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Value Added in Irrigated Contrary to Rainfed Corn Production[1]

Marko JELOČNIK*
Institute of Agricultural Economics, Belgrade, Serbia
**Corresponding author, marko_j@iep.bg.ac.rs*

Jonel SUBIĆ
Institute of Agricultural Economics, Belgrade, Serbia
jonel_s@iep.bg.ac.rs

Anna IVOLGA
Stavropol State Agrarian University, Stavropol, Russia
annya_iv@mail.ru

Vasilii EROKHIN
School of Economics and Management, Harbin Engineering University, Harbin, China
vasilii_erokhin@hrbeu.edu.cn

Abstract. *Occurred climate change and incurvation of weather patterns globally brings unpredictable production in many economic sectors, especially agriculture, or closely in crop production. In this circumstances, rainfed crop production in many countries used to become old-fashioned system of production, while implementing irrigation tends to be reality that provides long-term food security and farms' profit stability. The main goal of research is to economically justify the appliance of irrigation in conventional corn production at the farm level. In research used dataset corresponds to South Banat region in Serbia, while used method assumes calculation of contribution margin. Comparing the values of gross financial results gained in corn growing organized in similar production conditions, but with or without applying the irrigation, achieved results show its rise for almost six times after implementing the irrigation systems. Besides, overall profitability in rainfed corn production shows much higher sensibility towards the change in obtained incomes and variable costs.*

Key words: corn production, climate change, rainfed, irrigation, value added.

Introduction

Climate change is the global issue of nowadays society. It generates long-term weather changes across the Earth, hardly affecting the sustainability of many economic sectors, chiefly the agriculture and food production, forestry and fishery, energy production and mining, health care, tourism, etc. (Prowse et al., 2009; Rawat et al., 2024). Over the all, it affects the current quality of life and well-being, as well as strives to threat the survival of global population in upcoming centuries (Halley et al., 2018; Estoque et al., 2019). Some estimations have been shown that in last three decades climate change initiates natural accidents that are responsible for direct annual economic losses ranging between 0.2-0.5% of global GDP (Raihan, 2023).

Among the climate change related accidents that usually affects the primary agriculture and food sector are floods, heatwaves, drought, thunder and hailstorms, forest fires, spring frosts, etc. (Sivakumar, 2005; Van Aalst, 2006), as well as the problems linked to pests and disease spreading, impoverishing in

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biodiversity, intensification of deforestation and soil erosion processes, or loss in soil quality (Rhodes, 2014; Bebber et al., 2014; Skendžić et al., 2021; Ortiz et al., 2021).

Both, at macro and micro level, climate changes throughout the agriculture impacts the food security and safety, sectoral of farms' profitability, trade exchange balance and level of national GDP, mainly the life conditions and level of livelihood of rural population, etc.

In environmental conditions of Western Balkans, over the last several decades, climate elements that affect the most the crop (mainly grains and oilseed crops) production are occurrence of unstable rainfall patterns, more frequent and more intensive heatwaves and drought (Kovacevic et al., 2012; Jeločnik et al., 2019; Todorović et al., 2021), in general jeopardizing the volume and quality of obtained yields at certain localities.

Focusing on Serbia, some estimation showed that each second year was in some extent drought, while from the beginning of current millennium damages caused by drought in national agriculture ranges around 6 milliard USD. There are expectations of further drought intensification in this region (Gulan, 2021). Unfortunately, except certain adaptation measures linked to specific soil cultivation or using the drought tolerant varieties, irrigation is still present at the level of statistical error (especially in case of small farms), (Zubović et al., 2018). Some estimations show that during the next decade Serbia has to protect almost the third of its arable land against the drought (Ćurčić et al., 2021).

Its assumed that introduction of irrigation at the farm level represents the value-added activity which is focused to cover enlarged volume of consumers' needs and desires in higher quality in upcoming period, as well as to enable the farm to capture higher profitability (Hamilton & Gardner, 1986; Coltrain et al., 2000). According to grown crop, water and energy availability, price and access, or selected irrigation system, irrigation usually requests more intensive use of agro-inputs and mechanization, or change in organization at the farm level. Its implementation is often followed by large investments and adequate state support. Although is believed that its implementation and practicing is not profitable at small areas in crops growing (contrary to fruit and vegetable production), modern agriculture requires its presence providing several models and types of its exercising, even the relatively cheap alternatives (Baranchuluun et al., 2014; Subić et al., 2017; Rudić et al., 2019). Irrigation, and further intensification of production, with induced more complex production procedures and accounting recording, requires even simple bookkeeping and collecting of sufficient datasets later useful in agro-economic analysis (Patarlageanu, 2007).

The main goal of the research is to examine the economic justification of general use of irrigation in crop production, specifically corn growing, in climate conditions of Western Balkans, as well as to show the profit potential of mentioned agrotechnical measure appliance at same production entity.

Literature Review

There were performed several researches turned to techno-economic comparison of irrigation systems implementation contrary to rainfed crop production (Rockstrom et al., 2010; Valipour, 2013; Vanschoenwinkel & Van Passel, 2018). There are several direct and indirect benefits derived from irrigation use. They are mainly focused to: change in crop structure at the farm, due to growing intensification, high-value crops introduction and increase in productivity and further farm profitability; better utilization and public pricing of available water resources at certain territory; boosting the employment possibilities and needs, as well as increase in general incomes and wages; increase in agro-food sustainability and security; improved affordability of health food-products to constantly enlarged group of population; boosting the economic activity of to agriculture relaying sectors and impact on overall GDP; etc. (Abu Zeid, 2001; Hussain, 2007; Gohar et al., 2015; Darko et al., 2016; Bjornlund et al., 2017). Of course, there are several disadvantages that are linked to irrigation use, such are: intensification in spreading of pests and plant diseases; exhaustion of available drinking water reserves especially in areas where it could affect the communal issues; requiring the communal and energetic infrastructure; high initial investments and increase in further production costs; over-irrigation could impact on negative change in soil structure and soil salinization; requires certain specific knowledge and skills; formed water accumulations and irrigation channels could affect shrinking in available agricultural or industrial surfaces, and properties, while making marshes or over-wet areas; etc. (Rotem & Palti, 1969; Pereira et al., 2002; O'Shaughnessy et al., 2019; Belaud et al., 2020).

Introducing the irrigation directly indicates the increase in volume and quality of gained yields, creating the value added in previously organized production to specific farm. Its not linked just to crops growing in arid or semi-arid areas, but to any climate zone in which occurs certain level of drought intensity within the one period of growing season that could affect the crop stress and below average yields (precise irrigation). In this way it's given the value addition to usual crop production, or it generally focuses to increase in farms' net incomes (Berbel et al., 2011; Al Hinai & Jayasuriya, 2021).

Rainfed crop, more closely grains (corn) production globally dominates (Rao et al., 2015; Erenstein et al., 2022). Considering the irrigation and corn production, yields gained in dry farming could increase for several times after the systematical applying of water. Corn really well response to applied water (Henry & Krutz, 2016). For example, in USA regular corn production in rainfed conditions ranges from 2 to over 8 t/ha, while it jumps to around 21 t/ha in certain subregions under intensified irrigation (Grassini et al., 2009). This is similar to findings of Haarhoff & Swanepoel (2018) for global rainfed corn production, which depending to climate conditions and planting density ranges from almost 2.5 t/ha to over the 9 t/ha. In climate conditions of Serbia some experimental research show that the average corn yields under dry farming reaches around 10 t/ha, while irrigated corn gains for almost 50% higher yields (Kresovic et al., 2014).

Methodological Framework

Research encompasses agricultural enterprise specialized in conventional crop production, specifically mercantile corn growing located in south Banat in Serbia. Although the enterprise practices the corn production both in rainfed and under irrigation, it uses similar production patterns (i.e. climate and soil conditions, labor, mechanization, agro-inputs, production operations, etc.).

In order to realize if it is worthy for enterprise to skip to irrigate the entire surfaces under the corn, there were made comparation of economic elements gained in corn growing under or without irrigation. It's expected that derived results and conclusions will further facilitate the owner business decision.

As in some previous researches (Subić et al., 2015; Subić & Jeločlnik, 2016; Jeločnik et al., 2022), method used implies analytic calculations based on variable costs, i.e. calculation of contribution margin in conventional corn production for both observed production alternatives. Besides, it was done the sensitivity analysis of gained results in both production variants (additional development of sensitivity matrix), as well as it has been determined the impact of irrigation on gained gross financial result. Research also involves calculation of critical values of production at which the contribution margin equalizes with zero. All derived values and results were linked to production surface of one hectare, while they were shown in EUR, mostly in adequate tables.

Results with Discussion

According to given results in corn production (production year 2022/23.), with or without irrigation, achieved at enterprise property (Table 1. and Table 2.), there were developed the analytical calculations based on variable costs.

Enterprise has on disposal all required highly functional mechanization and equipment, as well as all necessary facilities in economic yard. In production peaks it is partly relying on external labor. Produced output and engaged agro-inputs are selling or purchasing at local market. Enterprise are practicing well managed crop rotation of few crop species, most often corn, wheat, soybean, alfalfa, sunflower, silage corn, etc. Production is organized in one part with exercising the irrigation. The water used for irrigation is drawing from public channel. Irrigation systems are Rangers with cannon of medium range.

Table 1. Contribution margin achieved in mercantile corn production in rainfed conditions (in 2022/23., in EUR/ha)

Element	Quantity	UM	Price per UM in EUR	Total in EUR/ha
A - Incomes				
Mercantile corn	8.5	T	174	1,479.00
Total				**1,479.00**
B - Variable costs				
Seed				140.00
Fertilizers				268.00
Pesticides				82.00
Costs of internal services				206.00
Energy (fuel)				126.00
Costs of transportation				1.00
Other energy costs				5.00
Water				3.00
Operative costs of irrigation				0.00
Costs of mechanization maintaining				6.00
Other material costs				16.00
Various analysis				5.00
Other costs				76.00
Labor				43.00
Depreciation				259.00
Other nonmaterial costs				36.00
Total				**1,272.00**
C - Contribution margin (A-B)				**207.00**

Source: Authors' calculation according to IAE, 2023.

In order to avoid potential impacts on income side of calculation, and further deviation of generated conclusions, subsidies have not included. Irrigation implementation drives to almost doubled crops' yield per hectare, i.e. to generation of for over the 85% higher farm income in corn production. In structure of variable costs in both production alternatives dominates the costs of fertilizers, while in second alternative (Table 2.), there come to increase in certain costs lines, especially in operative costs of irrigation (they contribute with almost 10% in the structure of overall variable costs). Meanwhile irrigation initiates for around 20% higher overall costs of corn production. At the end, introduced agro-technical measure boosts the value of contribution margin for 5.8 times.

Table 2. Contribution margin achieved in mercantile corn production under irrigation (in 2022/23., in EUR/ha)

Element	Quantity	UM	Price per UM in EUR	Total in EUR/ha
A – Incomes				
Mercantile corn	15.8	t	174	2,749.20
Total				**2,749.20**
B - Variable costs				
Seed				140.00
Fertilizer				308.20
Pesticides				82.00
Costs of internal services				236.90
Energy (fuel)				144.90
Costs of transportation				1.15
Other energy costs				5.75
Water				3.45
Operative costs of irrigation				152.00
Costs of mechanization maintaining				6.90
Other material costs				18.40
Various analysis				5.00
Other costs				87.40
Labor				49.45
Depreciation				259.00
Other nonmaterial costs				36.00
Total				**1,536.50**
C – Contribution margin (A-B)				**1,212.70**

Source: Authors' calculation according to IAE, 2023.

In next tables (Table 3-6.) are developed sensitivity analysis of contribution margin for bot production alternatives.

Table 3. Sensitivity analysis of contribution margin in rainfed corn production due to fall of corn yield or selling price

Fall of yield or selling price (in %)	Shift of contribution margin (in EUR/ha)
10	59.10
15	-14.85
Allowed fall of yield/selling price - 14.00% (equalizing the contribution margin with zero)	

Source: Authors' calculation according to IAE, 2023.

Table 4. Sensitivity analysis of contribution margin in rainfed corn production due to rise in variable costs

Rise in variable costs (in %)	Shift of contribution margin (in EUR/ha)
10	79.80
20	-47.40
Allowed rise in variable costs - 16.27% (equalizing the contribution margin with zero)	

Source: Authors' calculation according to IAE, 2023.

Critical fall of total output which will equalize the contribution margin with zero is 14%, or 44.11%, while the same situation will occur if variable costs increase for 16.27%, or 78.93%.

Table 5. Sensitivity analysis of contribution margin in corn production under irrigation due to fall of corn yield or selling price

Fall of yield or selling price (in %)	Shift of contribution margin (in EUR/ha)
25	525.40
45	-24.44
Allowed fall of yield/selling price - 44.11% (equalizing the contribution margin with zero)	

Source: Authors' calculation according to IAE, 2023.

Table 6. Sensitivity analysis of contribution margin in rainfed corn production due to rise in variable costs

Rise in variable costs (in %)	Shift of contribution margin (in EUR/ha)
40	444.45
80	-16.50
Allowed rise in variable costs - 78.93% (equalizing the contribution margin with zero)	

Source: Authors' calculation according to IAE, 2023.

In both alternatives, contribution margin is more tolerant to rise in variable costs of corn production than to fall in achieved yields or selling price of corn. In same manner, contribution margin achieved in corn growing under the irrigation sounds much more flexible.

Sensitivity analysis could be also presented through the sensitivity matrix for both production alternatives used in corn growing (Table 7. and Table 8.).

Table 7. Sensitivity analysis of contribution margin in rainfed production of mercantile corn related to differing of corn yield/selling price and variable costs of corn production

TO (Total output), (in EUR/ha)	VT (Variable costs), (in EUR/ha)				
	1,144.80	1,017.60	1,272.00	1,399.20	1,526.40
1,331.10	186.30	313.50	59.10	-68.10	-195.30
1,257.15	112.35	239.55	-14.85	-142.05	**-269.25**
1,479.00	334.20	461.40	**207.00**	79.80	-47.40
1,626.90	482.10	609.30	354.90	227.70	100.50
1,700.85	556.05	**683.25**	428.85	301.65	174.45

Source: Authors' calculation according to IAE, 2023.

Table 8. Sensitivity analysis of contribution margin in mercantile corn production under irrigation related to differing of corn yield/selling price and variable costs of corn production

TO (Total output), (in EUR/ha)	VT (Variable costs), (in EUR/ha)				
	921.90	307.30	1,536.50	2,151.10	2,765.70
2,061.90	1,140.00	1,754.60	525.40	-89.20	-703.80
1,512.06	590.16	1,204.76	-24.44	-639.04	**-1,253.64**
2,749.20	1,827.30	2,441.90	**1,212.70**	598.10	-16.50
3,436.50	2,514.60	3,129.20	1,900.00	1,285.40	670.80
3,986.34	3,064.44	**3,679.04**	2,449.84	1,835.24	1,220.64

Source: Authors' calculation according to IAE, 2023.

In line to previously developed contribution margins, there could be calculated the critical production values for certain production elements that enables equalization of determined contribution margins with zero (Table 9. and Table 10.).

Table 9. Critical values of certain production elements in rainfed mercantile corn growing (in EUR/ha, in t/ha)

Element	EUR/ha, t/ha
Expected yield (EY)	8.50
Expected price (EP)	174.00
Expected variable costs (EVC)	1,272.00
Critical price: CP= EVC/EY	**149.65**
Critical yield: CY = EVC/EP	**7.31**
Critical variable costs: CVC = EY x EP	**1,479.00**

Source: Authors' calculation according to IAE, 2023.

Table 10. Critical values of certain production elements in mercantile corn growing under irrigation (in EUR/ha, in t/ha)

Element	EUR/ha, t/ha
Expected yield (EY)	15.80
Expected price (EP)	174.00
Expected variable costs (EVC)	1,536.50
Critical price: CP= EVC/EY	**97.25**
Critical yield: CY = EVC/EP	**8.83**
Critical variable costs: CVC = EY x EP	**2,749.00**

Source: Authors' calculation according to IAE, 2023.

Higher level of flexibility in corn production under the irrigation compared to those produced in rainfed conditions is also visible in previous tables.

At the end, there were estimated the impact of introduced irrigation (Table 11.) on farm profitability (gross financial result) in observed production line.

Table 11. Effects of irrigation in mercantile corn production

Element	Total		Relation with or without irrigation
	(EUR/ha)	%	
Calculation without irrigation			
TO_0 (Total Output)	1,479.00		
VC_0 (Variable Costs)	1,272.00		
CM_0 [Contribution Margin (TO_0-VC_0)]	**207.00**		
Calculation with irrigation			
TO_1 (Total Output)	2,749.20		
VC_1 (Variable Costs)	1,536.50		
CM_1 [Contribution Margin (TO_1-VC_1)]	**1,212.70**		
Calculation of irrigation effects			
$TO_1 - TO_0 = TO_i$ (Increase in Total Output)	1,270.20	85.88	1.86
$VC_1 - VC_0 = VC_i$ (Increase in Variable Costs) = Tn (Costs related to irrigation)	264.50	20.79	1.21
$CM_1 - CM_0 = CM_i$ (Increase in Contribution Margin)	**1,005.70**	**485.85**	**5.86**

Source: Authors' calculation according to IAE, 2023.

At the end, main derived results from economic analysis could be summarized. Keeping aside the results from investment analysis that are crucial for final decision to implement or not certain irrigation system at the farm level, it was seen that the use of irrigation in corn production contrary to rainfed system of production leads to increase in variable costs for slightly over 20%, while generating the increase in total output (incomes) for over the 85%, or increase in contribution margin for almost 5.9 times.

Conclusions

In climate change world, modern agriculture has to adapt to new production circumstances that in areas of Western Balkan are usually colored with occurrence of different level of drought. Additionally, there comes to increase in global population, and constant strivings to provide food security but respecting food safety, in conditions of deficiency of free agriculture areas whose enlargement must not be at the expense of set environmental balance certainly become challenging issue. One of alternatives that will ensure the resilience of crops' yields, producers' incomes and overall profitability could be the implementation of certain irrigation system. Unfortunately, general introduction of this measure is still going so slow.

Performed economic analysis based on variable costs showed that growing the corn under irrigation contrary to rainfed production could be economically justified, as it boosts the contribution margin for almost six times (207.0 EUR contrary to 1,212.7 EUR), keeping equal all other production conditions. Use of irrigation system produce costs that contribute just with 10% within the structure of overall variable costs. They generate over 85% higher farm income in corn growing. Related to sensibility of contribution margin in both growing solutions (rainfed or irrigation) it is more sensible to decrease in gained incomes (yields or selling price), while irrigation appliance provides its additional flexibility.

Limitations linked to the performed research are reflected in fact that analysis is done just to single (case study) agricultural holding that practices crop production under the individually set production recipe, while intends to implement sprinkler irrigation system in upcoming period. Certain, maybe with relatively significant difference in gained results are expected to derive from the analyses that will involve several farms handling with mutually unlike technological base, applied agro-technics and activities. Future research has to be focused to investment analysis due to selection of the adequate irrigation system alternative that fits the best the crop production requirements respecting the size of farm, utilized agro-technics and technology of production, energy and water availability, soil quality, defined crop rotation, etc.

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