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Valuation of Water Alternative Use: Food or Energy Production †

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Abstract: Water is a multi-purpose resource, and almost all of these purposes are of essential importance for our contemporary society. The most important water use nowadays is in food and energy production, and these two uses are essential for the development of civilization. The products of the food and energy industries are valued on the market. In the case of sufficiency of both food and energy supplies, it is possible to evaluate alternative uses of water by a combination of the economic models utilized in the food and energy industries. This paper aims to investigate the alternative use of water in plant and energy production by modeling the relation between them. The additional investigation is based on including a consideration of land as consolidated and non-consolidated area.

Keywords: water; energy; alternative use of water; land consolidation

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1. Introduction

Water is undoubtedly one of the most significant resources for the maintenance and improvement of human life. The two main roles of water, excluding drinking, are for food and electricity production. In this research, we will evaluate the economic contribution of water if it were to be used either for food production or for electricity production.

The basic idea in this research is to compare the values generated by a certain amount of water used for food or electricity production. The importance of water for food production is explicated by yield response factor which varies with the growing stages of crops [1]. The yield response factor obtained as given by FAO (Food and Agriculture Organization of United Nations) for maize and wheat is $K_y \geq 1$, and that result is obtained by research provided in [2]. A yield response factor equal to or greater than 1 means that yield reduction is directly proportional to reduced water use (in cases where $K_y = 1$) and that crop response is very sensitive to water deficit because of stress [1]. Water stress can be reduced by supplying plants with enough nutrients [3], but in this research those aspects of crop yield were not included.

The case study is provided for the water used for electricity production on the hydroelectric power plants Djerdap 1 and Djerdap 2 (Iron Gate 1 and 2, respectively) upon the section of the river Danube located between the Republic of Serbia and Romania. These two countries divide the potential of Danube equally. The Iron Gate 1 and 2 power plants are located upon the Danube at the approximate coordinates 44°40′17.00″ N, 22°31′45.00″ E (Iron Gate 1) and 44°18′11″ N, 22°33′49″ E (Iron Gate 2).

The case study also encompasses the prediction of agricultural yield in the area of Vojvodina (Region of Serbia) if that water was used in agricultural production. Vojvodina is a region of the northern part of Serbia and its area is predominantly suitable for agricultural production, with fertile agricultural land.

This research is based on evaluating a certain amount of water contribution to the agricultural yield or to the electricity production with assumption that one amount of water is used alternatively. Figure 1 illustrates the approach utilized in this research.

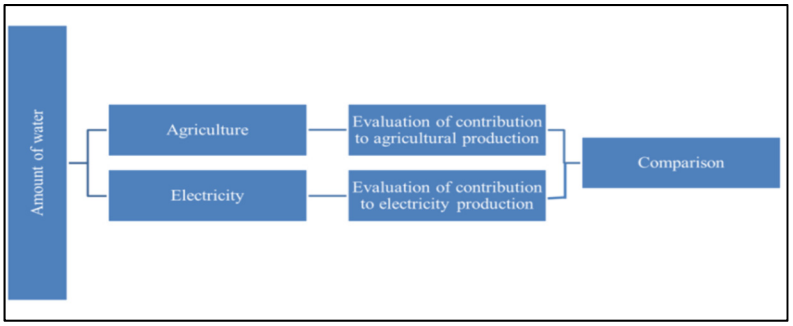


Figure 1. Main idea of provided research.

In this research, the assumption was made that food and electricity are of equal importance for people, but that they produce different economic values.

2. Materials and Methods

The material for this research is based on the data given on official websites about agricultural and electricity production, as well as the prices of a kilowatt hour and the prices of cereals per kg. The prices are given in euros (€).

The main characteristics of power plant Iron Gate 1, for the purposes of this research are [1]:

- The nominal installed power is 1083 MW, and
- The total controlled water flow through the turbines is 5040 m^3/s.

The main characteristics of power plant Iron Gate 2, for the purposes of this research are [2]:

- The nominal installed power is 280 MW, and
- The total controlled water flow through the turbines is 4200 m^3/s.

The available land in the region of Vojvodina is [3] 2,049,241 hectares but, for the purposes this research, the approximate value of 2×10^6 hectares will be used in order to simplify the calculation and without significant loss of accuracy of the conclusions.

The price of electricity in the Republic of Serbia [4] is 0.0591 €/kWh and the price of cereals are [5] 0.2834 €/kg.

The method for evaluation of water contribution is based on the assumption that a certain amount of water should be used either for the purpose of agricultural production or that of electricity production.

The amount of water is determined as the product of agricultural area and water needed for one irrigation cycle:

$$A_W = I_c \text{ m}^3/\text{hectare} \times P \text{ hectare} \quad (1)$$

where:

- A_W—amount of water needed for one irrigation cycle (m^3);
- I_c—amount of water in one irrigation cycle per hectare (m^3/hectare); and
- P—irrigated area (hectare).

This amount of water, passing through the turbines of Iron Gates 1 and 2, could produce the amount of electricity as follows:

$$A_E = A_W \times (1083 \text{ MW}/5040 \text{ m}^3/\text{s} + 280 \text{ MW}/4200 \text{ m}^3/\text{s})/3600 \text{ s} \times E_p \times 1000 \quad (2)$$

where A_E denotes the value of produced electricity and E_p denotes the price of a kilowatt hour in €.

The amount of water used for agricultural production certainly contributes to the increase of yield but it can not be determined precisely. Respecting this fact, we calculated

the contribution in the span of 1% to 15% of assumed average cereal yield per hectare as follows:

$$\Delta_A = P \text{ hectare} \times \text{yield kg/hectare} \times C_p \quad (3)$$

where Δ_A denotes the contribution of considered amount of water to agricultural production and C_p denotes the price of cereals per kilogram. The average yield of cereals in region of Vojvodina is approximately 6400 kg/hectare [6].

3. Results

For the purpose of agricultural production it is assumed that an amount of water 300 m^3 per hectare should be enough for one irrigation cycle, and that the total irrigated area is approximately P = 2,000,000 hectares. This numbers, even though approximate, will not significantly change the conclusion. That leads to the amount of water for the region of Vojvodina as follows:

$$A_W = 300 \text{ m}^3/\text{hectare} \times 2{,}000{,}000 \text{ hectare} = 600{,}000{,}000 \text{ m}^3 \quad (4)$$

This amount of water, passing through the turbines of Iron Gates 1 and 2, could produce the amount of electricity as follows:

$$A_E = 600 \times 10^6 \text{ m}^3 \times (1083 \text{ MW}/5040 \text{ m}^3/\text{s} + 280 \text{ MW}/4200 \text{ m}^3/\text{s})/3600 \text{ s} \times 0.0591 \text{ €/kWh} \times 1000 = 2.77 \times 10^6 \text{ €} \quad (5)$$

where A_E denotes the financial effects of energy production in euros (€) if the considered amount of water A_W was used for electricity production, according to actual prices of electricity in Serbia [7]. The financial effects of considered amount of water to agricultural production, according to market prices [8] and average yields [9] are explicated with following expression:

$$\Delta_A = 2 \times 10^6 \text{ hectare} \times 6400 \text{ kg/hectare} \times C_p \times p \quad (6)$$

where Δ_A denotes the financial effects of agricultural production increment if the amount of water A_W was used for agricultural production, C_p denotes the prices of cereals (€/kg) and p denotes the potential percentage of water contribution to the total agricultural production.

The coefficient of the contribution of the amount of water used for comparison is obtained as follows:

$$C_{Aw} = \Delta_A / A_E \quad (7)$$

where C_{Aw} is the coefficient of financial effects of a certain amount of water contribution to the agricultural and electricity production (Figure 2).

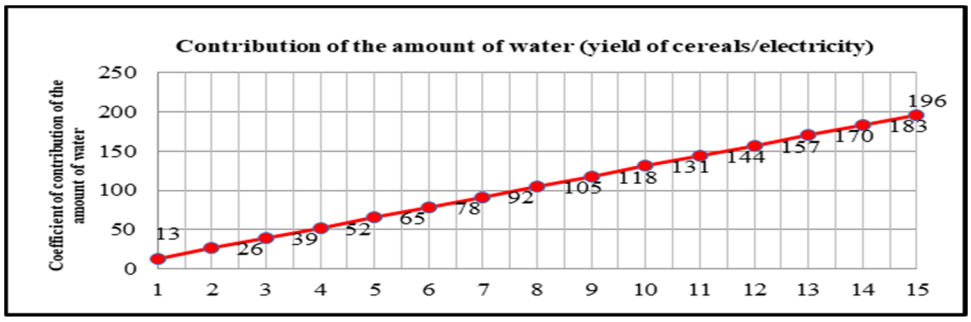


Figure 2. Contribution coefficient.

4. Discussions

The results of analysis in this research showed that the contribution of an amount of water in one irrigation cycle in a span of 1% to 15% could result in 13 to 196 times more economic effects if this amount of water was used for agricultural production instead for electricity production. Bearing in mind that the amount of 0.6 km^3 of water is only 0.5% of

total water flow of the Danube in one year, it could be assumed as negligible. But it can produce significant economic effects in agricultural production.

Additional positive effects of water utilization for food production instead of utilizing the water for electricity production could be obtain if the water is provided in sensitive stages of crop-growing periods. Studies of these effects were not provided because they need the inclusion of many parameters and exceed the domain of this research.

The additional effects of utilizing water could be obtained if the land was consolidated. Land consolidation, as a process of grouping and rearranging agricultural parcels, could additionally improve the water utilization in agricultural production because the process of land consolidation is usually realized along with irrigation systems which provide an efficient supply of water to the crops.

This proposed model for valuation of alternative uses of water, even though is approximate, shows the relation of water contribution to its different uses.

5. Conclusions

This research showed that even in cases of the smallest contribution, water utilization for agricultural production instead of electricity production is economically justified. Utilizing the water for food production will not reduce the electricity production significantly but could significantly increase food production, and consequently significantly increase financial effects.

More detailed research could improve the accuracy of the financial effects of alternative water use, but would not significantly alter the obtained results. The dispersion of values could be the result of different parameters such as: market prices of grain and electricity at the moment of analysis, the content of nutrients in considered agricultural land, and others, but regardless, the model could be utilized to give the general relation of water alternative use.

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