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DETERMINING THE LOWER LIMITS OF IRRIGATION CAPACITY USE

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Abstract: The objective of the study was to determine the limits of economic justification for irrigation system capacity use.

The first step was focused on determining the lower limit of capacity use by comparing the economic effects of irrigation with the costs of the irrigation system use. In addition, while determining these limits the need was stressed to consider the economic effects of irrigation by optimizing the production structure and the modes for limit determination under irrigation and non-irrigation conditions. Eventually, the empirically verified possibility stating that this limit may be determined by comparing the water processing prices with its cost price is given. The limit was found to be the point at which these two prices equalize.

Key words: cost price, lower limit of capacity use, net income, water processing price, irrigation system.

I n t r o d u c t i o n

Over the past decades a comparative decline of the available agricultural land has been recorded all over the world. According to the FAO agricultural land for the intensification of farming (cultivable land, orchards, vineyards) was approx. 0.43 ha and 0.25 ha in 1965 and 1995 respectively (1). The decline has been provoked by the decreasing possibility to change uncultivated to cultivable land, limited land area, occupation of agricultural land by buildings, roads, channels for irrigation and drainage, factories on one hand and the ever-growing population on the other.

The issue raising major concern focuses on how to increase food production in the future considering the constrained agricultural land area.

Increasing crop production output has been considered one of the alternatives contributing to food production increase due to the necessary bioenergy obtained.

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Until recently crop yield increase used to refer to the reliance on modern agricultural practices (high levels of use of mineral fertilizers, plant protection products, efficient systems of soil cultivation), new resistant, high-yielding cultivars, etc. However, irrigation needs to be implemented in order to raise production output, i.e. the installation of new and the rational use of the existing irrigation systems is advisable and justifiable.

Therefore, the future development of agriculture production refers to the reliance on the intensification of production meaning thereby not only the application of agricultural practices mentioned above but the changed structure of both crop and livestock production as well, i.e. higher investments may be expected to encourage future development. Inadequate investments in agricultural production may be expected to slow down the development of both industry and economy on the whole.

Considerable investments are needed for the preparation and implementation of an irrigation project. Therefore, economic arguments with regard to the advisibility and justification of the irrigation capacity utilization level need to be taken into account in the design of the irrigation system. The objective of this study was to discuss and contribute to the implementation of the procedure with regard to the determination of the lower level of irrigation capacity use.

Materials and Methods

An agricultural enterprise involved in the field crop/livestock production system was used as a model for determining the lower level of irrigation capacity use. The enterprise comprised 960 ha of cultivable land, uniform in quality having successfully solved the problem with regard to excessive waters on 400 ha by excavating a network of open channels. Livestock production focused on bullock fattening amounting annually to 1260 animals up to 250 kg and 740 animals up to 450 kg.

The enterprise was located in the region with low precipitation, unevenly distributed over the year. During the vegetation growth period average annual precipitation amounted to 300 mm/m^2. Due to water deficiency yields were far below the anticipated.

The installation of the system for irrigation on a net area of 316 ha on which an open channel network for excessive water drainage had previously been installed was hypothesized. The water required shall be obtained from wells of the uppermost water horizons. However, the maximal water amounts required from the standpoint of some field crop needs (soybean, sugar beet and alfalfa) in July and August shall not be met because during that period soil horizons are usually deficient of water. Namely, during these months approx. 110 000 m^3 of water may be expected to be provided.

The installation of an irrigation system may be expected to enhance agricultural production, increase yields and by changing the production structure raise the financial results of the enterprise. However, it is of major importance to know the economic effects of production under the conditions prior to and following the installation of an irrigation system in order to contribute to increased financial results.

In our case the economic effects of production under the conditions prior to and following the installation of an irrigation system shall be given by the net income as the difference between the final value and the external production costs without irrigation system costs and its maximal value shall be obtained by maximazing production. The optimal production structure under the given conditions may be projected using different methodological procedures including linear programming, the results of which shall be used in the study.

Using the linear programming method the economic effects under irrigated and non-irrigated conditions shall be obtained by determining the unknown xi, the function of which

$$F(x_i)=x_1 \cdot c_1 + x_2 \cdot c_2 + \cdot \cdot \cdot + x_n \cdot c_n \qquad (1)$$

along with the constraints

$$\begin{gathered} a_{11} \cdot x_1 + a_{12} \cdot x_2 + \cdot \cdot \cdot + a_{1n} \cdot x_n \leq b_1, \\ a_{21} \cdot x_1 + a_{22} \cdot x_2 + \cdot \cdot \cdot + a_{2n} \cdot x_n \leq b_2, \\ \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \\ a_{m1} \cdot x_1 + a_{m2} \cdot x_2 + \cdot \cdot \cdot + a_{mn} \cdot x_n \leq b_n, \end{gathered}$$

and under the condition $x_i \geq 0$, shall maximize net income, where:

F(xi) - equals the objective funcion value, i.e. in our case the economic effect of production (net income);
xi - unknown value (production activities);
ci, ai, bi - permanent numbers.

Using the linear programming method the problem may be solved by applying some of the general methods. In our case the simplex method shall be used whereby the previously hypothesized problem of the mathematical linear programming model shall be of help in converting the system of unequations to the system of equations.

Considering the objective of the installation of the irrigation system, namely to increase the financial result of the enterprise, it is of major importance while

planning its installation to determine the amount of water it can provide during July and August, i.e. the degree of capacity use required to raise the financial result. The degree of irrigation capacity use needed for financial result increase may be determined by comparing the change of net income with irrigation system costs. A loss shall be registered provided utilization costs are greater than net income increase. The degree of irrigation capacity use at which the change of net income equals costs represents the lower level of economic justification (usefulness threshold) of capacity use.

However, the economic effect of the water used for irrigation may be obtained by computing its processing price, i.e. by dividing the change of net income after irrigation with the amount of the water used:

$$pc=\frac{\Delta NP}{Q}, \qquad (2)$$

where:

pc - processing price of water

$\Delta NP = NP_1 - NP_0$,

NP_1 - net income under the conditions of irrigation

NP_0 - net income under the conditions of non-irrigation

Q - amount of water used for irrigation.

The lower limit of economic justification of the degree of irrigation capacity use may be obtained by comparing the processing price with the cost price using the following formula:

$$ck= vt+\frac{FT}{Q} \qquad (3)$$

where:

ck - cost price of water

vt - amount of variable cost per m^3 of water

PT - total amount of fixed costs of the irrigation system.

As long as the processing price of water is lower than its cost price, the use of the irrigation system does not contribute to the increase of the financial result. The lower level of capacity use may be expected to be achieved when these two prices equalize and the financial result starts increasing when the capacity use rises above this level.

Results and Discussion

The economic effect of production given as the net income under non-irrigated conditions was determined using the optimization of the simplex method and shown in Table 1.

T a b . 1. - Production structure and net income prior to the installation of the irrigation system

Production activities	Structure ha	Structure %	Net income (d)
Field crop production			
1. Wheat - x_1	158.39	16.50	82 205
2. Spring barley - x_2	321.61	33.50	176 242
3. Corn - x_3	54.18	5.64	-
4. Sugar beet - x_6	111.36	11.60	186 543
5. Alfalfa hay - x_7	131.44	13.69	-
6. Silage corn - x_8	183.02	19.07	-
I Total (1 to 6):	960.00	100.00	444 990
Livestock production			
7. Bullock fattening up to 250 kg - x_{10}	1 260		356 580
8. Bullock fattening up to 450 kg - x_{11}	750		606 800
II Total (7+8):			963 380
III Total (I+II):			1 408 370
9. Feed preparation -x_9			341
10. Earnings of seasonal manpower:			
May - x_{12}			6 282
July - x_{14}			820
October - x_{15}			7 293
11. Variable feed costs:			
Corn - x_3			24 218
Alfalfa hay - x_7			44 822
Silage corn - x_8			76 684
IV Total (9+10+11):			160 460
V NET INCOME (III-IV):			**1 247 910**

The economic effects of production under the conditions of irrigation and different water availability in July and August were determined using the optimization simplex method and shown in Table 2.

Total fixed costs and variable costs per m^3 of this irrigation system amounted to 174 494 Dinars and variable costs per m^3 0.0084 Dinars.

Tab. 2. - Net income achieved at different levels of irrigation capacity use

Production activity	The water (m^3) provided in July and August by the irrigation system						
	50 000	60 000	70 000	80 000	90 000	100 000	110 000
Field crop production							
a) Non-irrigated							
1. Spring barley - x_2	175 360	175 360	175 360	175 360	175 360	175 360	175 360
2. Sunflower - x_4	-	-	-	-	5 557	5 589	13 191
3. Sugar beet - x_6	112 038	-	83 600	161 175	213 632	213 569	199 002
Total (1 to 3):	287 398	175 360	258 960	342 535	394 549	394 518	387 553
b) Irrigated							
4. Wheat - x_9	132 838	112 389	95 135	77 880	65 557	66 650	55 393
5. Spring barley - x_{10}	14 238	31 287	45 625	59 988	70 247	69 337	69 428
6. Soybean - x_{13}	34 648	39 247	39 247	39 247	39 247	39 247	39 247
7. Rape seed - x_{14}	182 395	182 395	182 395	182 395	179 664	169 502	160 007
8. Sugar beet - x_{15}	-	-	-	-	5 470	25 821	44 841
Total (4 to 8):	364 119	365 318	362 402	359 510	360 185	370 557	368 916
Livestock production							
9. Bullock fattening up to 250 kg -x_{20}	356 580 606 800	356 580 606 800	356 580 606 800	356 580 606 800	356 580 606 800	356 580 606 800	356 580 606 800
10. Bullock fattening up to 450 kg - x_{21}							
Total (9+10):	963 380	963 380	963 380	963 380	963 380	963 380	963 380
I Total (1 to 10):	1 614 897	1 504 058	1 584 742	1 665 742	1 718 114	1 728 455	1 719849
11. Corn preparation for feed	341	341	341	341	341	341	341
12. Earnings of seasonal manpower	224 074	-	4 375	13 706	21 307	23 057	12 126
13. Variable feed costs	164 597	146 864	135 774	124 684	117 412	116 786	116 848
II Total (11 to 13):	389 012	147 205	140 490	138 731	139 060	140 184	129 315
III NET INCOME (I-II):	**1 225 885**	**1 356 853**	**1 444 252**	**1 526 694**	**1 579 054**	**1 588 271**	**1 590 534**

The changing amounts of net income and the financial result for the variously assumed possibilities of water supply intended for irrigation in July and August are given in Table 3.

Tab. 3. - Economic effects of irrigation for different degrees of irrigation capacity use

Degree of irrigation system capacity use (m^3)		Net income increase (ΔNP)	Costs of irrigation system use (d)	Profit increase (d)
Water supply in July and August	Total (Q)			
50 000	504 213	- 22 025	178 729	-200 754
60 000	515 664	108 943	178 826	-69 883
70 000	523 482	196 342	178 891	17 451
80 000	531 300	278 784	178 957	99 827
90 000	543 584	331 144	179 060	152 084
100 000	568 017	340 361	179 265	161 096
110 000	592 523	342 624	179 471	***163 153***

Both the processing and cost price of water as well as their differences for different degres of irrigation use are given in Table. 4.

T a b . 4. - Processing price and cost price of water for different degres of irrigation use

Degree of irrigation system capacity use (m^3)		Processing price of water (d/m^3)	Cost price of water (d/m^3)	Difference between the processing and cost price (d/m^3)
Water supply in July and August	Total (Q)			
50 000	504 213	-0.044	0.354	-0.310
60 000	515 664	0.211	0.347	-0.136
70 000	523 482	0.375	0.342	0.033
80 000	531 300	0.525	0.337	0.188
90 000	543 584	0.609	0.329	0.280
100 000	568 017	0.599	0.316	***0.283***
110 000	592 523	0.578	0.303	0.275

The determination of the lower limit of the degree of irrigation capacity use comparing processing prices with cost prices of water is presented in Fig. 1.

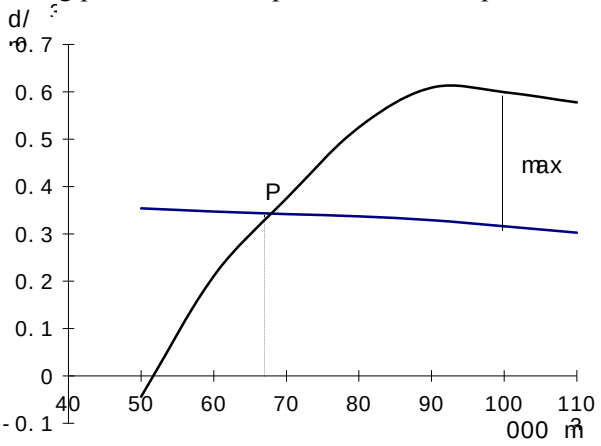

Fig. 1. - Determination of the lower limit of the degree of irrigation capacity use

In our case the lower limit of the degree of irrigation capacity use was determined graphically, i.e. by lowering the ordinates of the cutting points, the lines of the cost price and the processing price (point P) on the abscissa. Thus the lower limit of the irrigation system use was approx. 68 000 m^3 of water in July and August or a total of approx. 528 000 m^3.

Ensuring water above this limit tends to increase the difference between the processing and cost price of water. Providing 100 000 m^3 of water in July as well as in August the difference was the biggest. Knowing that the difference between the processing and cost price represents the average increase of the financial result per m^3 of water, a maximal amount would thus be achieved at the amount of water provided. Increasing the degree of capacity utilization tends to decrease the differences because total costs would rise rapidly compared with the net income due to the restricted production capacities and conditions.

At the low level of irrigation capacity use, i.e. water availability up to 68 000 m^3 in July and August the loss would be provoked by fixed costs due to the fact that in the total amount they would be higher in relation to the change of the net income.

Considering the dynamics of the financial result, i.e. comparing changes of net income with the costs of irrigation use (Tables 3 and 4), the procedure for determining the lower limit of the degree of irrigation capacity use gains in importance. The dynamics of financial results is shown in Fig. 2.

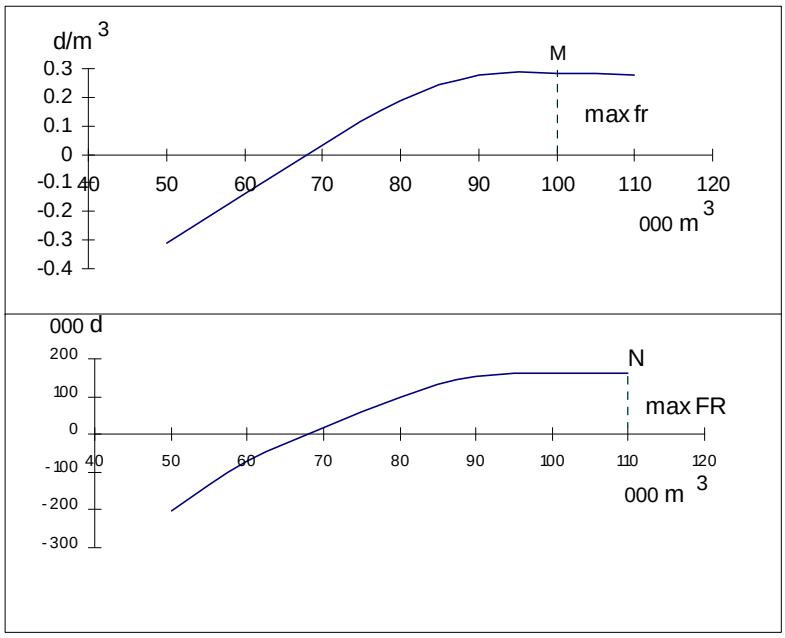

Fig. 2. - Dynamics of the average and total amount of the financial result

Based on the data shown (Fig. 2), the lower limit of irrigation system use amounts to approx. 68 000 m^3 of water available in July and August.

Based on the dynamics of the financial result in relation to the degree of irrigation capacity use (Tables 3 and 4 and Fig. 2), it can be concluded that the dynamics of the total financial result differs as does the dynamics of the average financial result. An average financial result may be achieved by providing July and August with 100 000 m^3 of water each. Maximal total financial result may be achieved at a greater degree of irrigation capacity use, i.e. maximal water availability in July and August, e.g. 110 000 m^3 of water each month.Thus, the optimal degree of irrigation system use may be found between these two points (5), i.e. system use output.

Conclusion

The lower limit of economic justification (usefulness threshold) may be determined by comparing income with costs , i.e. it may be detected at the point of capacity use at which incomes equal costs. When determining the limit for irrigation capacity use maximal amounts of economic production results should be considered under irrigated and non-irrigated conditions. The amount may be obtained by optimizing production using well known methodological procedures.

Our research has shown that the limit may also be determined by comparing the processing price with the cost price of irrigation water. The point at which these two prices equalize represents the lower limit of economic justification of the degree of irrigation capacity use, because the change of the financial result equals zero. The possibility of ensuring greater amounts of irrigation water, namely above the lower limit would contribute to financial result increase.

When planning the installation of an irrigation system, it is worth knowing the limit because during the vegetation growth period of some crops the need may arise to provide additional amounts of water.

REFERENCES

1. Gogić, P. (1990): Ocjena ekonomske opravdanosti ulaganja sredstava u hidromelioracione sisteme. Doktorska disertacija, Univerzitet u Beogradu, Poljoprivredni fakultet, Zemun.
2. Krištof, M. (1977): Kalkulacije u poljoprivredi, Skripta, Univerzitet u Beogradu, Poljoprivredni fakultet, Zemun.
3. Madjar, S. (1986): Odvodnja i navodnjavanje u poljoprivredi, NIRO ″Zadrugar″, Sarajevo.
4. Mellrowicz, K. (1957): Kosten und Kostenrechnung (I), Walter de Gruyter & Co., Berlin.
5. FAO The Sixth World Food Survey, Roma, Italia, 1996.

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ODREDJIVANJE DONJE GRANICE STEPENA KORIŠĆENJA KAPACITETA SISTEMA ZA NAVODNJAVANJE

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R e z i m e

U radu je ispitivano određivanje granice ekonomske opravdanosti korišćenja kapaciteta sistema za navodnjavanje.

Prvo je izložen način utvrđivanja donje granice stepena korišćenja kapaciteta upoređivanjem ekonomskog efekta navodnjavanja sa troškovima korišćenja sistema za navodnjavanje. Pritom je ukazano i na potrebu da se pri utvrđivanju ove granice polazi od ekonomskog efekta navodnjavanja, koji se dobija optimizacijom strukture proizvodnje, kao i na način njenog iznalaženja za uslove sa i bez navodnjavanja. Zatim je predstavljena i empirijski potvrđena mogućnost da se ova granica može odrediti poređenjem preradne cijene vode sa njenom cijenom koštanja, kao i da je ona u tački u kojoj se ove dvije cijene izjednačavaju.

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