Journal of Agricultural Sciences
Vol. 51, No 2, 2006
Pages 177-187

UDC: 658.5.018.2:631.67
Original scientific paper

EFFECT OF LIVESTOCK PRODUCTION ON THE ECONOMIC EFFICIENCY OF IRRIGATION SYSTEMS

P. Gogić[1]

Abstract: The aim of the study was to examine the effect of livestock production on the economic efficiency of investments in irrigation projects.

The study was based on a model focused on field crop/livestock production using the data of crop yields in field crop production with or without irrigation, financial results of cattle fattening and milk production and the input and output price relationship.

The influence of livestock production on the economic effects of irrigation system utilization was evaluated using the indices of economic efficiency of investments – internal rate of return, net present value and pay-back period. The data on the amount of investments required for the construction of the irrigation system, economic benefit achieved by optimizing production under both irrigated and non-irrigated conditions, with and without livestock production were used to determine these indices.

Key words: livestock production, irrigation system, optimal production structure, linear programming, internal rate of return, net present value, pay-back period.

Introduction

Irrigation as an agricultural practice was used more than 5000-8000 years ago in order to regulate artificially the water-airflow and temperature regime of the fertile soil layer. Archeological remains of what were once known as irrigation systems in Egypt, Mesopotamia, China and India date back as far as 4000 years.

It is rather difficult to imagine crop growing without irrigation in regions (the Near East, Mediterranean, Africa, South America, South Asia, etc.) lacking rainfall. Although agricultural production under the conditions of humid climate was found to be quite successful, based on the experience of some countries (the

[1] Petar Gogić, PhD, Professor, Faculty of Agriculture, 11081 Belgrade – Zemun, Nemanjina 6, Republic of Serbia

Netherlands, Great Britain) high and stable yields may only be ensured using irrigation.

In regions characterized by abundant although uneven rainfall, irrigation represents the only means contributing to the increase of food production in order to meet the rising needs.

Currently approx. 270 million hectares or about 18% of the total cultivable land area are known to be irrigated worldwide with Asia predominating (about 32%) followed by Europe (approx. 8% of cultivable land and pastures).

The region of Serbia and Montenegro is known to be the most unstable region in the world with regard to either excess or deficiency in water. Dry seasons are followed by years of frequent rainfalls and floods and it is for this reason that agricultural production ranks low. In nearly all the regions of Serbia and Montenegro during the summer period with the most intensive plant growth water deficiency predominates. The effect of water deficiency is even more prominent during dry seasons because the decreased agricultural production has an unfavorable influence on the economy on the whole. There are about 1.5 million hectares in the lowland region of Serbia and Montenegro (approx. 30% of the total cultivable land) that could be irrigated. Although experience in both our country and abroad has shown that irrigation may raise crop yields by 50-100% and even contribute to two harvests annually (V u č i ć, 1981), nevertheless irrigation in Serbia and Montenegro has been insufficiently utilized. The size of the irrigated land has been noted to vary even stagnate years running. Even the construction of new irrigation systems stagnated. On the other hand, the systems that had already been constructed were either insufficiently used or unutilized. Over the past two decades the constructed irrigation systems have been used to irrigate 30,000-80,000 ha, i.e. on average about 1.2% of the total cultivable land or approx. 1% of the total cultivable land and pastures.

The use of irrigation in all the neighbouring countries having similar climatic conditions is known to be considerable. For example, of the total cultivable land and pastures about 49% are irrigated in Albania, 17% in Bulgaria, 27% in Romania, 4% in Hungary and 9% in Macedonia.

The reasons for the insufficient utilization of irrigation in Serbia and Montenegro are numerous starting with the unfavorable position of agriculture with respect to other branches of economy, insufficient financial resources for the construction of irrigation systems but also for additional investments in agricultural machinery, animals, buildings, infrastructure etc. In addition, the reasons for the insufficient utilization of irrigation systems may be the use of inappropriate production technologies under the conditions of irrigation, insufficient availability of highly accumulative field crops, vegetables and livestock production, lack of appropriate processing capacities etc.

It is only with the help of a production program ensuring maximal utilization of available land that favorable economic results may be expected. Production programs including livestock production may contribute to positive economic results of irrigation projects. Therefore, the objective of the study was to examine the effect of different cattle-breeding programs on the economic efficiency of investments in the construction of irrigation systems.

Material and Methods

An agricultural enterprise model was developed involved in field crop production only or field crop/livestock production. The enterprise had 960 ha of plains of even quality at its disposal solving problems with regard to the excess of water with the help of an open channel network on 400 ha that had previously been built. It was hypothesized that livestock production included cattle fattening of 1260 animals up to 450 kg and 740 animals up to 250 kg annually or 900 milking cows, breeding heifers and ♀ cattle on a farm the construction of which required approx. the same investment. Cattle fattening involved the purchase of cattle up to 120 kg. Cow production involved breeding animals obtained from own reproduction and the use of the breeding animals was restored every five years. Culled ♂ cattle were sold on the market and ♀ cattle were bred up to 120 kg of which a certain number was kept as breeding heifers. The remaining animals were sold on the market. The percentage of calved milking cows was 90, whereby the ♂ and ♀ relationship was 50%:50%.

The structure of field crop production in the enterprise was restricted by the available land, capacity of permanent and seasonal labor in May, June, July and October but also by the crop rotation conditions (at least 50% of cereals, 10% of legumes, maximally 20% of sunflower and sugar beet). In addition to alfalfa hay and silage corn harvested as regular and succeeding crops, bulk feed was partly obtained using by-products, i.e. ground parts of sugar beet. Grain corn from own production was expected to be used as feed (ground corn) and the remaining quantity would be sold on the market. Alfalfa hay would also be used partly as feed and partly sold on the market.

The enterprise was located in the region lacking precipitation, which was unevenly distributed during the year and with approx. 300 mm/m^2 of rainfall during the vegetation period. Due to the lack of humidity, crop yields were far below from the expected.

To compensate for the lacking humidity, an irrigation system was constructed on an area of 316 ha where an open channel network for the drainage of excessive water had previously been built. Wells were used in order to meet water requirements. However, this was insufficient from the standpoint of maximal water requirements of the crops (soybean, sugar beet and alfalfa) in July and August because during those months the soil layer was lacking water. The maximal supply of water in those months was 110,000 m^3.

The construction of the irrigation system was expected to increase agricultural production contributing to the enhancement of the overall financial result thanks to yield increase and the changed production structure. To determine the increase of the financial result, it was necessary to know the economic effect of production under the conditions prior to and following the construction of the irrigation system with and without livestock production.

Net income as the difference between the final value of production and external variable production costs and the utilization of the irrigation system were used in order to compute the economic effect of production under the conditions with and without irrigation (F i n c i et al., 1975), i.e.

$$NP_i = VP_i - VT_i, \qquad (1)$$

where:

NP_i = net income

VP_i = final production value, and

VT_i = variable costs of production and utilization of the irrigation system.

The economic efficiency of the construction of an irrigation system was evaluated using net income of the enterprise achieved under the conditions without and with irrigation (G o g i ć, 1990). Production optimization was used to obtain its maximal value. The optimal production structure for the conditions stated may be projected using different methods, linear programming being one of them, the results of which were used in the study.

Using the linear programming method the economic effects under the conditions without and with irrigation were obtained by determining the unknown X_i whereby the function

$$F(x_i)=x_1 \cdot c_1 + x_2 \cdot c_2 + \cdots + x_n \cdot c_n \qquad (2)$$

along with the constraints

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

and under the condition $X_i \geq 0$, maximized net income,

where:

$F(x_i)$ = value of objective function, i.e. in our case the economic effect of production (net income),

x_i = unknown (production activities)

c_i, a_i, b_i = technical input-output coefficients of optimization of some activities per unit capacity (prices, labor input of manpower and machinery, water input, crop rotation conditions and available capacities of constraints), in the case of:

1. the activities, the products of which were realized on the market it was net income in the function of the objective denoted «+»;
2. the activities, the products of which were partly or fully used for further reproduction it was the amount of external variable costs and in the function of the objective denoted «- «;
3. the expenses for the engagement of seasonal labor (wages) per labor hour and in the function of the objective denoted «-« , and
4. sale prices of the products sold on the market and in the function of the objective denoted «+».

This problem may be solved with the help of different methods using linear programming. The standard simplex method using a PC was employed in order to determine the optimal production structure of the enterprise.

Technical input-output coefficients in the initial simplex table were determined based on the previous input and output price parities, labor input norms for manpower and machinery considering the current production conditions and crop rotation conditions, technical properties and production intensity in the enterprise – prior to and following the construction of the irrigation system, i.e. achieved yields per unit capacity.

The optimal production structure was defined assuming the following:

1. field crop production without irrigation and livestock production,
2. field crop production without irrigation but with livestock production: cattle fattening or milk production,
3. field crop production with irrigation but without livestock production and field crop production with irrigation and livestock production: cattle fattening or milk production.

The aim of the construction of the irrigation system was to achieve higher yields of field crops and by changing the production structure enhance the business results of the enterprise. Along with the projection and planning of the construction of the irrigation system it was necessary to determine the indicators of economic efficiency. The economic efficiency of the construction of the system for irrigation was evaluated based on the:

- net present value;
- internal rate of return, and
- pay-back period.

The indicators of economic efficiency of irrigation were determined with the help of the increasing economic benefit which was reported throughout the period of utilization of the system, i.e.

$$\frac{\Delta R_1}{r}+\frac{\Delta R_2}{r^2}+\frac{\Delta R_3}{r^3}+\cdots+\frac{\Delta R_n}{r^n}=0, \qquad (3)$$

where:

ΔR_i = change in the economic benefit after the construction of the irrigation system (change in the financial result increased by the amount of depreciation of the irrigation system and investment interest),

r = discounting factor which equals $1+\frac{p}{100}$, where p stands for the discounting rate or internal rate of return, and

n = total life period of the irrigation system or length of the investment pay-back period.

The change of the financial result may be obtained by subtracting the increase of fixed costs of the enterprise, i.e. fixed costs of utilization of the system of irrigation (other unalterable fixed costs of the enterprise do not effect the change of the financial result) and taxes on the increased profit obtained by optimizing production.

The effect of livestock production on the economic efficiency of construction of the irrigation system was examined based on the previous indicators of the dynamic methods of investment evaluation in cases when the enterprise was involved in field crop production only or field crop/livestock production. In addition, the aim was to study the effect of cattle production, i.e. cattle fattening or milk production on the economic efficiency of irrigation systems.

Results and Discussion

The hypothesized constraints used for the optimization of production in order to determine the structure of production contributed to the most favorable economic results in an agricultural enterprise under the conditions prior to and following the construction of the system for irrigation with and without the involvement in livestock production (table 1).

Under non-irrigated conditions and without livestock production, in addition to stubble crops (wheat and barley) whose production is determined by the conditions of crop rotation (50% at the most) the greatest share in the structure of field crop production was that of sugar beet (19.3%) and corn (14.7%) production. However, under the assumed production conditions and the availability of livestock production, the greatest share in the field crop production structure was that of crops providing bulk feed – silage corn, alfalfa hay and sugar beet (approx. 44% of the cultivable land) including corn required to feed a certain number of animals. Considering the above-mentioned conditions, industrial crops e.g. sunflower and soybean were found to be displaced from the production structure.

T a b. 1. - Production structure with and without irrigation

Production activity	Without irrigation						With irrigation					
	Without farm		Cattle farm		Cow farm		Without farm		Cattle farm		Cow farm	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
I Field crop production												
a) Without irrigation												
1. Wheat	127.9	13.3	158.4	16.5	151.6	15.8	114.3	17.9	21.4	3.3	23.4	3.7
2. Spring barley	352.0	36.7	321.6	33.5	328.4	34.2	205.7	32.1	298.6	46.7	296.6	46.3
3. Corn	140.9	14.7	54.2	5.6	56.7	5.9	65.3	10.2	63.6	9.9	57.5	9.0
4. Sunflower	48.9	5.1					62.7	9.8				
5. Soybean	104.9	10.9					64.0	10.0				
6. Sugar beet	185.7	19.3	111.4	11.6	163.8	17.1	128.0	20.0	125.0	19.5	128.0	20.0
7. Alfalfa hay			131.4	13.7	119.6	12.4			131.4	20.6	134.5	21.0
8. Silage corn			183.0	19.1	139.9	14.6						
Total (1-8):	960.0	100.0	960.0	100.0	960.0	100.0	640.0	100.0	640.0	100.0	640.0	100.0
b) With irrigation												
9. Wheat												
10. Spring barley							158.0	50.0	158.0	50.0	158.0	50.0
11. Corn											4.1	1.3
12. Sunflower												
13. Soybean							240	7.6	31.6	10.0	31.6	10.0
14. Oilseed rape							83.4	26.4	112.8	35.7	111.0	35.1
15. Sugar beet							43.0	13.6	13.8	4.3	11.3	3.6
16. Alfalfa hay							7.6	2.4				
17. Silage corn (regular sowing)												
18. Silage corn (postr. sjetva)									(87.4)		(84.5)	
Total (9-18):							316.0	100.0	316.0	100.0	316.0	100.0
II Livestock production												
19. Cattle fattening up to 250 kg			,260 animal						1,260 animal			
20. Cattle fattening up to 450 kg			740 animals						740 animals			
21. Milking cows					537 animals						604 animals	
22. Breeding heifers					107 animals						121 animals	
23. ♀ cattle 120 kg					242 animals						272 animals	

A similar field crop production structure of an agricultural enterprise was also noted after the construction of the irrigation system on non-irrigated land. Under such production conditions the hay of alfalfa as the succeeding crop would be obtained from non-irrigated land and silage from irrigated land only. On irrigated land spring barley production only would be preferred due to the more favorable economic result achieved in comparison to wheat production. Under such conditions the share of corn and alfalfa hay production for sale on the market would be negligible.

Currency flows of economic benefit obtained from the results of production structure optimization and the data on investments and costs of utilization of the system of irrigation were used in order to determine the contribution of livestock production on the economic efficiency of the construction of the irrigation system (table 2).

The use of the irrigation system without the inclusion of livestock production would decline the financial result of the enterprise by 54,304 d annually. The conclusion which tends to emerge is that yields (wheat, spring barley, corn, sunflower, soybean, sugar beet) increased by irrigation were insufficient in order to obtain a favorable economic result.

Considerable investments are known to be required for the construction of an irrigation system but also high costs for its utilization, which may only be compensated by the application of an appropriate production structure. Based on the results of the study conducted, the conclusion which tends to emerge is the need to focus on livestock production in order to obtain favorable economic results. In addition, crop rotation needs to involve field crops providing feed needed for the production of milk or cattle fattening. However, investigations have shown that the financial result was more favorable when focusing on cattle fattening than milk production.

The effect of livestock production on the economic efficiency of the construction of the irrigation systems needs to be analyzed from the standpoint of the indicators of the dynamic methods for investment as well as considering the fact that both livestock productions require different total investments (milk production requires smaller investments in permanent working assets than cattle fattening). Some major indicators of dynamic evaluation of investments (internal rate of return, net present value and pay-back period) are given in table 3.

Assuming the calculative discount rate were 8% (based on the interest rate for investment credits) then investments in the construction of the irrigation system without the involvement in livestock production cannot be considered economically justifiable because of the smaller internal rate of return compared with the calculative discount rate (2.86% < 8%), negative net present value (–531,725.1 d), and pay-back period which turned out to be much longer than the years planned for the utilization of the irrigation system (25 years).

T a b. 2. - Currency flow change after the construction of the irrigation system

Description	Year						
	1	2	3	4 - 15	16	17 - 27	28
Irrigation without livestock production							
1. Change of net income				151.267	151.267	151.267	151.267
2. Change of fixed costs							
2.1 Depreciation				103.038	103.038	103.038	103.038
2.2. Maintenance				20.266	20.266	20.266	20.266
2.3. Insurance				9.278	9.278	9.278	9.278
2.4. Labor costs				13.186	13.186	13.186	13.186
2.5. Interest				59.803	59.803	59.803	59.803
Total:				205.571	205.571	205.571	205.571
3. Change of the gross finan.result				**-54.304**	**-54.304**	**-54.304**	**-54.304**
4. Taxes and contribution margins							
5. Change of the net finan.result				-54.304	-54.304	-54.304	-54.304
6. Depreciation and interest				162.841	162.841	162.841	162.841
7. Income change (5+6)				108.537	108.537	108.537	108.537
8. Investments	401.024	1.004.011	32.549		714.736		
8.1. Fixed assets	401.024	1.004.011	32.549		714.736		
8.2. Permanent working capital							
9. Residual of investment value							129.751
10. Change of net income (7-8+9)	**-401.024**	**-1.004.011**	**-32.549**	**108.537**	**-606.199**	**108.537**	**238.288**
Irrigation with cattle farm							
1. Change of net income				340.488	340.488	340.488	340.488
2. Change of fixed costs							
2.1 Depreciation				103.038	103.038	103.038	103.038
2.2. Maintenance				20.266	20.266	20.266	20.266
2.3. Insurance				9.278	9.278	9.278	9.278
2.4. Labor costs				13.186	13.186	13.186	13.186
2.5. Interest				61.691	61.691	61.691	61.691
Total:				207.459	207.459	207.459	207.459
3. Change of gross finan.result				**133.029**	**133.029**	**133.029**	**133.029**
4. Taxes and contribution margins				13.303	13.303	13.303	13.303
5. Change of net finan.result				119.726	119.726	119.726	119.726
6. Depreciation and interest				164.729	164.729	164.729	164.729
7. Income change (5+6)				284.455	284.455	284.455	284.455
8. Investments	401.024	1.004.011	77.912		714.736		
8.1. Fixed assets	401.024	1.004.011	32.549		714.736		
8.2. Permanent working capital			45.363				
9. Residual of investment value							175.114
10. Change of net income (7-8+9)	**-401.024**	**-1.004.011**	**-77.912**	**284.455**	**-430.281**	**284.455**	**459.569**
Irrigation with cow farm							
1Change of net income				325.334	325.334	325.334	325.334
2. Change of fixed costs							
2.1 Depreciation				103.038	103.038	103.038	103.038
2.2. Maintenance				20.266	20.266	20.266	20.266
2.3. Insurance				9.278	9.278	9.278	9.278
2.4. Labor costs				13.186	13.186	13.186	13.186
2.5. Interest				60690	60690	60690	60690
Total :				206.458	206.458	206.458	206.458
3. Change of gross finan.result				**118.876**	**118.876**	**118.876**	**118.876**
4. Taxes and contribution margins				11.888	11.888	11.888	11.888
5. Change of net finan.result				106.988	106.988	106.988	106.988
6. Depreciation and interest				163.728	163.728	163.728	163.728
7. Income change (5+6)				**270.716**	**270.716**	**270.716**	**270.716**
8. Investments	401.024	1.004.011	53.869		714.736		
8.1. Fixed assets	401.024	1.004.011	32.549		714.736		
8.2. Permanent working capital			21.320				
9. Residual of investment value							151.071
10. Change of net income (7-8+9)	**-401.024**	**-1.004.011**	**-53.869**	**270.716**	**-444.020**	**270.716**	**421.787**

T a b. 3. - Indicators of dynamic evaluation of investments in the construction of the irrigation system

Indicators	Utilization of the irrigation system		
	Without livestock production	With cattle farm	With cow farm
1.Internal rate of return	2.86 %	14.71 %	14.14 %
2. Net present value	-53.725.1 d	928.194.7	828.069.9
3. Pay-back period	> 25	9.69 years	10.18 years

From the economic standpoint only livestock production may contribute to a justifiable irrigation project. Based on the previous results it can be concluded that the economic efficiency of investments in the irrigation system was significantly effected by cattle fattening compared with milk production. Cattle fattening was found to contribute to a greater internal rate of return (14.88% > 14.10%), greater net present value (928,194.7 d > 828,069.9 d) and a shorter pay-back period (9.69 years < 10.18 years).

Conclusion

The construction of the irrigation system requires enormous investments but also the costs of its utilization are high. Experience has shown that economic justification of its construction may be achieved, provided the available land is maximally utilized for the growth of highly accumulating field crops and vegetables, fruits and grapes. Economic justification of constructing the irrigation system cannot be achieved by growing field crops only. Crop rotation needs to include fodder crops. Eventually, the construction of the irrigation system cannot be economically justifiable without livestock production.

An optimal production structure with and without irrigation needs to be taken into account in order to evaluate the economic justification of investments in an irrigation system. Also, the optimal production structure needs to be determined with and without livestock production in order to evaluate the contribution of livestock production to economic justification of irrigation system utilization.

Based on the results of the study, it can be concluded that the construction of an irrigation system without livestock production cannot be considered economically justifiable because high costs of utilization of the irrigation system would decrease the financial result of the enterprise. If milk production or cattle fattening were to be included in the production program of an enterprise, then a favorable economic effect of utilization of an irrigation system may be expected under the hypothesized production conditions. Livestock production may be expected to ensure intensive utilization of land for the growth of fodder crops sown regularly and as succeeding crops. The indicators of economic efficiency of investments, e.g. internal rate of return, net present value and pay-back period were computed and it was determined that cattle fattening contribution to the economic efficiency of the construction of an irrigation system was greater than milk production.

REFERENCES

1. FAO Yearbook Production. Roma. 2001.
2. F i n c i, Ž., M u l i ć, J., J a h i ć, H. (1975): Primena simpleks metoda u optimizaciji proizvodnje poljoprivrednog gazdinstva. Nolit, Beograd.
3. G o g i ć, P. (1990): Ocjena ekonomske opravdanosti ulaganja sredstava u hidromelioracione sisteme. Doktorska disertacija, Poljoprivredni fakultet, Beograd –Zemun.
4. G o g i ć, P. (2002): Determining the lower limits of irrigation capacity use. Journal of Agricultural Sciences, Vol. 47 (1), 87-96
5. M a d a r, S. (1986): Odvodnja i navodnjavanje u poljoprivredi. NIRO "Zadrugar", Sarajevo.
6. Statistički godišnjak Srbije i Crne Gore1978-2002. Savezni zavod za statistiku, Beograd.
7. V u č i ć, N. (1981): Navodnjavanje i dve žetve godišnje. Dnevnik, Novi Sad.

Received June 5, 2006
Accepted December 28, 2006

UTICAJ STOČARSKE PROIZVODNJE NA EKONOMSKU EFEKTIVNOST SISTEMA ZA NAVODNJAVANJE

P. Gogić[1]

Rezime

U radu je istraživan uticaj stočarske proizvodnje na ekonomsku efektivnost investicionih ulaganja u izgradnju sistema za navodnjavanje.

Ovo istraživanje je zasnovano na modelu poljoprivrednog preduzeća ratarsko-stočarskog smjera proizvodnje, koji je sačinjen na osnovu podataka o prinosima ratarskih usjeva gajenih bez i sa navodnjavanjem, podataka o rezultatima tova junadi i proizvodnje mlijeka i određenom odnosu cijena inputa i outputa.

Uticaj stočarske proizvodnje na ekonomske efekte korišćenja sistema za navodnjavanje je ocijenjen na osnovu pokazatelja ekonomske efektivnosti investicionih ulaganja – interne kamatne stope, neto sadašnje vrijednosti i roka povraćaja. Za utvrđivanje ovih pokazatelja poslužili su podaci o iznosu potrebnih investicionih ulaganja, za, i u vezi sa izgradnjom sistema za navodnjavanje, kao i podataka o ekonomskim koristima dobijenim optimizacijom proizvodnje za uslove sa i bez navodnjavanja, sa i bez stočarske proizvodnje.

Primljeno 5. juna 2006.
Odobreno 28. decembra 2006.

[1] Petar Gogić, redovni profesor, Poljoprivredni fakultet, 11081 Beograd – Zemun, Nemanjina 6, Republika Srbija