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LAND SUITABILITY FOR OLIVE IRRIGATION. CASE STUDY: POSTIRA ON THE ISLAND OF BRAČ

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Abstract

The most relevant method to improve olive production in Mediterranean climate conditions is irrigation. The aim of this study was to evaluate the land suitability for olive irrigation in an area of 482 ha located in the northern part of island of Brač (Postira municipality). Olive trees have been sparsely planted without irrigation with densities of traditional groves between 70 and 150 tree/ha, and the soil periodically tilled. Evaluation of land suitability was based on detailed soil surveys and analyses of natural characteristics (terrain, climate, geology, hydrology and land use) according to FAO concept. In the research area dominant soil type is Terra rossa formed on the Cretaceous limestone and dolomites, partly terraced on steep slopes. The factors influencing the land suitability for irrigation were: physical soil properties (texture, soil depth/rooting depth), stoniness, rockiness that determine permeability and available water capacity, slope and possibility of using mechanized tillage. Integration, processing and analysis of soil and terrain parameters were performed in the GIS environment. This research has shown a wide range of land suitability for olive irrigation. Land suitable for olive irrigation covers area of 139.0 hectares (28.5% of total area). Moderately suitable, temporarily and permanently not suitable land covers 105.3 ha or 21.8% of total area. The largest area (237.7 ha or 49.3%) covers permanently not suitable land for olive irrigation. Conducted qualitative assessment of land suitability for olive irrigation is a good basis for decision-making and individual farmers in planning the development of olive production.
Key words: land, suitability, irrigation, olives

Introduction

Soil water deficit, especially in the summer –during the vegetation period, is one of the most limiting factors of agricultural production in the Mediterranean climate. In the Croatian Mediterranean region olive is the dominant crop, usually in extensive farming on marginal lands. Municipality of Postira has the biggest olive production on the island of Brač. It is a typical example of the described conditions and the irrigation is necessary agro-technical measure for its improvement. The aim of this study was to evaluate the land suitability for olive irrigation.

Study location

Postira municipality is located in the northern part of island of Brač (Adriatic Sea, Croatia) and occupies 480 ha. Investigated location has a Mediterranean climate (Csa) in the Köppen climate classification with hot, moderately dry summers and mild, wet winters. The average annual rainfall was 734 mm (Split, 1981-2000). Indicator of extreme drought in summer period is the lowest monthly average rainfall in July (22 mm). The average annual temperature for the study period was 16.2º C, with a monthly mean temperature of the warmest month - July 26.1º C and 2698 hours of annual sunshine.

Geologically, the investigated area is made of Cretaceous - Senonian limestone and crystalline dolomites and Quaternary Colluvium skeletal deposites (Marinčic, et all, 1969). Geomorphological structure is characterized by typical karst phenomena and can be distinguished following units: a very steep slope, terraced slopes, flat plateaus and narrow and elongated uvale and doci. The largest area occupied terrains with steep slopes (15-25 degrees). Although, there is no surface water streams, because very developed and expressed relief forms represented a large number of torrents.

Material and methods

Data sources

The evaluation was conducted using the following: Soil map at the scale 1:5,000 (Miloš, B. 2006), Digital ortho-photo (DOF), 1:5000; Basic Topographic Map of Croatia 1:5000 (BTMC); Geological map 1:100,000 (Marinčic, et all, 1969). Data on the structure of agricultural production and the land use of the municipality Postira were taken from the Census of Agriculture (2003) and the Spatial Plan of the municipality Postira in 2002.

Field work

Field pedocartographic research was carried out according to the methodology of making detailed soil maps. A total of 32 soil samples were taken from 18 soil profiles during the soil survey.

Laboratory investigation

On collected soil samples laboratory analysis were carried out by following methods: pH (ISO 10390:2004), humus content (Kotzman method), total carbonate content (ISO 10693:2004), content of available phosphorus and potassium (ammonium lactic method, JDPZ, 1966) and texture (ISO 11277:2004).

Integration, processing and analysis in the GIS environment

GIS is typically used to store and analyze spatially referenced data in a map based format. The entire cycle can accordingly be subdivided in four stages: 1.Collecting geo-spatial data; 2.Transfer the collected data to a format that is appropriate for further processing (preprocessing); 3.Analysis of the land parameters, and 4.Visualisation, editing and presentation. Based on the digital terrain model (DTM) developed in GIS environment using the topographic map (BTMC) at 1:5000 we have created maps of slope and elevation. Map of olive groves we have made by digital ortho-photo (DOF). In this research overlay method has been used to evaluate land suitability. Overall the database is ready to use by the software package Arc View 3.x. All spatial data are geo-referenced to the national coordinate system (Zone 6 Gauss-Krueger projection).

Land evaluation

Land suitability for olive irrigation is based on the FAO’s framework for land evaluation (FAO, 1976) and subsequent guidelines (FAO, 1983 and FAO, 1985). This is considered to be a standard reference system in land evaluation throughout the world (Purnell, M.F. 1979; Dent and Young, 1981; van Diepen et al., 1991; Smyth, A.J. and Dumanski, J. 1993). Land suitability for irrigation of olive groves was performed using soil parameters (soil depth and rooting depth, soil texture, rockiness and stoniness), topographic (slope and elevation), growth conditions (age and vitality of olive groves, the possibility of additional planting) and the possibilities of applying of mechanized tillage.

Results and discussion

The characteristics of the olive orchards

Spatial distribution of olive orchards is shown on enclosed map (Figure 1). The total area of olive orchards is 482 ha with 52.346 olive trees, average 109 trees per ha. The fundamental feature of the

olive orchard is large spatial variability of all olive indicators: age, vitality, vigor, appearance, growth technology, spacing between trees etc., on small area and especially their large spatial fragmentation. The lush and vital olive trees are in suitable soil conditions, on steep slopes with shallow soils dominated old and scrubby trees with poorly developed crown. The growth and yields of these olives are low and irregular.

The characteristics and classification of the studied soils

Variety of soil forming factors, especially of topography, parent material and human impact resulted in large variability of soil (and land) properties important for olive groves (soil and rooting depth, chemical and physical properties, rockiness and stoniness of terrain). Based on field soil survey (Miloš, B. 2006), laboratory analysis of soil samples and using soil classification (Škoric, A. et all 1985) soils of described location we classified as follows: Anthropogenic soil from Terra rossa on limestone and dolomites, Anthropogenic soil terraced from Terra rossa on limestone and crystalline dolomite and Anthropogenic soil on Quaternary colluvium. Subdivision into lower units is according to criteria relevant for their fertility: soil depth and gravel.

Anthropogenic soil from Terra rossa on limestone and dolomites

The basic morphological feature of this soils is characteristic reddish brown color (2.5 YR3/4 and 5YR 3/4; Munsell Soil Color Chart). Soil depth varied from extremely shallow (<15 cm) to deep (>70 cm) and it is related to layering of limestone and dolomites, as well as slope. Analyzed soils are non carbonate to medium carbonate with weakly acid to alkaline reaction. The entire soil profile has a very good humus supply while physiologically active nutrients phosphorus and potassium varied in a very wide range (Table 1). These soils dominantly have clayey and silty clayey texture and very good expressed polyhedric structure. Soils varied from non gravel to extreme gravel (>75% of gravel). Important limiting factors for mechanized soil tillage, rockiness and stoniness, varied in wide range 0-75%.

Anthropogenic soil terraced from Terra rossa on limestone and crystalline dolomite

The essential feature of these limestone-dolomites sediments is lower water permeability in relation to typical limestone. That is why they keeps more water and provides lateral percolation. Surface P1 horizons of these soils are reddish and reddish brown color (2,5 YR3/4 and 5YR 3/4) typical for previously described Terra rossa. These soils have a low content of carbonates and neutral to weakly alkaline reaction. They also have a good supply of humus like Terra rossa on limestone, medium stokes of potassium and low content of physiologically active phosphorus (Table 1). According to soil texture analyzed soil samples are non gravel and weakly gravelly loams to clay, in average loamy clay with polyhedric structure.

Anthropogenic soil on Quaternary colluviums

These soils occupied doce and uvale at the base of steep slopes. The properties of these soils are defined by composition of colluvial sediments, in particular by relationship between limestone gravels and soil particles.

These soils are dominantly extremely deep and gravelly. Total content of carbonate and soil reaction varies depending on limestone gravel content. Analyzed soils have low to high carbonate content, in average medium (15.4% in P1 horizon and 16.2% u P2 horizon) and neutral to alkaline reaction. Humus content is medium. Physiologically active potassium and phosphorus in these soils also varies greatly and in some samples have a high values which indicates strong and irrational fertilization, in particular by phosphorus. Gravel content varies from low (<25%) to extreme (>75%). According to soil texture, these soils are gravelly and very gravelly clayey loams and gravelly clays.

Table 1: Mean minimal and maximal values of chemical properties and soil texture of anthropogenic soils

Soil type Horizon/ depth	Statistics	pH		$CaCO_3$	Humus	K_2O	P_2O_5	Soil texture			
		H_2O	nKCl					Coarse sand	Fine sand	Silt	Clay
				%	%	mg/100g.		2-0.2	0.2-0.02	0.02-0.002	<0.002
Antr. soil from Terra rossa P1(0-30)	Mean	7,82	6,82	2,2	6,83	33,9	11,8	15,1	20,1	22,7	42,1
	Min	6,53	5,36	0,4	3,43	18.0	0,3	3,1	13,1	13,7	27,9
	Max	8,39	7,28	9,6	10,67	60,2	48,8	30,2	27,4	30,5	61,8
P2(30-60)	Mean	8,07	7.00	5,2	6,37	20,5	6,3	11,4	19,7	25,9	43,1
	Min	7,55	5,80	0,4	4,43	11,3	1.0	2,3	7,1	13,3	21,7
	Max	8,33	7,72	27.0	8,70	46,1	22,6	33,9	30,1	40.0	65,5
Teraced soil from Terra rossa P1(0-30)	Mean	8,05	7,15	11,4	6,44	28,7	1,8	16,2	24,1	25,3	34,4
	Min	7,85	6,65	0,4	4,16	21,2	0,3	3,1	18,5	19,7	20,2
	Max	8,39	7,38	22,9	8,35	46,6	2,9	26,8	33,3	30,5	51,5
P2(30-60)	Mean	8,24	7,31	8,1	6,78	14,9	1,45	18,4	19,9	26,5	35,3
	Min	8,15	7,10	1,7	5,68	11,3	1.0	3,7	19,1	24,5	21,7
	Max	8,33	7,72	25,4	7,88	18,5	1,9	33,1	20,7	28,5	48,8
Antr. soil on the Quat. colluvium P1(0-30)	Mean	7,92	7,19	15,4	7,42	89,4	68.0	17,5	17,6	24,9	42.0
	Min	7,83	7,12	8,3	4,60	63,5	57,1	8,4	12,1	7,8	33,2
	Max	8,02	7,29	35,1	8,77	121,9	80,1	30,4	24,7	35,6	49,7
P2(30-60)	Mean	8,08	7,29	16,2	5,61	60.0	15,5	14,5	15,6	27,6	42,2
	Min	7,91	7,12	7,8	4,10	27.0	2,2	6,1	9,3	13.0	29,1
	Max	8,25	7,44	36,3	7,47	121,9	32,8	41,5	19,3	36,7	64,6

Topography

Topographic analysis included the calculation and making maps of the slopes and elevation. The area and percentage share of each class of inclination and elevation are shown in Tables 2-3.

Table 2: Area of the olive orchards inclination classes

Inclination (degree)	<2	2-6	6-9	9-12	12-17	17-24	24-33	>33	Total
Area (ha)	67	82	75	61	60	72	60	3	482.0
Percentage (%)	14.0	17.1	15.6	12.7	12.5	15.0	12.5	0.6	100.0

Flat terrain and those with gentle slopes (< 9°) occupy 224 ha or 46.5% of area, while steep slopes (>9°) occupy 256 ha or 53.5% of area.

Olives are grown in range from sea level to over 350 m altitude. The water reserves on the land are on altitude of 150 m. Consequently, terrains above that altitude are less suitable for irrigation.

Table 3: Area of the olive orchards elevation classes

Elevation (m)	0-50	50-100	100-150	150-200	200-250	250-300	>300	Total
Area (ha)	7,9	74,8	123,4	185,3	44,0	39,1	7,5	482,0
Percentage (%)	1,6	15,5	25,6	38,4	9,1	8,1	1,6	100,0

Land suitability for olive irrigation

Evaluation of land suitability for olive irrigation is based on expert review and GIS tools. Summary of the land evaluation for olive irrigation appears in Table 4-5 and in Figure 1. Limiting factors are numerous and serious, such as soil depth, slope, rockiness and stoniness.

Table 4: Land suitability classes and limitations for olive irrigation

Class suitability	Description of the limitation*
S1	Highly suitable. Without limitations
S2	Moderately suitable. Moderately serious limitations (d/rd, g)
S3	Marginally suitable. The limitations are serious (d/rd, g, sr)
N1	Not currently suitable. Land with limitations (d/rd, s, g, sr, otc) that could be eliminated by technical means or investment, but that these changes are at present unfeasible
N2	Permanently not suitable. Serious limitations of generally a physical nature, which are assumed to be beyond solving over the long term (d/rd, s, g, sr, otc, e)

**d- soil depth; rd- rooting depth; g- gravel; s – slope; sr- stoniness and rockiness, e- elevaton: otc- olive tree condition*

Four mapping units of suitability were separated, of which three were complex (made up of two or more suitability classes). Land suitable for olive irrigation (Suitability order S; mapping units S1-S2 and S2-S3) covers area of 139.0 hectares (28,5%). Complex unit (Moderately suitable, temporarily and permanently not suitable land (S3-N1/N2) covers 105.3 ha or 21,8% of total area. Permanently not suitable land for olive irrigation occupy 237.7 ha or 49.3% of total area. These results show that the area of land suitable for olive irrigation is very limited.

Table 5: Description and area of mapping units of land suitability for olive irrigation

Class suitability	Mapping units of land suitability for olive irrigation				Total area
	S1-S2	S2-S3	S3-N1/N2	N2	
Area (ha)	68,3	70,7	105,3	237,7	482,0
%	14.2	14.7	21,8	49.3	100,0

Conclusion

Conducted evaluation found that the suitable land for olive irrigation on analyzed location are very limited amounted 139 ha or 28.5% of total area. On the rest of area land limitations are such that they cannot be changed (soil depth, slope, rockiness and stoniness). To improve efficiency of management and olive production we suggest implementation of irrigation system on suitable land.

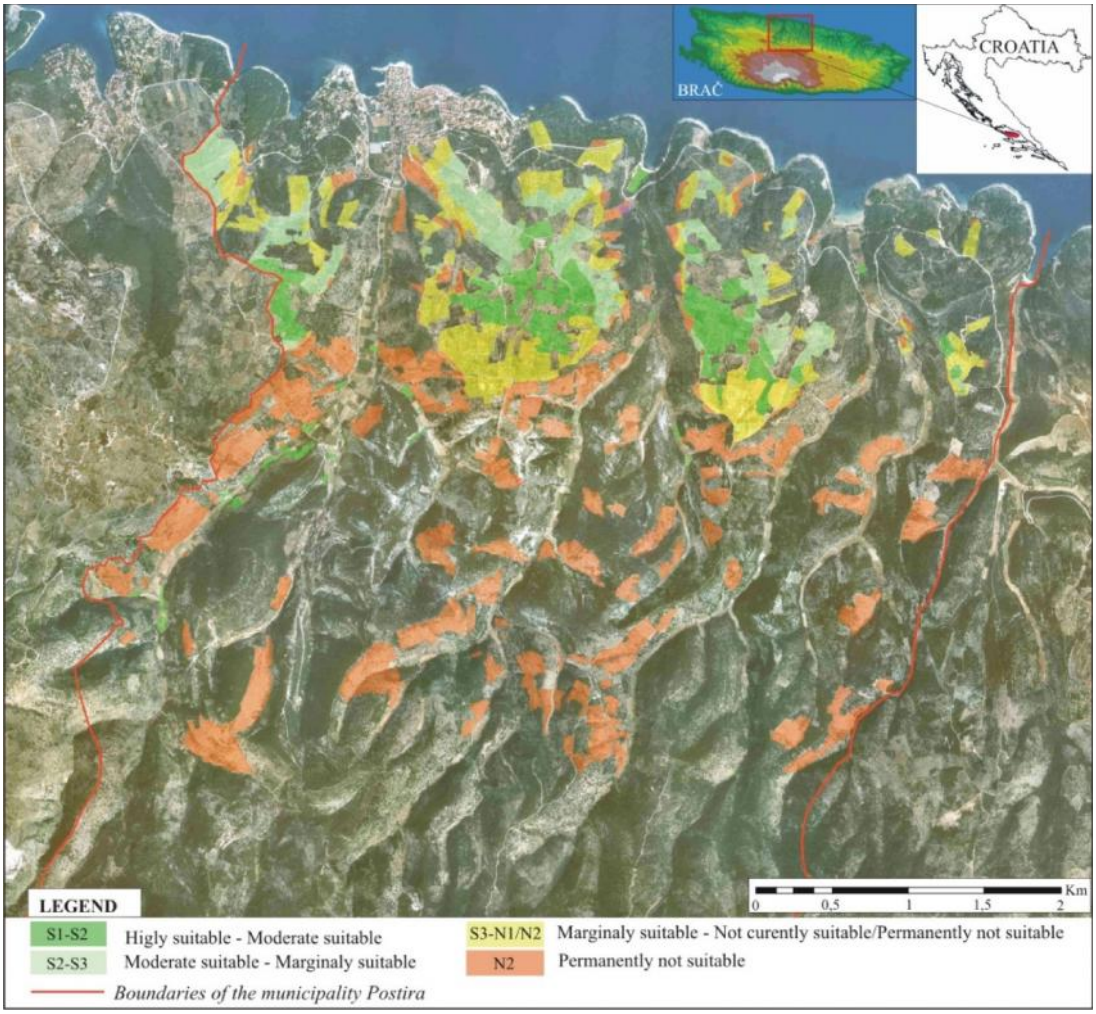

Figure 1: Land suitability map for olive irrigation

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