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Assessing the Crop-Based Pricing of Treated Wastewater in Agriculture

Tarımda Arıtılmış Atıksuyun Ürün Bazlı Fiyatlandırılmasının Değerlendirilmesi

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ABSTRACT

Water is a vital natural asset for life that cannot be replaced by anything else. Its association with nutrients is one of its main characteristics. Water resources have been depleted due to unhealthy urbanization, population growth, an increase in greenhouse gases, and industrialization. The balance between supply and demand is deteriorating day by day, and water scarcity reveals the necessity of alternative water resources. Therefore, in addition to the proper use of clean water resources, wastewater management is also important. This study includes the management and evaluation of the wastewater of Konya's central districts. For this purpose, the neighborhoods (Karatay, Meram, Selçuklu Districts) within the impact area of Konya Wastewater Treatment Plants, where the wastewater generated in Konya Province Centre is treated, are the target group. Data obtained from farmers who live in these neighborhoods and irrigate their lands with the water from the treatment plants were used. Thus, the wastewater price was calculated based on the value of agricultural products. In the calculations, wastewater pricing was made based on barley, wheat, and sunflower products commonly grown in the region, by which the treated wastewater price was determined. Accordingly, the wastewater cost was calculated as 0.18 USD/ton for barley production, 0.28 USD/ton for wheat production, and 0.21 USD/ton for sunflower production. Pricing and determining the economic value of water will ensure the balancing of supply and demand, and the efficient use or exploitation of scarce water and natural resources. When it comes to water prices in the classical sense, calculations are generally made based on operation, maintenance, and repair costs both worldwide and in Türkiye. However, this situation leads to not only the use of water, which is a natural asset, at a high price, but also causes uncontrolled use of natural resources. Calculations based on product value will ensure that they will lead to more efficient and fair use of water.

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ÖZ

Su, başka hiçbir şeyle değiştirilemeyen yaşam için hayati öneme sahip doğal varlıktır. Besinlerle ara bağlantısı olması bu ürünün ana özelliklerinden biridir. Sağlıksız kentleşme, nüfus artışı, sera gazlarındaki artış ve sanayileşmenin etkisiyle su kaynakları azalmaktadır. Arz ve talep arasındaki denge her geçen gün bozulmakta ve su kıtlığının yaşanması alternatif su kaynaklarının gerekliliğini ortaya çıkarmaktadır. Bu nedenle temiz su kaynaklarının doğru kullanımının yanısıra atık suların yönetimi de önemlidir. Bu çalışma, Konya merkez ilçelerinin atık sularının yönetimini ve değerlendirilmesini içermektedir. Bu amaçla Konya İl Merkezinde oluşan atık suların arıtıldığı Konya Atık Su Arıtma Tesislerinin etki alanı içerisinde yer alan mahalleler (Karatay, Meram, Selçuklu İlçeleri) hedef kitledir. Bu mahallelerde yaşayan ve arıtma tesisinden çıkan su ile sulama yapan çiftçilerden elde edilen veriler kullanılmıştır. Böylece tarım ürünleri değeri üzerinden atık su fiyatı hesaplanmıştır. Hesaplamalarda; Bölgede yaygın olarak yetiştirilen arpa, buğday ve ayçiçeği ürünleri üzerinden atık su fiyatlaması yapılmış ve arıtılmış atık su bedeli belirlenmiştir. Buna göre arpa üretiminde 0,18 USD/ton, buğday üretiminde 0,28 USD/ton ve ayçiçeği üretiminde 0,21 USD/ton olarak atıksu bedeli hesaplanmıştır. Suyun fiyatlandırılması ve ekonomik değerinin belirlenmesi, arz ve talebin dengelenmesi, kıt su ile birlikte doğal kaynakların verimli kullanılması veya değerlendirilmesi sağlanacaktır. Klasik anlamda su ücreti denildiğinde, genelde dünyada ve Türkiye'de işletme, bakım - onarım maliyetleri üzerinden hesaplama yapılmaktadır. Ancak bu durum, hem doğal varlık olan suyun yüksek bedelle kullanımına yol açmakta hem de doğal kaynakların kontrolsüz kullanımına neden olmaktadır. Ürün değeri üzerinden yapılacak hesaplamalar suyun daha verimli ve adil kullanılmasına yol açacaktır.

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1. INTRODUCTION

Water is an indispensable natural product for the survival of life in the entire biosphere. The increasing pollution of clean water resources and the increasing world population have made it essential to manage water resources and even wastewater in a rational and correct way. In Türkiıye, the problem of meeting the water demand has emerged due to the ever-increasing population and decreasing water resources. If water resources in Türkiıye are evaluated according to the Falkenmark index, it is seen that Türkiıye is among the countries suffering from water shortage with an annual available water amount of 1,652 m³ per capita in 2000, 1,544 m³ in 2009, and 1,343 m³ in 2021, which is the threshold value (Alagöz E., 2023).

As shown in Table 1, the available water potential per capita in Türkiıye decreased from 4,000 m³ in 1,960 to 1,600 m³ in 2,000. By 2030, considering population growth, it is predicted that the water potential will decrease to 1,120 m³ per capita (Demir Y., 2021-2025).

Looking at water from this perspective, Türkiye is not a water-rich country, as has been stated on every platform. The Konya basin is a basin with the lowest annual rainfall and no large surface water resources such as the Kızılırmak, Yeşilırmak, Seyhan, Tigris and Euphrates rivers. In this basin, even if the water is treated or untreated, it is valuable enough to contribute to the agriculture of the region with proper and effective management.

In the world, 97.5% of the total amount of 1,386 million km³ of water, including oceans, glaciers, lakes, rivers, groundwater, and water vapor in the atmosphere, is saline water in the oceans. Of the remaining 2.5%, only 0.5% is usable, while more than 90% of the so-called potable fresh water is found at the poles and underground (Survey, 2025). Groundwater is an important source of water, especially when surface water sources are unavailable due to drought or pollution. Groundwater can even be called mobilization water. Groundwater provides drinking water for at least half of the world's population and accounts for more than 40% of the water used for irrigation. In some regions, due to the scarcity of surface water and drought, this reserve water (groundwater) has unfortunately been used, and most of it has been consumed.

Table 1. Water status in Türkiye according to the Falkenmark index

Category	Amount of water available per person per year m³	Türkiye
Water poverty	Less than 1000 m³	1.120 m³ /person/year (2030)
Water scarcity	Less than 2000 m³	1.519 m³ /person/year (2008)
Water richness	More than 8.000 - 10.000 m³	4.000 m³ /person/year (1960)

When water use is carefully analyzed, it is seen that the main user is the agricultural sector and agriculture is carried out with irrigation water. Moreover, water is used free of charge in this sector. However, a fair, acceptable and efficient pricing of water can not only help the world's resources to be used properly but also provide a solution to the food problem by increasing agricultural output. For this purpose, water pricing studies should be carried out in a way to protect farmer welfare as well as cropping patterns, yield, and water consumption. Water resources in the world are limited. The distribution of water in the world according to these resources is shown in Table 2. On the other hand, the amount of wastewater is not known. Therefore, wastewater is used free of charge. Due to the diminishing water resources in the world, it is considered that wastewater to be used as derivative water may also have a value and a price.

Although it is right to use wastewater free of charge, opinions have emerged that this water should also have a value. This is because water resources are gradually decreasing and cannot be replaced. Approaches that value wastewater are mostly based on treatment costs. The rationale for using wastewater in crop irrigation is primarily driven by the increasing scarcity of freshwater resources and the need for sustainable agricultural practices. Treated wastewater offers a viable alternative, providing essential nutrients and organic matter that can enhance soil fertility and crop growth (Mishra et al., 2023). In this study, the value of wastewater is calculated based on agricultural products. As is known, irrigation is one of the resources that directly affect agricultural production. Irrigation is the delivery of additional water to the plant without harming the environment and nature in cases where the water required for plant growth cannot be met by natural means (Kütahya İl Tarım ve Orman Müdürlüğü, 2015).

The growing scarcity of water resources worldwide has prompted researchers and policymakers to explore alternative water sources, including the use of treated wastewater in agriculture. Wastewater reuse not only helps mitigate water scarcity but also supports sustainable agricultural practices, particularly in arid and semi-arid regions (Qadir et al., 2010). (Bahri A., 2009; Can & Dulkadiroğlu, 2021).

Despite advancements in wastewater treatment technologies, both human health and the environment may still face significant risks, especially in the context of growing water scarcity. Wastewater often contains hazardous substances, including heavy metals, pharmaceutical residues, and pathogenic microorganisms, which can lead to serious illnesses such as hepatitis, typhoid fever, and dysentery if not properly treated. Improperly treated wastewater used for agricultural irrigation poses additional risks by contaminating food crops, which compromises food safety and threatens public health (Can & Dulkadiroğlu, 2021).

Environmental impacts are also considerable. Uncontrolled discharge of wastewater can lead to surface and groundwater contamination, eutrophication, and loss of biodiversity. High levels of salinity and chemical buildup in wastewater may deteriorate soil structure over time, while emissions of gases such as hydrogen sulfide and ammonia contribute to air pollution and offensive odors. Nonetheless, when appropriately treated, wastewater can serve as a valuable resource. It can reduce reliance on freshwater sources and provide essential nutrients to improve soil fertility. However, these benefits can only be realized through the application of advanced treatment methods such as filtration, oxidation, and disinfection, as well as through strict monitoring of water quality before use in agriculture (Can & Dulkadiroğlu, 2021; Demir Ö., 2017). (Demir Ö., 2017).

Table 2. Estimates of global water distribution (Gleick & Howe, 1995)

Water source	Water volume (km³)	Percentage of freshwater (%)	Percentage of total water (%)
Oceans, Seas, and Gulfs	1.338.000.000	--	96.54
Glaciers, Melting Glaciers and Permanent Snow	24.064.000	68.7	1.74
Groundwater	23.400.000	--	1.69
Salt-free water	*10.530.000*	*30.1*	*0.76*
Saline water	*12.870.000*	--	*0.93*
Soil humidity	16.5	0.05	0.001
Ice under water and glaciers in permafrost	300	0.86	0.022
Lakes	176.4	--	0.013
Salt-free water	*91*	*0.26*	*0.007*
Saline water	*85.4*	--	*0.006*
Atmosphere	12.9	0.04	0.001
Swamp water	11.47	0.03	0.0008
Rivers	2.12	0.006	0.0002
Biological water	1.12	0.003	0.0001

Therefore, it is essential to implement integrated reuse and recycling strategies and conduct comprehensive assessments of treated wastewater to ensure safety and sustainability.

The use of treated wastewater for crop irrigation has gained increasing importance in the context of global water scarcity and the pursuit of sustainable agricultural practices. In response, many countries have established regulatory frameworks to govern the safe reuse of wastewater, aiming to strike a balance between environmental protection, public health, and economic viability. These regulations typically include guidelines for treatment standards and permissible uses, with a primary focus on minimizing health risks and environmental degradation (Mishra et al., 2023).

In the European Union, for example, specific directives have been introduced to promote the reuse of treated wastewater, emphasizing high-quality treatment standards to safeguard both human health and ecological systems (Santos et al., 2023). A key concern addressed in these legislative measures is the presence of pathogens and toxic elements such as heavy metals. Consequently, robust treatment protocols are mandated to ensure that wastewater meets safety thresholds before its application in agriculture (Ungureanu et al., 2020).

Environmental regulations further aim to protect soil and water resources from contamination and degradation. This includes measures to prevent the accumulation of harmful substances in the soil, which could impair fertility and productivity over time (Mishra et al., 2023). Compliance with such regulations often requires substantial investment in wastewater treatment infrastructure, which is essential not only for regulatory adherence but also for promoting the long-term feasibility of wastewater reuse in agriculture (Ungureanu et al., 2020). (Rebora, 2011).

Despite the supportive legislative environment, concerns persist regarding the potential long-term health impacts and environmental sustainability of wastewater reuse. Therefore, achieving an effective balance between maximizing resource efficiency and minimizing risks remains a critical challenge in the broader adoption of wastewater irrigation practices.

The reuse of wastewater worldwide is increasing, especially in crop production. There are many irrigation methods used to exploit amended wastewater. Regardless of the type of irrigation method, the important thing is the amount of water to be given per decare. Because giving too much water is as much of a problem as giving too little. For this reason, pricing should be based on the amount of water, not the decare. However, measuring and charging for this brings along many problems. The water to be given to crops that consume a lot of water should be covered by the income from the crops. Otherwise, this leads to irreversible waste of water. It is known that irrigation water will directly affect yield and thus income. For this purpose, a formula was developed by Direk et al. (2022) since the difference between the same two crops grown with and without irrigation is due to irrigation. In this empirical calculation, it is known that although many factors affect yield, irrigation has the greatest effect. The effect of irrigation on yield is the value of the increased inputs according to the ceteris paribus assumption used by economists, i.e., the principle of "other things being equal". The degree to which the treatment of wastewater affects plant yield is calculated based on this yield (John; & OpenStax, 2018) (Bayraktar & Erkmen, 2023; Daniel, 2005). According to this formula, a value is assigned to the wastewater, and it is recommended to be used in wastewater pricing. In this study, the wastewater value was calculated according to 3 different crops commonly grown in the region.

Economic valuation of wastewater reuse is crucial for water resource management, ensuring fair allocation and efficient use of scarce water resources (Robert A. Young, 2005) (Dinar & Mody, 2004) Several studies have explored the economic aspects of wastewater reuse, emphasizing pricing mechanisms and farmers' willingness to pay for treated wastewater (Hellegers & Leflaive, 2015; Tsur et al., 2004).

In Türkiye, rapid urbanization, population growth, and climate change have increased pressure on water resources, making sustainable water management a key priority (Can & Dulkadiroğlu, 2021; Demir Y., 2021-2025). Particularly in the Konya Basin, with its low annual rainfall and limited surface water resources, the reuse of treated wastewater has emerged as a promising alternative for agricultural irrigation (Demir, 2022).

2. MATERIALS AND METHODS

In this study, using the wastewater cost calculation method developed by Direk et al. (2022), the wastewater value was calculated based on the plants growing in the irrigation areas along the discharge route of Konya Wastewater Treatment Plants. For this purpose, the neighborhoods located in the impact area of Konya Wastewater Treatment Plants where the wastewater treatment process is carried out in Konya City Centre (Karatay, Meram, Selçuklu) were selected as the research area. It is known that the products grown in these neighborhoods are mostly grown using wastewater. In the study, data were obtained through a questionnaire. The subjects who were surveyed were selected from the producers who are close to the Wastewater Treatment Plant and located on the route of the canal through which the plant discharges. For this purpose, Acidort, Gocu, Karakaya, Ortakonak and Sakyatan neighborhoods, which are 5 neighborhoods up to the 2nd pumping station of the State Hydraulic Works after the outlet of the treatment plant, were selected. In addition to the calculation of the economic value of the treated wastewater, the effects on the producers were also examined through the products produced with wastewater by the producers living in these neighborhoods and engaged in agricultural activities. The data obtained from the questionnaire forms prepared in this context were used as the main material of the study. The questionnaire form applied to the producers consists of 3 different sections.

a) Personal Information: Questions measuring personal information such as family structure, education, age, occupation, etc.

b) Economic information: Questions to measure the economic situation of producers such as enterprise size, cropping pattern, land use, etc.

c) Environmental Impacts: It consists of questions about whether the treatment plants create problems such as odour, noise, and traffic around the treatment plants, measuring the level of knowledge of the producers about treated wastewater and treatment sludge, which are by-products of the treatment plants, willingness to use these products, whether the treatment plant is an economic resource and their expectations from the treatment plants.

With the help of the formula given in Direk et al. (2022), in light of the primary data obtained from the neighborhoods above, the value of the water from the Wastewater Treatment Plant was calculated based on the values of the commonly grown crops in the region. At the same time, this is a pricing method requested by 77% of the enterprises in the study area. The formula shown below was used to calculate this value. The formula is empirical and was developed by researchers.

D=*Z***C*= X/Y *(A-B)

C=*A-B*

Z=*X/Y*

K=*D*F* => P=K/X

According to this formula, the value of wastewater can be calculated with given formula by Direk et al. (2022) (Table 3).

According to the farmer registration system of Karatay District Directorate of Agriculture and Forestry; there are 181 farmers in Sakyatan, 84 in Ortakonak, 113 in Acidort, 236 in Karakaya and 235 in Gocu villages. A total of 849 farmers in the research area constituted the main population. The number of samples from this main population was found by using the following formula (Yamane, 1967).

$$n = \frac{N\sigma^2}{(N\text{-}1)\, D^2+\sigma^2}$$

$$D = \left(\frac{d}{t}\right)$$

n = Sample size

N= Number of units in population

σ= Standard deviation

d = Margin of error = 0,10

t = Confidence interval = 1.65 according to 10%

In the sample made according to the number of producers residing in the research area, it was calculated that 63 questionnaires could represent the region. The distribution of the surveys to the neighborhoods was made proportionally. The surveyed neighborhoods and the number of surveys are shown in Table 4.

Table 3. Meaning and units of symbols Direk et al. (2022)

Symbols	Meaning	Unit
X	Amount of Wastewater Produced at the Treatment Plant	t/year
Y	Water Requirement of the Plant per Decare	t/da
A	Crop Yield in Irrigated Lands	kg/da
B	Crop Yield in Non-irrigated Lands	kg/da
F	Sales Price of the Plant	US Dollar/kg
C	Contribution of Water to Yield	kg/da
Z	Area Irrigated with Wastewater	da/year
D	Total Contribution of Wastewater Amount	kg/year
K1	Economic Value of wastewater	US Dollar/year
P1	Unit Price of wastewater	US Dolar/t

3. RESULTS AND DISCUSSION

3.1. Information About the Study Area

In the research area, according to the farmer registration system of Karatay District Directorate of Agriculture and Forestry, there are 849 farmers in Sakyatan, Ortakonak, Acidort and Karakaya neighborhoods. According to the evaluations made on 66 farmers sampled, it is seen that the female population is less than the male population. However, women work in the same rate as men in en-

Table 4. Number of samples by population numbers (John; & OpenStax, 2018)

Sequence No.	Neighborhoods	Main Population	Ratio	Number of Samples Calculated	Number of Surveys Conducted
1	Sakyatan	181	21.32	13.37	14
2	Ortakonak	84	9.89	6.21	7
3	Acidort	113	13.31	8.35	9
4	Karakaya	236	27.80	17.44	18
5	Gocu	235	27.68	17.36	18
Total	849	-	62.73	66	

terprises or in the workforce. When analyzed according to the neighborhoods, it is seen that the male population is higher than the female population except for the Acidort, especially the male population has the highest percentage in the Sakyatan with 64.10%. This unbalanced structure can be explained by the fact that the villages are located very close to the city and families, especially women, reside in the city center. When the occupational status and fields of work in the enterprises are analyzed, it is seen that the highest percentage is farming, the second highest is housewives, but all housewives are also engaged in agricultural activities. On the other hand, another important point is that the number of students ranks third, which means that the importance given to education in the villages is high. When the age interval of the labor force in the enterprises is examined, it is seen that the child population is more than the elderly population, while the most productive working population (36-45) has the second highest percentage. This situation is considered positive in terms of labor force resources for the future of the enterprises. When the distribution of social security in the enterprises is examined, it is seen that nearly 96% of the population is a farmer BAG-KUR and SSI. It can be said that this rate is satisfactorily high. When the enterprises in the research area are examined, it is seen that the villages with the highest number of foreign workers is Gocu, while the villages that does not employ foreign workers is Sakyatan. This shows that the Sakyatan does not need foreign labor in irrigation, shepherding, and cattle breeding. When this situation is evaluated through the data, the fact that the male population in Sakyatan is higher than that in other villages supports the understanding that there is less need for foreign labor. On the other hand, Sakyatan village is located right next to Konya city center, and temporary labor can be easily obtained. When the wages paid by the enterprises to the foreign labor force are examined, it is seen that the highest salary is paid for the shepherd job (Table 5).

3.2. Economic Information for the Study Area

It was observed that farmers in the studied region have 312.9 da of land on average, 91.08% of which is irrigable. Wheat, barley and sunflower are generally grown on these lands (Table 6). More than 90% of the land is irrigable and most of it is irrigated with wastewater. Wheat is grown 46%, barley 37.9% and sunflower 16.1%. (Fig. 1). Other field crops such as corn, sugar beet, millet, clover are also grown, albeit to a lesser extent. Regarding land holdings, it was observed that the highest amount of enterprise land was in Ortakonak village, followed by Sakyatan, Karakaya, Gocu and Acidort villages respectively (Table 6).

According to the neighborhoods, the gross profits of the products produced in the enterprises examined were calculated. Accordingly, the gross profit obtained from

Table 5. Distribution of the population according to age intervals in the enterprises surveyed

Age interval	Male (no)	Male (%)	Female (No)	Female (%)	Total (%)
0-15	10	9.17	7	9.33	9.24
16-25	18	16.51	12	16.00	16.30
26-35	23	21.10	8	10.67	16.85
36-45	20	18.35	14	18.67	18.48
46-55	14	12.84	18	24.00	17.39
56-65	16	14.68	13	17.33	15.76
66-75	8	7.34	3	4.00	5.98
Total	109	100.00	75	100.00	100.00

Table 6. Amount of cultivated land by villages

Villages	Barley		Wheat		Sunflower		Irrigated Land (%)	Total (da)
	Production area (da)	%	Production area (da)	%	Production area (da)	%		
Gocu	125.3	51.4	103.1	42.3	15.3	6.3	62.6	243.6
Ortakonak	314.3	48.6	207.1	32.0	125.0	19.3	100	646.4
Acidort	72.8	36.3	127.8	63.7	0.0	0.0	94.5	200.6
Sakyatan	118.9	32.7	152.9	42.0	92.1	25.3	100	363.9
Karakaya	58.1	21.6	161.8	60.1	49.3	18.3	98.4	269.1
Total (da)	118.5	37.9	144.0	46.0	50.4	16.1	91.2	312.9

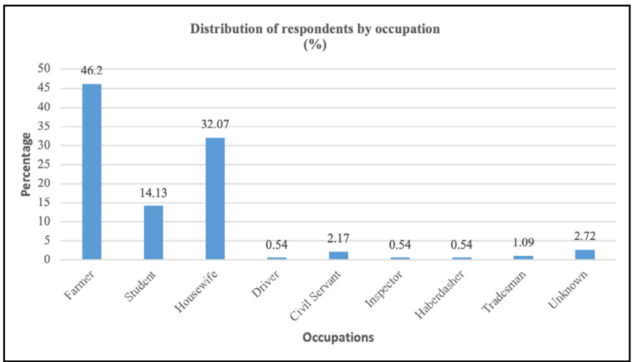

Figure 1. Distribution of the population by occupation in the surveyed enterprises.

barley varies between 117.49 USD/da and 117.72 USD/da, the gross profit obtained from wheat varies between 145.87 USD/da and 146.41 USD/da, and the gross profit obtained from sunflower varies between 169.36 USD/da and 170.05 USD/da (Table 7, 8 and 9). Farming has been practiced in the research area for many years and the crops produced are mostly cool climate cereals. However, corn and sunflower have also been included in the production pattern in recent years. In a study conducted in the region, it is stated that more than one rotation system is applied (Aydın, 2023). In this study, it was observed that the producers practiced rotation.

Table 7. Gross profit in barley production

Production costs (USD/da)	Gocu	Ortakonak	Acidort	Sakyatan	Karakaya	Ortalama
Seeds (USD/kg)	19.78	22.12	21.00	21.59	21.92	21.28
Plantation (USD/da)	1.92	0.92	1.23	0.92	1.48	1.29
Fertilizers (USD/kg)	21.66	18.02	20.35	19.17	22.64	20.37
Fertilizing (USD/da)	1.51	1.85	2.46	1.39	2.09	1.86
Pesticides (USD/L)	8.18	5.29	10.71	5.95	9.53	7.93
Spraying (USD/da)	1.09	1.08	0.62	0.69	0.99	0.89
Harvesting (USD/da)	6.78	6.16	6.43	6.16	6.64	6.43
Threshing (USD/da)	5.55	5.51	5.06	4.97	5.27	5.27
Transportation (USD/kg)	0.14	0.11	0.11	0.12	0.13	0.12
Total variable costs (USD/da)	66.62	61.06	67.97	60.95	70.68	65.46
Sales (USD/da)	184.13	178.55	185.70	178.61	188.36	183.07
Gross Profit (USD/da)	117.51	117.49	117.72	117.66	117.68	117.61

At the time of the survey, the dollar exchange rate was USD/TRY=18.67. Calculations were made accordingly.

Table 8. Gross profit in wheat production

Production costs (USD/da)	Gocu	Ortakonak	Acidort	Sakyatan	Karakaya	Ortalama
Seeds (USD/kg)	23.67	17.35	23.49	28.08	22.93	23.11
Plantation (USD/da)	1.85	1.23	1.94	2.26	1.62	1.78
Fertilizers (USD/kg)	26.51	12.85	20.09	26.96	22.70	21.82
Fertilizing (USD/da)	1.23	0.62	1.23	1.23	1.12	1.09
Pesticides (USD/L)	9.64	53.56	5.02	7.77	5.48	16.29
Spraying (USD/da)	0.92	0.62	1.14	1.03	1.06	0.95
Harvesting (USD/da)	6.96	5.36	6.73	6.25	6.91	6.44
Threshing (USD/da)	5.36	5.89	5.43	5.36	5.36	5.48
Transportation (USD/kg)	0.01	0.01	0.01	0.01	0.01	0.01
Total variable costs (USD/da)	76.16	97.49	65.08	78.94	67.21	76.98
Sales (USD/da)	222.29	243.90	211.41	224.83	213.07	223.10
Gross Profit (USD/da)	146.13	146.41	146.33	145.89	145.87	146.12

At the time of the survey, the dollar exchange rate was USD/TRY=18.67. Calculations were made accordingly.

Table 9. Gross profit in sunflower production

Production costs (USD/da)	Gocu	Ortakonak	Sakyatan	Karakaya	Ortalama
Seeds (USD/kg)	21.07	18.53	21.78	17.70	19.77
Plantation (USD/da)	2.05	0.80	1.23	0.92	1.25
Fertilizers (USD/kg)	70.34	72.04	55.35	51.29	62.25
Fertilizing (USD/da)	2.46	1.54	2.05	1.85	1.98
Pesticides (USD/L)	21.42	21.42	17.68	15.80	19.08
Spraying (USD/da)	0.82	0.92	1.64	1.85	1.31
Harvesting (USD/da)	9.82	9.11	8.39	8.57	8.97
Threshing (USD/da)	7.86	7.77	7.14	6.96	7.43
Transportation (USD/kg)	0.01	0.01	0.01	0.01	0.01
Total variable costs (USD/da)	141.40	138.84	121.88	111.91	128.51
Sales (USD/da)	311.01	308.89	291.24	281.80	298.24
Gross profit (USD/da)	169.61	170.05	169.36	169.88	169.73

At the time of the survey, the dollar exchange rate was USD/TRY=18.67. Calculations were made accordingly.

3.3. Environmental Information for the Study Area

Producers are compulsorily members of several professional and non-professional organizations along with the intensive agricultural activities. When producers were asked about their organizational status, they stated that they are members of organizations such as Agricultural Development Cooperative, PANKOBIRLIK, Agricultural Credit Cooperative, Irrigation Cooperative, Dairy Union, and Cattle Breeders Union. This is a good situation in terms of farmers acting together. A strong society can only be stronger with a strong organization. The most common membership in agricultural organizations is membership in the Irrigation Union. It is seen that the neighborhoods in the region have drinking water networks but not sewage networks. There is no systematic sewage network. It has been determined that producers solve their sewage problems by digging pits. Although it seems that there is no environmental problem in the long term, this situation can be seen as a threat to groundwater. The willingness to use wastewater was analyzed in the investigated enterprises. Producers expressed their willingness to use wastewater without treatment. As a matter of fact, in another study, land irrigated with wastewater was considered more valuable than others. However, although wastewater is valuable in the eyes of farmers, it is not known what its long-term effects will be. Although wastewater contains organic materials, it should not be forgotten that it may also contain heavy metals and harmful elements. For this reason, although wastewater may seem advantageous in the short term, it is not correct to use it without treatment due to the unknown long-term effects. When the level of knowledge of the enterprises about treated wastewater is analyzed, it is seen that 40.91% of them have sufficient knowledge about treated wastewater. This means that the majority in the region somehow know the quality of the water they use in irrigation. However, it is important to investigate the effects of wastewater treated with on agricultural crops. At least seventy percent of the enterprises find treated wastewater safe. This rate clearly shows the trust and willingness of the region towards treated wastewater (Fig. 2). The rate of those who believe in the effect of treated wastewater on productivity exceeds 86%.

When the distribution of farmers who stated that wastewater treatment plants improve the impact of wastewater on the environment is analyzed (Fig. 3), it is seen that 65.15%

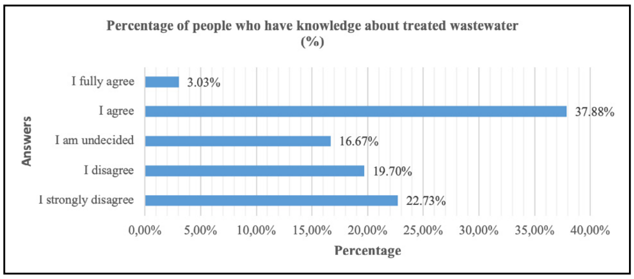

Figure 2. Proportion of people with knowledge about treated wastewater.

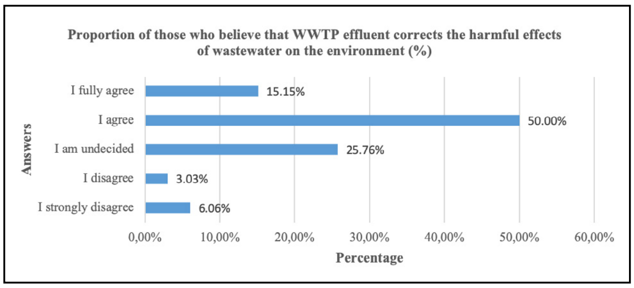

Figure 3. Proportion of those who believe that WWTP effluent corrects the harmful effects of wastewater on the environment (%).

of them find this situation positive. This clearly shows how important the existence and operation of wastewater treatment plants are.

The rate of those who believe that the construction of WWTPs is beneficial for the region and the environment and that they believe in their positive effects is quite high. Therefore, the rate of those who approve the construction of WWTPs (Fig. 4) is as high as 87.88%.

It was determined that 86.37% of the respondents stated that the value of the lands near the WWTPs increased while the value of the land far away decreased (Fig. 5). This result makes WWTP facilities strategic for the producers to increase the value of their land, along with the increase in the yield of the products they grow. Similarly, in another study that found the same result, it was determined that the value of lands irrigated with wastewater was 50% more valuable than lands not irrigated with wastewater.

According to the results of the survey conducted in the region, 87.88% of the enterprises stated that they approved the Wastewater Treatment Plants, and in case of charging for the water they use from the plants (Fig. 6), they stated that it would be more appropriate to make pricing according to the agricultural product pattern they produce (77.27%).

When we look at the reasons why they find this pricing appropriate (Fig. 6), 45.71% stated that it would be fairer pricing, and 41.90% stated that it would be a more accurate practice since it is a pricing based on yield increase.

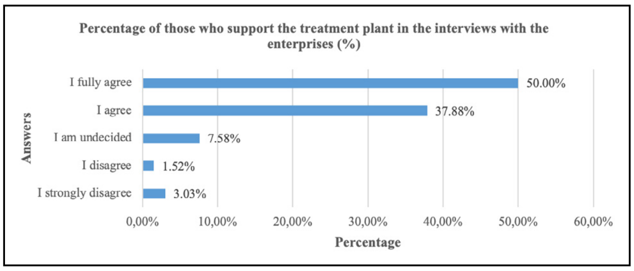

Figure 4. Proportion of those who support the treatment plant in interviews with enterprises.

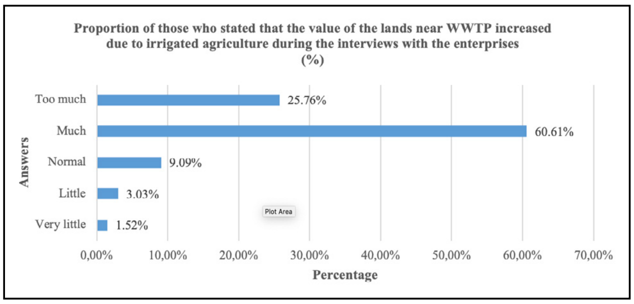

Figure 5. Proportion of those who stated that the value of the land near WWTP increased due to irrigated agriculture during the interviews with the enterprises.

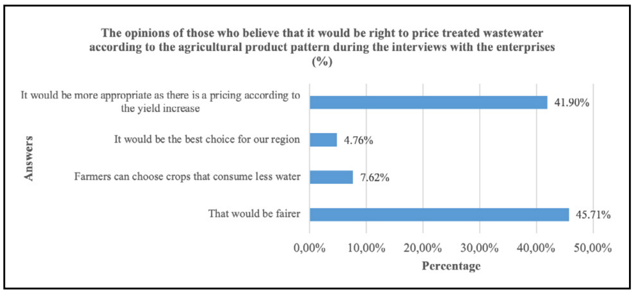

Figure 6. The opinions of those who believe that it would be correct to price the value of treated wastewater according to the agricultural product pattern in the analyzed enterprises.

3.4. Calculation of Wastewater Cost in the Study Area

Wastewater is used free of charge worldwide. However, the scarcity of water has led to the emergence of views that this water should also have a value. Approaches that value wastewater are mostly based on operating costs. In this study, the value of wastewater is calculated based on agricultural products. As is known, irrigation is one of the resources that directly affect agricultural production. Irrigation is the supply of water, which is necessary for plant growth, but cannot be met by natural means, to the plant without harming the environment and nature. **Based on the assumption that the yield difference between irrigated and non-irrigated crops will be the increase due to irrigation, the assumption was developed that the difference will be the cost of water**. Thus, wastewater will be priced based on the barley, wheat and sunflower crops commonly grown in the region. Grain and silage corn are also grown in the region. However, since these crops for which wastewater is used are not widely cultivated in the region, no calculation has been made over these crops. According to this formula, the calculation made according to the yields of the products that are widely cultivated in the region in irrigated and non-irrigated lands is shown in the following charts.

During the survey period, the dollar exchange rate was USD/TRY=18.67. It was calculated that wastewater should be valued at 0.18 USD/ton for barley production, 0.28 USD/ton for wheat production and 0.21 USD/ton for sunflower production (Table 10, 11 and 12). Thus, wastewater has a value based on barley, wheat, and sunflower, which are widely grown in the region.

4. CONCLUSION

Pricing of water is important for sustainable water management and agricultural enterprises to determine a policy in terms of production. Pricing of water and determination of its economic value will ensure balancing of supply and demand, efficient use or utilization of natural resources together with water, which is a scarce resource. From this point of view, this method can be taken as a basis instead of the calculation made by calculating the operation, main-

Table 10. Price of wastewater for barley cultivation (USD/ton)

Symbols	Meaning	Unit	Result
X	Amount of Wastewater Produced in Treatment	t/year	67.078.941.00
Y	Water Requirement of the Plant per Decare	t/daa	398.23
A	Plant Yield in Irrigated Environment	kg/da	413.00
B	Plant Yield in Dry Environment	kg/da	194.27
F	Sales Price of the Plant	USD/kg	0.32
C	Contribution of Water to Yield	kg/da	218.73
Z	Area Irrigated with Wastewater	da/year	168.442.71
D	Total Contribution of Wastewater	kg/year	36.843.474.29
K1	Economic Value of Wastewater	USD/year	11.789.911.77
P1	Unit Price of Wastewater	USD/ton	0.18

At the time of the survey, the dollar exchange rate was USD/TRY=18.67. Calculations were made accordingly.

Table 11. Price of wastewater for wheat cultivation (USD/ton)

Symbols	Meaning	Unit	Result
X	Amount of Wastewater Produced in Treatment	t/year	67.078.941.00
Y	Water Requirement of the Plant per Decare	t/da	500.00
A	Plant Yield in Irrigated Environment	kg/da	456.73
B	Plant Yield in Dry Environment	kg/da	72.14
F	Sales Price of the Plant	USD/kg	0.37
C	Contribution of Water to Yield	kg/da	384.59
Z	Area Irrigated with Wastewater	da/year	134.157.88
D	Total Contribution of Wastewater	kg/year	51.595.779.84
K1	Economic Value of Wastewater	USD/year	19.090.438.54
P1	Unit Price of Wastewater	USD/t	0.28

At the time of the survey. the dollar exchange rate was USD/TRY=18.67. Calculations were made accordingly.

Table 12. Price of wastewater for sunflower cultivation (USD/ton)

Symbols	Meaning	Unit	Result
X	Amount of Wastewater Produced in Treatment	t/year	67.078.941.00
Y	Water Requirement of the Plant per Decare	t/da	800.00
A	Plant Yield in Irrigated Environment	kg/da	315.99
B	Plant Yield in Dry Environment	kg/da	52.00
F	Sales Price of the Plant	USD/kg	0.64
C	Contribution of Water to Yield	kg/da	263.99
Z	Area Irrigated with Wastewater	da/year	83.848.68
D	Total Contribution of Wastewater	kg/year	22.135.212.04
K1	Economic Value of Wastewater	USD/year	14.166.535.71
P1	Unit Price of Wastewater	USD/t	0.21

At the time of the survey, the dollar exchange rate was USD/TRY=18.67. Calculations were made accordingly.

tenance, and repair costs, which are generally used in the world and Türkiıye. This will ensure sustainable agricultural production as it will limit the unlimited use of natural resources. In the interviews with the enterprises, those who wanted the pricing to be based on the agricultural product pattern were dominant. When asked why, they stated that a calculation based on the agricultural product pattern would be fairer, that an evaluation based on yield increase would be correct, and that such a calculation would enable enterprises to prefer products that consume less water.

Recycling and reuse of wastewater is one of the best solutions to water scarcity in terms of acquiring new water resources and protecting existing water resources. However, its implementation depends on many different factors such as management, policy, technical, economic, environmental, and social issues. Agriculture is usually the main water user. Historically, the use of human waste and other living wastes in agriculture has been a common practice for thousands of years. However, water is a natural resource that is very easily polluted, and pollutants cannot be easily removed. In this respect, it is essential to treat and reuse this polluted natural resource. The most important point to be considered in the reuse of wastewater treated is following the scientific approaches from amendment to application to the crop fields. Besides, testing the residue of any harmful microorganisms or heavy metals. The feasibility of reusing wastewater is very significant, particularly considering the initial cost and crop productivity. A significant amount of wastewater is generated near cities. Irrigating agricultural land close to cities with treated water is an easy way to reuse it. Wastewater can therefore provide 15–80% of the available irrigation water in some arid areas. This lessens the strain on pure natural water supplies, which is crucial for sustainable water management. Moreover, to lower the price of delivering this water from processing facilities to the final consumer. In this sense, it might overlook potential environmental or health risks brought on by unwise management. Treatments like filtration and disinfection should be prioritized to implement technologies that allow treated wastewater to be utilized in agricultural irrigation and meet standard values.

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REFERENCES

Alagöz E., Reis Manap, G., Aydın S., & Onur M. (2023). Çevresel Göstergeler. T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı.

Aydın, E. (2023). *Konya İli Karatay İlçesi Tarım Arazilerinde Atik Su Kirliliğinin Değerlendirilmesi* [Presentation]. Fen Bilimleri Enstitüsü.

Bahri A. (2009). *Managing the other side of the water cycle: Making wastewater an asset*. Global Water Partnership.

Bayraktar, H., & Erkmen, B. (2023). Evaluation of water quality parameters of wastewater and ıts use as agricultural ırrigation water: Ankara case. *Journal of Ahi Evran University Faculty of Agriculture, 3*(2), 164–177. [Turkish]

Can, S., & Dulkadiroğlu, H. (2021). Treated wastewater reuse in agriculture and its risk assessment for human health. *Nevşehir Bilim ve Teknoloji Dergisi, 10*(2), 124–134. [Turkish] [CrossRef]

Daniel, L. (2005). *What does ceteris paribus mean in economics?* https://www.investopedia.com/terms/c/ceteris-paribus.asp Accessed on Dec 03, 2025.

Demir Ö., Y. M., Sercan Ü., Arzum C. Ş. (2017). Wastewater reclamation and reuse. *Harran University Journal of Engineering, 2*, 1–14. [Turkish]

Demir Y. (2021-2025). *Agricultural irrigation sector policy document (2021-2025).* Ankara: TAGEM https://www.tarimorman.gov.tr/TAGEM/Belgeler/yayin/Tar%C4%B1msal%20Sulama%20SPB_2021-2025.pdf?utm_source=chatgpt.com Accessed on Dec 03, 2025.

Demir, A. (2022). *KOSKİ-2022 Faaliyet Raporu*. Konya https://www.koski.gov.tr/sayfa/faaliyet-raporlari Accessed on Dec 03, 2025.

Dinar, A., & Mody, J. (2004). Irrigation water management policies: Allocation and pricing principles and implementation experience. *Natural Resources Forum, 28*(2), 112–122. [CrossRef]

Direk, M., Güngör, L., & Acar, R. (2022). Importance, value and agriculture relationship of wastewater. *Ulusal Çevre Bilimleri Araştırma Dergisi, 5*(1), 47–54. [Turkish]

Gleick, P. H., & Howe, C. W. (1995). Water in crisis: a guide to the world's fresh water resources. *Climatic Change, 31*(1), 119–122.

Hellegers, P., & Leflaive, X. (2015). Water allocation reform: what makes it so difficult? *Water International, 40*(2), 273–285. [CrossRef]

John;, L., & OpenStax, E. (2018). *Principles of Economics* (Hawai Ed.). OpenStax.

Kütahya İl Tarım ve Orman Müdürlüğü. (2015). *Sulama yöntemleri ve sulamanın önemi*. Kütahya İl Tarım ve Orman Müdürlüğü, Kütahya. Accessed on Dec 03, 2025.

Mishra, S., Kumar, R., & Kumar, M. (2023). Use of treated sewage or wastewater as an irrigation water for agricultural purposes- Environmental, health, and economic impacts. *Total Environment Research Themes, 6*, Article 100051. [CrossRef]

Qadir, M., Wichelns, D., Raschid-Sally, L., McCornick, P. G., Drechsel, P., Bahri, A., & Minhas, P. S. (2010). The challenges of wastewater irrigation in developing countries. *Agricultural Water Management, 97*(4), 561–568. [CrossRef]

Rebora, C., Lelio, H., Gómez, L., & Ibarguren, L. (2011). Waste-Water Use in Energy Crops Production. In F. S. García Einschlag, (Ed.), Waste Water - Treatment and Reutilization (pp. 361–374). InTech. [CrossRef]

Robert A. Young, J. B. L. (2005). *Determining the Economic Value of Water Concepts and Methods* (2nd ed.). Taylor & Francis, RFF Press.

Santos, A. F., Alvarenga, P., Gando-Ferreira, L. M., & Quina, M. J. (2023). Urban Wastewater as a Source of Reclaimed Water for Irrigation: Barriers and Future Possibilities. *Environments, 10*(2), Article 17. [CrossRef]

Survey, U. S. G. (2025). *Where is the Earth's Water?* U.S. Geological Survey. https://www.usgs.gov/water-science-school/science/where-earths-water Accessed on Dec 03, 2025.

Tsur, Y., Dinar, A., Doukkali, R. M., & Roe, T. (2004). Irrigation water pricing: policy implications based on international comparison. *Environment and Development Economics, 9*(6), 735–755. [CrossRef]

Ungureanu, N., Vlăduţ, V., & Voicu, G. (2020). Water scarcity and wastewater reuse in crop irrigation. *Sustainability, 12*(21), Article 9055. [CrossRef]

Yamane, T. (1967). *Elementary sampling theory*. Englewood Cliffs. Prentice-Hall.