Suitability of Agricultural Land for Irrigation on the Territory of Istria County

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Summary

The County of Istria, with an area of 2.813 km^2, covers about 90 % of the Istrian peninsula. It contains 145.350 ha of agricultural land, which is 51,7 % of the county's area. Most of it, or 56,4 %, is unused or neglected agricultural land, and the remaining part, or 43,6 %, is used for various purposes. Of the total area of agricultural land in certain geomorphological units, 87 % area of White Istria, 60 % of Gray Istria, and 45 % of Red Istria is unused. The aim of this paper is to show the suitability of soil for irrigation on agricultural land of Istria County. Soil characteristics are presented based on a Soil Suitability Map of the Republic of Croatia at a scale of 1:300.000. The suitability of pedosystematic units for irrigation was assessed according to the FAO Land Evaluation Method. A total of 19 pedosystematic units were found in the county, which is shown on the map in 22 soil mapping units. The total area of soils suitable for irrigation in the Istrian County is 78.584,8 ha (68,4 % of the total agricultural area), of which 2.900,7 ha (2,5 %) belong to the S-1 good suitability class, 53.916,1 ha (46.9%) belong to the S-2 moderate suitability class, while 21.768,0 ha (19,0 %) belong to the S-3 limited suitability class. There are 36.362,0 ha of unsuitable soils for cultivation (31.6 % of the total agricultural area), of which 4.906,5 ha (4.3 %) belong to the class U-1 temporarily unsuitable soils, while 31.455.5 ha (27.3 %) belong to the class U-2 permanently unsuitable soils. Considering the area of S-1 and S-2 suitability classes for irrigation, and the fact that 46 % of these soils are located on unused agricultural land, it can be stated that in Istria there are very valuable land resources suitable for planning of intensive and sustainable agricultural development in conditions of irrigation.

Key words

Istria County, agricultural land, soil, assessment, irrigation

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Introduction

With 2.813 km^2, the County of Istria occupies the largest part of the Istrian peninsula, which is 4,98 % of the total area of the Republic of Croatia (Region of Istria, 2020a). According to the data from 2011, there are 208.055 inhabitants in the County (Region of Istria, 2020a), and similar data (209.020) are provided by the Eurostat (2019), which gives an average population of 73 inhabitants per km^2. As part of planning further economic development of the County, significant potential exists in agriculture. Over the last two decades, significant attention has been paid in the County to the revitalization of agriculture, especially viticulture and olive tree cultivation. However, underutilized agroecological potential remains significant. Observed climate changes in the last two decades (Sertić, 2020.), as well as analyzes show that intense droughts in Croatia occur on average every three to five years (Romić et al., 2005), and that Croatia has great potential for irrigation of agricultural land (Husnjak et al., 2005; Husnjak and Bensa, 2018). These changes are the reason for planning the development of irrigation for intensive agricultural production in the County. The agricultural sector is the largest global consumer of freshwater, which accounts for about 70 % of total freshwater consumption (FAO, 2017). The growing global water shortage has contributed to agricultural production reduction, which adversely impacts the food security and severely affects the regional economy and socioeconomic development (Anane et al., 2012; Montgomery et al., 2016). Therefore, within the search for ways for further development of agriculture, this paper presents the suitability of agricultural land for irrigation in the Istrian County in the current climate change. This is stated in accordance with the 'Plan for Irrigation and Management of Agricultural Land and Waters in the Republic of Croatia' (Romić and Marušić et al., 2005), which aims to create conditions for more rational and intensive use of agricultural land in food production.

Materials and Methods

The following documents and maps were used in the preparation of this paper:

- Pedological map of the Republic of Croatia at a scale of 1:300.000 (Bogunović et al., 1996)
- Map of hydromelioration systems of detailed drainage of the Republic of Croatia at a scale of 1:25.000 (Mustać et al., 2019)
- Map of forest in the Republic of Croatia at a scale of 1:50.000 (Kušan et al., 2020b)
- Map of agricultural land of the Republic of Croatia at a scale of 1:50.000 (Kušan et al., 2020a)
- Land resources and soil suitability for irrigation (Husnjak et al., 2005)
- Data from the Croatian Bureau of Statistics, (https://www.dzs.hr).

The assessment of soil suitability for irrigation was made according to the qualitative method and FAO criteria (1976, 1985), and the calibration and correction of this method according to Vidaček (1981), where pedosystematic units are grouped according to the degree of suitability and restrictions for irrigation into suitability categories, that is, classes and subclasses.

Results and Discussion

Geomorphological Units of Istria

According to the geological and geomorphic structure, the Istrian peninsula can be divided in three different geomorphologically units (Istrian Encyclopaedia, 2005). On each of them, soils have been developed in accordance with the combinations of present pedogenetic factors and processes. This is the reason that soils developed in certain geomorphologically units at the same time characterized this units.

The mountainous part of Istria, which consists of Ćićarija and Učka, is located in the northern part of the peninsula. The parent material consists mainly of limestone and dolomites, which are on large slopes and are "bare" and of white colour. Because of that, this part of Istria is also known as "White Istria" (Figure 1). This area is dominated by shallow, rocky and stony soils. The soil types which are dominant are Lithosol, Rendzina, Calcomelanosol, and Calcocambisol.

Figure 1. Geomorphological units of Istria
Source: http://istra.lzmk.hr/clanak.aspx?id=957

The central part of Istria is dominated by the flysch as parent material, which is gray in colour, and because of that, this area is also called "Gray Istria" (Figure 1). This is an area dominated by hills and mountains. Of the soil types, the most common are Regosol, Rendzina, Vertisol, Eutric Cambisol and Anthrpogenic soil.

In the western part of Istria, more specifically from the Piran Bay to Plomin, there is a low limestone-dolomite plateau. Soils types that are dominant here are Terra Rossa, Calcocambisol, and their anthropogenic pedosystematic units. Due to the shades of red colour in these soils, this area is known as "Red Istria" (Figure 1).

Land Use

In the area of Istria County, a total of 145.350 ha of agricultural land has been identified (Kušan, 2020a) (Table 1) that equals an average of 0,70 ha per capita, which is more than the average in Croatia which is about 0.6 ha per capita. However, most or 56,4 % of the total agricultural land is unused or neglected, and the remaining part or 43,6 % is used for various purposes.

Table 1. Area of agricultural land in Istria (reference year 2020)

Ownership	Agricultural land, ha		
	Unused	Used	Total
State	10.422,7	8.812,4	19.235,1
Mixed	3.391,1	3.946,4	7.337,5
Private	68.107,7	50.669,7	118.777,4
Total	**81.921,5**	**63.428,5**	**145.350,0**

With regard to the ownership of agricultural land, private land predominates (81,7 %), state land has 13,2 %, while mixed ownership is determined on only 5,1 % of agricultural land, Table 1. However, only mixed-ownership has determined the dominant representation of used (53,8%) in relation to unused land (46,2%).

The spatial distribution of used and unused agricultural land, as well as forests in Istria County is shown in Figure 2.

The reason for such a large part of unused or abandoned agricultural land is the pronounced depopulation of the rural areas of Istria after World War II. According to the Croatian Bureau of Statistics (2014), most of Istria experienced littoralisation in the period 1961-2011, i. e. a drastic decrease in the number of inhabitants in the interior, while coastal and tourist areas had an increase in the number of inhabitants in the same period (Figure 3).

According to these data, in some municipalities, less than 50 % of the population (dark red colour on the map) remained in that period compared to the 1961 population. On the other hand, there are municipalities in which the population has increased significantly and even by more than 200 % (darker green colour on the map). In the last 10 - 20 years, there has been a recultivation trend of abandoned agricultural land. However, this process is still very slow.

The spatial distribution of used and unused agricultural land in Istria County, given the ownership structure, is shown in Figures 4 and 5.

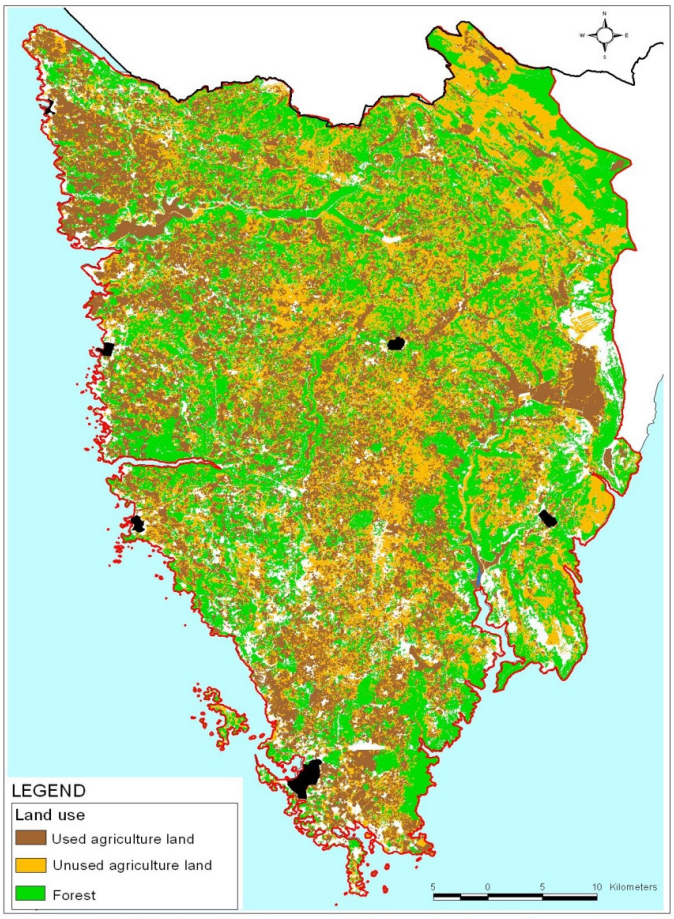

Figure 2. The map of land use in the County of Istria

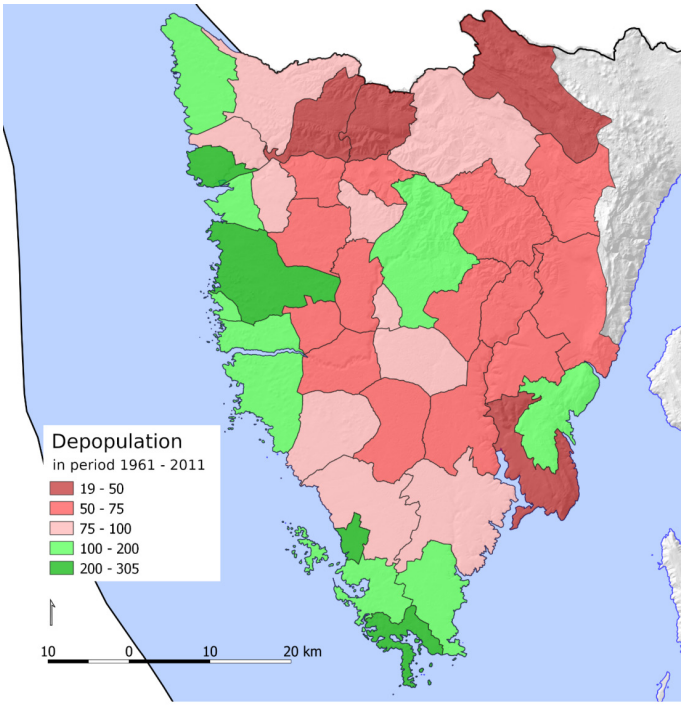

Figure 3. Change in population (% remain) in the period 1961-2011
Source: (https://www.dzs.hr)

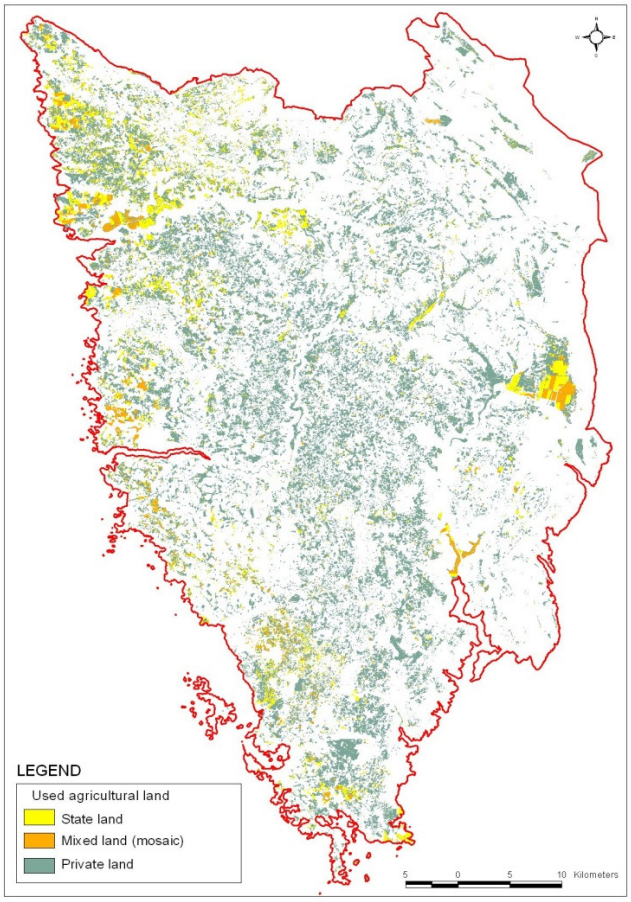

Figure 4. Ownership of used agricultural land

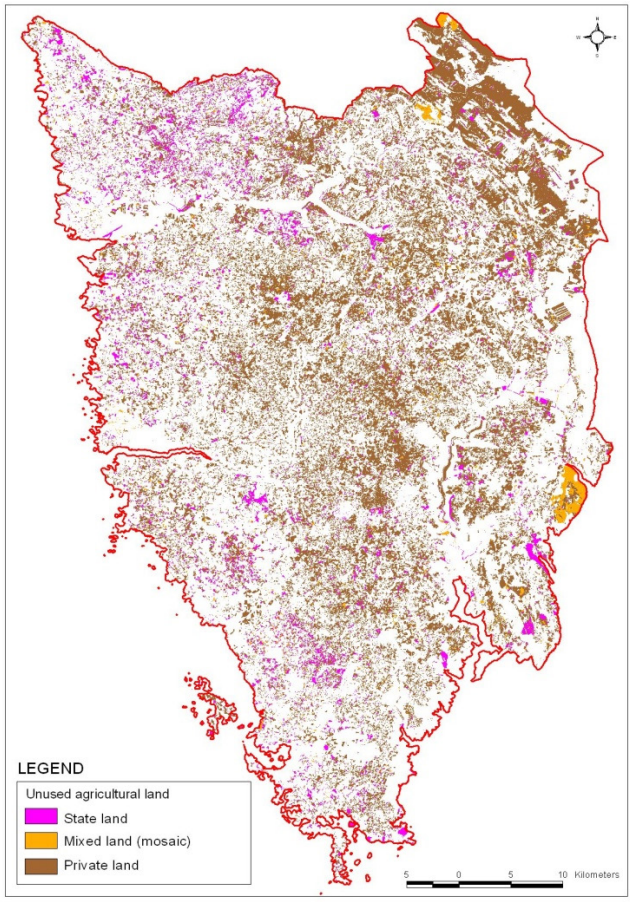

Figure 5. Ownership of unused agricultural land

Soil characteristics and suitability for irrigation on agricultural land of Istria County

Basic Soil Characteristics

Soil characteristics are presented based on a Soil Suitability Map of the Republic of Croatia at a scale of 1:300.000, Figure 6. A total of 19 pedosystematic units was found in the area of Istria County, which is shown on the map in 22 soil mapping units.

In the pedosphere of agricultural areas, according to the Croatian soils classification (Husnjak, 2014), the most common are terrestrial soils (94,4 %) which are moistened by percolating surface water (soil types - lithosol, regosol, colluvial soil, calcomelanosol, rendzina, vertisol, eutric cambisol, dystric cambisol, terra rossa, calcocambisol, luvisol and antropogenic terrestrial soils).

Only 3,9 % of semiterrestrial and hydromorphic soils are excessively moistened by very slowly percolating and perched water and/or groundwater within 1 m depth and there are defined next soil types: alluvial soil, pseudogley, fluvisol, semigley, eugley and histosol. There are also 1,7 % of hydromeliorated soils whose water regime is regulated by canals or pipe drainage.

The most common soil types are terra rossa (39,6 %), calcocambisol (13,1 %), antropogenic terrestrial soils (10,5 %), rendzina (10,4 %), calcomelanosol (5,8 %) and regosol (4,4 %). Other soil types (13) occupy the remaining 16,3 %, i.e., less than 4 % area individually (Figure 7).

More detailed properties of individual soil types are presented in the existing literature (Škorić et al., 1987; Bašić et al., 2001, Bašić et al., 2007, Husnjak, 2014). For the purposes of presenting the assessment of soil suitability for irrigation, only the characteristics of soil mapping units are shown, Table 2.

Soil Suitability for Irrigation

In the area of Istria county, a significant lack of water in the soil was found for agricultural crops (Šimunić et al. 2007.; Šimunić et al. 2009.), and because that there is a need for the introduction of irrigation in agricultural production.

The total area of agricultural soils in Istria County is 145.350,0 ha, of which rocks participate in 30.403,1 ha or with 20,9 % of the area. Accordingly, the soil area with different degrees of suitability for irrigation is 114.946,9 ha, which was the subject of suitability assessment.

The total area of soils suitable (S) for irrigation in the Istrian County is 78.584,8 ha (68,4 % of the total agricultural area) of which 2.900,7 ha (2,5 %) belong to the class S-1 of good suitability, 53.916,1 ha (46,9 %) to the class S-2 of moderate suitability, while 21.768,0 ha (19,0 %) belong to the class S-3 of limited suitability. The area of unsuitable soils (U) for cultivation is 36.362,0 ha (31,6 % of the total agricultural area), of which 4.906,5 ha (4,3 %) belong to the class U-1 temporarily unsuitable soils and 31.455,5 ha (27,3 %) belong to the class U-2 permanently unsuitable soils, Table 3.

Table 2. Legend and dominant characteristics of soil mapping units on agricultural land of Istria County

Soil mapping units (m.u.)			Basic charasteristics of soil mapping units						
No. m.u.	Composition and structure		Rockyness %	Stonyness %	Terran slope %	Ecological soil depth cm	Soil drainage	The dominant moinstening of the soil	Area hectares
	The dominant pedosystematics units	Other pedosystematics units							
3	Eutric cambisol	Luvisol, Humofluvisol, Eugley	0	0	0-1	>100	good	semigleyicc	814,8
11	Luvisol typical, on marl and soft limestones	Rendzina calcareous, Pseudogley on slope, Eutric cambisol, Regosol silliceous-calcareous, Colluvial soil with prevailing of soil material, Eugley	0	0	5-20	50-150	moderately good	automorphic	127,6
12	Hydroameliorated soil	Fuvisol	0	0	0-1	50-100	poorly	amphigleyic	356,7
13	Colluvial soil with prevailing of soil material	Eugley, Humofluvisol, Pseudogley	0	0	0-3	50-100	moderately good	automorphic, amphigleyic	2.267,4
14	Terra rossa, luvic	Distric cambisol on relict Terra rossa, Calcocambisol on limestone, Luvisol acric (two layers), Calcomelanosol	0-3	0	0-5	70-200	good	automorphic	5.259,5
15	Terra rossa, luvic and typical, deep	Calcocambisol on limestone, Calcomelanosol	0-1	0	0-3	50-100	good	automorphic	48.907,2
17	Rendzina on marl, flysch or soft limestone	Rigosol (vineyard), Regosol silliceous-calcareous, Luvisol on marl or less, Swampy gley soil, Eutric cambisol	0	0	8-30	30-150	good	automorphic	18.082,4
20	Vertisol on marl or soft limestone	Anthropogenic soil, Rendzina on flysch, Regosol silliceous-calcareous, Calcocambisol on limestone	0	0	5-20	50-150	incomplete	automorphic	2.278,7
21	Eutric cambisol on flysch or soft limestone	Rendzina on marl, Luvisol, Calcocambisol on limestone and dolomite, Regosol silliceous-calcareous	0	0	5-20	50-100	incomplete	automorphic	602,2
31	Anthropogenic soils of flysch and karst synclines and on colluvium	Rendzina on flysch (marl), Regosol silliceous-calcareous, Eugley, Pseudogley on slope, Colluvial soil	0-1	0-5	0-5	50-150	partly excessively	automorphic	13.230,1
32	Luvisol typical and acric, on limestone and dolomite	Distric cambisol on relict Terra rossa, Terra rossa typical and luvic, Rendzina on dolomite	2-10	0	0-7	50-200	good	automorphic	51,4
43	Eugley, partially hydroameliorated	Colluvial soil with prevailing of soil material, Rendzina on proluvium, Pseudogley on plain, Pseudogley-gley	0	0	0-1	20-90	poorly	amphigleyic, hypogleyic	32,8
55	Terra rossa, shallow and medium deep	Calcocambisol on limestone, Calcomelanosol, Anthropogenic soil	50-70	10-20	3-30	30-50	partly excessively	automorphic	16.745,5
56	Calcocambisol on limestone	Calcomelanosol, Rendzina, Luvisol on limestone, Terra rossa, Rigosol of karst, Eutric cambisol, Regosol on marl	50-80	10-20	3-30	30-50	partly excessively	automorphic	14.792,7
57	Calcocambisol on limestone	Terra rossa, typical and luvic, , Calcomelanosol, Rendzina on limestone detritus, Luvisol on limestone, Lithosol, Rigosol	50-70	10-30	3-30	30-70	partly excessively	automorphic	14.444,6
58	Calcocambisol on limestone	Luvisol on limestone, Calcomelanosol, Rendzina, Colluvial soil	50-60	5-30	10-45	40-80	good	automorphic	125,7
61	Calcomelanosol	Kalkokambisol on limestone and dolomite, Rendzina on limestone detritus, Luvisol on limestone and dolomite	30-50	20-40	16-45	10-30	partly excessively	automorphic	3.187,5
65	Eugley, vertic	Gley soils,, Histosol	0	0	0-1	10-50	very poorly	epigleyic	2.213,9

Continued

Soil mapping units (m.u.)			Basic charasteristics of soil mapping units						
No. m.u.	Composition and structure: The dominant pedosystematics units	Composition and structure: Other pedosystematics units	Rockyness %	Stonyness %	Terran slope %	Ecological soil depth cm	Soil drainage	The dominant moinstening of the soil	Area hectares
Drained soils by pipe drainage									
67	Alluvial-colluvial, gleyic		0	0	0-1	50-100	good to moderately good	automorphic	955,8
72	Humofluvisol shallow gleyic		0	0	0-1	70-100	good	automorphic, semigleyic	655,6
73	Hipogley		0	0	0-1	30-100	poorly to moderately good	semigleyic, hypogleyic	14,2
76	Amphigley		0	0	0-1	30-60	poorly to incomplete	amphigleyic, semigleyic,	203,8
Total for soil mapping units									**145.350,0**

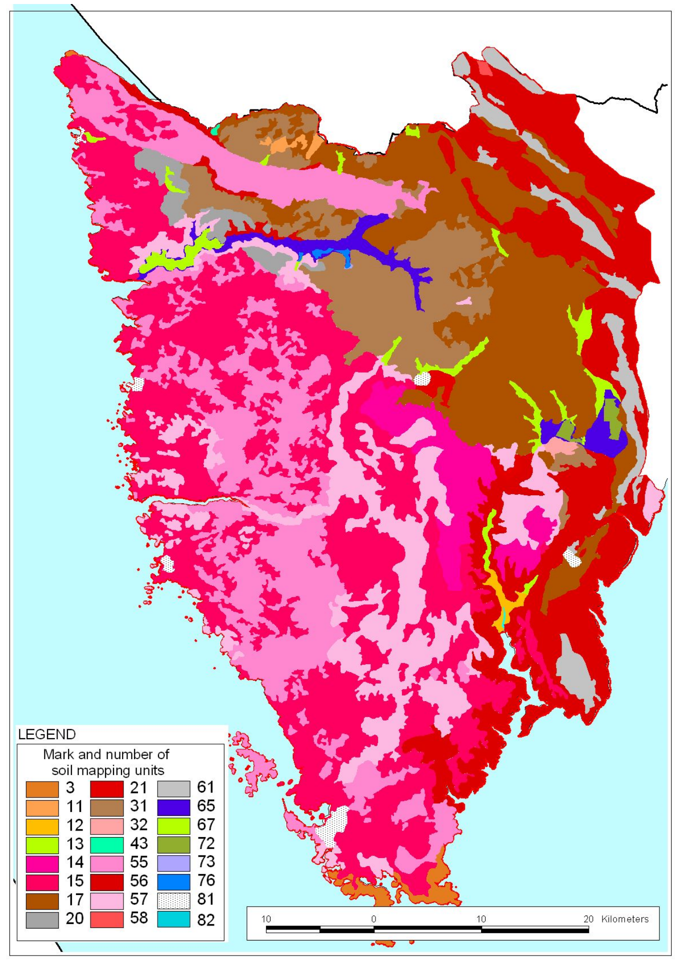

Figure 6. Soil map of Istria County (1:300.000 scale)

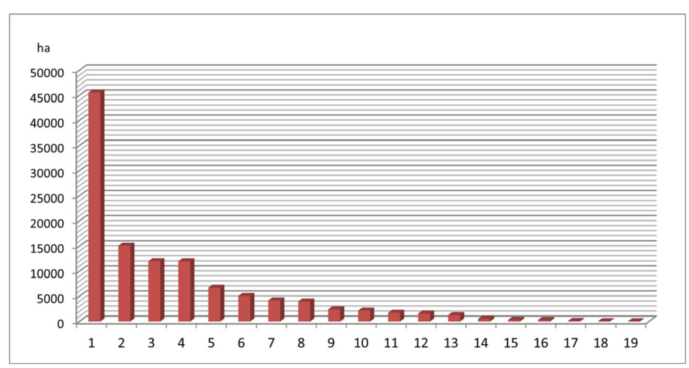

Figure 7. Area of the soil types on the agricultural land of Istria County

Legend:

1 – Terra rossa
2 – Calcocambisol
3 – Antropogenic terrestrial soils
4 – Rendzina
5 – Calcomelanosol
6 – Regosol
7 –
8 – Luvisol
9 – Colluvial soil
10 – Hydroameliorated soils
11 – Eutric cambisol
12 – Dystric cambisol
13 – Vertisol
14 – Pseudogley
15 – Humofluvisol
16 – Lithosol
17 – Pseudogley-gley
18 – Histosol
19 – Fluvisol

Table 3. Area of suitability classes for irrigation on agricultural land (ha)

Sutability classes	Agricultural land				Total	
	Used	%	Unused	%	ha	%
S-1	2.239,8	4,1	660,9	1,1	2900,7	2,5
S-2	28.618,6	52,9	25.297,6	41,6	53916,1	46,9
S-3	8.353,1	15,4	13.415,0	22,0	21768,0	18,9
U-1	2.506,3	4,6	2.400,2	3,9	4906,5	4,3
U-2	12.348,1	22,8	19.107,4	31,4	31455,5	27,4
Total	**54.065,9**	**100,0**	**60.881,0**	**100,0**	**114946,9**	**100,0**

The results indicate that on used agricultural land over half of the soils (52,9 %) belong to the class of moderate suitability for irrigation (class S-2) while only 4,1 % of the soils are without any restrictions (class S-1). The presence of soils U-2 class that are permanently unsuitable for irrigation (22,8 %) is also significant. The main limitations related to applying the irrigation are rockiness, stoniness, terrain slope and ecological soil depth. Moderately suitable soils for irrigation predominate also on unused agricultural land.

Similar research on the assessment of soil suitability for irrigation in Croatian agricultural regions was conducted by Husnjak and Bensa (2018). They found that as much as 88,0 % of suitable soils for irrigation are located in the Pannonian agricultural region, while the most limited suitable soils of S-3 class (46,0 %) are located in the Adriatic agricultural region. For the North Adriatic agricultural subregion, to which the County of Istria belongs, they determinate 1,7 % of good suitable soils (S-1 class), 35,6 % of moderately suitable soils (S-2 class), and 12,4 % of limited suitable soils (S-3 class) for irrigation, while permanently unsuitable soils (U-2 class) predominate (as much as 47,4 %).

Numerous researchers evaluated agricultural land suitability for irrigation in certain regions or countries in Africa and Asia. Dagnenet (2013) found that in the Foger Basin in Ethiopia about 72 % of the area is suitable for irrigation, out of which only 1 % of soil is without any restrictions, 28 % moderately suitable soils, and 43 % soils with limited irrigation suitability. Worqlul et al. (2015) assessed the suitability of the soil for irrigation in the Ethiopian Plateau taking into account the interaction of climate, hydrology, pedology, land cover and relief, and found that almost 20 % of the area is suitable for surface irrigation. Albaji et al. (2014) found that on part of the Ramhormoz Plateau in southwestern Iran, there is only 3,0 % of S-1 suitability class, 5,1 % of S-2 suitability class, and 23,4 % of S-3 suitability class. From unsuitable soils, temporarily unsuitable or U-1 class takes 21,8 %, while permanently unsuitable or U-2 class covers 41,3 %. Similar results were obtained by Tomić and Vranješ (2006) for the Šibenik-Knin County in Croatia. The authors determined that only 30,1 % of the total agricultural land was suitable for irrigation, while even 69,9 % was unsuitable.

Table 4 shows the areas of individual suitability classes according to geomorphological units of Istria County. In the area of "White Istria" permanently unsuitable soils for irrigation predominate. In the area of "Gray Istria" limited and moderately suitable soils predominate, while in the area of "Red Istria" moderately suitable soils for irrigation predominate.

The spatial distribution of soils with different degrees of suitability for irrigation on agricultural land of Istria County is shown in Figure 8.

Table 4. Area of suitability classes for irrigation on agricultural land according to geomorphological units (ha)

Sutability classes	White Istria		Gray Istria		Red Istria		Total	
	Used	Unused	Used	Unused	Used	Unused	Used	Unused
S-1			813,4	377,0	1.426,4	283,9	2.239,8	660,9
S-2			4.195,8	6.953,8	24.422,7	18.343,8	28.618,6	25.297,6
S-3	77,7	442,9	7.381,8	11.684,3	893,6	1.287,8	8.353,1	13.415,0
U-1			2.297,8	2.290,3	208,5	109,9	2.506,3	2.400,2
U-2	868,2	5.757,8	895,0	1.974,1	10.584,9	11.375,5	12.348,1	19.107,4
Total	**945,9**	**6.200,7**	**15.583,8**	**23.279,5**	**37.536,2**	**31.400,8**	**54.065,9**	**60.881,0**

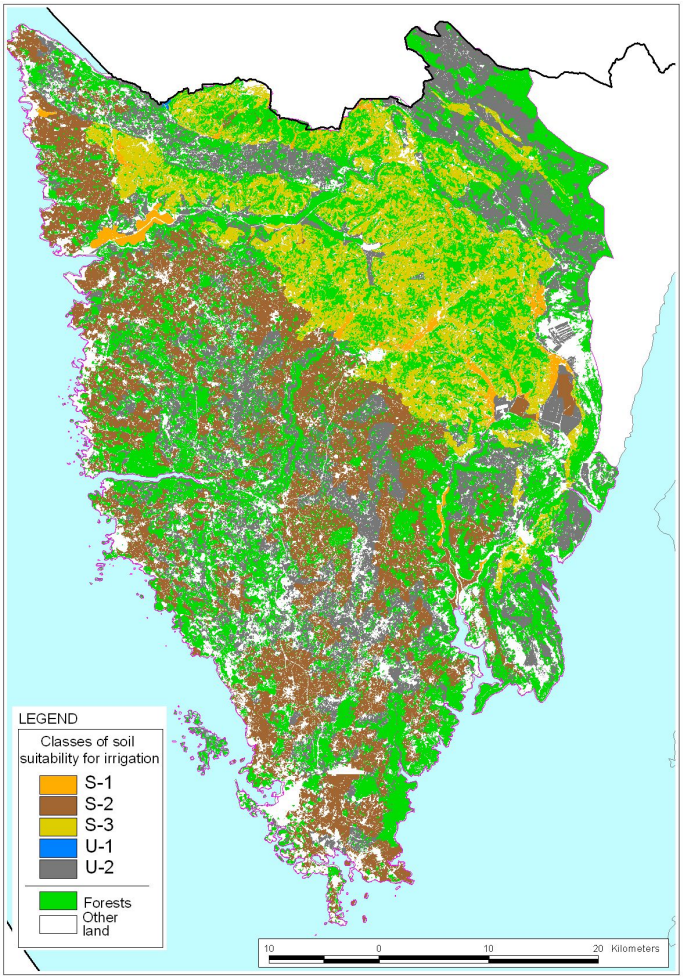

Figure 8. Map of soil suitability classes for irrigation

The soils of S-1 and S-2 classes of suitability are characterized by limitations that do not significantly affect the application and benefits of irrigation.

Soils of other classes are characterized by numerous limitations for the application of irrigation, of which the most significant are: rockiness, stoniness, terrain slope, shallow ecological depth, poor drainage, vertic properties and long-lasting occurrence of excessive moistering by groundwater and/or stagnant surface water. The removal of these limitations is a precondition for the application of irrigation systems on such soils.

Conclusion

Regarding the geomorphological units in the County of Istria, in the area of "Red Istria" there is 60,0 % of the total agricultural area, in the area of "Gray Istria" 33,8 %, while in the area of "White Istria" there is only 6,2 % of total agricultural area.

Of the total area of agricultural land in the "Red Istria", 54,5 % of the area is being used, in the "Gray Istria" 40,1 % of the area, and in the "White Istria" only 13,2 % of the area is being used. The representation of unused agricultural area in all geomorphological units is significant.

The total area of suitable soils for irrigation in "White Istria" is 520,6 ha (or 7,3 %). Only 15 % is on used land, while 85 % is on unused land. In "Gray Istria" there are 31.406,1 ha (80,8 %) soils suitable for irrigation. The smaller area is on used agricultural land (39,5 %) while the larger area is on unused land (60,5 %). In "Red Istria" 46.658 ha (67,7 %) soils are suitable for irrigation. Here, a larger area is on used agricultural land (57,3 %) while a smaller area is on unused land (42,7 %).

Maintaining effective soil fertility in irrigation conditions presupposes regular control of the condition and changes in the basic fertility factors, that is, the condition of the water-air and nutritional regime, especially for the use of soil in the intensive crop rotation.

The area of Istria Country is an area with significant land resources and great opportunities and irrigation demand, taking into account that the application of irrigation should provide sufficient water of good quality under present agroecological conditions (climate, soil, relief, and plant).

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