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The economic dimension of directing treated wastewater to the production of green fodder in Saudi Arabia

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ABSTRACT

This study aimed to identify the economic dimension of directing treated wastewater to the production of green fodder. To achieve its objectives, the study relied on economic equations, the method of using multiple criteria, and a scoring technique for prioritization. The study showed that green fodder is a crop that depletes water, as it consumes about 67.27% of the water used for agricultural purposes. In determining the priority of regions intending to use treated wastewater, the ranking put Riyadh region first, followed by the eastern region, the Qassim region, Hail, Makkah Al-Mukarramah, Tabuk, Asir, Al-Jawf, Jizan, Madinah, Najran, the northern borders, and Al-Baha, in this order. The area that can be cultivated with forage crops is estimated to be about 53.05 thousand hectares, with a production of 953.75 thousand tons. The cost of treating wastewater to make it usable amounts to 2126.22 million riyals, while the value of the benefits gained from its use is 2508.95 million riyals; thus, the Saudi agricultural economy achieves a net gain estimated at about 382.73 million riyals annually. Therefore, this study recommends the use of treated wastewater in the production of green fodder.

1. Introduction

Water sources are confined to rainwater, surface water, renewable and nonrenewable groundwater, treated wastewater, desalinated water, and agricultural drainage water. Water resources are relatively scarce in the Kingdom of Saudi Arabia, as it is located in a very hot and dry area. Rainfall rates are highly irregular and fluctuate annually. As shown in Fig. 1, rainfall rates ranged between 55 and 99 mm during the period 2010–2019.

Despite the water scarcity in the Kingdom, the total water consumption increased from 17.79 billion m^3 in 2008 to approximately 23.83 billion m^3 in 2018 (Ministry of Environment, Water and Agriculture, 2020). To achieve the goal of preserving, developing, and rationalizing water resources, Resolution No. (335) was issued on 21/11/2007, which stipulates the following: (1) The General Organization for Grain Silos and Flour Mills will stop purchasing locally produced wheat within a maximum period of 8 years, at an annual rate of decrease of 12.5%. (2) The export of locally produced wheat will continue to be prevented. (3) The Ministry of Agriculture will continue to stop issuing licenses for the production of wheat, barley, and fodder. (4) The export of vegetables produced in open cultivation will be stopped gradually over the next 5 years (General Secretariat of the Council of Ministers, 2007). To implement the Cabinet's decision, the Ministry of Agriculture issued a circular stopping the export of potatoes, onions, squash, and melons, as of 11/1/1433 AH. However, as most farmers continued to expand the cultivation of fodder and dates, the depletion of water resources increased. This is evidenced by the increase in the area planted with green fodder from 160.44 thousand hectares, representing 19.2% of the total crop area in 2009, to 195.6 thousand hectares, representing 28.2% of the total crop area in 2013.

The Ministry of Environment, Water and Agriculture (2018) prepared the National Water Strategy 2030. The strategy stated

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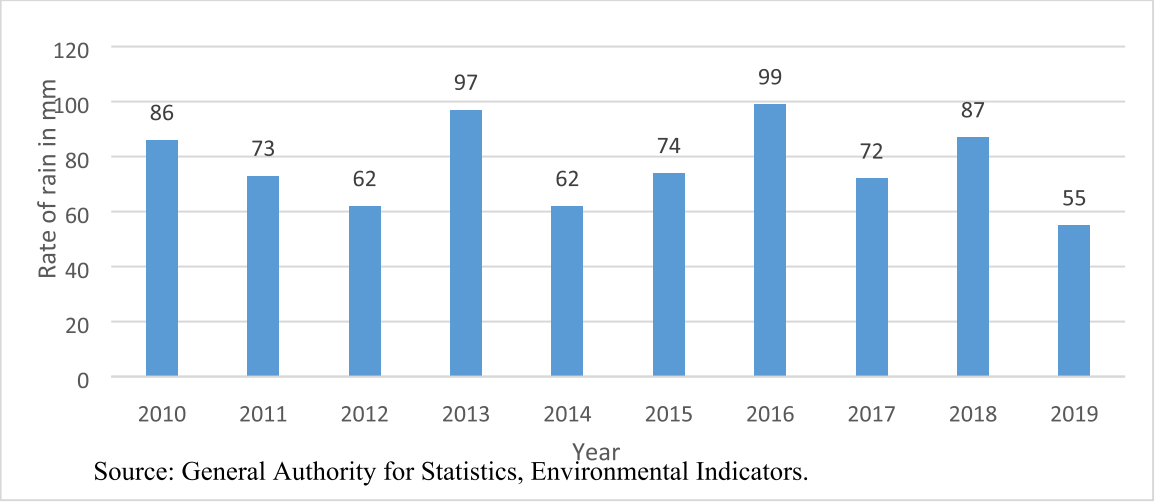


Fig. 1. Rainfall rate during 2019–2020.

that forage crops alone consume about 79% of the volume of water used for agricultural purposes. Irrigation efficiency is currently 50%. In light of the current rates of water consumption, some regions in the Kingdom may face a depletion of the reserve stock during the next 12 years. In view of the continued wasting of water resources, the Council of Ministers Decision No. 66 was issued on 2/25/1437 AH to stop planting green fodder within a period not exceeding 3 years; then, the Council of Ministers decided in its meeting on October 17, 2016 to approve the application controls of Cabinet Decision No. (66) issued regarding stopping the cultivation of green fodder within a period not exceeding 3 years.

In the economic evaluation of the decision to stop the cultivation of fodder, the total current value of savings in groundwater amounted to 6.15 billion riyals, whereas the current value of the sacrificed production amounted to 5.03 billion riyals at a discount rate of 10%. The benefit-to-cost ratio was 1.22, and the net present value was 1.13 billion riyals, so the decision to stop planting green fodder was in the interest of the Kingdom of Saudi Arabia (Al-Ruwis et al., 2017).

Despite the decisions related to limiting the cultivation of green fodder, the area planted with green forage crops increased to 418.93 thousand hectares in 2019, representing about 48.84% of the total crop area of 857.76 thousand hectares (Ministry of Environment, Water and Agriculture, 2019). Green fodder is known to be one of the most important fodder resources for livestock in the Kingdom of Saudi Arabia, amounting to 13.47 million head, of which about 9.06 million head are sheep (67.23%), about 3.56 million head are goats (26.45%), about 471.70 thousand head are camels (3.5%), about 354.28 thousand head are cows (2.63%), and about 24.36 thousand head are draft, riding, and other animals (0.18%) (General Authority for Statistics, 2015).

To preserve the number of livestock in the Kingdom of Saudi Arabia while limiting the consumption of nonrenewable water resources with limited regeneration, treated wastewater can be used in the production of green fodder. Milad et al.'s (2019) study showed that the use of treated wastewater in irrigation leads to saving water and expanding cultivated areas for crop production, in addition to reducing costs related to chemical fertilizers, given the presence of the elements necessary for plants in wastewater. The Food and Agriculture Organization (2016) assessed treated wastewater intended for agriculture in Lebanon. This study showed that wastewater can be converted from a potential threat to an additional good source of water, as additional quantities of fresh water can be provided for agriculture and household uses. Ali et al.'s (2011) study confirmed that triple treated wastewater is an important source and tributary that can be used to improve water scarcity, as well as increase the area of wheat, fodder, and crop production for sustainable agriculture in the Sultanate of Oman.

The increase in the Kingdom's population, which reached 33.41 million people in mid-2018, resulted in the country moving toward urban expansion. Through the proportional distribution of household sanitation sources at the Kingdom level, presented in Fig. 2, the main source of sanitation in homes in 2019 was found to be the public network at 61.65%, followed by the pit at 37.67%, and the private network at 0.67%. To ensure the availability of water and sanitation services, the value of official development assistance related to water and sanitation increased from 287.69 million riyals in 2010 to 3277.75 million riyals in 2016.

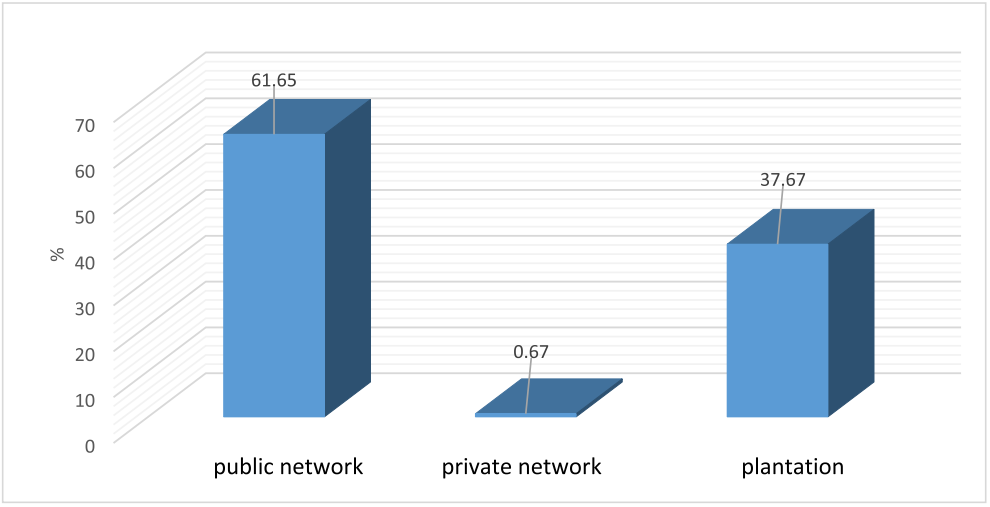
Despite the water scarcity in the Kingdom, treated wastewater has not been used adequately because of limited infrastructure and the challenges related to the acceptability of this water in some areas. In this regard, this study raises several questions, the most important of which are as follows:

1. What are the priority areas for using treated wastewater to produce green fodder?
2. What is the amount of area that can be cultivated with fodder crops and how is it distributed among the productive areas?
3. What are the benefits and economic costs of directing treated wastewater to produce green fodder?

1.1. Research objectives

This study mainly aimed to determine the economic dimension of directing treated wastewater to produce green fodder in the Kingdom of Saudi Arabia, by studying the following objectives:

1. The current status of green forage area and its water consumption in the Kingdom of Saudi Arabia.
2. Determining the priority of production areas in the use of treated wastewater.
3. Determining the area that can be cultivated with fodder crops in light of the volume of treated wastewater and its distribution to the productive areas.
4. Estimating the benefits and economic costs of using treated wastewater in the production of green fodder.



Source: General Authority for Statistics (2019), Home environment survey.

Fig. 2. The proportional distribution of the main source of sanitation in homes at the Kingdom level in 2019.

2. Materials and methods

This study is based on determining the priority of production areas for the use of treated wastewater, by using the multiple criteria method and the scoring technique for prioritization. A set of criteria was used, the most important of which are as follows:

1. The cumulative total of the lengths of the sewage networks, where priority is given to the regions with the longest sewage networks.
2. The volume of treated wastewater, where priority is given to the regions that produce the largest volume of treated wastewater.
3. The number of wastewater treatment plants, where priority is given to regions with the largest number of stations.
4. The cumulative total of the numbers of household connections for sewage, where priority is given to the regions with the highest cumulative number of household connections.
5. The relative importance of the number of livestock in the production regions, where priority is given to the regions that have the largest number of livestock (sheep, goats, camels, cows, and other animals).
6. The relative importance of the area planted with green forage crops, where priority is given to the regions that grow the largest area of green forage crops.
7. Productivity efficiency per unit area (hectare), expressed as the average productivity per hectare, where priority is given to regions with higher productivity.
8. The efficiency of using the water unit, expressed as the average productivity of the water unit (thousand m^3), where priority is given to the regions with the highest water use efficiency.
9. Water needs of the terrestrial unit, where priority is given to regions with the lowest water needs.

A gradation rating between zero and 100 was used, and then the scores for each region were combined and prioritized in the use of treated wastewater. To estimate the value of the economic benefits and costs resulting from the use of treated wastewater in the production of green fodder in the Kingdom of Saudi Arabia, this study relied on the following economic equations (Ghanem et al., 2018):

1. Productivity per unit of water = average productivity per hectare ÷ water requirements per hectare.
2. The value of the productivity of the water unit = the productivity of the water unit × the farm price of the unit produced.
3. Return value of water used = value of productivity per unit of water × volume of water used in the production of green fodder.
4. The value of the saving of groundwater = the cost of extracting the water unit × the volume of the groundwater used in the production of green fodder.
5. Total value of benefits gained = value of return for water used + value of savings of groundwater.
6. The value of the wastewater treatment costs that can be used = the cost of treating the water unit × the volume of wastewater that can be used.
7. The value of economic gains and losses = the total value of the benefits gained –the value of the wastewater treatment costs that can be used.

Finally, in achieving its objectives, this study relied on data issued by the General Authority for Statistics, especially the statistical yearbook data and the detailed results of the 2015 agricultural census. This study also relied on the data of the statistical book issued by the Ministry of Environment, Water and Agriculture, in addition to the data contained in the National Water Strategy 2030 Studies and research related to the subject of study.

3. Results

3.1. The current status of green forage area and its water consumption during the period 2014–2019

By studying the development of the area cultivated with fodder crops and its water consumption during the period 2014–2019, the data presented in Tables 1 and 2 evidently show that the area planted with fodder crops decreased from 501.21 thousand hectares, representing 47.84% of the total cropped area in 2014, to 464.06 thousand hectares, representing 48.52% of the total cropped area in 2019. In light of the cultivated area and the water needs of green fodder crops in the sedimentary shelf areas of 28.65 thousand m^3/hectare, the volume of water used in the production of green fodder decreased from 14.36 billion m^3, representing 73.22% of the volume of water used for agricultural purposes in 2014, to 12.0 billion m^3, representing 59.66% of the volume of

Table 1
Green fodder area and its ratio to the total crop area during the period 2014–2019.

Year	Green fodder area (thousand hectare)			Crop area (thousand hectare)	Ratio of fodder area to crop area (%)
	Alfalfa	Other fodder	Total		
2014	432.13	69.08	501.21	1047.77	47.84
2015	432.66	69.06	501.72	1038.12	48.33
2016	433.20	69.04	502.23	1026.91	48.91
2017	434.11	3.86	437.97	900.06	48.66
2018	420.84	1.48	422.32	869.91	48.55
2019	418.37	0.56	418.93	857.76	48.84
Average	428.55	35.51	464.06	956.76	48.52

Source: General Authority for Statistics (2019), Statistical Yearbook.

Table 2
Volume of water used in the production of fodder and its ratio to the total water consumption for agricultural purposes during the period 2014–2019.

Year	Total fodder area (thousand hectare)	Average water requirements (m^3/ha)	Volume of water used (million m^3)		
			Fodder	Agricultural purposes	%
2014	501.21	28.65	14,359.67	19,612	73.22
2015	501.72	28.65	14,374.28	20,831	69.00
2016	502.23	28.65	14,388.89	19,789	72.71
2017	437.97	28.65	12,547.84	19,200	65.35
2018	422.32	28.65	12,099.47	19,000	63.68
2019	418.93	28.65	12,002.34	20,119	59.66
Average	464.06	28.65	13,295.41	19,758.50	67.27

Sources:
1. Ministry of Environment, Water and Agriculture (2019), Statistical Book.
2. Al-Amoud et al. (1431 AH).

water used for agricultural purposes in 2019. The above data show clearly that green fodder is one of the crops that deplete water, as its acquired area of 464.06 thousand hectares represents 48.52% of the average crop area. Therefore, the volume of water used in the production of green fodder was about 13.3 billion m^3, representing 67.27% of the volume of water used for agricultural purposes during the period 2014–2019.

The cultivation of green fodder is concentrated in the sedimentary shelf areas (Riyadh, Qassim, Eastern, Hail, Tabuk, Al-Jouf, and the northern borders), where the total relative importance of fodder crops planted in those areas reached 98.74%, whereas the relative importance of fodder crops planted in the rest of the regions is not more than 1.26% (General Authority for Statistics, 2019). Most of the sedimentary shelf areas depend on nonrenewable groundwater, which requires preservation for sustainable development and for future generations. In these areas, treated wastewater can be used in the production of green fodder both as a means to reduce the depletion of nonrenewable groundwater and to preserve the area cultivated with green fodder crops.

3.2. The priority of production regions for using treated wastewater

The priority of production regions for using treated wastewater has been determined based on a set of criteria listed in Table 3. These criteria are as follows: (1) the cumulative total length of the sewage networks, as it ranged from a minimum of 317 km for the Al-Baha area to a maximum of 11.63 thousand km for the Riyadh region by the end of 2019 (Ministry of Environment, Water and Agriculture, 2019); (2) the volume of treated wastewater, which ranged from a minimum of 492.42 thousand m^3 for the Al-Baha region to a maximum of 540.11 million m^3 for the Riyadh region in 2019 (Ministry of Environment, Water and Agriculture, 2019); (3) the number of wastewater treatment plants, which ranged from a minimum of two stations for the Hail and Al-Jawf regions to a maximum of 17 stations for the Asir region in 2019 (Ministry of Environment, Water and Agriculture, 2019); (4) the cumulative total number of household connections related to sanitation, which ranged from a minimum of 325 connections in the Al-Baha region to a maximum of 407.71 thousand connections in the Riyadh region in 2019 (Ministry of Environment, Water and Agriculture, 2019); (5) the relative importance of the wealth of livestock in the Kingdom of Saudi Arabia, which ranged between a minimum of 0.11% for the northern border region and a maximum of 24.90% for the Riyadh region in 2019 (General Authority for Statistics, 2019); (6) the relative importance of the area cultivated with green fodder crops in the Kingdom of Saudi Arabia, which ranged between a minimum of 0.003% for the northern border region and a maximum of 35.35% for the Riyadh region in 2019 (General Authority for Statistics, 2019); (7) the productivity per unit area expressed as the average productivity per hectare, which ranged from a minimum of 15.64 tons/hectare for the Al-Baha region to a maximum of 23.97 tons/hectare for the Al-Jouf region in 2019 (General Authority for Statistics, 2019); (8) the water needs of the land unit, which ranged from a minimum of 26.79 thousand m^3/hectare for the Qassim region to a maximum of 44.24 thousand m^3/hectare for the Madinah region (Al-Amoud et al., 1431 AH); and (9) the productivity of the water unit, expressed as the average productivity, which ranged between a minimum of 0.359 tons/thousand m^3 for the Al-Baha region and a maximum of 0.871 tons/thousand m^3 for the Al-Jouf region.

It is evident from the data in Table 4 that the priority of productive areas for using treated wastewater based on the results of the nine criteria combined puts the Riyadh region in first place, followed by the Eastern region, the Qassim region, Hail, Makkah, and Tabuk. As for the Asir region, it ranked seventh, followed by Al-Jawf, Jizan, Madinah, Najran, the northern border, and Al-Baha, in this order.

3.3. The area that can be cultivated with green fodder crops, based on the treated wastewater volume and its distribution to productive areas

The area that can be cultivated with forage crops was estimated and determined according to the volume of treated wastewater used, based on the following assumptions:

Table 3
Criteria used to determine the priority of production areas in the use of treated wastewater.

Region	Cumulative total length of sewage networks (km)		Volume of treated wastewater (million m^3)		Number of wastewater treatment plants		Cumulative total number of household connections		Relative importance of livestock numbers (%)		Relative importance of fodder area (%)		Average yield per hectare (tons)		Water requirements (thousand m^3/ha)		Productivity of water unit (tons/thousand m^3)	
	Length	Rank	Quantity	Rank	Number	Rank	Number	Rank	%	Rank	%	Rank	Yield	Rank	Quantity	Rank	Yield	Rank
Al-Riyadh	11,634	1	540.11	1	15	3	409,707	1	24.9	1	35.35	1	19.12	3	33.38	8	0.573	6
Al-Qassim	3533	5	79.89	5	5	7	141,253	4	14.55	2	10.3	4	15.78	12	26.79	1	0.589	5
Eastern Region	6528	3	423.12	3	16	2	279,160	3	6.01	8	8.89	5	18.3	4	29.92	6	0.612	4
Al-Jouf	613	11	16.46	10	2	10	17,974	12	2.61	11	29.29	2	23.97	1	27.52	4	0.871	1
Hail	1731	7	24.45	8	2	10	37,687	8	8.06	4	11.44	3	17.61	6	27.27	3	0.646	3
Tabuk	1417	8	46.29	7	3	9	43,819	7	5.01	10	3.47	6	20.34	2	27.03	2	0.752	2
Northern Region Borders	538	12	7.22	11	3	9	19,041	11	0.11	13	0.003	13	16.07	10	31.5	7	0.51	8
Makkah Al-Mukarramah	8220	2	456.26	2	7	6	293,190	2	9.64	3	0.23	9	16.6	8	41.24	11	0.403	11
Al-Madinah Al-Monawarah	2952	6	105.12	4	4	8	73,462	6	7.35	6	0.4	7	16.18	9	44.24	13	0.366	12
Jizan	962	10	21.75	9	13	4	23,674	9	6.84	7	0.32	8	15.86	11	28.57	5	0.555	7
Asir	3974	4	76.48	6	17	1	98,369	5	7.53	5	0.06	11	16.85	7	38.42	9	0.439	10
Najran	1310	9	4.24	12	3	9	21,272	10	5.21	9	0.19	10	18.23	5	38.89	10	0.469	9
Al-Baha	317	13	0.49	13	9	5	325	13	2.18	12	0.05	12	15.64	13	43.58	12	0.359	13
Kingdom of Saudi Arabia	43,729	–	1801.87	–	99	–	1,458,933	–	100	–	100	–	19.85	–	–	–	–	–

Sources:
- Ministry of Environment, Water and Agriculture (2019), Statistical Book.
- General Authority for Statistics (2019), Bulletin of Agricultural Production Survey 2019.
Al-Amoud et al. (1431 AH).

Table 4
Results of priority criteria for production areas in the use of treated wastewater.

Region	Cumulative total length of sewage networks (km)	Volume of treated wastewater (million m^3)	Number of wastewater treatment plants	Cumulative total number of household connections	Relative importance of livestock numbers (%)	Relative importance of fodder area (%)	Average yield/ha (tons)	Water requirements of ground unit (thousand m^3/ha)	Productivity of water unit (tons/thousand m^3)	Total number of points	Priority order of areas
Al-Riyadh	100	100	80	100	100	100	80	50	60	770	1
Al-Qassim	60	60	40	70	90	70	10	100	60	560	3
Eastern Region	80	80	90	80	30	60	70	70	70	630	2
Al-Jouf	10	20	10	10	10	90	100	90	100	440	8
Hail	40	30	10	30	70	80	60	100	80	500	4
Tabuk	30	40	20	40	20	50	90	100	90	480	6
Northern Region Borders	10	10	20	10	0	0	20	60	40	170	12
Makkah Al-Mukarramah	90	90	50	90	80	20	40	20	10	490	5
Al-Madinah Al-Monawarah	50	70	30	50	50	40	30	0	0	320	10
Jizan	20	30	70	20	40	30	10	80	50	350	9
Asir	70	50	100	60	60	10	50	40	20	460	7
Najran	30	10	20	10	20	20	70	30	30	240	11
Al-Baha	0	0	60	0	10	10	0	10	0	90	13

Sources: Data provided in Table 3.

Table 5
Estimate of the area that can be cultivated to produce green fodder based on the amount of treated wastewater for different productive areas.

Region	Volume of treated wastewater (million m^3)	Water requirements (thousand m^3/ha)	Area that can be cultivated (thousand hectares)		Average productivity/hectare/ton	Production (thousand tons)	
			Direct routing	Priority regions		Direct routing	Priority regions
Al-Riyadh	540.11	33.38	16.18	7.48	19.12	309.37	143.04
Al-Qassim	79.89	26.79	2.98	5.44	15.78	47.06	85.86
Eastern Region	423.12	29.92	14.14	6.12	18.30	258.79	112.01
Al-Jouf	16.46	27.52	0.60	4.27	23.97	14.34	102.47
Hail	24.45	27.27	0.90	4.86	17.61	15.79	85.55
Tabuk	46.29	27.03	1.71	4.66	20.34	34.83	94.86
Northern Region Borders	7.22	31.50	0.23	1.65	16.07	3.68	26.54
Makkah Al-Mukarramah	456.26	41.24	11.06	4.76	16.60	183.65	79.03
Al-Madinah Al-Monawarah	105.12	44.24	2.38	3.11	16.18	38.45	50.31
Jizan	21.75	28.57	0.76	3.40	15.86	12.07	53.93
Asir	76.48	38.42	1.99	4.47	16.85	33.54	75.31
Najran	4.24	38.89	0.11	2.33	18.23	1.99	42.51
Al-Baha	0.49	43.58	0.01	0.87	15.64	0.18	13.68
Kingdom Saudi Arabia	1801.87	–	53.05	53.44	–	953.75	965.09

Sources: Data in Tables 1, 2, 4.

1. *Direct guidance of the volume of treated wastewater to each area to grow fodder crops*: The data presented in Table 5 reveal clearly that, based on the volume of treated wastewater available and the water needs of fodder crops, the area that can be cultivated was estimated to range from a minimum of 0.01 thousand hectares for the Al-Baha region to a maximum of 16.18 thousand hectares for the Riyadh region, with a total area of 53.05 thousand hectares. Based on the average productivity per hectare and the area that can be cultivated with fodder crops, the production of fodder was estimated, ranging from a minimum of 0.18 thousand tons for the Al-Baha region to a maximum of 309.37 thousand tons for the Riyadh region, with a total of 953.75 thousand tons.
2. *Estimation of the area that can be cultivated with green fodder crops*: Based on the total volume of treated wastewater at 1.80 billion m^3 and the average water requirement of 33.72 thousand m^3/hectare, the area that can be cultivated is estimated to be about 53.44 thousand hectares, distributed to the productive regions according to their rank of using water from treated sewage. The data presented in Table 4 show that the regions garnered a total of 5500 points. By multiplying the average share of one point out of the total cultivable area of about 0.00972 by the number of points obtained by each region, the area that can be cultivated ranged from a minimum of 0.87 thousand hectares for the Al-Baha region to a maximum of 7.48 thousand hectares for the Riyadh region. Based on the average productivity per hectare and the area that can be cultivated with fodder crops, fodder production was estimated to range from a minimum of 13.68 thousand tons for the Al-Baha region to a maximum of 143.04 thousand tons for the Riyadh region, with a total of 965.09 thousand tons (Table 5).

3.4. Estimating the economic benefits and costs of using treated wastewater in the production of green fodder

Of the studies that have estimated wastewater treatment costs, the most important is Zahid's (2007) study, where the total costs of wastewater treatment according to drip filtration methods, wastewater mixed completely with aerobic microorganisms, and the method of oxidative disposal of aerobic microorganisms were found to reach SAR 1.06, 1.23, 1.25/m^3, respectively. The data in Table 6 show clearly that based on the average treatment cost of SAR 1.18/m^3 for wastewater and the volume of treated wastewater that can be used, the value of treated wastewater ranges from a minimum of 0.58 million riyals for the Al-Baha region to a maximum of 637.33 million riyals for the Riyadh region, and a total of 2126.22 million riyals for all the regions.

The efficiency of water use in the production of green fodder was measured to range from a minimum of 0.359 kg/m^3 with a value of SAR 0.617/m^3 for the Al-Baha region to a maximum of 0.871 kg/m^3 with a value of SAR 1.498/m^3 for the Al-Jouf region. Based on the productivity of a unit of water and the volume of treated wastewater that can be used in each region, the return value of the water used ranges between a minimum of 0.30 million riyals for the Al-Baha region and a maximum of 532.12 million riyals for the Riyadh region, and a total of 1640.44 million riyals for all the regions. The use of treated wastewater in the production of green fodder also results in the saving of nonrenewable groundwater equivalent to the volume of treated wastewater that can be used. Considering the average cost of extracting groundwater of SAR 0.482/m^3 at a discount rate of 10% (Nashwan, 2016), the value of groundwater savings ranges from a minimum of 0.24 million riyals for the Al-Baha region to a maximum of 260.33 million riyals for the Riyadh region, with a total of 868.51 million riyals for all the regions.

Table 6
Total value of the costs and benefits gained from using treated wastewater in the production of green fodder in the Kingdom of Saudi Arabia.

Region	Water use efficiency		Costs of using treated water		Value of benefits gained from using treated wastewater (million riyals)		
	Productivity of water unit (kg/m^3)	Productivity value of the water unit (SAR/m^3)	Average treatment cost (SAR/m^3)	Value of treated water (1 million riyals)	Return value of treated wastewater	Value of savings in nonrenewable groundwater	Total value of benefits earned
Al-Riyadh	0.573	0.985	1.18	637.33	532.12	260.33	792.46
Al-Qassim	0.589	1.013	1.18	94.27	80.94	38.51	119.45
Eastern Region	0.612	1.052	1.18	499.28	445.12	203.94	649.07
Al-Jouf	0.871	1.498	1.18	19.42	24.66	7.93	32.59
Hail	0.646	1.111	1.18	28.85	27.16	11.78	38.94
Tabuk	0.752	1.294	1.18	54.62	59.91	22.31	82.22
Northern Region Borders	0.510	0.877	1.18	8.52	6.34	3.48	9.82
Makkah Al-Mukarramah	0.403	0.692	1.18	538.39	315.89	219.92	535.80
Al-Madinah Al-Monawarah	0.366	0.629	1.18	124.04	66.13	50.67	116.79
Jizan	0.555	0.955	1.18	25.67	20.77	10.48	31.25
Asir	0.439	0.754	1.18	90.25	57.69	36.86	94.56
Najran	0.469	0.806	1.18	5.00	3.42	2.04	5.46
Al-Baha	0.359	0.617	1.18	0.58	0.30	0.24	0.54
Kingdom of Saudi Arabia	–	–	–	**2126.22**	**1640.44**	**868.51**	**2508.95**

Source: Data in Table 5.

From the above data, the value of the benefits resulting from the use of treated wastewater in the production of green fodder ranges from a minimum of 0.54 million riyals for the Al-Baha region to a maximum of 792.46 million riyals for the Riyadh region, with a total of 2508.95 million riyals for all the regions. The difference between the total benefits gained and the total costs incurred means that the Saudi agricultural economy achieves net gains from the use of treated wastewater in the production of fodder, estimated at about 382.73 million riyals annually.

4. Conclusions and recommendations

The results of this study showed that green fodder is one of the crops that deplete water, using about 67.27% of the total water used for agricultural purposes during the period 2014–2019. Green fodder cultivation is concentrated in the sedimentary shelf areas (Riyadh, Qassim, Sharkia, Al-Jawf, Hail, and Tabuk) that depend on nonrenewable groundwater. Green fodder is known to be an important fodder resource for livestock, which amounted to 13.47 million head in 2019. In the context of sustainable development and achievement of the Kingdom's 2030 vision, it is necessary to preserve nonrenewable groundwater for future generations. In light of water scarcity in the Kingdom, 1.8 billion m^3 of treated wastewater can be used in the production of green fodder. The available volume of treated wastewater can support the growth of green fodder in an area of 53.05 thousand hectares, with a total production of 953.75 thousand tons of fodder. The costs of wastewater treatment and the benefits gained from using treated wastewater also resulted in net gains for the Saudi agricultural economy, estimated at about 382.73 million riyals annually. Therefore, this study recommends the use of treated wastewater for the production of green fodder.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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