Economic Analysis of Agricultural Water Usage Efficiency in the GAP-Harran Plain: Cotton Production Sampling, Sanliurfa-Turkey

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Abstract: The aim of this study is to make an economic analysis of agricultural water utilization efficiency in GAP-Harran Plain in terms of cotton production in Sanliurfa-Turkey and to reveal the economic value of the water. The main material comes from GAP-Harran Plain which has 165,855 hectares of irrigation areas in 2016 and has a share of 26% of Turkey. Analysis are done based on the guide of water consumption of irrigated crops in Turkey and rainfall, plant water need and water consumption amount were determined. Then, analyzes were made to determine the economic value of the water. The results indicate that at present, irrigation water requirement for cotton plants was 18,304.4 m³/ha. If the targeted ratio is realized, the water requirement will be 13,764.9 m³/ha. In this case, a hectare of 4,539.5 m³ of water will be saved. At present, the economic value of water in cotton production is 0.65 Turkish Lira (TL)/m³, and if the target situation is reached, the economic value of water will be 0.86 TL/m³. If the targeted situation is realized, the economic value of the water for the Harran Plain will increase by $139.51 million per year. The economic value of water comes to the forefront in the allocation of water resources. Cotton production is important for Turkey which is the 4th country that imports the most cotton in the world. This research is the first of its type for GAP-Harran Plain. The results of this research could be helpful for policy and decision makers about planning of water resources.

Keywords: Agricultural irrigations, Cotton production, Economic value of water, GAP-Harran Plain, Sanliurfa, Turkey.

Article Received: 11 Nov. 2018 Revised: 22 Nov. 2018 Accepted: 30 Nov. 2018

Introduction

There are increasing pressures on water resources and the environment, due to rapid population growth, urbanization, industrialization, climate change and agricultural irrigation in all over the world [1]. Water is a strategic element for all nations and is an indispensable source of living together with the environment. Today, the importance of protecting the environment and water resources and using them within the principles of efficiency is increasing day by day. In many countries, planning is done on the basis of allocation and use of water between sectors in recent years. On the other hand, due to climate changes and droughts, which are starting to be seen more frequently, studies on the social and economic value of water have been carried out especially in regions which are located in arid and semi-arid climate regions [2]. In addition to providing food safety, agriculture is also a very important sector in terms of
input into agricultural industry and employment. One of the most important inputs of agriculture is water [3]. Water is most commonly used in agricultural irrigation in worldwide [4] and is around 70% [5]. The share of agricultural sector in terms of water usage in Turkey is around 73% among the other sectors [6]. Therefore, agricultural irrigation is the most important factor in the planning and management of the usage of water resources. It is essential to improve the efficiency of water use in agricultural irrigations, to make economic analyzes based on water, and to plan the amount of water usage properly.

Ensuring productivity in agricultural irrigation is also important in terms of conscious, efficient and effective use of water and water resources and increasing agricultural production. Irrigation efficiency in agriculture has a big impact on yield amounts. In agriculture, all inputs cultivation, seeds and fertilizer used correctly in agriculture, expected economic benefits may not be achieved due to inadequate water, improper irrigation system or excessive water usage.

This might be result to deterioration the structure of the soil due to the risks such as erosion, elevation of groundwater level and salting. There are drainage problems arise from improper irrigation methods that is mainly furrow irrigation in Harran plain [7] because of excessive water usage. On the other hand, returned waters also have negative effects on the environment due to excessive irrigation. Increasing efficiency in agricultural irrigation has known benefits in terms of soil loss, soil conservation, productivity and water saving.

In addition, there are also important economic functions, such as agro-industry and employment, quality assurance and standardization of the product, irrigate more fields. The Imambakir water user association (WUA) is located in the lowest altitude of the Harran plain where groundwater level is high, intensive salinity is observed some areas in WUA because of excessive water use and results to significant yield losses [8]. Salinity decreases cotton yield almost 30% in GAP-Harran Plain [9] and has led to an 1,840-ton cotton yield losses in a year, the resulting income loss was almost 1 million $ in 2009 in the Akcakale, within GAP-Harran Plain irrigations [10].

Cotton is a plant with a wide range of uses. It provides great benefits to the country's economy because of its added value and employment opportunities. In this respect, cotton is a product which has strategic importance that is the main raw material of woven and textile industries. At the same time cotton seeds are used in oil industry, and pulps are also used as animal feeds. Cotton is also used in recent years to reduce environmental concerns caused by oil-derived fuels and external dependence on petroleum.

The oil obtained from cotton seed has started to be used as a raw material in the increasing amount of biodiesel production. In this respect cotton is also a part of energy agriculture. Therefore, cotton plants provide positive contributions to the development of both the agriculture and the industry of the cultivated regions and countries [11]. The ecology of few countries in the world is suitable for cotton cultivation. Therefore, almost 80% of world cotton production is produced by a small number of countries, including in Turkey, too [12].

According to the International Cotton Advisory Committee’s 5 - year period between 2012 and 2016, an average of 33.4 million hectares of cotton land has been planted in the world. An average of 25.8 million tons of fiber cotton was obtained from these planting areas. China was the first country in terms of largest cotton producing areas of China in the world, while India ranks first in the production increases in recent years.

Turkey, according to estimates of 2016/17 production season’s figures, is located 9th in the world together with 416 thousand hectares of cotton cultivation in terms of area. And the eighth in the world in terms of the amount of cotton production, while 4th place in terms of the amount of cotton consumption in industry.

Turkey was the 5th place in the world, in terms of efficiency of production amounts which is obtained from the unit area of cotton cultivations in 2016/17 season. And also, Turkey is located 4th place in the world in terms of amount of cotton imports in this period.
Turkey’s exports of cotton value were 124 million dollars, while cotton imports were 1,238 billion dollars in 2016 [12]. According to the International Cotton Advisory Committee (ICAC) research, cotton fiber production in the world does not meet consumption. The demand is met with stocks of past years [13].

This situation increases the importance of cotton production globally. Despite the expected increase in cotton prices, high levels of stock amounts are a factor that prevents this trend from occurring. According to the Turkish Statistical Institute (TUIK) data, 416 thousand hectares of cotton cultivation is done in 2016 in Turkey. The amount of produced cotton to meet the demand rate was 52.14% in Turkey. Southeast Anatolia Region is the first place in terms of the size of cotton cultivation areas. The share of Southeastern Anatolia Region in all cotton cultivation areas was 57% in 2016. Sanliurfa has 1st place in Turkey, both in terms of produced fiber cotton amount as well as cultivation area, which was 41.1% of the country. The most cotton cultivation and production area in Sanliurfa is GAP-Harran Plain which has a share of 26% of Turkey.

Materials and Methods
The Southeastern Anatolian Project (GAP, in its Turkish acronym) is a multi-sectorial regional sustainable development projects that is mainly based on soil and water resources at South eastern part of Turkey. Agriculture is the leading sector with a 3.13 million ha of land in the GAP Region, Within the GAP’s scope; there are 22 dams, 19 hydroelectric power plants and irrigation of 1,822 million ha of agricultural land [14] and 424,710 ha of land was being irrigated. There are nine provinces in GAP region that is almost 10% of Turkey in terms of area and population. Sanliurfa is the second crowded city of GAP, covers 22.3% of region’s populations, 37.7% of agricultural land and Harran plain is located in Sanliurfa [15], GAP is the largest investment for regional development in the history of Turkey and fourth largest irrigation project in the world [16, 17].

Harran Plain is the research area that has 165,855 ha of irrigation areas together with Upper-Harran Plain irrigations. Irrigation has begun first time in Harran plain within the scope of GAP at 1994. It is located at southeast part of Turkey at 375 meters of altitude that is the lowest altitude locations in the GAP. The average precipitation is between 300-365 mms and annual evaporation is 1,848 mms according to the data of State Meteorology Works (SMW) [18]. The soil texture is the storage area for water accessible to the plant by the root system.

The texture and depth which are two basic physical characteristics of the soil texture determining the total water supply available to the plant. Soil characteristics, or the relative distribution of sand, silt, and clay particles, is the major determinant of water holding capacity of the soil and these mixtures forms agricultural soils [19]. The soil texture is important in terms of water need of crops in agricultural irrigations. Harran Plain has clay loamy soil. Clay content is between 40% and 70%, silt content is between 18% and 32% [20]. The amount of water needed by each plant varies during the growing season, depending on the climatic conditions of the planting area. In this study, the water needs of the cotton plant for each months during the growing season are calculated based on the water consumption guide of the irrigated plants in Turkey [21].

In this study, monthly values of water consumption of cotton plants belonging to Sanliurfa and Akcakale research stations which are representing Harran Plain were used. The monthly average values of these stations are used for cotton plant water consumption calculation. These values are given below in Table 1. Climatic factors such as temperature, wind, rainfall and relative humidity significantly affect the boll production of cotton. High temperature, especially more than 30°C, reduces yield amount due to the boll retention and strong winds may also reduce the yield due to boll shedding and also rain during flowering and boll opening reduce fiber quality [22].

The net irrigation water requirement of conventional irrigation methods is calculated by subtracting effective rainfall from plant water consumption. While effective rainfall values were calculated, precipitation averages were used for long terms from meteorological stations which are representing the Harran Plain according to the data of water consumption guide of irrigated crops in Turkey. According to the guide, 80% of this value is considered as...
effective rainfall. The net irrigation water demand is calculated from the need for water consumption of the plant, by subtracting effective rainfall, that is \( \text{dn}=\text{Etc-\text{Pe}} \). Where, \( \text{dn} \): Net irrigation water requirement, \( \text{Etc} \): Plant water consumption requirement and \( \text{Pe} \): Effective rainfall. Water application productivity is an important and determining factor for evaluation of water value.

Water application efficiency is obtained by multiplying water transmission efficiency with on-field water application efficiencies. The total irrigation water requirement is determined by division of net irrigation water demand by the water application efficiency, which is \( \text{dt}=\frac{\text{dn}}{\text{Ea*Ec}} \). Where: \( \text{dt} \): total irrigation water requirement (mm), \( \text{Ea} \): water transmission efficiency and \( \text{Ec} \): on-field water application efficiency. In this study, when calculating the total water requirement irrigation water transmission efficiency was 94%, while the on-farm water application efficiency was taken as 44%. According to these values, the water application efficiency was 41.36%. These values are derived from the data obtained from the relevant institutions.

**Results and Discussions**

According to the Geographical Information System (GIS) data of 2016, 64.8% cotton seeds are planted in Harran Plain including the second crop plant. This rate corresponds to 40.83% of cotton fields cultivated in the GAP Region. A total of 2.47 billion \( m^3 \) of water was supplied for Harran Plain irrigation by means of the Atatürk Dam, along the Sanlıurfa tunnels together with underground water pumping supplies to the irrigation canals in 2016. With these waters, 165,855 ha area was irrigated in 2016 and 14,892.5 \( m^3/ha \) of water was used according to the current crop pattern.

The 88.5% of the Harran plain under gravity irrigation and 11.5% of them under pumped irrigation [23]. The cotton plant water needs were calculated as 7,570.7 \( m^3/ha \) in a cotton production season in Harran Plain, according to the water consumption guide of irrigated crops in Turkey. Calculations are given below in Table 2. The cultivated cotton area in Harran was 107,474.04 hectares and the average cotton yield was 6,262.5 kg/ha. Generally, it is expected that the water application efficiency in an irrigation network is not less than 50-60% [24].

The water application efficiency in the Harran Plain irrigation was 41.36% in 2016. According to this, irrigation water requirement for cotton plant was 18,304.4 \( m^3/ha \). Another conclusion drawn from here is that, 10,733.7 \( m^3/ha \) of more irrigation water was used in terms of the cotton plant water needs and 4,539.5 \( m^3/ha \) of more water was used in terms of irrigation water requirements in the plain of Harran in 2016. According to these figures, 0.342 kg of cotton was produced with 1 \( m^3 \) of water.

In other words, 2.923 tons of water is used for the production of 1 kg of cotton in the GAP-Harran Plain. On the other hand, it was also showed in some research that a kilogram (kg) of cotton production normally needs 2.5 ton of water in Harran Plain for surface irrigation [10, 25]. Even if this amount of water consumption is still higher, but at the same time, this rate is still well below the amount of global cotton production water consumption.

The global average water footprint for 1kg of cotton is 10 tons, cotton uses 8 tons per kg. in US with irrigation, while producing 1kg of cotton in India consumes 22.5 ton of water, on average, according to research done by the Water Footprint Network [26]. The water consumed to grow India’s cotton exports in 2013 would be enough to supply 85% of the country’s 1.24 billion people with 100 liters of water every day for a year. Meanwhile, more than 100 million people in India do not have access to safe water [27].

In Turkey, "Regulations on the Control of Water Use in Irrigation Systems and Reduction of Water Loss in Irrigation" [28] have been published in February 2017. In accordance with the principles of this regulation, responsible institutions are assigned to raise irrigation efficiency.

Accordingly, it is required to take necessary measures to raise the irrigation efficiency to 55% within seven years. This can only be possible through rehabilitation of existing irrigation systems, dissemination of modern irrigation systems and training of farmers in irrigation. In fact, farmers are aware of the importance of effective irrigations, both in terms of income and the sustainable usage of natural resources. In a survey conducted on GAP-Harran plain, it was found that farmers have willingness to pay for efficient irrigation.
for sustainable usage of resources of $133.7 per hectare [25]. In this study, a new calculation was made using the available data for 55% of the targeted water application efficiency. The differences between the current situation and the targeted situation are given below in Table 3. According to the results obtained from calculations; more of 35,443.56 hectares of cotton cultivation area will be irrigated with the amount of water to be saved with the improvements that may occur by the targeted water application efficiency.

In this case, 2,198 tons of water will be used for 1 kg of cotton production. The product yield based on average yield values from this area was calculated as 221.96 million kg of cotton. Seasonal average selling price of cotton was 1.9 TL/kg in Sanliurfa in 2016. According to these results, the additional gross product value to be obtained will be 421.73 million TL. This value is denominated in US dollars, an average of 2016 per 1 USD = 3.023 TL [29] and is calculated as 139.51 million USD.

This value corresponds to Turkey’s 11.27% of the total value paid to cotton imports in 2016. The realization of this targeted situation, where Turkey is a net importer of cotton, will provide a positive contribution to the economy of Turkey. According to the present water application efficiency, the economic value of water in cotton production is 0.65 TL/m³, and if the target water application efficiency is reached, the economic value of the water will be 0.86 TL/m³. In other words, the economic value of water in cotton production will increase by approximately 33%.

Cotton varieties also effects the used amounts of irrigation waters. Some varieties might be considered to be among the most drought tolerant crops grown in the semi-arid regions of Turkey. In such a case the economic value of water will be more in GAP-Harran plain. On the other hand, in order to reach the targeted irrigation efficiency, in addition to the effective irrigation, rehabilitation of existing irrigation systems is also required.

This is a situation that requires public funding. The Gediz basin which is located in the west of Turkey, has an approximately 192 thousand hectares of irrigation areas in 2016 and 85% of gravity irrigation is done in the field. The Gediz basin is similar to the GAP-Harran plain in terms of irrigation systems. An investment cost of 19,079.16 TL per hectare was calculated for rehabilitation, renewal and addition of irrigation facilities of Gediz Basin for efficient irrigations with the prices of 2016 [30].

With these costs taking into account, it would also be possible to rehabilitate an area of 22,080 hectares with additional gross product value to be obtained in the case of targeted irrigation efficiency. On the other hand, harvesting of cotton is common in the GAP region and Harran Plain without machine. It is generally harvested by hand collection and the seasonal workmanship in cotton plantations is 1,867.3 TL per hectare [31]. If the irrigation efficiency target is met, additional seasonal employment of 7,354 people will be provided with the additional irrigation area of cotton.

The average household size in GAP-Harran Plain is 7.04 people [23]. In this case, an additional 51,771 people will have a seasonal livelihood. This will be positively reflected in the region and the country’s economy both in terms of social and economic aspects.

<p>| Table 1: Monthly precipitation averages of the stations representing the Harran Plain (mm) |
|------------------------------------|------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Precipitation</th>
<th>Akcakale</th>
<th>Sanliurfa</th>
<th>Total</th>
<th>Mean Value</th>
<th>Effective Precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>44,1</td>
<td>76,6</td>
<td>120,7</td>
<td>60,35</td>
<td>48,28</td>
</tr>
<tr>
<td>February</td>
<td>41,1</td>
<td>69,9</td>
<td>111,0</td>
<td>55,5</td>
<td>44,40</td>
</tr>
<tr>
<td>March</td>
<td>36,8</td>
<td>63,9</td>
<td>100,7</td>
<td>50,35</td>
<td>40,28</td>
</tr>
<tr>
<td>April</td>
<td>24</td>
<td>40,9</td>
<td>64,9</td>
<td>32,45</td>
<td>25,96</td>
</tr>
<tr>
<td>May</td>
<td>16,8</td>
<td>26,3</td>
<td>43,1</td>
<td>21,55</td>
<td>17,24</td>
</tr>
<tr>
<td>June</td>
<td>1,1</td>
<td>4,2</td>
<td>5,3</td>
<td>2,65</td>
<td>2,12</td>
</tr>
<tr>
<td>July</td>
<td>0,9</td>
<td>0,9</td>
<td>1,8</td>
<td>0,9</td>
<td>0,72</td>
</tr>
<tr>
<td>August</td>
<td>0</td>
<td>1,2</td>
<td>1,2</td>
<td>0,6</td>
<td>0,48</td>
</tr>
<tr>
<td>September</td>
<td>1,4</td>
<td>4,0</td>
<td>5,4</td>
<td>2,7</td>
<td>2,16</td>
</tr>
<tr>
<td>October</td>
<td>19,7</td>
<td>27,7</td>
<td>47,4</td>
<td>23,7</td>
<td>18,96</td>
</tr>
<tr>
<td>November</td>
<td>32,9</td>
<td>50,2</td>
<td>83,1</td>
<td>41,55</td>
<td>33,24</td>
</tr>
<tr>
<td>December</td>
<td>40,4</td>
<td>67,6</td>
<td>108</td>
<td>54,0</td>
<td>45,20</td>
</tr>
</tbody>
</table>
Table 2: Irrigation water needs of cotton in Harran Plain, according to the water consumption guide of irrigated crops in Turkey

<table>
<thead>
<tr>
<th>Cotton</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>November</th>
<th>dn</th>
<th>m$^3$/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akcakale</td>
<td>16,20</td>
<td>92,70</td>
<td>230,50</td>
<td>217,70</td>
<td>143,40</td>
<td>54,20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanliurfa</td>
<td>22,40</td>
<td>105,70</td>
<td>249,90</td>
<td>240,50</td>
<td>162,80</td>
<td>61,50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>38,60</td>
<td>198,40</td>
<td>480,40</td>
<td>458,20</td>
<td>306,20</td>
<td>115,70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean Value (Etc)</td>
<td>19,30</td>
<td>99,20</td>
<td>240,20</td>
<td>229,10</td>
<td>153,10</td>
<td>57,85</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Differences arising on the basis of the present situation and the targeted water application efficiency

<table>
<thead>
<tr>
<th>Cotton</th>
<th>Current Water Application Efficiency (41.36%)</th>
<th>Targeted Water Application Efficiency (55%)</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation water requirement (m$^3$/ha)</td>
<td>18,304.40</td>
<td>13,764.91</td>
<td>4,539.49</td>
</tr>
<tr>
<td>Total irrigation water (m$^3$)</td>
<td>1,967,247,818</td>
<td>1,479,370,488</td>
<td>487,877,330</td>
</tr>
<tr>
<td>Water-based production yield (kg/m$^3$)</td>
<td>0.342</td>
<td>0.455</td>
<td>0.113</td>
</tr>
</tbody>
</table>

Conclusion

The economic sustainability of resources could be considered as use of various strategies for applying existing resources optimally so that a responsible and beneficial balance can be achieved over the longer term [32] usage. Water resources are not infinite and unlimited resources. There is competition among sectors such as industry, household use, agriculture, ecology, and recreation, in determining the amount of water resources to use. This competition concerns the determination of the economic value of used water and its use in the most productive areas [33].

Therefore, the importance of efficient and effective use of water is increasing each passing day. Water is most used in agriculture in Turkey and the world. The economic value of water will be increased by means of improvements that can occur in the rehabilitations of irrigation systems and by using effective irrigation systems such as pressurized irrigations. In such a case, environmental and water resources will be protected and sustainability could be achieved.

The development of drought-tolerant cotton varieties and dissemination are also important and more researches are needed to determine how different varieties, respond to irrigation at different stages in plant development. There are researches on these issues in regions that produce cotton and water deficiency in the world [34]. In this case the amount of water to be used will be further reduced. In such a case, both the economic value of the water will increase and the income from the cotton will increase, too.

If Turkey’s target rate as provided in agricultural water use, USD 139.51 million gross product value will additionally have obtained and this value corresponds 11.27% of the total value which was paid to cotton imports in 2016. With this additional income, it would also be possible to rehabilitate an area of 22,080 hectares. At the same time, an additional seasonal employment of 7,354 people will be provided, thus the seasonal livelihood of 51,771 persons.

The results obtained from this study will be used in determining the economic value of the water, and in inter-sectoral usage planning. This issue can be considered as water footprint for sustainable usage of water in terms of resource efficiency, welfare and social equity of water use in agricultural irrigations in GAP-Harran Plain. The results of this research could be also helpful for policy and decision makers about sustainability assessment of water resources...
to identify and prioritize strategic planning’s levels, individually and collectively.

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