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Investigation of Irrigation Water Application Rates to Landscaped Areas in Riyadh

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Abstract. The objective of this study was to determine, using field observation technique, irrigation water application rates to green areas in the City of Riyadh, with special emphasis on private residential areas. Sixty-two (62) out of a total of seventy seven (77) investigated samples, *i.e.* 80% of the studied green areas, were chosen from private residences. The other three categories that were studied during three periods of the year were road medians, public parks, and special developments.

Based on the field data collected in the study, irrigation water application rates were determined. Rates increased from relatively low values of under 15 l/m^2/day in the months of December-January, to a peak rate of 33 l/m^2/day in the April-May period. Water application rates to green areas in public parks and special developments were within the maximum rates used under a well managed irrigation scheme. However, excessive water usage was observed in the categories of green areas in private residences and road medians. Water application rates in these categories were double the needed rates, reaching 23 and 33 l/m^2/day respectively, *v.s.* a recommended rate of 15 l/m^2/day during the peak season. It is of prime importance to raise the awareness of the general public concerning the effects of over-irrigation and their education in water conservation. It is recommended that guide-lines be formulated for the irrigation of landscaped areas and mechanisms for their implementation and reinforcement be established.

Introduction

Irrigation water needs for green areas are essential criteria for the planning of both the extent of landscaping and the water supply schemes in a city. Water application rates should be based on local conditions and formulated according to the prevalent environmental, economic, and conservational aspects, in addition to the actual needs of the plants themselves.

In Riyadh area, landscape development is proceeding at a great pace. According to the Landscape Irrigation Master Plan [1], the total public landscaped area in the City was 337 ha in 1984 and is expected to increase to 1894 and 2800 ha in the years 1990 and 1996 respectively. The projected developments for the City by the end of the next decade totals at least some 4600 ha of parks, gardens, road way intersec-

tions and medians, etc. [2]. In additoin, private landscaping of domestic premises and commercial developments is also increasing though accurate figures are not yet available. Ar-Riyadh Development Authority (ADA) is currently conducting an extensive study which will be completed by the end of the current year.

No study of actual irrigation water application rates, particularly for green areas in private residential developments, is available for any city in the Kingdom. The study of water application rates for the irrigation of green areas in Riyadh City is of great importance. Firstly, a lot of effort has been made to landscape the City with green areas and trees to improve its environment. Secondly, the nature of the region, being semi-arid, makes it imperative to have good water management in order to conserve water and simultaneously have maximum possible extent of green coverage. And thirdly, optimum water application rates for the city landscaped areas will, to a great extent, help in the current effort to control the rising ground water level in the city and its associated problems [3].

Objectives and Scope of Study

The purpose of this study was to determine and evaluate the water application rates to manually irrigated landscaped areas in the City of Riyadh. The study covered the various types of landscapes, namely in private residences, road medians, public gardens and parks and in special developments. Water application rates were measured during three periods of the year in order to determine the seasonal variations and henceforth, to obtain an overall picture of the yearly water use in irrigation.

Irrigation Water Requirement

Water for irrigation must be properly managed in order to avoid losses due to over-application of irrigation water. Considerable efforts have been made to determine the most suitable water quality, to improve methods of irrigaiton and to decrease water losses. The overall goal is to raise the irrigation efficiency, conserve water, and simultaneously attain optimum production. Irrigation efficiency is also influenced by cost and quality of labor, ease of handling water, method of irrigation, type of plants, and soil characteristics [4].

Irrigation Methods

Irrigation water may be applied to a planted area by flooding it on the land surface, by applying it beneath the soil surface, by spraying it under pressure, or by applying it in drops [4-6]. The predominant method of landscape irrigation in Riyadh

is by surface irrigation (Manual hose irrigation). However, in the last few years sprinkler irrigation (rotating sprinklers or bubblers) and drip irrigation (emitters of single or multi-tube types) have been used especially in new parks (*e.g.* Thummamah Park) and special developments (*e.g.* Diplomatic Quarter). The last method aims at minimizing both evaporation and percolation losses, hence it is the most efficient in water use. However, it requires costly investment and consequently is mostly justified where water is scarce and expensive to supply, a situation which is predominant in Saudi Arabia.

Water Application Rates for Irrigation

Irrigation water requirements are usually calculated from basic evapotranspiration figures, which in turn, are determined by one of the accepted formulae which operate on climatic data. The water application rates are then estimated by empirical translation of basic evapotranspiration rates into usage figures, by means of [7-10] vegetation factors, (type of planting, canopy area, depth of plant root), soil factors (type of soil, potential for water holding), and irrigation efficiency (method of irrigation, water losses).

The most common losses of irrigation water are represented by surface runoff and evaporation, seepage, leakage, spills, and percolation below the root zone [4, 9, 10]. Irrigation by surface application, long irrigation runs, and excessive single applications, all contribute to large losses.

The empirical factors relating water application rates to evapotranspiration figures are generally derived from an agricultural background, where the cirteria is obviously to produce the maximum economic return on capital invested, the return being in the form of yield, and the capital invested being in the form of the cost of applied water. In the landscape context, the development of such maximum growth would lead to a heavy maintenance requirement, as the plant (*e.g.* grass) would require regular cutting, producing a material which would mainly be considered as a waste product. The landscaping requirement from plants would be to promote a green lush appearance, with the minimum actual plant growth that would consequently require less water to maintain than a plant to produce a maximum crop. The correlation of evapotranspiration figures to landscape planting needs is an area where there is very little existing information [2]. The reason for this is of course its less importance to the economy in comparison with crop production.

In this decade, several extensive landscape irrigation schemes have been designed in Riyadh area. The master plan for the irrigation of the municipal landscaping in the city was based on a peak water application rate of 14 l/m^2/day [1]. The peak irrigation rate that is being actually applied in the Diplomatic Quarter [11] is 15 l/m^2/day (see Table 1). The landscaping for Thummamah Park [12], located 80 km north-east of Riyadh, has been designed so that the water application rate on its ground cover will not exceed 10 l/m^2/day (see Table 2).

Table 1. Peak irrigation application rates at the Diplomatic Quarter, Riyadh, Saudi Arabia [11]

Planting type	Water application rate*
Trees:	
Palm	100 l/day every other day
Large	75 l/day
Small	50 l/day every other day
Shrubs and Climbers	15–20 l/shrub/day
Grass and Ground Cover	15 l/m^2/day

*Automatically operated sprinkler and drip irrigation system

Table 2. Design peak irrigation application rates at the Thummamah Park, Saudi Arabia [12]

Planting type	Water application rate*
Trees:	
Large	120 l/day every other day
Small	80 l/day every other day
Desert/Camp Tree	50 l/day every other day
General Under Planting	5 l/m^2/day
Ground Cover	10 l/m^2/day

*Automatically operated sprinkler and drip irrigation system

Methodology

The study area, sampling, data collection, and measurement of actual irrigation water application rates selected for this study are briefly described below.

Study Area and Sampling

Considering the vast extent of the green areas in the City of Riyadh, it was obvious that it is impractical to actually measure the irrigation water application rates for

each and every planted area in the city. Water application rates have to be inferred from measurements taken from samples, which in turn, have to be selected to show an accurate prediction of the total irrigated areas.

The green areas in the city were divided into four categories. These included planted areas in:

1) Private residences.
2) Road medians.
3) Public gardens and parks.
4) Special developments.

Ten to fourteen samples of private residences were selected from the various residential areas of Riyadh namely, Um Al-Hamam, Al-Malaz, Al-Naseem, Al-Rouda, and Olaya Quarters (see Fig. 1). Table 3 shows a summary of the number of samples from each quarter along with their designations. Overall, a total of sixty two (62) private residences were selected for this study.

Nine stretches of road medians were chosen for the determination of irrigation water application rates (see Fig. 1). The designation for each stretch, name of road and quarter in which it is located are shown in Table 4.

Two public gardens namely, Foutah Park and Jabal Abo Makhrouk Park, were chosen to represent the category of public gardens and parks available in Riyadh. The location of the parks are shown in Fig. 1.

To represent the category of special developments in the city, the campus of King Saud University was chosen. Four green areas from the campus were selected for the determination of irrigation water application rates.

Data Collection

The data for this study consisted of measurements of water application rates for a total of 77 (seventy seven) samples of green areas distributed among the various categories of manually irrigated planted areas in the city. The number of actual field measurements of water application was 3×77 *i.e.* 231 times. This was necessary in order to determine the variation of water application rates for the various seasons. All measurements were performed in the period from December 1987 to May 1988.

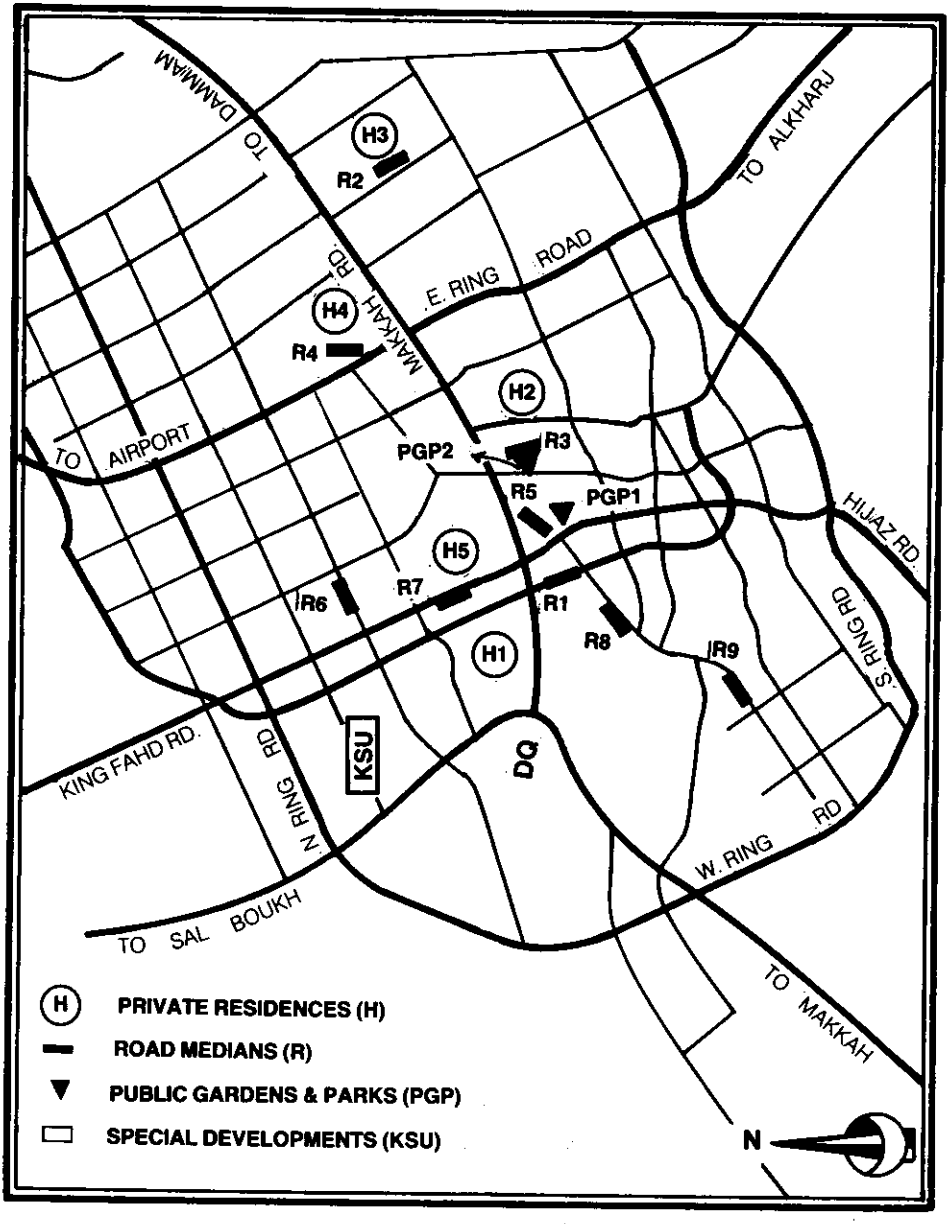

Fig. 1. Location of studied landscaped areas in Riyadh

Table 3. Designation, number, and name of quarter for samples from private residences

Designation	Name of quarter	Number of samples
H_1	Um Al-Hamam	10
H_2	Al-Malaz	12
H_3	Al-Naseem	13
H_4	Al-Rouda	13
H_5	Al-Olaya	14
	Total number of samples	62

Table 4. Designation, number, and name of quarter for samples from road medians

Designation	Road/Street name	Quarter
R_1	Al-Takhassosi	Al-Ma'ther
R_2	Abdulrahman Ibn 'Anf	Al-Naseem
R_3	Salah Al Din Al Ayoubi	Al-Malaz
R_4	Amir Mohammad Ibn Faisal	Al-Rouda
R_5	Al Ma'ther	Al-Sulaymaniyah
R_6	Amir Abdullah Ibn Abdulaziz	Al-Malik Fahad
R_7	Al-Olaya	Al-Olaya
R_8	Al-Ma'ther	Al-Nassiriyah
R_9	Amir Sattam Ibn Abdulaziz	Al-Badia'h

Measurement of Actual Irrigation Water Application Rates

A volumetric method of water measurement was used for landscaped areas, which were surface irrigated manually by means of plastic hoses. This is a simple method of collecting the flow from an irrigation hose in a container of known volume for a measured period of time. By calculating the flow rate and using the measured irrigated area and period of irrigation, the water application rate in $L/m^2/day$ was determined.

A variation of this technique was used when irrigation was performed directly from a tanker truck. In this case, the water application rate was determined from the known volume of the tanker, the measured irrigated area, and frequency of irrigation (*i.e.* whether daily, every other day or twice a week etc...).

Results and Discussion

Based on the data collected from field measurement, individual irrigation water application rates for the seventy seven (77) samples of green areas (three measurements for each) were determined. The results of the actual water application rates, in $l/m^2/day$, during three different periods of the year, for the four categories of green areas in Riyadh are shown in Tables 5-8 for private residences, road medians, public gardens and parks, and special developments respectively.

Irrigation Water Application Rates in Private Residences

A great emphasis in this study was given to the irrigation practice in private residences. This is apparent from the large number of samples selected from this category, 62 out of 77 samples *i.e.* about 80% of the total. The reason for this is two fold. Firstly, private irrigation is the greatest unknown and least controlled component when compared to public irrigation. And secondly, potable water of prime quality is universally used in Riyadh for the irrigation of grean areas in private residences. This leaves the door wide open for water conservation measures to be enacted that can lead to appreciable saving in the high cost of production, transport, and distribution of the city potable water supply.

The results of the study of water application rates to green areas in private residences are shown in Table 5. The residential average water application per square meter of green area per day for all five quarters in the city was equal to 23.2 $l/m^2/day$ during the months of April-May. The variation in individual rates was high ranging between 10.6 and 43.6 $l/m^2/day$ with a standard deviation of 7.8 $l/m^2/day$. During December-January months, the average application rate was equal to 7.0 $l/m^2/day$ (30% of the April-May rate) while during February-March, the rate was 10.2 $l/m^2/day$ (44% of the April-May rate).

The highest water application rate, in the neighborhood of 25 $l/m^2/day$, was recorded for the three quarters of Um Al-Hamam, Al-Malaz and Al-Naseem. Al-Rouda came next with an irrigation water rate of 22.5 $l/m^2/day$ followed by Al-Olaya Quarter which had the lowest April-May rate of 19.5 $l/m^2/day$. The minimum water irrigation rate, 4.9 $l/m^2/day$, was recorded in the December-January months in Al-Malaz Quarter.

Irrigation Water Application Rates in Road Medians

The irrigation water application rates to green areas in road medians, showed a considerable variation among the various stretches of roads (see Table 6). The highest rates, in the months of April-May, varied between a minimum of 12.1 $l/m^2/day$ for

Table 5. Irrigation water application rates to green areas in private residences (H).

Location quarter		Water application rate l/m²/day									No. of samples
		December–January			February–March			April–May			
		Aver-age	Standard deviation	Range	Aver-age	Standard deviation	Range	Aver-age	Standard deviation	Range	
Um Al-Hamam	(H1)	7.2	3.3	2.1–12.0	12.2	5.4	3.6–19.0	25.2	9.3	10.6–38.0	10
Al-Malaz	(H2)	4.9	2.0	1.0– 6.9	9.4	4.1	3.0–16.1	24.6	10.2	11.2–43.6	12
Al-Naseem	(H3)	7.7	3.3	2.6–12.6	11.4	4.0	2.9–16.8	25.8	7.5	12.1–34.5	13
Al-Rouda	(H4)	7.8	2.8	5.0–12.7	10.2	3.4	6.0–18.5	22.5	4.8	12.6–29.5	13
Al-Olaya	(H5)	7.0	3.0	2.3–13.6	7.2	2.5	3.3–11.8	19.5	4.3	11.4–25.0	14
All quarters	(H1–H5)	7.0	3.0	1.0–13.6	10.2	4.2	2.9–19.0	23.2	7.8	10.6–43.6	62

Table 6. Irrigation water application rates to green areas in road medians (R)

Sample road*	Water application rate l/m²/day		
	Dec. – Jan.	Feb. – Mar.	Apr. – May
R_1	11.9	16.7	35.7
R_2	21.3	18.4	44.7
R_3	14.6	15.5	36.9
R_4	20.9	22.9	38.7
R_5	6.0	6.2	12.1
R_6	8.1	9.1	38.4
R_7	22.4	19.7	30.4
R_8	7.5	8.1	24.4
R_9	20.1	18.8	35.2
Range	6.0–22.4	6.2–22.9	12.1–44.7
Average	14.8	15.0	32.9
Standard deviation	6.6	5.8	9.6

*Names of roads/streets and quarters are shown in Table 4.

the stretch of Al-Ma'ther Road in Al-Sulaymaniyah Quarter (R5), to a maximum of 44.7 l/m²/day for a stretch of Abdulrahman Ibn 'Arf Road in Al-Naseem Quarter (R2). These values correspond to 36% and 136% of the average April-May irrigation rate of 32.9 l/m²/day for all studied road medians.

In contrast to residential green areas, the average water application rates for the months of December-January and February-March, were almost identical at 14.8 and 15.0 l/m²/day respectively. For the same periods, the water irrigation rates in private residences were 30 and 44% of the April-May months, while for the road medians the ratio was the same for both periods at 45% of the average rate of April-May months.

Irrigation Water Application Rates in Public Gardens and Parks and in Special Developments

The average April-May water application rate for the two public gardens and parks namely, Foutah Park and Jabal Abo Makhrouk Park, was 12.3 l/m²/day. The average rates in December-January and February-March periods, were 3.2 and 6.7 l/m²/day (26% and 54% of April-May rates) respectively (see Table 7).

Table 7. Irrigation water application rates to green areas in public gardens/parks (PGP)

Samples area	Water application rate l/m²/day		
	Dec. – Jan.	Feb. – Mar.	Apr. – May
PGP 1	3.1	7.8	14.6
PGP 2	3.3	5.6	10.0
Range	3.1–3.3	5.6–7.8	10.0–14.6
Average	3.2	6.7	12.3
Standard deviation	0.1	1.6	3.2

The average high water irrigation rate of the four samples of green areas, selected from the Campus of King Saud University to represent an example of irrigation in special developments, was 5.6 l/m²/day (see Table 8). The minimum rate at KSU, 1.2 l/m²/day, was in the period of December-January. An intermediate application rate of 2.8 l/m²/day was observed during the months of February-March. These values correspond to 21% and 50% of the high April-May water application rates respectively.

Table 8. Irrigation water application rates to green areas in special developments (KSU)

Samples area	Water application rate l/m²/day		
	Dec. – Jan.	Feb. – Mar.	Apr. – May
1	0.9	1.4	2.8
2	1.1	1.7	3.3
3	1.5	2.3	4.6
4	–	5.9	11.9
Range	0.9–1.5	1.4–5.9	2.8–11.9
Average	1.2	2.8	5.6
Standard deviation	0.3	2.1	4.2

Comparison of Irrigtion Water Application Rates

A summary of observed water application rates for the various categories of green areas in Riyadh is shown in Table 9. The relationship between these rates and those of the Diplomatic Quarter in Riyadh are shown graphically in Fig. 2.

Table 9. Summary of water application rates to various categories of green areas in Riyadh

Category	Water application rate l/m²/day(*)								
	Dec. – Jan.			Feb. – Mar.			Apr. – May		
	Average	Standard deviation	Range	Average	Standard deviation	Range	Average	Standard deviation	Range
Private residences	7	3	1–14	10	4	3–19	23	8	11–44
Road medians	15	7	6–22	15	6	6–23	33	10	12–45
Public gardens, and parks	3	0	3–3	7	2	6–8	12	3	10–15
Special developments (KSU)	1	0	1–2	3	2	1–6	6	4	3–12

*All rates were adjusted to the nearest one liter per square meter per day

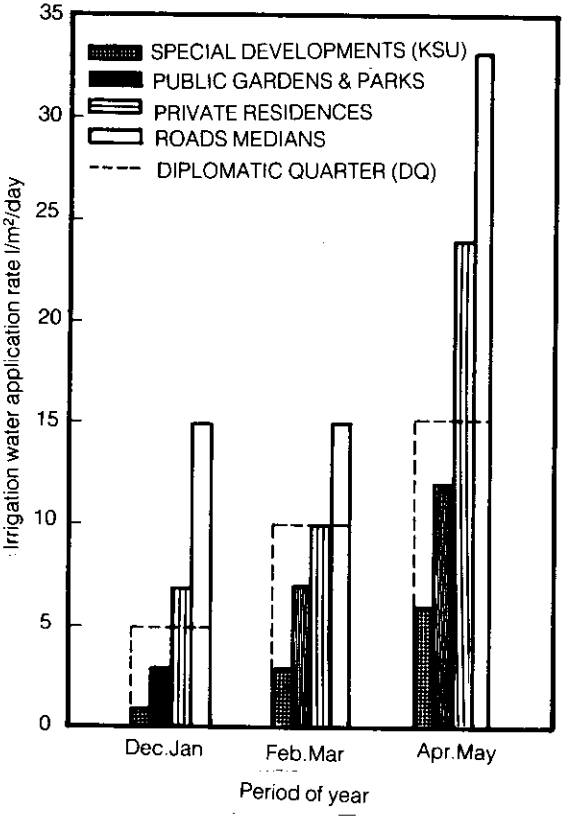

Fig. 2. Comparison of irrigation water application rates

The irrigation water application rates at the Diplomatic Quarter (D.Q.) in Riyadh are the most dependable and realistic data available locally; hence their use as a basis for comparison. Firstly, the data have been determined under actual controlled field conditions in which best plant appearance and green ground cover are maintained with minimum water use and maintenance. Secondly, D.Q. water application rates correspond well with the actual evapotranspiration rates in Riyadh area as determined by Salih and Sendil [13]. This conformity of the D.Q. water application rates with the evapotranspiration data at Riyadh is shown in Table 10. The 20% difference between the rates corresponds to an efficiency of 80% in water application.

Table 10. Relationship of Diplomatic Quarter (D.Q.) irrigation water application rates to actual evapotranspiration rates at Riyadh

Season	D.Q. irrigation water application rate [11] $l/m^2/day$	Mean evapotranspiration at Riyadh [13] $mm/day = l/m^2/day$
Winter	5	4
Spring/fall	10	8
Summer	15	12

The highest water use is observed to be in the category of green areas in road medians. This is followed by the green areas in private residences. The last two categories of green areas in public gardens and parks and special developments (KSU) showed much lower water application rates, ranging between one quarter to one half of the actual water rates applied in the first two categories. This behavior is to be expected, and in fact it reinforces the importance of good management in irrigation projects. The public gardens and parks and special developments in the city have their own well established and defined operation and maintenance personnel, compared to the use of contracted tankers in the irrigation of road medians and the manual haphazard watering of green areas in private residences.

The results of this study as depicted in Fig. 2, demonstrate the increase in irrigation water applicaiton rates as the air temperature, and hence evapotranspiration rates, increased from the months of December-January up to April-May. The water application rates in the warmer and dryer months of April-May were double and triple to quadruple the observed rates in the other two periods, February-March and December-January respectively.

The relationship between actual water application and evapotranspiration rates, during the three two-months periods, for the categories of green areas is shown in Table 11. As expected, irrigation water application rates increased with rising evapotranspiration rates for every category of green areas. For private residences, as evapotranspiration rate rose from 3.4 to 5.3 to 8.0 mm/day for the three studied periods, the corresponding water application rates increased from 7 to 10 to 23 l/m^2/day. Similar behavior can be noticed for the other three categories of planted areas.

Table 11 also shows the ratio of irrigation water application rate to evapotranspiration rate (I/E ratio), for every cateogry over the three periods. Except for special developments, the I/E ratio is either equal to or greater than unity. This indicates that the amount of water applied is larger than what is required by evapotranspiration. For public gardens and parks, the overall I/E ratio of 1.2 with a range from 0.9 to 1.5 is quite reasonable. However, in the cases of both private residences and road medians, the high I/E ratios of 2.3 (range 1.9 to 2.9) and 3.8 (range 2.8 to 4.4) respectively, illustrate the widespread practice of applying excess irrigation water in these areas.

Over-irrigation has serious results and implications, not only on environmental conditions (*e.g.* rising groundwater problems) and economical issues (*e.g.* wastage of precious water and installation of groundwater drainage schemes), but also on the irrigated plants themselves. Supplying the plants with excess water leads to waterlogging of the soil. This in turn results in the gradual salinisation of land, degradation of the quality of landscape and inevitably, the death of the plants [2, 6].

The existence of an impervious layer at a small depth of 1 to 10 m below the surface, coupled with low permeability of the soil, creates an ideal situation for groundwater rise and soil waterlogging in Riyadh. The estimate by Ar-Riyadh Development Authority (ADA) is that irrigation water contributes about one quarter of the total infiltrated groundwater [3]. Therefore, the control of over-irrigation would go a long way towards alleviating the groundwater table rise in the city.

Environmental Impact of Landscape Irrigation

Riyadh environment is harsh, with extremes of temperature (up to 47°C in summer), minimal rainfall (86.2 mm/year), low humidity (monthly means 20 to 54%) and fairly frequent dust storms. Planning of Riyadh has always recognised the importance of planting and landscape within and around the city in order to enhance the quality of life and temper the desert environment. In fact, it has been shown [2] that the intensive development within the city has already resulted in a significant

Table 11. Comparison of irrigation water application and evapotranspiration rates

Period	December–January			February–March			April–May			
Category	I	E	Ratio I/E	I	E	Ratio I/E	I	E	Ratio I/E	Overall ratio I/E
Private residences	7	3.4	2.1	10	5.3	1.9	23	8.0	2.9	2.3
Road medians	15	3.4	4.4	15	5.3	2.8	33	8.0	4.1	3.8
Public gardens & parks	3	3.4	0.9	7	5.3	1.3	12	8.0	1.5	1.2
Special developments	1	3.4	0.3	3	5.3	0.6	6	8.0	0.8	0.6

I : Irrigation water application rate $l/m^2/day$

E : Evapotranspiration rate mm/day = $l/m^2/day$ [13]

environmental impact by reducing the desert radiation effect, cutting down the intensity of dust storms, tempering the dryness, and providing an aesthetic effect for the enjoyment of the population.

However, under the ambient climatic conditions no worthy planting will survive without constant irrigation. The available quantity of water is limited, and therefore, it is essential to insure that the expensive water made available for landscape purposes is applied in the most efficient manner, keeping the right balance between lanscape irrigaton and the long term strategic environmental implications.

The effect of irrigation on groundwater rise due to the irrigation practice in the city, and the expensive drainage and dewatering schemes required to control the groundwater rise, have become serious problems to landscape planting. A particular issue which adds a further dimension to this situaiton is that the implications that have resulted, or may result in the furture due to groundwater rise, are occurring in an environment where such phenomena are both unusual and unwanted.

In many cases foundations, walls, basements, pavements and utilities, which are normally not designed to resist high water pressures, have cracked [3]. Other impacts observed have been the settlement of utility trenches, deterioration of electrical cables and overloading the capacities of sanitary and storm sewers. In areas where groundwater contaminated with sewage appears on the ground surface, unsightly pools were formed. Consequently, potential sources for mosquito breeding and health hazards were created.

A further consequence of high groundwater levels, as mentioned in the previous sectoin, is waterlogging of soil. The groundwater in Riyadh generally has a high salt content, especially in sulphates and chlorides. This fact coupled with the high evaporation rate (9.4 mm for an average day and 15.3 mm for a peak day in June), increase the risk of salt buildup in the capillary zone above the water table. This process of soil salinisation will eventually lead to the degradation of the landscape, which is in direct contradiction with the original objective of landscape conservation and expansion.

The importance of establishing guide-lines for landscape irrigation as well as mechanisms for their implementation and reinforcement cannot be over-stated. With a limited and precious supply of irrigation water on the one hand, and the long term environmental implications of over-irrigation on the other, it is the good management of irrigation which determines the overall success of landscape development.

Conclusions

The objective of this study was to determine, using field observation technique, irrigation water application rates to green areas in the City of Riyadh. Particular emphasis was placed on irrigation of private residential areas; however, manually irrigated road medians, public gardens and parks and special developments were also investigated. Based on the field data collected in this study, the following conclusions were made:

1) In general, water application rates were proportional to evapotranspiration rates during the study period from December 1987 to April 1988. The irrigation rates in private residences, corresponding to evapotranspiration rates of 3.4, 5.3 and 8.0 mm/day, were 7, 10 and 23 l/m^2/day respectively.

2) Water application rates to green areas in public gardens and parks and special developments were within the maximum rates used under a well managed irrigation scheme. In some instances, water application rates (KSU) were even less than the evapotranspiration rates. The ratios of irrigation to evapotranspiration rates for these categories were 1.2 and 0.6 respectively.

3) High water use was observed in the categories of green areas in both private residences and road medians. Water application rates in these areas were more than double the needed rates, reaching 23 and 33 l/m^2/day respectively. The ratios of irrigation to evapotranspiration rates were 2.3 for private residences and 3.8 for road medians.

4) In the category of road medians, the highest rates in the months of April-May varied between a minimum of 12 l/m^2/day to a maximum of 45 l/m^2/day with a standard deviation of 10 l/m^2/day. These values correspond to 36% and 136% of the road medians overall average April-May irrigation rate of 33 l/m^2/day.

5) The average April-May water application rate for public gardens and parks was 12 l/m^2/day. The average rates in December-January and February-March periods were 3 and 7 l/m^2/day respectively.

6) The average maximum water application rate for KSU (special development) was 6 l/m^2/day in the April-May period. The minimum average rate of 1 l/m^2/day was observed in the period of December-January.

Recommendations

1) It is of prime importance to raise the awareness of the general public concerning the negative effects of over-irrigation. This effort should emphasize the hazards of over-irrigation to the plants themselves, to the environment, and the financial implications of the extra water supply costs. For this effort to be successful, an effective water pricing policy is also required.

2) The education of people in water conservation can be reinforced through the use of the various media. Television programs, radio, newspapers, and specially prepared and freely distributed pamphlets would be extremely useful.

3) It is recommended that guide-lines be formulated for the irrigation of landscaped areas in both private and public developments. These guide-lines should include recommendations on types of plants, types of irrigation systems (especially the use of automatic drip irrigation), and corresponding water application rates, for the various seasons of the year.

4) Mechanisms for the implementation and reinforcement of the irrigation guide-lines should be established.

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دراسة معدّلات استخدام المياه في ري المناطق الخضراء في مدينة الرياض

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ملخص البحث. الهدف من هذا البحث هو استقصاء لمعدّلات المياه المستخدمة في ري المناطق الخضراء في مدينة الرياض وخاصة في ري الحدائق المنزلية. لقد تم اختيار٦٢ عينة من أصل ٧٧ عينة، أي ٨٠٪ من مجموع العينات، من المناطق الخضراء التابعة للوحدات السكنية. أما المجموعات الثلاث الأخرى التي تمت دراستها خلال ثلاث فترات مختلفة من السنة فهي المناطق الخضراء في الشوارع والحدائق العامة والمجمّعات العمرانية.

بناء على معلومات المسح الميداني تم حساب معدّلات المياه المستخدمة في ري المناطق الخضراء المختلفة من المدينة. لقد وُجد أن معدّلات المياه ترتفع من ١٥لتر/م٢/يوم في أشهر ديسمبر- يناير، إلى معدّلات قصوى تبلغ ٣٣لتر/م٢/يوم في أشهر ابريل - مايو. إن معدّلات استخدام المياه لري المناطق الخضراء في الحدائق العامة والمجمعات العمرانية كانت معقولة عند مقارنتها مع الكميات التي تحتاجها الزراعة التجميلية المُدَارة بشكل جيد. ولكن كميات المياه المستخدمة في ري المناطق الخضراء في المساكن الخاصة والشوارع كانت أكثر بكثير مما يجب. بلغت معدّلات الري في هذه المجموعات أكثر من ضعف الكميات اللازمة حيث وصلت إلى ٢٣ و ٣٣ لتر/م٢/يوم على التوالي مقارنة مع المعدّل الأقصى اللازم للري وهو ١٥لتر/م٢/يوم.

إنه لمن الأهمية القصوى تثقيف المواطنين بالنسبة للتأثير السيء لكثرة استعمال المياه في الري وتوعيتهم حول ضرورة الترشيد في استعمال المياه. وأخيراً يوصى بضرورة تحضير دليل خاص يحدد القواعد المثلى التي يجب اتباعها في ري المناطق الخضراء وكذلك ايجاد الآلية اللازمة للتأكد من تطبيقها.