sustainability

Article

Enhancing the Method of Decentralized Multi-Purpose Reuse of Wastewater in Urban Area

Saeid Ghafoori [1], Hossein Hassanpour Darvishi [1,*], Hossein Mohamadvali Samani [1] and Pezhman Taherei Ghazvinei [2]

[1] Water Resources Engineering Department, Faculty of Engineering, Shahr-e-Qods Brach, Islamic Azad University, Tehran 37437541, Iran; saeid_ghafoori@yahoo.com (S.G.); hossein.samani@gmail.com (H.M.S.)
[2] Young and Elite Researchers Club, Shahr-e-Qods Branch, Islamic Azad University, Tehran 37437541, Iran; p.taherei@gmail.com
* Correspondence: hhassanpour87@gmail.com

Abstract: The reuse of treated wastewater is attractive as a communal source of excess water source in water-scarce counties and nations. The expansion of the urban population and the increase in the coverage of water supply networks and sewage networks will raise the amount of municipal sewage. This can turn into a new-fangled water resource. In the current research, the new campus city was selected as the first case study to design a wastewater reuse and recycling system. Accordingly, one of the most important innovations in the proposed research is the unique applied dimensions, in addition to its first-time performance, and the application of the Geo-land method in wastewater recycling as the theoretical dimension of the design. Clustering the decentralized reuse of wastewater for urban areas showed that significant parts of residential areas are located in the first high priority group. Urban planners can consider the results in establishing a comprehensive plan to prioritize the decentralized use of wastewater in the urban area.

Keywords: wastewater; reuse; clustering; urban; water management

check for updates

Citation: Ghafoori, S.; Hassanpour Darvishi, H.; Mohamadvali Samani, H.; Taherei Ghazvinei, P. Enhancing the Method of Decentralized Multi-Purpose Reuse of Wastewater in Urban Area. *Sustainability* **2021**, *13*, 13553. https://doi.org/10.3390/su132413553

Academic Editor: Alessio Siciliano

Received: 6 October 2021
Accepted: 11 November 2021
Published: 8 December 2021

1. Introduction

Cities that carefully and creatively use their water resources for strategic development will have the advantage of a better city and, ultimately, a more vibrant, safe and sustainable environment. The sustainable management of water resources plays a major role in creating sustainable environments for residents. With the increasing population, the problem of water supply to meet human needs is an important limitation in the development of communities [1–3]. With the current trend of population growth in Iran, it is predicted that only 70% of the required water will be available in the next 20 years. Considering that it is not possible to find new water resources, in addition to the usual methods of water resources management in order to provide a sustainable supply of drinking water and consumption management, an effective and possible solution is to adjust overdrafts from resources at peak consumption, reuse and recycle wastewater and reduce the direct consumption of drinking water in non-drinking consumption. Most economic models still rely on vital services provided by freshwater ecosystems, while this option often leads to the unsustainable use of water resources and the destruction of aquatic ecosystems [4,5]. Therefore, the adoption of sustainable environmental economic policies must be based on ecosystems, the internal relationships of ecological systems to address human impacts and meet the needs of healthy fertile ecosystems. The reuse of treated wastewater is suitable as a conjoint source of surplus water in a number of water-scarce areas [6]. Reusing water fulfills two objectives: minimizing the demand for fresh water and reducing the need for extra wastewater treatment. As a result, wastewater reuse reduces the extraction of fresh water and wastewater, thus activating a continuous water cycle in metropolitan environs. Through diminishing the discharge of fresh water and sewage, reusing wastewater acts a major role in the sustainable urban water cycle. The straightforward attitude of wastewater reuse is to decrease the gap among ineffective water resources and definite water usage goals [1,7]. In semi-arid and arid regions, the proper methodology to answering water inadequacy can be deliberate over water reuse, including smaller programs. The overall result of studies on available water resources, wastewater production and the current and future capacities of urban society and its suburban communities is the optimization use of existing and alternative water resources (wastewater) considering climatic, social and economic conditions [8–10].

The city of Pardis, with a population of 850,000 in 2025, was designed as a population overflow for Tehran, the Capital, for a sustainable life. On the other hand, during the years 2013 to 2015, in addition to the initial plan, attention to its development was considered as an important center in the construction of social supply housing in the National Development Plan. This factor led to the expansion of the geographical area of the new campus city and the need to develop primary water, electricity and sewage networks. Consequently, the network efficiency was overshadowed by the need to provide basic services in the development of the city. A review of the literature [11–16] showed that several limited studies on a large scale (province or region of a country) have been conducted to evaluate the use of wastewater in multiple uses. In addition, other related research has been conducted mainly with the aim of using wastewater in limited and occasional applications such as the irrigation of landscapes, aquifer recharging, use in small industries, etc. So far, comprehensive research has found in simulation the wastewater reuse in the framework of residential communities and the suburbs for all its applications [5–7,11,17–23]. Moreover, an inclusive comparison between centralized wastewater reuse (outflow of large urban wastewater treatment plants) and decentralized reuse (outflow of local urban wastewater treatment plants) consistent with the current research problem was not found [6,14,19,22,24–26].

Therefore, the current study was conducted with the objective of evaluating the positive impact of the decentralized use of wastewater to cover all urban and suburban needs as a model to influence the community of decision makers and design engineers, especially in water resources engineering.

2. Literature Review

The reuse of wastewater is not a new achievement. There are indications that sewage was applied for irrigation in ancient Mayan and Greece civilizations. During the 1950s and 1960s, the benefits of using groundwater in the Western Hemisphere as an advanced wastewater treatment expertise and the treated quality have been continuously improved. Underground direction is a cost-effective way to discharge wastewater into the streams [11]. Sewage has been recycled for agriculture purposes for centuries sourced from the wastewater disposal of cities such as Berlin, London, Milan and Paris. Meanwhile, in China, India and Vietnam, sewage has been recycled to deliver nutrients and develop soil features. Recently, sewage has become very important in areas with water scarcity where any change will diminish the supply of vegetables for communities [23].

In Mexico, mostly untreated sewage is used to irrigate about 260,000 hectares of gardens [27]. In California, 656 million cubic meters of municipal wastewater is reused annually, while, in Tunisia, 4.4% of the available water resources is supplied from treated wastewater, which could reach 11% by 2030. The share of reused water resources in Palestine was 20% in 2010 [28].

There are several reasons why wastewater has to be deliberated as an alternate to water resources. The first reason is preserving the high water quality for potable water [29]. Economically, the average charge of secondary treatment for local wastewater in MENA is USD 0.5 per cubic meter; that is more economy than the development of new resources in the region [11]. As a second reason, wastewater collection and treatment protect the valuable freshwater resources, the environment in general and public health. In fact, Wastewater Treatment Reuse (WTR) not only protects valuable freshwater resources, but it can also supply these freshwater resources by recharging the aquifers [20,26]. Accordingly, it was revealed that if the real and enormous benefits of environmental protection and public health were properly addressed in economic analysis, wastewater collection, treatment and reuse would be the top priorities for public economic deficits and development [30].

Third, with proper management, treated wastewater is a permanent source of water, nitrogen and phosphorus to provide greater performance than fresh water drinking water without the use of additional fertilizer [31–33]. The real rate of wastewater treatment is certainly less than the environmental cost of releasing wastewater [34].

In Iran, the sewage production in all urban and rural areas of the country in 1994 was estimated at 3100 million cubic meters, which is projected to reach 5900 million meters by 2025, excluding industrial and agricultural wastewater. With the aim of comparing the results of the analysis and the latest world standards (nationally and internationally), the quality of treated wastewater for agricultural and irrigation purposes was examined by at monthly intervals. It was found that the aquifers of the study area were contaminated with natural salinity and geogenetic sources. The results showed that it was essential to review the use of treated urban wastewater for irrigation to prevent environmental and health hazards [35]. In order to develop a forecasting model on the reuse of wastewater in an urban area, Zeng et al. (2008) conducted a study. The needs and capacity for wastewater reuse was evaluated by dividing the regions into the five main categories. Economic and feasible options for wastewater recycling were allocated into nationally developed, state-developed, developing, susceptible and preferential development groups [36]. In a multi-criteria assessment, the characteristics of an area in relation to the pressure on water resources and the economic viability for the reuse of wastewater was considered [1,18,37]. The four main stages, (1) region documentation, (2) data collection, (3) indexing and (4) cluster analysis, were performed.

In water distribution systems, as well as sewer systems, water quality monitoring is essential to protect public health in addition to resources. Biological, chemical and physical parameters observe rises in the probability of timely revealing water quality deterioration, which diminishes the incident of surpluses as well as the improvement of water quality. A research work was conducted to examine Bayesian procedures to recognize optimum sensor distribution to resolve contamination detection and position problematic [38]. Although this aspect is essential in any WTR, it is out of the scope of the current research as the researchers concentrated to assess the capability of the proposed method in the multi-purpose reuse of wastewater.

3. Materials and Methods

3.1. Study Area

In order to attract the surplus population of Tehran (the Capital), 5 urban suburbs area were proposed in the Tehran master plan, including Hashtgerd, Eshtehard, Zavieh, Ab-e-Anjirk and Robat Karim. Primarily, the new city of Pardis was known as Ab-e-Anjirk lands (Figure 1). The new city of Pardis is bounded from the north by the Alborz Mountains and the Jajrud region, Keresht, Siah Sang and Taherabad and Bumehen from the north, south, east and west, respectively. The average height above sea level is about 1800 m.

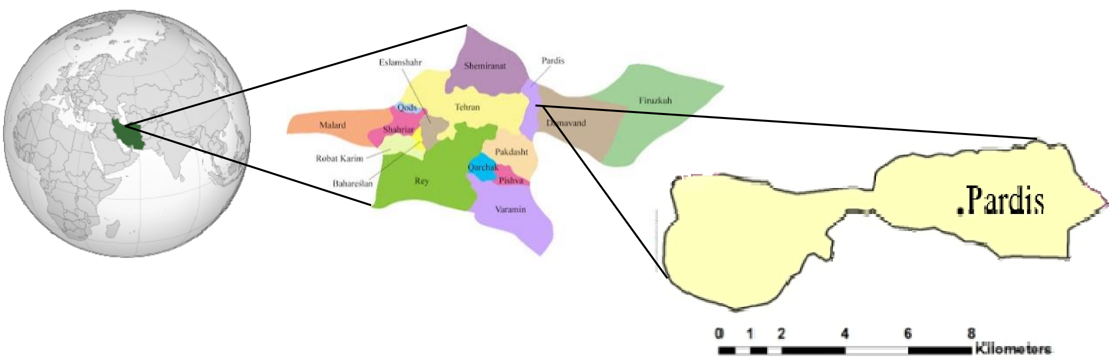

Figure 1. Pardis location.

After the approval of the Supreme Council of Urban Planning and Architecture in 2008, the capacity for the population of Pardis was developed to 402,000 people, while later, the National Housing Plan increased the capacity to 538,000 by 2020. Accordingly, the population of Pardis had been increased more than twice the population of the primary master plan. In the plan of the new city of Pardis so far, and after frequent changes, eight residential regions, two industrial regions and one region of educational and research centers have been allocated. The total population is 538,000 persons, with a density of 165 person per hectare. The climatic conditions of Pardis are largely dependent on the conditions of the whole study area and are affected by the altitude factor, the characteristics of which are generally part of areas with a cold sub-desert climate and close to the Mediterranean region with spring and semi-desert rain. At present, the water consumption of Pardis for the initial city population is supplied from Latian Dam with a total permit of 1000 L per second, and from Flemand wells group of 700 L per second. The supplied raw water is transferred to Pardis city water treatment plant, then it will be distributed in the city's water distribution network. The population of the city is projected to be more than 450,000 on the project horizon (2025). To meet the potable water consumption of the population, the need for water supply will increase to 2 times the current situation. Currently, the main problem is that the supply of drinking water to the subscribers of Pardis during peak consumption time and the water required for landscape and other public uses of the city is provided with difficulty with the pressure on the allocated water resources. Consequently, the city is going to meet water scarcity in a near future. In order to sustain long-term water resources and respond to other needs of the city and public uses, including irrigation of landscape and irrational and unjustifiable use of potable water, urban wastewater can be considered as an alternative source to other urban water sources. The proposed method is described in the next section in detail.

3.2. Dataset Preparation

The proposed research was carried out within the city of Pardis. In the stage of collecting records and data, all related projects such as comprehensive studies of the construction plan of Pardis city as well as specialized studies of water resources, wastewater treatment and available environmental assessment were reviewed. All environmental and climatic, geographical, demographic, economic and urban parameters were extracted for use in the process. Demographic loading process, the allocation and amount of potable water consumption and the use (current and future without replacement plan with wastewater), amount and quality of wastewater production and its forecast in the horizon of the different uses in society urban and suburban areas and the amount of consumption and water quality required were determined. The constructed water distribution network (WDN) and wastewater collection system (WCS) and their development were reviewed. In all the urban regions, each region's corresponding data were extracted as a geographical information layer. Figure 2 shows the overall flow of studies on the purpose of treated wastewater. The main stages of the research includes collecting the required data and information, simulation of the hydraulic model of wastewater collection and treatment network, allocating the potential of reuse of wastewater according to the type of use, volume and costs of wastewater treatment in a centralized and decentralized manner and the evaluation of the centralized and decentralized reuse applications.

3.3. Allocating the Potential of Wastewater Reuse According to the Type of Use, Volume and Costs of Wastewater Treatment in a Centralized and Decentralized Manner

3.3.1. Cost Components and Processing per Unit Volume of Wastewater Effluent

Considering the aim of the research for comparative evaluation of decentralized and centralized reuse method, the cost components and benefits of using each of these methods for comparison with other executive and applied factors was extracted. According to the basics of water economics and appropriate to the topic of wastewater reuse, the following consequences were identified: reducing the environmental costs of the aquifer, the cost of transportation and treatment of raw water, the cost of water, transportation and centralized treatment costs and waste disposal costs (total) in the environment, creating the cost of local (decentralized) wastewater treatment as well as operating the system. Then, the cost components of the project according to the useful time of the project (10 consecutive years), the cost of construction of the required facilities, energy costs and annual operation (during the project time) was calculated and converted to the current value. Next, the comparison of centralized and decentralized costs has been conducted accordingly. Table 1 shows the cost components and references for each of them.

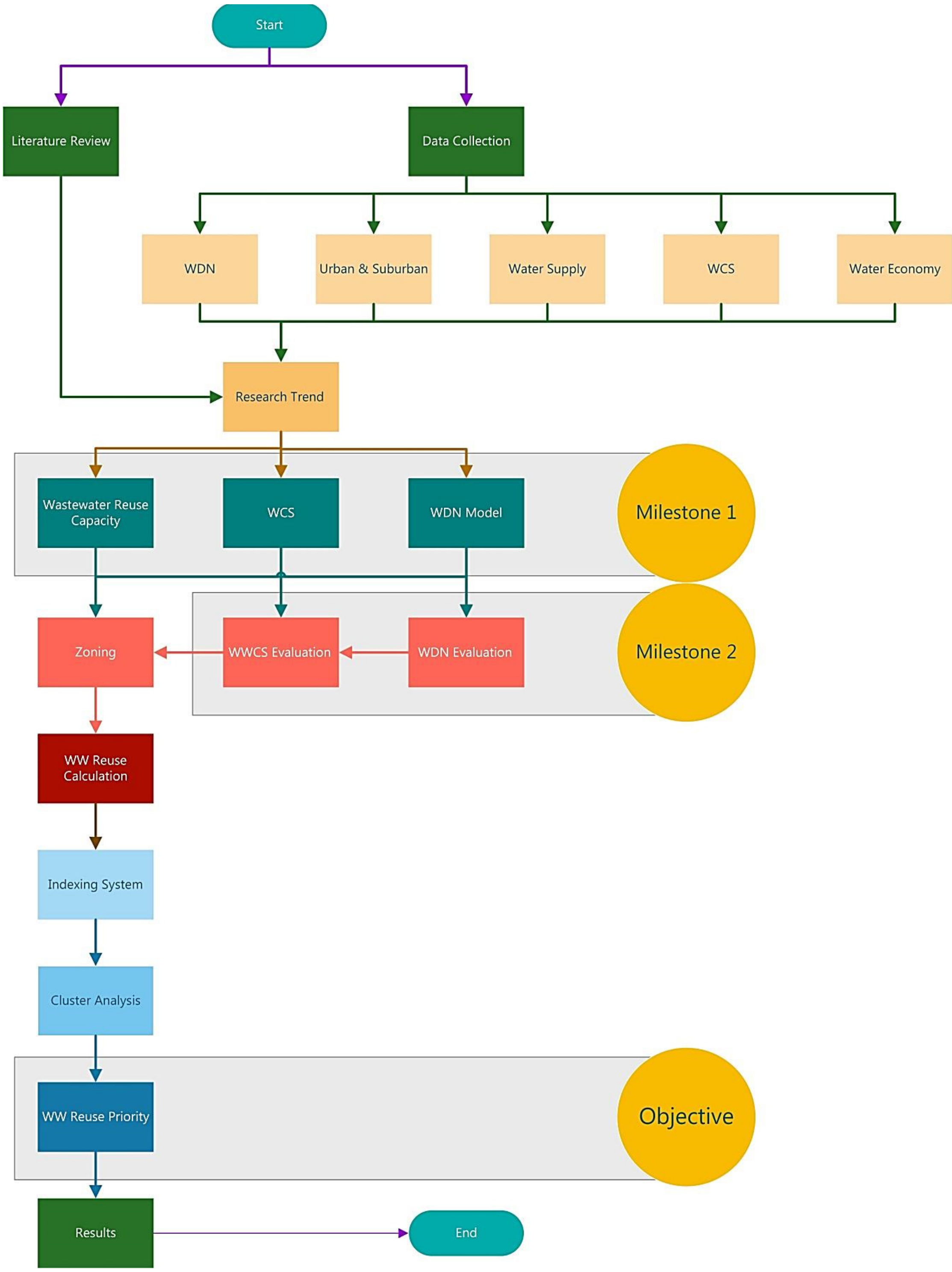

Figure 2. Flow chart of the studies on the purpose of reuse of treated wastewater.

Table 1. Cost components.

Row	Component	Price (IRR * in m3)
1	Costs of transmitting and treatment of raw water from water resource	6210
2	Water price (tariff)	36,183
3	Installation and operation of local wastewater treatment package	23,425
4	Environmental costs of wastewater disposal	53
5	Social and business income	2404
6	Costs of installation and operation of decentralized wastewater treatment packages	0.055
7	Savings of replaced wastewater (million IRRs per year for every 1000 cubic meters)	66,592
8	Household financial savings and replaced landscape effluent (million IIRs per year for every 1000 cubic meter)	65,871

* 10^3 IIR = USD 0.045.

3.3.2. Indexing Development

The proposed method for effluent reuse districting is constructed on the improvement of an indicator method and the subsequent cluster analysis methodology. The nature of this method is the integrated multi-criteria assessment that is frequently applied in water resources management. These indicators are designed to show the characteristics of an area in terms of pressure on water resources as well as economic efficiency for wastewater reuse (Table 2). The four main stages in this districting include: area identification, system development based on consumption, data gathering, ranking and index weight and the integration of list and cluster analysis. To calculate the resilience of potable water resources, the relative allowable limit of current water consumption and financial probability, the amount of every indicator was ranked in 5 degrees (numbers 5 for high, 4 medium high, 3 medium, 2 medium low and 1 low). Grading boundaries were determined by a variety of approaches, containing reference to internationally valid standards (United Nations, 1997), as well as expert evaluation.

Table 2. Local water resources index system.

Practical Advice	First Group (n)	Second Group (m)
Essential for reusing wastewater	Severe degree of water consumption	Drinking water consumption Annual landscape water consumption
	Acceptable degree of water consumption	Water consumption of commercial/recreational/workshop units Effluent recycling possible Financial savings of replaced effluent
Economical to reuse wastewater	Economic advice for using wastewater locally	Generate annual local surplus revenue of annual wastewater after recycling

3.3.3. Integration and Cluster Analysis

The local strategic districting method is shown in Table 3. In the first step, according to the grading limits of the index, the value of each index was specified. The higher the value, the further desirable to reuse in the area. After evaluating the scale, this index became dimensionless. Second, according to the value of the unit index in the second stage, the weighted average method was used to calculate the value of the index in the first stage. Third, the cluster analysis method was applied to perform local districting with three indicators as variables and areas of research scope. The cluster analysis method was selected because of its simplicity and usefulness in presenting the results according to the literature. All areas were located in a cluster that was considered for 5 different strategic areas (n and m indices). Each area was associated with a pattern of urban wastewater reuse advance according to the characterization of the respective cluster. Not only the result of districting helps city managers to decide whether the reuse of municipal wastewater in a particular area is immediate and binding, potentially needed or not, but clustering results also guided the decision makers whether the current socio-economic conditions support reuse in each particular area.

Table 3. Clusters' definition.

Level of Need for Wastewater Reuse	The Level of Economic Feasibility of Reusing Wastewater	Definition and Explanation of Clusters
High	High	Cluster I: Due to the need to provide the main uses and the conditions of the local economy, the use of wastewater needs to be recommended and implemented as the main priority and alternative source. To this end, emphasis and basic executive actions by the city administration are necessary.
High	Low	Cluster II: Due to the specific water shortage, the use of effluent is recommended. However, local economic conditions are not conducive to supporting the required infrastructure.
Medium	High	Cluster III: Water shortage is not severe. Since the local economy is good, the use of wastewater can be recommended as one of the options to move towards sustainable urban water management.
Medium	Low	Cluster IV: Since urban water shortage is not a limiting factor and local economic conditions are not suitable, the use of wastewater in these conditions is not considered.
Low	Low/High	Cluster V: The required water resources are fully available. As a result, even weak economic problems do not occur, and the use of wastewater is not required.

4. Results and Discussion

4.1. Data Processing

4.1.1. Districting the Study Area

According to the constraint of the residential areas and slope (ground and wastewater collection network), the study area was specified in 61 separate neighborhoods. The characteristics of these neighborhoods were applied in process in terms of determining the volume of incoming effluent and the output, as well as access to the passages and places and spaces required for the proposed facilities (Figure 3). Table 4 shows a summary of the data of these neighborhoods.

Table 4. Summary of the data of the study areas.

Description	Number of Areas	Total Discharge	Very Low and Low Residential Density	Medium to Very High Residential Density	Park and Landscape	Other Uses
Unit	-	Lit/Sec	Ha	Ha	Ha	Ha
Amount	61	3657	505.76	475.24	250.35	844.22

4.1.2. Determining the Amount of Wastewater Consumption

According to the loading of water consumption in the water distribution network and also the direct relationship between the amount of wastewater produced by the drinking water supply, population and regions' distribution, the amount of wastewater production in each region was calculated. Then, the effluent discharge from the lowest point of the main transmission line was determined from each district. It was obvious that the resulting discharge was the maximum possible discharge for use in part of the district and also the possibility of the transfer and recirculation of the effluent in the downstream connected districts can be planned. Formerly, the components for calculating the main values for classification are listed based on the basic indicators (m index). In the next step, the values related to each of the indicators were calculated based on the relevant components and placed in the table of the indicators. Table 5 shows the statistical summary of the calculated values associated with each index.

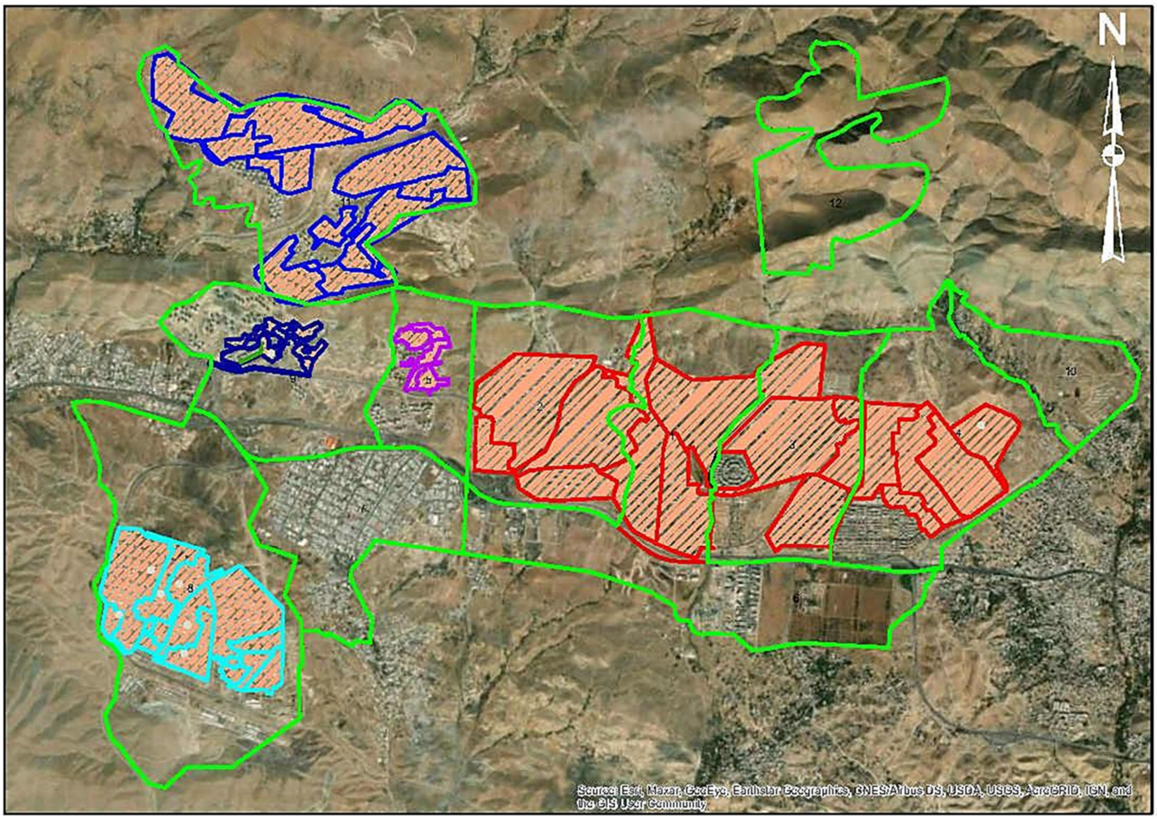

Figure 3. Flow chart of the studies on the purpose of reuse of treated wastewater.

Table 5. Summary of the data of the study areas.

Statistic	m1	m2	m3	m4	m5	m6	m7
Number of observations	61	61	61	61	61	61	61
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	8,109,845.971	395,950.757	684,284.000	1.00	85,004,346.000	82,815,229.000	5,640,868.000
1st Quartile	94,272.818	1393.752	17,376.000	0.176	2,628,459.000	1,814,851.000	32,847.000
Median	226,740.041	11,342.333	45,018.000	0.229	5,474,447.000	3,947,471.000	175,104.000
Mean	461,884.360	33,705.526	94,526.016	0.745	8,550,638.230	6,330,421.525	329,364.377

4.1.3. Determining the Value of the Normal Index and Classify the Indices

The extracted values related to the indicators in the previous step were normalized in order to compare them. Accordingly, the domains as well as the mode of each index were extracted to identify the five ranks of the indices (Table 6).

4.2. Discussion

In this step, the k-means processing option was used for cluster analyzing. According to the method intended for the classification of the wastewater use index, the first category was based on practical recommendations: (I) essential for the use of wastewater; (II) economic efficiency for the use of wastewater through the group of n; (n1) degree of severe water consumption; (n2) acceptable degree of water consumption; and (n3) economic recommendations for the use of wastewater in the local area. The above were divided into five clusters (classes) in total. Table 7 summarizes the results of classification of study area in the decentralized reuse of wastewater.

Table 6. Summary of the data of the study areas.

Category/Index	Grade	m1	m2	m3	m4	m5	m6	m7
High	5	0–3	>45	>30	>7	>30	>9	<=1
Medium to high	4	3–5	30–45	20–30	5–7	20–30	7–9	1–2
Medium	3	5–7	15–30	10–20	3–5	10–20	5–7	2–3
Low to medium	2	7–9	1–15	1–10	1–3	1–10	3–5	3–4
Low	1	>9	1<	1<	1<	1<	3<	>4

Table 7. Summary of results of wastewater use classification for 61 areas of the study area.

Cluster	I	II	III	IV	V
Number of districts located on this floor	21	14	16	6	4
Variance	1.848	4.676	1.992	3.700	7.917
Minimum distance from the center of the floor	0.725	1.141	0.713	1.323	1.521
Average distance from the center of the floor	1.245	2.009	1.289	1.715	2.311
Maximum distance from the center of the floor	2.371	2.780	2.033	2.255	3.437

Figure 4 shows the districting of wastewater use priorities in the study areas. In addition, Table 8 summarizes the situation of the clustering result in terms of districts, financial savings and regional surplus income. Accordingly, it can be seen that in class I, the high need and economic possibility for the use of wastewater and the highest amount of savings and financial surplus income (36.17% and 31.25%, respectively) are where the total savings and income in all areas were observed. Meanwhile the level of development and the coverage of wastewater treatment facilities in this category is about 16% of the total area under study. On the other hand, the level, savings and financial surplus income for the V category, the need and economic possibility of using low effluent, is only the last priority for only 1.15% of the total level, and even if implemented, the savings and surplus income from the use of the effluent will be equal to 6.94% and 6.25% of the corresponding total values, respectively. Therefore, in addition to social conditions, environmental prioritization of the studied areas has also taken into account the financial (cost and income) and social economy in general. Municipal service planning managers can provide the long-term plan for achieving maximum social, economic and environmental benefits by taking into account the priorities recommended for areas in the use of wastewater and prevent the loss of capital and time.

Table 8. Summary prioritization of wastewater reuse clustering district.

Priority	Number of Districts	%	Area		Financial Savings	Extra Income	
			m^2	%	106 IRR/year	106 IRR/year	%
I	21	15.59	2,822,667	36.17	904,160	221,148	31.25
II	14	69.72	12,626,404	23.93	598,225	221,086	31.24
III	16	3.93	712,021	24.24	605,871	176,896	25.00
IV	6	9.62	1,742,015	8.71	217,843	44,246	6.25
V	4	1.15	207,686	6.94	173,535	44,229	6.25

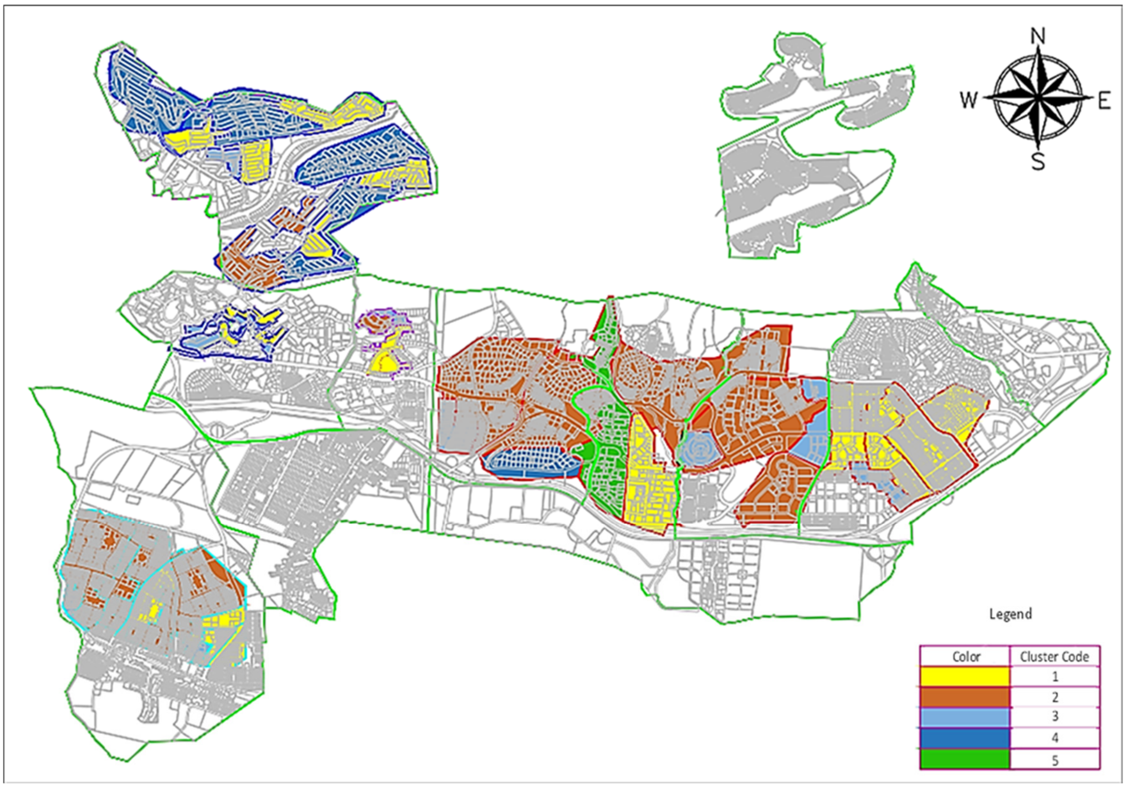

Figure 4. Cluster districting priorities in the study areas of wastewater reuse.

5. Conclusions

The literature review showed that several limited studies in large dimensions (provincial or regional studies of a country) have been conducted to evaluate the use of wastewater in multiple uses. In addition, related research has been conducted mainly with the aim of using wastewater in limited and occasional applications. So far, comprehensive research in the simulation of multi-purpose effluent in the framework of the residential communities, including the comparison with the centralized manner, was found. In addition to the above-mentioned primary research works, the current research was designed as a new hypothesis for simulation and evaluation of decentralized wastewater reuse in urban areas. In addition to the collecting and reviewing data on water and wastewater collection systems, records and documents related to water economy and wastewater use, the usage and amount of water in small industries, the landscape, education, etc., in the urban and suburban areas were surveyed and categorized. To achieve the research objective, data classification and clustering processing in was also designed. In this regard, the use of regional wastewater instead of centralized in terms of cost savings increases the local income of residents, and environmental costs and related indicators were determined and evaluated. The method of cluster analysis was also applied in addition to the statistical evaluation. A total of 61 separate districts were identified based on the elevations of the wastewater collection network and wastewater demographic homogeneity. These districts, along with water consumption information, land uses and secondary products and effluent consumption, were compiled in the clustering system. In cost issues, the cost and benefit of using and replacing decentralized wastewater in terms of application aspects, treatment, social economy and the environment were processed and evaluated. The evaluation of the possibility of using wastewater in a centralized manner in all districts showed that decentralized reuse was an economic advantage over the centralized option. Correspondingly, the use of wastewater and reducing the use of drinking water in different uses caused local (regional) ultra-economic value. The prioritization of the decentralized reuse of wastewater for urban areas showed that this strategy was the first priority for a significant part of urban areas (reducing water consumption along with economic savings and increasing regional income). The research outcomes can be considered by urban planners in establishing a comprehensive plan to prioritize the decentralized reuse of wastewater. Obviously, the application of the current research method in the primary stage of urban designing will bring more desirable impacts.

Author Contributions: Conceptualization P.T.G.; methodology, P.T.G.; software, S.G.; validation, S.G., H.H.D.; formal analysis, S.G.; investigation, S.G.; resources, S.G.; data curation, S.G.; writing—original draft preparation, S.G.; writing—review and editing, H.H.D.; visualization, H.M.S.; supervision, H.H.D.; project administration, H.H.D.; All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Aggeli, K.; Kalavrouziotis, I.K.; Bezergianni, S. A proposal of a treated wastewater reuse design system in urban areas. *Fresenius Environ. Bull.* **2009**, *18*, 1295–1301.
2. Al-Jayyousi, O.R. Greywater reuse: Towards sustainable water management. *Desalination* **2003**, *156*, 181–192. [CrossRef]
3. Aoki, C.; Memon, M.; Mabuchi, H. *Water and Wastewater Reuse: An Environmentally Sound Approach for Sustainable Urban Water Management*; United Nations Environmental Program: Osaka, Japan, 2005.
4. Asano, T. *Wastewater Reclamation and Reuse: Water Quality Management Library*; CRC Press: Boca Raton, FL, USA, 1998; Volume 10.
5. Aziz, F.; Farissi, M. Reuse of treated wastewater in agriculture: Solving water deficit problems in arid areas. *Ann. West Univ. Timis. Ser. Biol.* **2014**, *17*, 95.
6. Hochstrat, R.; Wintgens, T.; Melin, T. Development of integrated water reuse strategies. *Desalination* **2008**, *218*, 208–217. [CrossRef]
7. Bozdogan, E.; Sogut, Z. Determination of reuse potential of treated wastewater at urban green area. *J. Selcuk. Univ. Nat. Appl. Sci.* **2013**, *1*, 835–845.
8. Eslamian, S.; Okhravi, S.; Reyhani, M.N. Urban water reuse: Future policies and outlooks. In *Urban Water Reuse Handbook*; Eslamian, S., Ed.; CRC Press: Boca Raton, FL, USA, 2016; pp. 1107–1114.
9. Qadir, M.; Sato, T. Water reuse in arid zones. In *Urban Water Reuse Handbook*; Eslamian, S., Ed.; CRC Press: Boca Raton, FL, USA, 2016; pp. 867–875.
10. Zhang, Y.; Shen, Y. Wastewater irrigation: Past, present, and future. *Wiley Interdiscip. Rev. Water* **2019**, *6*, e1234. [CrossRef]
11. Al-Shreideh, B. Reuse of treated waste water in irrigation and agriculture as a non-conventional resource in Jordan. In *Advanced Short Course: Water Saving and Increasing Water Productivity: Challenges and Options, Amman (Jordan)*; CIHEAM-IAMB: Bari, Italy, 2001.
12. Angelakis, A.; Gikas, P. Water reuse: Overview of current practices and trends in the world with emphasis on EU states. *Water Util. J.* **2014**, *6*, 67–78.
13. Bahri, A. Water Reuse in Tunisia: Stakes and prospects. In *Atelier du PCSI (Programme Commun Systèmes Irrigués) sur une Maîtrise des Impacts Environnementaux de l'Irrigation*; Cirad-IRD-Cemagref: Montpellier, France, 2001.
14. Bazza, M. Wastewater recycling and reuse in the Near East Region: Experience and issues. *Water Sci. Technol. Water Supply* **2003**, *3*, 33–50. [CrossRef]
15. Friedler, E. Water reuse—An integral part of water resources management: Israel as a case study. *Water Policy* **2001**, *3*, 29–39. [CrossRef]
16. Hidalgo, D.; Irusta, R. The cost of wastewater reclamation and reuse in agricultural production in the Mediterranean countries. In Proceedings of the IWA Conference on Water Economics, Statistics and Finance, Rethymo, Greece, 8–10 July 2005.
17. El-Rawy, M.; Zlotnik, V.A.; Al-Raggad, M.; Al-Maktoumi, A.; Kacimov, A.; Abdalla, O. Conjunctive use of groundwater and surface water resources with aquifer recharge by treated wastewater: Evaluation of management scenarios in the Zarqa River Basin, Jordan. *Environ. Earth Sci.* **2016**, *75*, 1146. [CrossRef]
18. Hajkowicz, S.; Collins, K. A review of multiple criteria analysis for water resource planning and management. *Water Resour. Manag.* **2007**, *21*, 1553–1566. [CrossRef]
19. Lim, R.; Gale, S.; Doyle, C.; Lesjean, B.; Gibert, M. Endocrine Disrupting Compounds in Sewage Treatment Plant (STP) Effluent Reused in Agriculture–Is There a Concern? In Proceedings of the First Symposium Water Recycling Australia, Adelaide, Australia, 19–20 October 2000; CSIRO Land and Water, and Australian Water Association: Sydney, Australia, 2000.

20. Pintilie, L.; Torres, C.M.; Teodosiu, C.; Castells, F. Urban wastewater reclamation for industrial reuse: An LCA case study. *J. Clean. Prod.* **2016**, *139*, 1–14. [CrossRef]
21. Visvanathan, C.; Asano, T. The potential for industrial wastewater reuse. *Wastewater Recycl. Reuse Reclam.* **2009**, *1*, 299–313.
22. World Health Organization. *Regional Overview of Wastewater Management and Reuse in the Eastern Mediterranean Region*; World Health Organization, Regional Office for the Eastern Mediterranean Regional, California Environmental Health Association: Cairo, Egypt, 2005.
23. Al-Balawenah, A.; Al-Karadsheh, E.; Qadir, M. Community-based reuse of greywater in home farming in Food security and climate change in dry areas. In Proceedings of the an International Conference, Amman, Jordan, 1–4 February 2010.
24. Barrio, D.H.; Irusta, R.; Fatta, D.; Papadopoulos, A.; Mentzis, A.; Loizidou, M. *Analysis of Best Practices and Success Stories for Sustainable Urban Wastewater Treatment and Reuse in the Agricultural Production in the Mediterranean Countries*; REWAS'04—Global Symposium on Recycling, Waste Treatment and Clean Technology: Madrid, Spain, 2005; pp. 1255–1264.
25. Braadbaart, O. An Assessment of Centralized and Decentralized Wastewater Reclamation Systems in Beijing. Master's Thesis, Wageningen University, Wageningen, The Netherlands, 2006.
26. Nitivattananon, V.; Sa-nguanduan, N. Urbanization and water reuse. In *Urban Water Reuse Handbook*; Eslamian, S., Ed.; CRC Press: Boca Raton, FL, USA, 2016; pp. 15–26.
27. Schoups, G.; Addams, C.L.; Minjares, J.L.; Gorelick, S.M. Sustainable conjunctive water management in irrigated agriculture: Model formulation and application to the Yaqui Valley, Mexico. *Water Resour. Res.* **2006**, *42*. [CrossRef]
28. Zimmo, O.; Imseih, N. Overview of wastewater management practices in the Mediterranean region. In *Waste Water Treatment and Reuse in the Mediterranean Region*; Springer: Berlin/Heidelberg, Germany, 2010; pp. 155–181.
29. Bastian, R.; Murray, D. *Guidelines for Water Reuse*; US EPA Office of Research and Development: Washington, DC, USA, 2012.
30. Reznik, A.; Feinerman, E.; Finkelshtain, I.; Fisher, F.; Huber-Lee, A.; Joyce, B.; Kan, I. Economic implications of agricultural reuse of treated wastewater in Israel: A statewide long-term perspective. *Ecol. Econ.* **2017**, *135*, 222–233. [CrossRef]
31. Fatta-Kassinos, D.; Dionysiou, D.D.; Kümmerer, K. *Advanced Treatment Technologies for Urban Wastewater Reuse*; Springer: Berlin/Heidelberg, Germany, 2016.
32. Delgado-Ramos, G.C. Water and the political ecology of urban metabolism: The case of Mexico City. *J. Political Ecol.* **2015**, *22*, 98–114. [CrossRef]
33. Oyebode, O.J. Effective management of wastewater for environment, health and wealth in Nigeria. *Int. J. Sci. Eng. Res.* **2015**, *6*, 1028–1059.
34. Asano, T.; Bahri, A. Global challenges to wastewater reclamation and reuse. *Water Front.* **2011**, *2*, 64–72.
35. Rahimi, M.H.; Kalantari, N.; Sharifidoost, M.; Kazemi, M. Quality assessment of treated wastewater to be reused in agriculture. *Glob. J. Environ. Sci. Manag.* **2018**, *4*, 217–230.
36. Zeng, S.; Chen, J.; Fu, P. Strategic zoning for urban wastewater reuse in China. *Water Resour. Manag.* **2008**, *22*, 1297–1309. [CrossRef]
37. Durrant, S.; Nurse, L.; Stoddard, A. *Monitoring the Effect of below Average Precipitation on Water Resources in Paget Farm, Bequia, Grenadines*; MSc Research Report Submitted to Center for Resource Management and Environmental Studies: Cave Hill, Barbados, 2007.
38. Sambito, M.; Freni, G. Strategies for improving optimal positioning of quality sensors in urban drainage systems for non-conservative contaminants. *Water* **2021**, *13*, 934. [CrossRef]