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Irrigation, a Component of the Sustainable Agriculture in North Western Romania in the Context of the Climate Change

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Abstract

The paper is based on the researches carried out during 1976-2010 in the long term trial placed on the prelvosoil from Agricultural Research and Development Station Oradea. The main field crops of the area (wheat, maize, sunflower, soybean, bean, potato, sugarbeet, alfalfa) were studied. Based on the soil moisture determination ten to ten days, the soil water reserve was maintained between easily available water content and field capacity on the watering depth. Pedological and strong pedological drought (the decrease of the soil water reserve on watering depth bellow easily available water content, bellow wilting point respectively) were registered every year. The use of the irrigation determined the improve of the water/temperature + light (Domuta climate index) report, the increase of the daily and total water consumption, yield gains very significant statistically, the improve of the yields stability and yields quality, the increase of the water use efficiency. The use of the good soil management didn't worsen the soil structure and the chemical and biological parameters of the soil were improved. The researches sustain the irrigation opportunity for sustainable agriculture in the North-Western Romania.

Keywords: irrigation, yield level, soil water content, pedological drought

JEL Classification: Q15, Q54, Q25.

1. Introduction

The appearance of the sustainable agriculture concept is belong to the United National Conference for Human Environment from Stockholm in 1972 and "Broundland Report" of ONU Conference on Environment and Development from Rio de Janeiro. These were the crucial moments in definition of the development sustainable concept, especially sustainable agriculture. The researchers who published about this problem were Tinbergen (1956), Odum (1971), Clarck and Mun (1986), Hall (1995) and all (Domuța C., 2009b).

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There was in Romania in 1999 a reference moment regarding this problem, Hera.Cr, organized the symposium ”The performant sustainable agriculture”, scientifically manifestation of Plant Crop Section belonged to ASAS “Gheorghe Ionescu Şişeşti”. Many and interesting papers were presented in the symposium; those written by Puia and Soran, Toncea, Săulescu, Iliescu, Sin, Picu Hera 1999). Budoi and Penescu (1996), Guş and all (1998) in the treatises of Soil Management had an important contribution in knowledge of this concept, too. All these papers sustain the crop rotation like central pivot and presume a variation structure of crops. In this system, the organic fertilization it's very important, the chemical fertilization can be used with moderate rates, the soil tillage must be right executed, the plants protection is realized by integrated management; all this things assured the conservation of the soil, water and biodiversity reserve and obtaining an ecological and profitable yields.

If it's used correctly, the irrigation is a component of sustainable agriculture (Doorembos and Kassam, 1986, Doorembos and Pruitt, 1992, Domuța C., 2005, 2009).

2. Material and method

The researches were obtained in Oradea in the north part of Crişurilor Plain during 1976-2010, in a long term trial on preluvosoil.

On the ploughed depth, the preluvosoil has a hydraulic conductivity with big value, median on 20-60 cm depth and very small below 60 cm depth. On 0-20 cm depth the soil is small settled (BD = 1,41 g/cm3) and very settled on the irrigation depth of the crops studied and on the depth (0-150 cm) for soil water balance. Field capacity (Fc) is median on the all soil profile and wilting point (Wp) has a median value till 80 cm depth and big value below this depth. Easily available water content (Wea) was established by formula (Botzan 1966, Grumeza and all, 1989):

$$Wea = Wp + 2/3\ (Fc - Wp);$$

Soil reaction is low acid, the humus content (1,8%) is small and the total nitrogen content (0,127-0,156 ppm) is small- median; the mobile potassium content is small – median, too. The annual fertilization with the doses specifical for irrigated crops increased the phosphorus content from 22.0 ppm to 150,8 ppm.

The water source for irrigation is water ground (15 cm depth). The irrigation water has a low natrium content (12.9 %), the salinization potential is low (CSR = -1.7) and SAR index (0.52) is low too.

The irrigation equipment of the research field permitted to measure exactly and to distribute uniformly the irrigation water.

Soil moisture determined ten to ten days maintaining the soil water reserves on irrigation depth (0-50 cm for wheat and bean; 0-75 cm for maize, soybean, sunflower, potato, sugarbeet, alfalfa 1st year, maize for silo; 0-100 cm for alfalfa 2nd year) between easily available water content and field capacity.

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Domuța Climate Index was calculated after following formula:

$$ICD = \frac{100\ \mathrm{W} + 12{,}9\ \mathrm{A}}{\sum t\ +\ Sb}$$

Were:
W = water (irrigation, rainfalls, water ground)
A = air humidity, %
Σt = the sum of monthly average temperature, °C;
Sb = sun brilliance, hours

The climate characterization after ICD value is: < 3 excess droughty; 3.1-5.0 very droughty; 5.1-7.0 droughty; 7.1-9 median droughty; 9.1-12 median wet; 12.1-15 wet I; 15.1-18 wet II; 18.1-25 – wet III; > 25 excess wet.

The crops technologies wished to be the optimum one, for this part of the country. Crop rotation used were: alfalfa 1st year – alfalfa 2nd year- maize – bean – wheat – soybean – sugarbeet – sunflower – potato. The fertilization system had a rate of 40 t/hamanure for sugarbeet and potato and annual medium rate on crop rotation of N 140 kg/ha a.s., P 110 kg/ha a.s. and K 90 kg/ha a.s. were used. (Brejea R., 2010)

The structure of soil was determined with Cseratzki method and water consumption with soil water balance method; balance depth was 0 –150 cm.(Domuța C., 1995, 2003, 2009a)

The water use efficiency was calculated like report between the yield and water consumption (Borza I., 2007)

3. Results and discussions

3.1. The influence of irrigation on soil

A right leading of irrigation regime (through maintaining the soil water reserve between easily available water content and field capacity on irrigation depth), the application of melioration crop rotation and a organo-mineral system of fertilization for irrigated crops determined the realization of structured degree of 35.98%, with 3% bigger than structured degree determined in unirrigated wheat- maize rotation. In unirrigated melioration crop rotation the structured degree (47,52%) was bigger than the wheat – maize crop rotation with 34% (table 1).

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Table 1: The influence of the melioration crop rotation and irrigation on macrostructure stability of the preluvosoil, Oradea 1976-2010

Nr. crt	Crop rotation	Ø 5 mm		Ø 2 mm		Ø 1 mm		Ø 0.25 mm		Σ	
		Agreg %	Dif. %	Agreg %	Dif. %	Agreg %	Dif. %	Agreg %	Dif. %	Agreg %	Dif. %
1	Wheat-maize unirrigated	1.93	100	1.76	100	2.45	100	29.12	100	35.26	100
2	Melioration unirrigated	3.93	204	0.96	55	1.96	80	40.67	139	47.52	134
3	Melioration irrigated	0.56	29	0.63	36	1.12	48	33.42	114	35.98	103

3.2. The pedological drought

The periods with soil water reserve on watering depth below easily available water content on irrigation depth was considered the pedological drought. (Domuța C, 1995).

The pedological drought was present in each of 35 years reseached, the maximum frequency at wheat crop was established in June in wheat and in August in maize, sugarbeet and alfalfa. In potato the maximum frequency (92%) was registered in July (table 2).

In other years, soil water reserve on irrigation depth decreased below wilting point.

Table 2: Monthly situations of periods with soil water reserve below easily available water content on irrigation depth in main crops, in unirrigated conditions from Oradea, 1976-2010

Nr. crt	Crop	Specif.	Month					
			IV	V	VI	VII	VIII	IX
1	Wheat	1	12	21	24	10	-	-
		2	82	96	100	70	-	-
2	Maize	1	2	8	13	23	29	25
		2	21	46	79	88	100	92
3	Sugarbeet	1	6	10	21	26	28	24
		2	39	48	87	87	100	96
4	Potato	1	6	8	17	24	21	-
		2	35	54	83	92	83	-
5	Alfalfa 1st year	1	5	12	19	27	29	27
		2	35	65	96	96	100	100

1= Number of days with soil water reserve below easily available water content
2 = Frequency of days with soil water reserve below easily available water content

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3.3. The irrigation influence on microclimate

The irrigation determined the improvement of microclimate conditions. The value of report water/temperature + light (Domuța Climate Index, ICD) calculated for irrigated maize crop was bigger with 135% in August, 115% in July, 49% in June and 32% in May. In irrigated maize, the microclimate was characterized "median wet" vs "median droughty" in May, "wet II" vs "median wet" in June, "wet III" vs "median droughty" in July, "wet I" vs "droughty" in August (table 3).

Table 3: The modifications of the water/temperature + light report (Domuța Climate Index/ICD) under the influence of the irrigation in maize crop, Oradea 1976-2010

Variant	V		VI		VII		VIII	
	ICD	%	ICD	%	CD	%	ICD	%
Unirrigated	8.9	100	10.7	100	8.6	100	6.3	100
Irrigated	11.8	132	15.91	149	18.5	215	14.8	235
Variation interval of differences	0-383		0-302		0-795		28-3126	

3.4. The irrigation influence on water consumption

The irrigation determined the increase of the values of daily water consumption. In this case the total water consumption had values bigger than total water consumption of unirrigated crops, the differences was registered between 36.6% (wheat) and 108.4% (maize for silo double crop).

The most important part from total water consumption was covered with rainfalls registered in the period of the vegetation crops. For the assurance of optimum water consumption of these crops (maintaining the water reserve below easily available water content and field capacity) the irrigation was necessary every year; the participation averages in the covering sources have values between 33.7% (wheat) and 58.7% (maize for silo double crop); the maximum values of the variation interval were registered between 61.0% (maize) and 103.2% (maize for silo double crop), (table 4).

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Table 4: The water consumption Σ (e + t) and the covering sources, Oradea 1976-2010

Crop	Σ(e+t),m3/ha			Covering sources of Σ(e+t) optimum, m3/ha				
						Σm		
	Unirrigated	Irrigated	Difference Irrigated-Unirrigated %	Ri-Rf	Rv	m3/ha	%	Variation interval %
1.Wheat	3138	4289	36.6	535	2307	1447	33.7	0-61.8
2.Maize	4253	6223	46.3	509	3237	2477	39.8	13.5-61.0
3.Sunflower	3947	5900	49.5	933	2798	2169	36.8	6.2-63.0
4.Soybean	3828	5826	52.2	563	3049	2214	38.0	9.4-61.5
5.Bean	3211	4184	30.3	324	2472	1388	33.2	7.0-71.4
6.Sugarbeet	4618	6992	51.4	840	3459	2694	38.5	8.3-67.9
7.Potato	3803	5292	39.2	516	2953	1823	34.4	7.1-61.1
8.Alfalfa 1st year	4681	6698	43.0	525	3578	2595	38.7	9.1-64.7
9.Alfalfa 2nd year	5074	7791	53.5	945	3796	3050	39.1	14.3-61.2
10.Maize for silo 2nd crop	1378	2872	108.4	-145	1333	1685	58.7	10.5-103.2

Ri-Initial reserve; Rf-Final reserve, Rv-Rainfalls from vegetation period; Σm- Irrigation rate

3.5. The irrigation influence on yields level

The average of the yields obtained during 1976-2010 in irrigation conditions were bigger than in unirrigated conditions, the relative differences registered had the values between 39% (wheat) and 127% (maize for silo double crop).

The amplitude of the variation interval for yield differences between two variants was 104% at sunflower, 116% at wheat crop, 176 % alfalfa crop 2nd year, 218% sugarbeet crop, 291% at alfalfa 1st year, 353 % soybean, 358 % at potato, 800 % at bean, 806% maize for corn and 25745% at maize for silo double crop (table5).

3.6. The influence of irrigation on yield stability

The quantification of the yield stability was made using the “standard deviation” indicator. In all crops, the irrigation determined the increase of yield stability, the differences between standard deviations for irrigated and unirrigated conditions was 8.7% (sunflower) and 50.4% (maize for silo double crop) (table 6).

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Table 5: The level of yields in main crop, in irrigated and unirrigated conditions, Oradea 1976-2010

Crop	Variant	Yield level			
		Average		Variation interval	
		kg/ha	%	kg/ha	%
1.Wheat	Unirrigated	4547	100	2736-7100	100
	Irrigated	6343	139	3993-8300	105-221
2.Maize	Unirrigated	6608	100	1510-12600	100
	Irrigated	11993	181	17880-16480	107-912
3.Soybean	Unirrigated	1836	100	300-3400	100
	Irrigated	3087	168	1380-4080	107-460
4.Bean	Unirrigated	1439	100	180-2720	100
	Irrigated	2170	151	1321-3770	105-905
5. Sun flower	Unirrigated	2289	100	1350-3140	100
	Irrigated	3394	148	1757-4580	106-210
6.Sugar beet	Unirrigated	39895	100	18960-80900	100
	Irrigated	64453	162	44850-87800	109-327
7.Potato	Unirrigated	24137	100	11500-43700	100
	Irrigated	38284	159	20670-66050	106-464
8. Alfalfa 1st year	Unirrigated	45472	100	18500-89800	100
	Irrigated	69905	154	30500-120850	113-404
9. Alfalfa 2nd year	Unirrigated	60953	100	29500-118590	100
	Irrigated	96822	159	57000-145420	119-295
10. Maize for silo 2nd crop	Unirrigated	13890	100	0-31000	100
	Irrigated	31470	227	10160-44640	115-25860

Table 6: Standard deviation in unirrigated and irrigated crops, Oradea 1976-2010

Variant	Crops for grain									
	Wheat		Maize		Sunflower		Soybean		Bean	
	Kg/ha	%	Kg/ha	%	Kg/ha	%	Kg/ha	%	Kg/ha	%
Unirrigated	922	100	3271	100	580	100	814	100	820	100
Irrigated	642	69.6	1879	57.4	530	91.3	547	67.2	680	82.9
Crops for stalk and roots										
Variant	Sugarbeet		Potato		Alfalfa 1st year		Alfalfa 2nd year		Maize for silo 2nd crop	
	Kg/ha	%	Kg/ha	%	Kg/ha	%	Kg/ha	%	Kg/ha	%
Unirrigated	9240	100	9440	100	37950	100	30160	100	9310	100
Irrigated	6920	79.9	5480	58.1	33630	88.6	25720	85.3	4620	49.6

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3.7. The influence of irrigation on quality of yield

In irrigated maize, the quantity of total nitrogen in grain was bigger than unirrigated maize with 19.7%. Taking in consideration the yield differences between irrigated and unirrigated maize, results much more protein (135.4%) in irrigated conditions,(table 7).

The participation of the big potato in the yield of the irrigated variant was of 84.4% with 11.6% more than unirrigated variant (table 8).

Table 7: The influence of irrigation on protein content in maize corn, Oradea 1987-2010

Variant	Total nitrogen content in maize grain		The protein content in grains
	%	%	Kg/ha
Unirrigated	1.42	100	556.94
Irrigated	1.70	119.7	1311.52

The improve of the yield quality was registered in soybean and sugarbeet, too (Domuța Cr., 2010).

Table 8: The influence of the irrigation on the big tuberous participation from potato crop, Oradea, 1976-2010

Variant	The big tuberous participation		Variation interval of big tuberous participation
	Values %	%	Kg/ha
Unirrigated	75.6	100	71.6-82.5
Irrigated	84.4	111.6	80.1-92.4

3.8. The influence of irrigation on water use efficiency

Excepting the sunflower crop, in all the crops, the irrigation determined the improve of water use efficiency, for 1m3 water consumpted was obtained a bigger quantity of the main yield than unirrigated conditions, the relative differences had medium values between 2% (wheat) and 25% (maize for silo double crop), (table 9).

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Table 9: Irrigation influence on water use efficiency, Oradea 1976 – 2010

Variant	Crops for grain									
	Wheat		Maize		Sunflower		Soybean		Bean	
	Kg/m3	%	Kg/m3	%	Kg/m3	%	Kg/m3	%	Kg/m3	%
Unirrigated	1.45	100	1.55	100	0.58	100	0.48	100	0.45	100
Irrigated	1.48	102	1.93	125	0.58	100	0.53	110	0.52	115
	Crops for stalk and roots									
Variant	Sugarbeet		Potato		Alfalfa 1 st year		Alfalfa 2nd year		Maize for silo double crop	
	Kg/m3	%	Kg/m3	%	Kg/m3	%	Kg/m3	%	Kg/m3	%
Unirrigated	8.64	100	6.35	100	9.71	100	11.94	100	10.08	100
Irrigated	9.22	106.7	7.23	114	10.44	108	12.42	104	10.95	109

3.9. Correlations from soil –water- plant- atmosphere system

Over the years was quantified the correlations from soil – water – plant-atmosphere system for all researched crops (Domuța, 1995, 2009, Domuța Cr., 2010). In this paper were presented the correlations at one of important crop in this area which is maize.

Between number of days with water reserve below easily available water content and yield, respectively water use efficiency and between number of days with water reserve on irrigation depth below wilting point and yield determined an inverse links, statistically very significant. Between numbers of days with water reserve below easily available water content and yield gain obtained using the irrigation was quantified a direct link, statistically very significant.

A direct links, statistically very significant were quantified between microclimate conditions and yield, respectively between water consumption and yield. These correlations sustained the need of irrigation in maize from this area. (table 10).

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Table 10: Correlation in the soil – water – plant – atmosphere system in maize, Oradea 1976-2010

Nr. crt.	Correlation	Regression function	Correlation coefficient
Correlation between soil moisture stress and yield			
1	Nr.of days with WR<WP x yield	y = 601,33 x0,9047x	R = 0,88 ooo
2	Nr. of days with WR<Wea x yield	y = 158,88 e-0,0148x	R = 0,66 ooo
3	Nr. of days with WR<Wea x WUE	y = 3,5236 e-0,0144x	R = 0,62 oo
4	Nr. of days with WR<Wea x spor yield.	y = 0,0935 x-0,0127	R = 0,78 xxx
Correlation between microclimate and yield			
5	ICD x yield	y=-0,2931x2+13,57x-21,108	R = 0,88xxx

WR = water reserve on 0-75 cm depth; WP = wilting point; WEA = easily available water content; WUE = water use efficiency; kg/m3; ICD = Domuța Climate Index.

4. Conclusions

The paper is based on the researches carried out during 1976-2010 in Oradea, in a long term trial at ten different crops.

The presence of irrigation in the components of the sustainable agriculture is sustained by following arguments:

- The evolution of the soil structure. In the conditions when was used alfalfa as ameliorative crop rotation, and the fertilization system included manure, the structured degree (35.98%) was maintaining to the level of the structure degree from crop rotation unirrigated wheat- maize (35.26%);
- The decrease of soil water reserve on watering depth below easily available water content every year and in other years even below wilting point level;
- The droughty microclimate of unirrigated crops and the positive influence of the irrigation on water/ temperature + light report (Domuta climate index);
- The improve of the crops water consumption; the differences in comparison with unirrigated crops were between 36.6% (wheat) and 108,4% (maize for silo double crop). The optimum water consumption can be assured using the irrigation only. This participation in the covering sources was between 33.2% (sunflower) and 58.7% (maize for silo double crop).
- The highest level of yields; median differences, were between 39% (wheat) and 127% (maize for silo double crop). The maximum values of the variation interval are between 110% (sunflower) and 25760 (maize for silo double crop). The quality of yield is better than unirrigated conditions;
- A better stability of the yield, standard deviation values were smaller than unirrigated conditions with relative values between 8,7% (sunflower) and 50,4% (maize for silo double crop);

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• The increasing of water use efficiency with values between 2% (wheat) and 25% (maize);
• The correlations from soil-water-plant-atmosphere system:
• The inverse correlations between number of days with pedological drought and yield, respectively water use efficiency;
• The direct correlations between number of days with pedological drought and yield gain obtained using the irrigation;
• The direct correlations between water/temperature + light report (Domuța Climate Index) and yield, respectively between water consumption and yield.

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