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DROUGHT MANAGEMENT MODEL SUGGESTION FOR THE SUSTAINABLE AGRICULTURAL PRODUCTION. SILIVRI REGION

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Abstract. The earth zone will come into intensive and long-term dry periods. It is essential to take precautions mainly for providing continuous food production and saving and planning water supplies against this natural disaster which impacts will rapidly increase in the near future. In this project, a model has been proposed which will provide the optimum water consumption and continuous agricultural production. The Silivri district was chosen as study area because it has got the highest agricultural potential in the province of Istanbul. All data which have been carried by 1:25 000 scaled soil map, air photos, satellite images and fieldworks are stored in a GIS database. Through the quarries in terms of topoghraphical database and physical and chemical soil characteristics, land use suitability classes (LUSC) have been determined and mapped. Further water-holding capacity of the agricultural land was determined according to the soil texture. Also the existent agricultural crops in the region and the new proposed agricultural crops, which can be able to adapt to changing conditions, have been listed. Consequently an agricultural crop pattern has been designed for the Silivri region against the drought periods by means of water-holding capacity of soil, annual water consumption of plants and LUSC.

Keywords: sustainable agricultural production, drought management, land use suitability classes (LUSC), crop pattern design.

AIMS AND BACKGROUND

Nowadays, one of the most important environmental issues is climate change and its probable negative effects. The first one of these effects results in decrease in water supplies. Significant changes have occurred in the climate of the Earth over the past hundred years. Climate change experts predict that the year 2007 will be the warmest year on record globally. Global warming is one of those environmental issues that are most closely linked to socio-economic development[1]. The average annual temperatures increased with 0.2–0.6^{o}C, and the precipitation decreased with 10–50 mm towards the averages per 1 hundred years[2].

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The changes in the precipitation regimes cause the difficulties to achieve the fresh water and consequently the water scarcity. In the Mediterranean region, the competition for water consumption among urban, agricultural, industrial, and environmental demands is strongest in times of water scarcity. Precipitation decreases may likely be translated into drought periods in most cases. Nevertheless the water scarcity not only depends on drought or precipitation deficits but also on the water management[3].

Irrigated agriculture counts for some 70% of total water withdrawals. At global level roughly 7000 billion m^3/year water are at present required for food production, from which 1800 billion m^3 are supplied by irrigation, the other 5200 billion m^3 coming directly from precipitation. Globally water is not limiting for agriculture. But heterogeneity prevails and some countries will increasingly face different forms of water scarcity[4].

Scarcity of water resources and growing competition for water in many sectors reduce its availability for irrigation. Effective management of water for crop production in water scarce areas requires efficient approaches. Increasing crop water productivity and drought tolerance by genetic improvement and physiological regulation may be the means to achieve efficient and effective use of water[5].

The first one of the urgent preventions for the drought management is the planned and optimised water management. Minimum savings in high water consumpting agricultural activities will be gained as an important supply to decrease the greater absence in other sectors. For the optimised agricultural irrigation it is necessary the agricultural land use planning. Land use suitability class (LUSC) is becoming important in terms of agricultural land use planning. LUSC is a process which compares the land characteristics, land use classes and land demands and aimed to compose a database for the agricultural land use planning. There are some requirements like land topography, physical and chemical characteristics of soil and irrigation levels. Finally the land quality of region determination and comparison with land demand and the regional LUSC database are achieved by means of GIS-supported mapping methods[6–8].

By the negative impacts on agricultural production, drought represents the main risk factor in the potential decreasing of food production. One of the solution for the prevention the production decrease due to drought conditions is the crop pattern design. The temporal divergence in crop pattern has direct implications on geospatial approach of drought assessment[9]. Crop pattern design is related directly to surface and ground water supplies. Optimal crop planning through the conjunctive use of surface and groundwater is necessary for the agricultural development[10]. Several studies noted that an ecologically sound solution can be found in alternative agricultural practices and cropping systems for the agricultural sustainability and the optimised food production against the water scarcity[11–13].

The Silivri district has got very high agricultural potential, although its agricultural potential has yearly 521–708 mm precipitation. So its yearly precipitation value is one of the lowest in the Istanbul province. Therefore drought management is becoming very important in Silivri.

In this study, a model has been proposed which will provide the optimum water consumption and sustainable agricultural production. Through the querries in terms of land use map, topoghraphical database, physical and chemical soil characteristics and irrigation levels, LUSC have been determined and mapped with water holding capacity separately. Consequently an agricultural crop pattern was designed for the Silivri region against the drought periods by means of water holding capacity of soil, yearly water consumption of plants and LUSC.

EXPERIMENTAL

Study area. The Silivri district is chosen as study area. It is a region in the west side of the Istanbul province which is located in the Marmara region in Turkey and has 86 200 ha area (Fig. 1). Silivri is a neighbouring district near to the Corlu district in the Tekirdag province. The largest land use type are forest areas and rainfeed agricultural areas, respectively (Table 1). Forest areas are located on the north side of the region. The agricultural areas are located consistently between the forest areas and the settlement areas on the coastal region together with some agricultural areas in the forest areas.

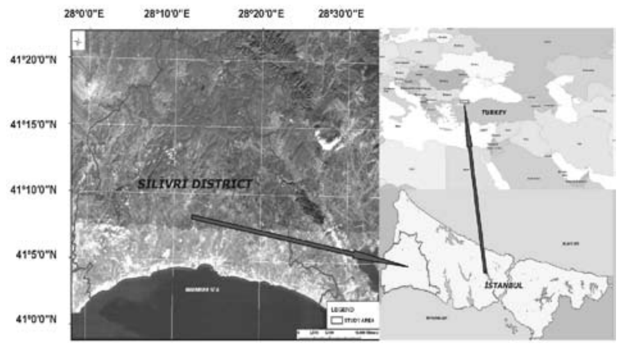

Fig. 1. Study area

Table 1. Land use in the Silivri district

Land use	Area (ha)
Rainfeeed agricultural areas	34772.30
Irrigated agricultural areas	1351.19
Marginal agricultural areas	13382.48
Forest areas	28319.37
Forest 2B areas	1902.61
Meadows and pastures	1176.60
Lake and ponds	96.31
Mining areas	29.30
Settlements	5285.25
Total	86215.39

The Silivri district is one of the few regions which has got intensive agricultural activity in the Istanbul province. Almost 4946.6 ha irrigated and insufficiently irrigated area are available throughout Istanbul. 68% of irrigated land are located in the European part and they are mostly in the Catalca and Silivri districts. Also 123 624.4 ha rainfeed agricultural land are available throughout the Istanbul province. Of these areas, 109 192 ha are in the European part of Istanbul and 48% of them are in the Silivri district. Approximately 57% of wheat planting areas are in Silivri.

Material and method. 1:25 000 scaled digital soil database maps, land use maps, Ikonos satellite image (2008 dated, an 1-m resolution) and air photos are used for the study. Groundwater condition in the region are taken from the General Directorate of State Hydraulic Works. Water consumption values of the plants in the region are taken from the Ministry of Agriculture and Rural Affairs. All data are stored in a GIS-supported database system. ArcGIS ArcInfo 9.2 software is used for the data processor. The flow diagram of the study is shown in Fig. 2.

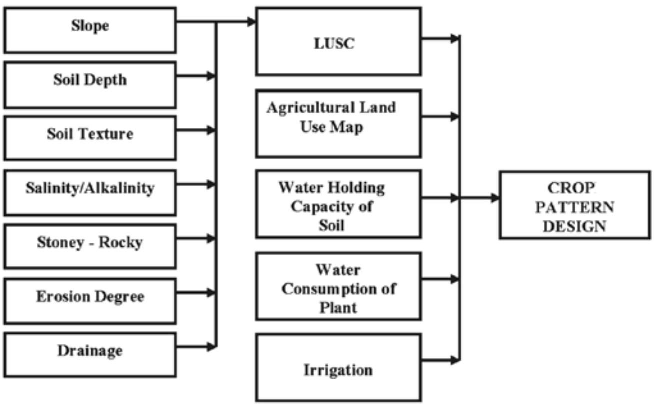

Fig. 2. Flow diagram

Determining LUSC. The parameters of soil inventory used for determining the LUSC are named as slope class, soil depth, soil texture, salinity/alkalinity, stoney/rocky, erosion degree and soil drainage. Each parameter is rated and scored according to the former American soil classification by Baldwin et al. (1938). So each parameter is divided into subdivisions and scored between 0 and 1 according to the quality classes of each subdivisions. While scoring the quality classes of subdivisions of the parameters a value given close to 1 under the best quality conditions and close to 0 under the worst quality conditions of the subdivisions. For example, the quality class of slope parameter scored 0.8 point while its slope value has the miniumum degree (0–2%) and 0.1 while its slope value has the maximum degree (>30%) (Table 2). Later the weighted average values of the subdivisions of parameters are calculated which has been scored between 0 and 1. Then the index values are calculated through the arithmetic means of the weighted average values of the subdivisions. Each index value consists of only one subdivision value of each parameter. Subsequently calculated index values are graduated between 1 and 100 and the LUSC is determined according to the graduated index values. The formulation and the LUSC results are given below.

Table 2. Parameters rated and scored according to the former American soil classification by Baldwin et al. (1938)

Parameters	Classification	Index point	Parameters	Classification	Index point
Slope	% 0–2	0.8	salinity/	none	0.8
	% 2–6	0.7	alcalinity	h	0.6
	% 6–12	0.6		s	0.4
	% 12–20	0.4		a	0.4
	% 20–30	0.2		k	0.2
	>% 30	0.1		v	0.1
Soil depth	>90 cm	0.8	stoney/rocky	none	0.3
	90–50 cm	0.6		t	0.2
	50–20 cm	0.4		r	0.1
	20–0 cm	0.2	erosion degree	none	0.4
	litosolic	0.1		low	0.3
Soil texture	M	0.6		medium	0.2
	F	0.4		high	0.1
	H–S	0.2	drainage	well	0.4
	L/V	0.1		imperfectly	0.2
				poorly	0.1

Calculating the weighted average value of each subdivision of each parameter (P) we have the following:

$$P = (ab) / n,$$

where a is scored point for each subdivision of each parameter according to the quality classes; b – subdivision number of each parameter; n – total subdivision number.

Determining index value (S) as following:

$$S = \sum P/z,$$

where P is weighted average value of each subdivision of each parameter (each index value consists of only one subdivision value of each parameter); z – number of total parameters.

Index value (S)		% Value		LUSC		Suitability
0.087–0.079	→	100–85	→	S_1	→	very suitable
0.079–0.070	→	85–65	→	S_2	→	suitable
0.070–0.060	→	65–45	→	S_3	→	low suitable
0.060–0.039	→	45–1	→	N	→	no suitable

Water holding capacity of soil. Water holding capacity of soil is an important factor for optimum use of water which is very important input for the sustainable agricultural production. Soil texture database is used for determining the water holding capacity. Mainly 3 soil texture types are determined in the region named as clay (C), clay loam (CL) and sandy loam (SL), respectively. Soil texture types affect the water holding capacity. Clay and clay loam has higher water holding capacity than sandy loam. Consequently the regions determined as most suitable for the agricultural using and have the highest water holding capacity of soil by means of quarry of the digitally LUSC values and digitally soil texture values by GIS supported database system.

Water consumption of plants. The publication named as 'Water Consumption Guide for the Irrigated Plants in Turkey' which has been prepared by the Ministry of Agriculture and Rural Affairs[14] is used for determining the water consumption of the plants in the Silivri region. There is no direct water consumption data for the Silivri region in publication. For this reason water consumption values in the Corlu district in the Tekirdag province are used for the study. Corlu is a neighbouring district near to the Silivri region and climate conditions and land chractarestics in the Corlu region are similar to the Silivri region. The agricultural lands in both districts show continuance and integrity of each other. The water consumption values of the mainly agricultural products in the region are shown in Table 3.

Table 3. Monthly water consumption of plants (mm)

Plant	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Clover	30.1	80.1	153.4	240.2	259.8	304.2	165.2	19.7[b]
Wheat	30.1	84.9	225.5	129.1	8.8[b]			
Barley	68.9	43.2	130.5	204.2				
Sunflower		48.6	75.5	223.7	250.9	97.6		
Corn		25.3	75.5	170	205	112	37.1	
Melon		14.4	41.2	87.1	91.9	94.3	16.9	
Potato		10.3	88.1	135.1	212.1	96	31.5	
Sugar beet		30.1	54.9	202.7	220.9	208.2	137.1	
Bean		30.8	50.4	144	209	66.7	14.6[a]	
Vetch		51.4	107.6	193.7	24.7			
Tomato			30.9[c]	174.2	219.1	193.6	110.2	75.3[b]
Pepper			82.4[c]	64.6	160.8	245.6	179.8	75.3[b]

[a] 10-day water consumption; [b] 15-day water consumption, [c] 20-day water consumption.

RESULTS AND DISCUSSION

Through the quarries in terms of topoghraphical database and physical and chemical soil characteristics, LUSC have been are determined and mapped. LUSC values in the Silivri district are determined as very suitable (S1) and suitable (S2) mostly according to the 1:25 000 scaled agricultural land use map. LUSC value of the irrigated agricultural land in Silivri is generally S1 class. Agricultural land use and LUSC results in Silivri are shown in Table 4 and Fig. 3.

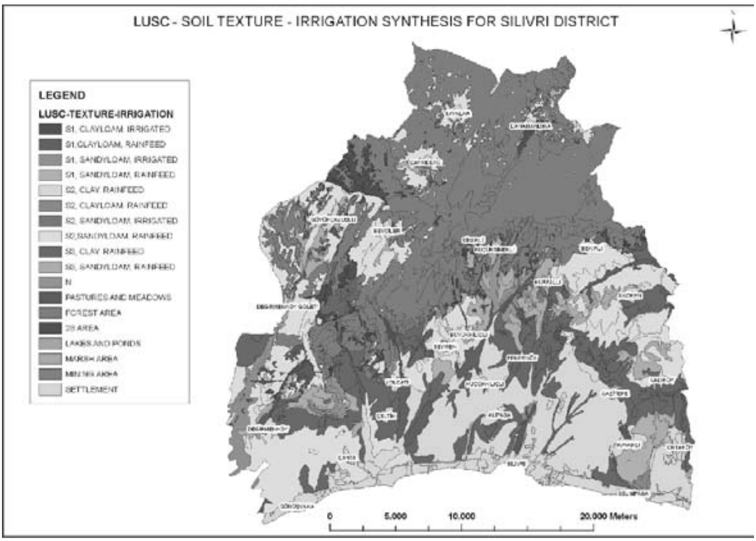

Fig. 3. Synthesis of LUSC–soil texture–irrigation

Table 4. Land use and LUSC in the Silivri district

LUSC–texture–irrigation	Area (ha)
S1 – clayloam, irrigated	187.10
S1 – clayloam, rainfeed	1536.71
S1 – sandyloam, irrigated	1039.87
S1 – sandyloam, rainfeed	1285.48
S2 – clay, rainfeed	9725.58
S2 – clayloam, rainfeed	284.68
S2 – sandyloam, irrigated	122.79
S2 – sandyloam, rainfeed	17225.82
S3 – clay, rainfeed	11921.29
S3 – sandyloam, rainfeed	4875.14
N	1200.48
Pastures and meadows	1176.60
Forest area	28319.37
2B area	1902.61
Lakes and ponds	96.31
Marsh area	1.02
Mining area	29.30
Settlement	5285.25
Total sum	86215.39

Groundwater potential in Silivri is very high. The Silivri region is a high level groundwater drawing area according to the General Directorate of State Hydraulic Works. The total area of suitable (S1) and very suitable (S2) agricultural areas in the region is about 31 400 ha. But the total area of the existing irrigated agricultural land is about 1300 ha. Suitable agricultural areas are mostly rainfeed areas. Increasing the possibility of the irrigation will provide the higher agricultural production and yield in the region which has mostly suitable and very suitable areas for agricultural production.

The proposed crop pattern design in Silivri is determined according to LUSC, water holding capacity of soil, water consumption of plants and irrigation condition. Seasonal crop patterns of the plants which are growing in the region are shown in Table 5.

Table 5. Crop pattern design for the Silivri region

LUSC	Soil texture	Irrigation	Alternative crops for winter/summer rotation
S1	clayloam	irrigated	sugar beet, tomato, pepper, clover, vetch, rice
		rainfeed	corn, sunflower, canola
	sandyloam	irrigated	melon, watermelon, bean, vetch, cucumber, leek, potato, spinach, orchard
		rainfeed	wheat, barley
S2	clay	rainfeed	corn, sunflower, clover, vetch
	clayloam	rainfeed	vetch, wheat, barley, sunflower, canola
	sandyloam	irrigated	silage corn, tomato, potato, bean, pepper, soybean, orchard
		rainfeed	wheat, barley, vetch, sunflower
S3	clay	rainfeed	wheat, barley, canola
	sandyloam	rainfeed	wheat, barley, canola

CONCLUSIONS

Nowadays, one of the most important environmental issues are climate change and its probable negative effects. One of these effects results in decrease in water supplies. The earth zone including Turkey will come into intensive and long-term dry periods. It is essential to take precautions mainly for the providing the continuous food production and saving and planning water supplies against this natural disaster which impacts will rapidly increase in the near future. In this project, a drought management model has been proposed which will provide the optimum water consumption and continuous agricultural production in the Silivri district which has got the highest agricultural potential but the lowest yearly precipitation value in the province of Istanbul. LUSC of the agricultural areas have been determined and mapped for the Silivri district. Water holding capacity of the agricultural land was determined according to the soil texture. Also the existent agricultural crops in the region and the new proposed agricultural crops which can be able to adapt to changing conditions have been listed. Consequently an agricultural crop pattern has been designed against the drought periods for the Silivri region by means of water holding capacity of soil, yearly water consumption of plants and LUSC. According to the 1:25 000 scaled agricultural land use map LUSC values in the Silivri district are determined as very suitable (S1) and suitable (S2) mostly. Groundwater potential in Silivri is very high. Increasing the possibility of the irrigation will provide the higher agricultural production and yield in the region which has mostly suitable and very suitable areas for agricultural production.

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