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Efficiency of the Treatment Sewage Effluent Networks in Improving the Quality of the Urban Environment in Riyadh Saudi Arabia Using Geographic Information System Analysis

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Abstract

Improving the treatment sewage effluent network for the mega greening projects in the city of Riyadh Including the usage of the rain storm water and provide a guideline methodology for linking all of the waste water networks to the irrigation systems across the city for the big public city parks, neighborhood parks and the main roads network. Will be appointing the aim of the study which is prove the effect of using the Treated sewage effluent in improving the Urban environment and the livability of a city.

Using the treated water in the irrigation had a long history in large scale city development projects and plans. In this research we will set up a methodology to define how and where we will be using the irrigation network, how to measure the usage of the water and in which scale it can be provided to the end user or the stake holders in the city. Our assessment criteria will define the components of the grey water and how it will be processed. We will use the geospatial analysis modeling to define where to start and how to cover the prioritized zones across the city of Riyadh as a case study.

Keywords: Multi-Criteria Assessment Model, GIS (geographical information system), Stakeholder's Engagement, sewage treatment, Saudi Arabia, Mega greening projects, Irrigation, Urban Planning.

1. INTRODUCTION

The metropolitan areas have been filled with concrete and there is an enormous demand for the greening and recreational projects. This need is facing a lot of challenges specially in the Middle East where the water is almost covering the human daily usage. Which will lead landscaping projects to search for a creative and innovative way to fix the irrigation issues and not to waste the investment of the stakeholders. From this point, this research will cover the current usage of the sewage treatment as the most efficient way to reuse the waste water and how it will effect on improving the record of greening per capita.

The population of the Capital of Riyadh is generating large volumes of wastewater; in the year 2019 of an average daily flow of approximately 1.3 million m3 per day2. Wastewater also comes from industry and commerce. Treated wastewater, known as Treated Sewage Effluent (TSE), is normally discharged to the environment such as Valley of Hanifa, requiring proper management to protect public health and the environment.

Nowadays, only a small part of the available TSE of around 240,000 m3 per day or 15% is reused, mainly for agricultural irrigation.

Recently, Authorities in Riyadh, developed and approved the "Green Riyadh Strategy", a program to monitor and effectively manage and increase urban and suburban greening in the Capital of Saudi Arabia. The Strategy aims to strategically increase the quality and quantity of all vegetation in both urban and suburban setting and develop a strategically planned interconnected network of natural and semi-natural areas with a range of other environmental features designed and managed to deliver a wide range of ecosystem services.

Recognizing the social, environmental and economic benefit of water reuse the implementation of the Green Riyadh

Strategy until the year 2030 is establishing a fundamental paradigm shift towards the improvement of livability for the citizens of Riyadh.

Globally, treated sewage effluent reuse is encouraged and accepted when it is safe and practicable; in this context TSE is forming a valuable resource to address overall water scarcity problems in the region.

This research covers the framework, principles and objectives that should be considered when establishing a system that uses TSE. The development of sustainable effluent reuse schemes requires a common understanding of not only the technical solutions, but also environmental and socio-economic interactions.

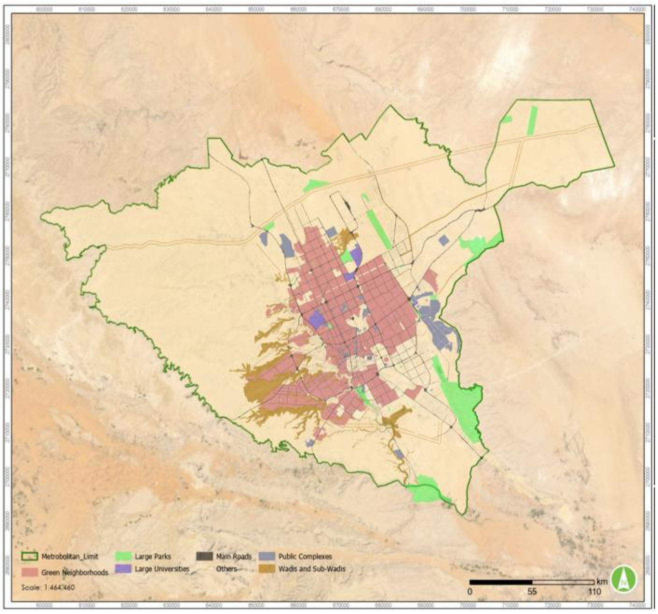

Figure 1: Map of Riyadh City Saudi-Arabia

2. METHODOLOGY

The Methodology will Study the Nature of the case study area, Analyzing the current situation and the new governmental approach to manage and develop until the target is reached.

I. Study Area

This study was carried out in Riyadh city which is considered as a heart of the kingdom of Saudi-Arabia. This area is under the jurisdiction of local and federal entities as it consists of a huge number of human activities including conservation and political zones. This study focused on the intensive activity of the waste water reuse to be applied in the mega project and strategy of Green Riyadh.

Riyadh area is a complex mosaic of human activities and habitats. The main uses typically fall under recreational, Natural conservation, governmental and financial centers.

II. Current Situation Analysis:

In the City of Riyadh, a range of wastewater treatment options are available such that any level of water quality can be achieved depending upon the use of TSE. Nevertheless, until today TSE reuse is limited to land application (agricultural irrigation for crop production) and environmental services such as the discharge into Valley of Hanifa. Driving factors defining the reuse opportunities are the installed (and planned) treatment technologies. Figure. 2 indicates that even secondary treated wastewater can be reused, however potential opportunities are limited by the generated TSE quality.

Figure 2: Water Quality Levels and the Related Reuse

Source: US EPA, 2012: Guidelines for Water Reuse

Analysis regarding TSE reuse have to go beyond the definition of technical standards and the requirements must also cover additional aspects such as quality monitoring, potential socio-economic and environmental impacts, as well as the responsibilities and rights of the parties involved. Specifications are needed for safety measures, reporting and compliance monitoring. In addition, clear specifications on consequences must be defined in case the requirements are not fulfilled.

Until the year 2030 the reused TSE volume should stepwise increase to around 1 million m3 per day.

Table 1 below provides a general overview of TSE reuse opportunities.

The aims of this research are to:

- Provide guidelines for planning, designing, installing, operating and monitoring TSE reuse systems with a view to reduce risks to public health, and the environment.
- Outline the statutory requirements that may be needed for an ecologically and socio-culturally sustainable mode of operation.
- Encourage the beneficial use of TSE in accordance with national standards and international best practices.

This Section provides information on best management practices where TSE is reused.

Table 1: Overview of TSE reuse opportunities

Potential areas for TSE reuse	***Type of locations***	***Main purpose of TSE reuse***
Parks	City parks, natural parks, neighborhood parks	Irrigation
Residential areas	Spots, areas	Irrigation, cleaning
Environmental services	valleys, valley branches, greenbelts, riverbanks	Irrigation, Ground water recharge, Environnement, Habitat Development
Public buildings	Mosques, schools, medical facilities, universities	Irrigation
Agriculture	Fields, strips, spots	Irrigation
Empty plots	Open spaces, strips along roads	Irrigation
Utility corridors	Linear strips	Irrigation
Commercial areas	Spots, areas	Cleaning, production, district cooling
Industrial zones & cities	Areas	Production, cleaning, irrigation

Source: Riyadh Development Authority

3. COVERAGE OF THE RESEARCH

The coverage of this section of the research is primarily oriented towards serving the implementation of the Green Riyadh Strategy, including all stakeholders involved in this process using the treated sewage water.

I. TSE Quality and Risk Management

1. TSE Quality Standards:

In the year 2006, the Ministry of Water and Environment, launched the Executive Regulation for Treated Sewage Water and its Reuse, Royal decree No. M/6 dated 13/2/1421H; Implementing Regulations for water and wastewater treatment.

The regulation is formulating the legislative framework for the 'Usage of Treated Sewage Water for Municipal Purposes. Defining TSE applicability for unrestricted/restricted reuse:

- **Unrestricted reuse:** irrigation of public parks, playgrounds and other public areas

- **Restricted reuse:** irrigation of green belts, plants and trees in road medians

Table 2 shows the imposed TSE quality monitoring parameter for unrestricted and restricted reuse.

In the international context the Royal decree No. M/6 regulation is establishing a rather restrictive regulation concerning strictness of imposed parameters, comparable with the legislation of Title 22 of the California Code of Regulations (1978).

II. Microbial Risk in TSE Reuse

The major risks associated with human or animal contact with effluent are from infection by microorganisms, such as bacteria (e.g. Salmonellae), viruses (e.g. Hepatitis sp.), protozoa (e.g. Giardia and Crytosporidium) or helminths (tape worms). Thus, the control of pathogenic organisms is fundamental to the protection of public health. The diversity and concentration of pathogens in TSE is highly variable and dependent upon numerous locally specific factors.

Populations of microorganisms in wastewater are reduced by the wastewater treatment process, followed by disinfection process applying chlorine (referred as to Chlorination), ozone or ultraviolet treatments. The likely level of pathogens in the final effluent product is assessed by knowledge of the specific treatment processes and by measurement of indicator organisms such as the presence of total and/or Fecal coliforms.

Helminth eggs can be found on crops contaminated with untreated wastewater or grown in soil irrigated with TSE (WHO 2011)[3]. With varying levels of resistance to chlorine disinfection, helminths are agents of gastrointestinal disease which must be properly eliminated, especially when using TSE for irrigation.

Table 2: Imposed TSE quality monitoring parameter of Royal decree No. M/6

Parameter	*Unit*	*Unrestricted*	*Restricted*
Physico-chemical characteristics			
BOD5	mg/l	10 (monthly av.) 15 (weekly av.)	40 (monthly av.)
TSS		10 (monthly av.) 15 (weekly av.)	40 (monthly av.)
pH		6 - 8.4	6 - 8.4
Turbidity	NTU	5	5
TDS	mg/l	2,500	2,500
Ammonia (NH3-N)		5	5
Nitrate (NO3-N)		10	10
Free Chlorine		0.5 (not less than 0.2)	0.5
Phenol		0.002	0.002
Oil and Grease		nil	nil
Microbiological characteristics			
Fecal coliform		2.2 (weekly av.) 23 (in any sample)	1,000 (monthly av.)
Intestinal Nematodes	viable eggs/l	1	1
Heavy metals / trace elements			
Fluoride	mg/l	1	1
Arsenic		0.1	0.1
Cadmium		0.01	0.01
Chromium		0.1	0.1
Copper		0.4	0.4
Lead		0.1	0.1
Mercury		0.001	0.001
Nichel		0.2	0.2
Zinc		4	4
Aluminum		5	5
Manganese		0.2	0.2
Selenium		0.02	0.02
Molybdenum		0.01	0.01
Boron		0.75	0.75
Vanadium		0.1	0.1
Lithium		2.5	2.5
Beryllium		0.1	0.01
Iron		5	5
Cobalt		0.05	0.05
Barium		2	

Source: Ministry of Water and Environment Saudi Arabia

Chlorine may be added to some effluent to ensure a residual disinfection process if TSE is being delivered through long pipes.

Table 3 indicates the presence of Fecal coliforms and intestinal nematodes (eggs) for unrestricted and restricted reuse in accordance with the imposed national regulation.

Table. 3: Imposed TSE quality monitoring parameter of Royal decree No. M/6 – Pathogens and free chlorine

Parameter	Unit	Unrestricted	Restricted	Sampling frequency
Fecal coliform		2.2 (weekly av.) 23 (in any sample)	1,000 (monthly av.)	daily
Intestinal Nematodes	viable eggs/l	1	1	weekly
Free chlorine	mg/l	0.5 (not less than 0.2)	0.5	daily

Source: Ministry of Water and Environment Saudi Arabia

III. Options For TSE Management

1. Urban Reuse

Urban reuse for landscape irrigation, in particular in densely populated metropolitan areas, is characterized by fast development and will play a crucial role for the sustainability of cities in the future, including energy footprint reduction, human well-being, and environmental restoration.

Urban reuse is often divided into applications that are either accessible to the public or have restricted access, in settings where public access is controlled or restricted by physical or institutional barriers, such as temporal access restriction.

The water demand for landscape irrigation varies with geographic location, season and type of vegetation. Since this particular use of TSE reuse is typically in public areas, there is the potential for more public exposure to the TSE, and therefore a higher water quality level is usually required in terms of pathogen levels when compared to agricultural applications. Thus, landscape irrigation requires regular quality monitoring controls and acceptance of health and safety considerations.

Typically, tertiary or an equivalent level of treatment and disinfection is required for irrigation of landscaped areas with the exception of subsurface irrigation systems, which do not pose as high a risk to public health.

The water quality requirements for TSE reuse in irrigation of landscapes will also depend on the type of vegetation. Constituents in the water and the tolerance of plants to these constituents need to be considered. Constituents that should be monitored include sodium, chloride and boron, as well as the effects of salinity and solidity (i.e., high sodium content) on irrigated land and landscape plants. Nutrients are considered beneficial and may create significant savings in fertilizers costs; however, excessive loading may cause biofilm growth in the reclaimed water distribution system as well as having a long-term adverse effect on the land.

Leaching and drainage of the area should be considered when developing a water irrigation system. Landscape irrigation with TSE should benefit the plants or grass areas and excessive runoff should be minimized to protect the surrounding environment.

When selecting the species (composition) to be irrigated, information on plant nutrient requirements must be obtained. This includes not only total species requirements but also requirements at critical plant growth periods (e.g. fruiting or flowering). The extent of nutrient recycling for the particular land management system must also be established. Grass mown without catchers returns nutrient to the site and deciduous horticultural crops and tree plantations return nutrients when their leaves fall. These nutrient returns must be accounted for in nutrient mass balance calculations.

2. Environmental Reuse

Temporary surface waters, especially the valleys (Valley of Hanifa) or natural and/or artificial lakes (lake Al Hair) represent a receiving environment for TSE discharges. Potentially, TSE discharge may be considered to:

- Streamflow management, dry weather flow, lakes enhancement
- Ecosystem management such as protecting healthy aquatic ecosystems (habitat for plants, aquatic organisms and wildlife).
- Recreation opportunities at lakes and ponds and along valley courses

In each situation where reuse is considered, there is the potential to shift water balances and effectively alter the prevailing hydrologic regime in an area. For instance, in temporary streams (Valleys) where dry weather base flows are groundwater dependent, TSE discharge can cause an increase in base flows if the prevailing groundwater elevation is raised. Furthermore, increases in stream flows during wet periods can occur from tributary watersheds.

In addition to water quantity issues, reuse TSE discharge can potentially impact aesthetics or recreational use and damage ecosystems associated with streams where hydrologic setting is significantly affected. Where TSE discharges have occurred over an extended period of time, the flora and fauna can adapt and even become dependent on that water. A new or altered ecosystem can arise and a reuse program implemented without consideration of this fact could have an adverse impact on such a community.

Most serious concerns with TSE application for environmental reuse are associated with the transfer of pathogens and nutrients (nitrogen, phosphorus) may cause significant environmental risks.

3. Industrial Reuse

Reusing TSE in industry has the potential to reduce the costs of water supply and wastewater treatment by industries and reduces pressure on water resources. Depending on the type and quality of the TSE, it may either be reused directly, or additionally treated before reuse (i.e. recycled). For TSE reuse application no specific requirements are outlined; in any case the potential user has to apply for respective permit granting. The advantages and disadvantages of reusing TSE in industry are summarized in Table 4

Table. 4: Advantages versus disadvantages of TSE reuse in industry

Advantages	*Disadvantages*
Reduces the overall water consumption used in industry	Requires high knowledge about quality of water for reuse
Reusing TSE is an attractive economic alternative and helps conserve an essential commodity for future generations 'Cleaner production approach'	Requires financial investments
Reduces costs through recycling management	Requires modification of current operations both for direct reuse and treat-and-reuse options.
For wastewater treatment plant operator, if managed properly, TSE selling may represent of stable source for income generation	Requires a high level of trust between industries.

Source: Riyadh Development Authority

Other factors to that have to be taken into consideration include rapidly depleting resources, environmental degradation, public attitude and health risks to workers and consumers.

Typical reuse applications requiring simple treatment processes are:

- washing floors.
- cleaning water/wash downs.
- concrete mixing.
- firefighting purposes.

If TSE is not suitable for direct reuse, there is not a single specific technology that may reduce the level of contaminants to a level that is safe for reuse.

Reuse applications requiring additional treatment processes are:

- industrial process water.
- district cooling activities.

Technologies that are used for additional treatment can include the following:

- refinements of methods of precipitation and sedimentation
- biological treatment
- evaporation and crystallization
- filtration through media or membranes
- disinfection
- reverse osmosis or
- ion exchange.

Most serious concerns with TSE application for industrial reuse are associated with mechanical constraints like corrosion, biological growth, and scaling.

4. Commercial Reuse

I. District Cooling

District cooling means the centralized production and distribution of cooling energy. Cooled water is delivered via an underground insulated pipeline to office, industrial and residential buildings to cool the indoor air of the buildings within a district. Specially designed units in each building then use this water to lower the temperature of air passing through the building's air conditioning system.

The output of one cooling plant is enough to meet the cooling-energy demand of building complexes. District cooling can be run on electricity or natural gas, and can use either seawater or regular freshwater that might be partially replaced by TSE. District cooling constitutes.

A modern form of energy service and is applied in Riyadh in several building complexes and utilities.

Cooling towers are recirculating evaporative cooling systems that use TSE to absorb process heat and then transfer the heat by evaporation. As the cooling water is recirculated, makeup water (TSE) is required to replace water lost through evaporation. Water must also be periodically removed from the cooling water system to prevent a build-up of dissolved solids in the cooling water.

Where TSE shall be applied for district cooling purposes it usually requires tertiary treatment and proper disinfection process at the WWTP.

Beyond this type of treatment additional treatment is required in order to minimize the risk of corrosion, scaling, formation of biofilms and fouling of system components in the district cooling plant.

Biological growth, one of the major issues with reclaimed water use in cooling towers, relates to the occurrence of biological growth when nutrients are present. Biological growth can produce undesirable biofilm deposits.

Scaling can also be a problem in cooling towers; the primary constituents resulting in scale potential from reclaimed water are calcium, magnesium, sulfate, alkalinity, phosphate, silica, and fluoride.

As for potential TSE reuse in industries and also for district cooling purposes, these additional treatment requirements are subject to the effort to be taken by each one individually.

5. TSE SYSTEM IMPLEMENTATION CONSIDERATIONS

I. Specific Design Suggestions

Overall, the design and implementation of TSE systems must consider the following procedures to maximize the benefits of TSE reuse and avoid risks to human health and the environment:

- The general philosophy is that the TSE distribution and irrigation system must be designed and operated to maximize the beneficial use of TSE.
- All uses of TSE require proper site management to ensure appropriate management of the risks. The stringency of the specific controls depend on the TSE quality and also on the human exposure potential associated with each reuse option.
- The planning of TSE transfer and reuse systems need to consider varying TSE demands throughout the year, especially for irrigation schemes. This situation usually arises during wet weather or winter periods when the irrigation demand is significantly decreasing or is even zero. This means, for example, that pumping stations are designed for peak demand in summer. On the other hand, for the configuration, control and monitoring of the pumping station, the low demand in winter must be taken into account. The installation of appropriate SCADA systems and their professional operation are the key element.
- To improve distribution reliability, TSE transfer and distribution systems should be designed in accordance with internationally recognized rules of technology and National Standards:
  - to ensure the separation and prevention of cross connection between TSE and potable water systems.
  - to allow the disinfection or slug dosing of distribution pipe work with disinfectant or algaecide to control biological solids and bacterial regrowth.

<u>General considerations</u>

TSE must meet the required quality before it is transported to the designated user(s) or reuse storage facility;

- using multiple storage reservoirs is encouraged.
- the flow to and from storage needs to be designed to minimize short-circuiting.
- Artificial aeration in deep storage basins to minimize stratification and odours and to prevent oxygen depletion should be considered.

<u>Irrigation purposes:</u>

For irrigation, the storage facility must be large enough to contain the average daily TSE flow occurring outside the normal irrigation season. The normal irrigation season is defined as the time when irrigation is required because of a climatic moisture deficit during the growing season. It is estimated from the length of the normal growing season, climatic trends, the annual climatic moisture deficit, and knowledge of irrigation periods in the different zones.

<u>Wet climates:</u>

The storage facility may have to provide an allowance for cumulative volumes of TSE because of reduced irrigation in wet weather. If the average seasonal irrigation requirements are used to determine the irrigation area, then this is not necessary. If the land base area is not sufficient to accommodate the average seasonal irrigation requirement, then a cumulative capacity should be added to storage.

I. TSE Transfer TSE supply by tankers

In general, TSE transfer by tankers is considered as not environmentally sound and its use should be restricted or replaced by more efficient options of TSE transfer and distribution.

If TSE is to be supplied by tankers, procedures must ensure that this does not result in spillage, odours or the contamination of the water being transported. Suggested best practice measures include:

- ensuring that the full quantity of TSE tankers is delivered to the reuse site.
- transporting TSE in a watertight and enclosed tanker.
- ensuring that the tanker or pipeline is not contaminated with other sources of waste that will in turn contaminate the TSE and cause public health, crop contamination or environmental problems on the reuse site.
- ensuring that TSE is not transported in tankers used for transporting potable water for human drinking.

II. Minimizing Public Health Concerns

- Avoiding direct contact between the public and disease-causing organisms in wastewater and specifically TSE is the main goal in reducing health concerns. Several approaches can be used to avoid direct contact.
- Reliable disinfection to reduce the number of bacteria and other pathogens is one approach In addition to testing for fecal coliform bacteria, quick tests for chlorine residual can increase confidence in the disinfection system.
- For urban TSE reuse, restricting irrigation to times of the day or period when people are not present is another way to avoid direct contact. Irrigation only at night or when a facility is closed, can be incorporated into a management plan. This could have a significant impact on the design and technical operation of a TSE system.
- Also, for urban reuse, establishing buffer areas between the site to be irrigated and the site border(s) is another approach to avoid contact. Fencing or signs may be needed to help define the buffer area.
- Labelling and signs are needed to advise potentially

effected groups (workers, landscaping staff) and the general public that TSE is being used and that certain precautions are necessary.

- Internationally, it has become accepted to mark pipes, water plumbing and taps for recycled water at the end users with colour. In Australia e.g. such colour coding for pipes is defined in standards. Pipes are marked with the colour lilac/light purple and often with the words: "RECYCLED WATER — CAUTION NOT FOR DRINKING". Some examples are given in Figure 3.

Source: Sydney Water, Working with recycled water, SW20 07/12

Figure 3: International examples of colour coding of pipes for recycled water

Source: Aquatherm Pipe systems *Source: Sydney Water*

Buffer Area

In addition to the introduced fecal coliform limits in accordance with the national regulation for restricted and unrestricted TSE reuse (Chapter 2), Table 5 lists the proposed buffer area requirements allowing safe access to sites where TSE is applied.

The indication of buffer area requirements are advisory only and not legally binding.

Table 5: Proposed fecal coliform concentrations in MPN* per 100 ml and buffer areas for safe access.

Public access buffer area	*Unrestricted reuse*	*Restricted reuse*
Less than 25 m	23 m, night application	23 m
25 m	-	23 m
30 m	-	200 m
60 m	-	1,000 m
90 m	-	
Additional buffer areas proposed for safe access:		
Private water well	30 m	
Community water well	90 m	
Surface water	15 m	
Sink hole	30 m	
Drainage channel	15 m	
Road - Right of way	30 m without wind break using spray irrigation 5 m with windbreak	
Property border	15 m	

(Source: UNEP, 2005) – Guidance for Treated Wastewater Use in Irrigation)

IV Human Exposure Control

This research is not addressing TSE reuse in the agricultural sector (with highest exposure to TSE), where the risk of coming into direct contact with pathogens or substances leading to health risks for human beings is low. Nevertheless, there are individuals or groups of people with potentially higher exposure to TSE that may require the risks to be prevented or at least minimized.

Three groups are at risk in TSE reuse:

- Members of the urban landscaping business (workers, landscapers, nurseries, TSE transport and distribution, especially by tankers etc.)
- Those living near the areas irrigated with TSE
- Industrial and commercial clients (staff responsible for cleaning, irrigation, and gardening works and firefighting)

In view of the different risk potentials, various methods of exposure control may be applied for each group.

Control measures aimed at protecting people involved in the urban landscaping business and staff of industrial and commercial clients, includes:

- Ensuring that employees are not placed at risk through exposure to TSE,
- Provision, and insistence on the wearing, of protective clothing such as impervious gloves and footwear, protective masks, hats and clothing that will reduce their risk of exposure to TSE,
- Maintenance of high levels of hygiene and immunization against selected infections (for example polio, diphtheria, tetanus),
- Provision of adequate training so that employees can work safely and responsibly,
- Provision of well-documented work and emergency procedures, and ensure that employees are trained to use them,
- Conduct regular educational and training programs to ensure up-to date knowledge for employees,
- Ensure the effective and safe operation of all equipment including proper maintenance of all equipment, and
- Ensure that employees develop and maintain good personal hygiene, such as washing their hands before eating and before leaving work, as well as not smoking while at work.

Those living near the areas irrigated with TSE should be:

- Kept fully informed on the use of TSE so that they and their children can avoid these areas during irrigation periods.

In addition:

- Where appropriate, low contact irrigation methods should be given preference such as buffer strips near dwellings and clear signage of TSE (see Fig. 3 and Table 5).
- Special care must be taken to ensure that TSE is not used for drinking or domestic purposes by accident or for lack of an alternative.

V. Multi-criteria Assessment model followed steps

A. Create a prediction model:

Forest-based Classification and Regression (Spatial Statistics):

Prediction is an important part which has been done to detect the future upcoming needs model of the city and it’s components in the below section will be elaborating the tools included in the future analysis.

- **Summary**

  Creating models and generating predictions using an adaptation of Leo Breiman's random forest algorithm, which is a supervised machine learning method. Predictions can be performed for both categorical variables (classification) and continuous variables (regression). Explanatory variables can take the form of fields in the attribute table of the training features, raster datasets, and distance features used to calculate proximity values for use as additional variables. In addition to validation of model performance based on the training data, predictions can be made to either features or a prediction raster.*"esri resources Documentation"*

- **How Forest-based Classification and Regression works**

  - The Forest-based Classification and Regression tool trains a model based on known values provided as part of a training dataset. This prediction model can then be used to predict unknown values in a prediction dataset that has the same associated explanatory variables. The tool creates models and generates predictions using an adaptation of Leo Breiman's random forest algorithm, which is a supervised machine learning method. The tool creates many decision trees, called an ensemble or a forest, that are used for prediction. Each tree generates its own prediction and is used as part of a voting scheme to make final predictions.

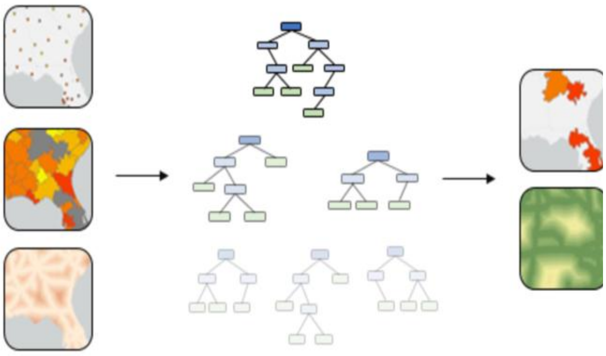

Figure 4: *Forecast based Classification*

Source: esri Documentation Resources

  - The final predictions are not based on any single tree but rather on the entire forest. The use of the entire forest rather than an individual tree helps avoid overfitting the model to the training dataset, as does the use of both a random subset of the data and a random subset of explanatory variables in each tree that constitutes the forest.

  - When the Calculate Uncertainty parameter is checked, the tool will calculate a 90 percent prediction interval around each predicted value of the Variable to Predict. When Prediction Type is Train only or Predict to features, two fields are added to either Output Trained Features or Output Predicted Features. These fields, ending with _P05 and _P95, represent the upper and lower bounds of the prediction interval. For any new observation, you can predict with 90 percent confidence that the value of a new observation will fall within the interval, given the same explanatory variables. When the Predict to raster option is used, two additional rasters representing the upper and lower bounds of the prediction interval are added to the Contents pane.

B. <u>Create a suitability model:</u>

- **Summary**

  - Suitability modeling is one of the most foundational approaches to solving spatial problems where are the best, or most suitable, locations for something. Whether you are trying to identify the most suitable location for a store or conservation area, following the same basic steps.

1. **Define the problem:** Defining the problem will help to identify a specific and measurable goal for the suitability analysis.
2. **Identify the criteria:** The subject of suitability model will respond to different phenomena, referred to as criteria (for example, slope). The criteria should support the defined goal of the suitability model.
3. **Derive the criteria:** If we there's no data that represents each criterion, we can derive the criteria from a base dataset (for example, a slope criterion is derived from an elevation base dataset).
4. **Transform criteria values:** Criteria values are measured using different scales, so we must transform these values to a common scale so that they can be compared and combined.
5. **Weight and combine criteria:** Some criteria may be more important than others. we can weight the criteria relative to one another before combining them to create a single suitability layer.
6. **Locate the site:** The suitability layer reflects the characteristics of a location. In this step, we will integrate the spatial requirements of the subject of our suitability model and use these spatial requirements to identify the best locations from the suitability layer.
7. **Analyze the results:** Analyze the results to confirm that the selected site meets the requirements and ensure that we achieved the goals of the analysis.

<u>One of the Criteria's as per the following:</u>

Category 1 (Weight 30%)

Water resources

- Potential for accessing water resources:
- Access to utility networks (TSE, storm water...) Flood area
- Ground water network

Category 2 1 (Weight 46%)

Urban environment

- Urban & environmental conditions
- Population density
- Green coverage
- Access to infrastructure network
- Proximity to other green projects etc.

Category 3 1 (Weight 24%)

Greening opportunity

- Potential for greening projects
- (subcomponent): Existing & future parks
- Mosques Streets (<36 m wide)
- Schools Health facilities.

This Criteria was selected to define the most priority neighborhoods to start launching the greening projects.

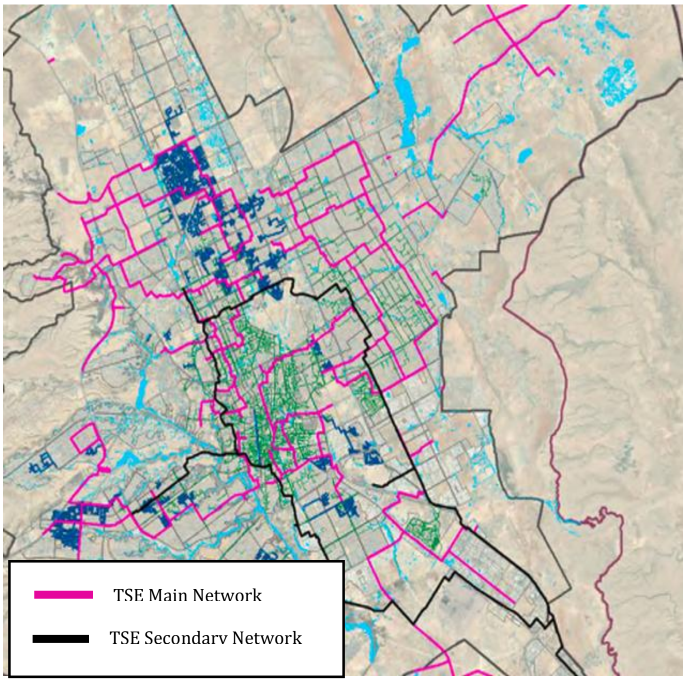

Figure 5: TSE Network Across the City

4. RESULTS AND DISCUSSION

The multi criteria assessment analysis confirmed that the priority of the development should be starting from the sites that located around the new TSE Networks and for the ease of the planting of the Parks that will be under The Green Riyadh Strategy. Using the distance allocation function to check the availability and the existence of the other development projects in the city such as metro and BRT.

5. CONCLUSION

This paper focuses on developing an MCAM methodology for environmental conflict management in the usage of the TSE Network and the Mega greening projects in Riyadh, Saudi-Arabia. Possibly an increase in the greening per Capita which will improve the quality and the livability of the urban environment. The effectiveness of the MCAM in achieving its objectives can be developed by future stakeholders in cooperation with the governmental sector.

The multitude of sometimes conflicting resource uses and activities require more elaboration and systematic planning. This study is an important contribution as it is providing a methodological approach that could be applied in managing the Treated water effluent (TSE) Networks and integrating with the current wastewater networks, tanks, and plants. conflicts whilst simultaneously maximizing ecosystem gains. Spatial conflict analysis could be used proactively to understand the degree of controversy to develop the planning accordingly. Locating exactly where conflict hotspots are likely to emerge in response to changes in management policy can lead the policymakers and enable them to avoid some areas or to implement a process that includes conflict management. Treated Sewage effluent and spatial planning are crucial for the optimal and sustainable use of wastewater resources from economic, social, and environmental perspectives. The methodology employed in this study would be useful in establishing guidelines for the allocation of resources between conflicting uses and therefore, help in conflict avoidance. Mapping environmental conflicts can be used as a tool that can guide planners to make informed policy decisions with economic, social, and environmental objectives in mind.

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