "bad lands " (20–40 points) (Table 3, Figure 4). For large leaf tobacco, the "very good" and good soils are the Alluvial, Alluvial-meadow, Deluvial, Deluvial-meadow soils and their varieties with a total area of 584.26 ha. The moderately good lands represent 464.03 ha. However, the largest area are the "bad" and "unsuitable lands", – the undeveloped and shallow Cinnamonic Forest soils, the Rendzinas, as well as the strongly leached to slightly podzolized Cinnamonic Forest soils, uneroded and slightly eroded, and the Alluvial-deluvial soils, slightly stony with lighter soil texture, a total of 1630.41 ha (Table 3, Figure 5).

In the lands of the villages of Edrevo and Panicherevo, there are moderately good and good conditions for growing fruit crops (apples, pears, plums, peaches and cherries). There are also "very good lands" for plums and cherries, although not large areas, respectively 77.60 ha for plums and 60.15 ha for cherries. "Unsuitable lands" for fruit species are the undeveloped and shallow Cinnamonic Forest soils and the Rendzinas, where, as mentioned above, the limiting factor is the shallow soil profile (Table 3, Figures 6 and 7).

Of the fodder crops, alfalfa, pastures and meadows can be grown on part of the agricultural land. For these crops, there are „moderatly good" and „good" lands in the study area. For alfalfa, the "modertely good lands" are 1616.45 ha, and the "good lands" are 335.67 ha (Table 3, Figure 8). For pastures and meadows, the values are respectively 464.03 ha of „moderately good lands" and 1488.1 ha of „good lands" (Table 3, Figure 9). The undeveloped and shallow Cinnamonic Forest soils and the Rendzins are also defined as „unsuitable" and „bad" lands for growing alfalfa, pastures and meadows. The "unsuitable" land for alfalfa is 726.57 ha, and the "bad land" for pasture and meadow is 626.57 ha.

From the vegetable crops, tomatoes can be grown on part of the land. An area of 353.17 ha was defined as „moderately good lands" and 584.04 ha as „good lands". The undeveloped and shallow Cinnamonic Forest soils and Rendzinas, 726.57 ha are again the "unsuitable lands". The Strongly leached to slightly podzolized Cinnamonic Forest soils are defined as „bad lands" – 1011.91 ha (Table 3, Figure 10).

Conclusions

According to the officially applied methodology in our country, land evaluation of the agro-ecological potential of the areas of the villages of Edrevo and Panicherevo, Stara Zagora region has been made, as well as harmonization with the classification scheme recommended by FAO, whereby

the following key findings were established:

– The agricultural lands of the studied areas are defined at the 3rd, 4th, 5th, 6th, 9th and 10th categories. The land evaluation categories are determined under non-irrigation conditions, and in case irrigation is applied, the category changes in a positive direction, and accordingly, the possibilities for growing certain crops are improved;

– According to the FAO classification, the studied agricultural lands belong to class S2 – moderately suitable lands, S3 – marginally suitable lands and N2 – currently and potentially unsuitable lands;

– The most favorable conditions of the cereal crops are for the cultivation of wheat; of the technical crop; for oriental and large-leaf tobacco; of the permanent plantations for fruit crops (mainly plums and cherries); of the fodder crops, alfalfa, pastures and meadows can be grown, and of the vegetable crops, tomatoes are the most suitable.

The data from the land evaluation (average agronomic rating (AAR), land category, field ratings of crops, FAO classes) have been added to the developed geographic information system (Part I). Geospatial processing and analysis of the data, as well as visual interpretations, a map of the categories of agricultural land according to AAR, of land suitability classes according to FAO, and maps of the suitability of agricultural land for growing the most suitable crops have been performed.

The approach used to manage and process the collected data, namely geographic information systems (GIS), is a modern tool for the organization, analysis, modeling and management of soil resources and enables the addition of new information from different sources at any time in the future (paper maps, statistics, field surveys, satellite images, aerial photographs, etc.), as well as for various visual interpretations.

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