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Water availability for the greening of Kuwait

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Abstract

Water resources for agricultural development and landscape enhancement in Kuwait are very scarce; the quality is saline (brackish), and the soil texture is sandy, incapable of holding nutrients and moisture. Most of the rainfall in Kuwait either evaporates due to the high temperatures or percolates through the soil. The rainfall is not sufficient to recharge the underground water supply. A variety of alternative water sources have been studied, including seawater desalination and wastewater treatment. Wastewater treatment proved to be convenient due to the relatively low salinity detected in the treated water. Furthermore, the amount of wastewater is expected to increase as more residential areas are connected to the sewage system as the population increases.
The development of a greenery plan for Kuwait requires intensive water management. This goal can be achieved through manpower training in landscape development, selection of plants tolerant to arid environments, usage of appropriate irrigation and drainage systems, promotion of greenery programs within public and the governmental agencies for their direct participation in urban area beautification, and extension of wastewater treatment techniques.

Key words: Kuwait – saline – agriculture development – desalination plant – wastewater treatment – greenery – water resources

Introduction

The State of Kuwait is located at the northwestern corner of the Arabian Gulf between latitudes 28° 30′ and 30° 06′ north of the Equator and between longitudes 46° 30′ and 48° 30′ east of Greenwich (Fig. 1), which produces weather in the country that is typical of a desert geographical region. It is bounded on the south by Saudi Arabia, on the north and west by Iraq, and on the east by the Arabian Gulf. The total land area is 1,781,800 ha, and the total population is 2,274, 980 (MOP 1998). The coastline of Kuwait is 290 km long (ABOU EL-NIL et al. 2001).

Kuwait's climate is characterized by harsh summers and mild winters. Temperature extremes are high, with means ranging between 46.2 °C in summer and 6 °C in winter (MOP 1998) (Fig. 2). Winter brings occasional frost. Rainfall is minimal, not exceeding 115 mm/yr. Evaporation is very high, averaging 14.1 mm/d. The relative humidity is low, and winds are strong. Dry and hot northwesterly winds prevail during summer, particularly in June and July. They vary from strong to light winds and sometimes raise extensive dust storms during which visibility deteriorates to a few meters, especially at noon. Kuwait's soils are high in calcareous materials, especially calcium carbonate. The soil is sandy in texture,

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alkaline, and low in plant nutrient material (SULEIMAN et al. 2002). Water resources in Kuwait are scarce, and the brackish water currently used is saline with dissolved salt concentrations ranging from 3,000 to 8,000 mg/l.

The development of ornamental plants for urban areas in Kuwait has been underway since the early 1950s. Species of trees like *Eucalyptus*, *Tamarix*, and *Zizyphus*, and shrubs like *Jasminum* and *Lantana* were first introduced to parks and motorways in the country at that time. Some of the introduced plants proved to be highly tolerant to the existing environment. Scientists and researchers had explored the world of flora, and a wide variety of ornamental plants proved to be capable of enduring Kuwait's harsh climate.

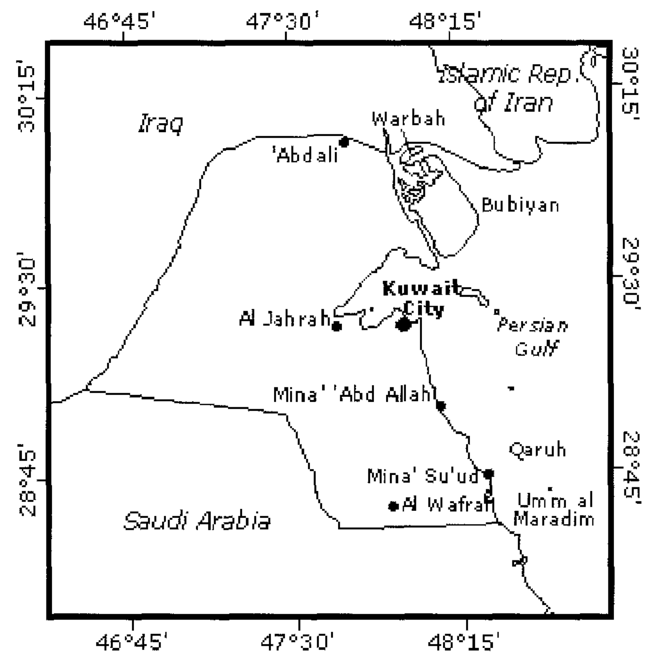

Fig. 1. Map of Kuwait. Symbols: Locations of the desalination power plants.

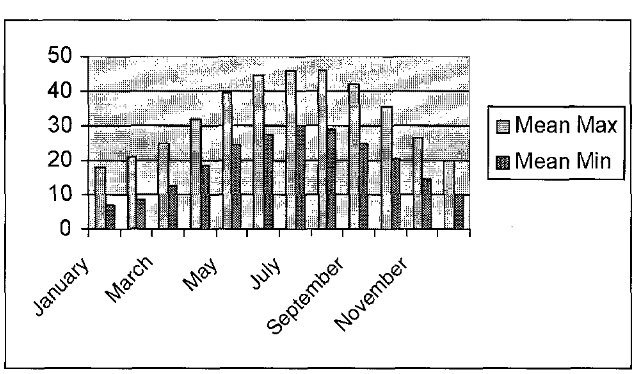

Fig. 2. Mean temperatures (in °C) in Kuwait, 1989–1999. Source: MOP (1998).

Augmenting landscape enhancement has been planned and partially executed. Adequate water resources with low salinity levels and reasonable prices are essential for full implementation of the proposed landscaping projects. The water resources used at present for ornamental and agricultural purposes are primarily underground aquifers and treated municipal wastewater. The current resources are not capable of satisfying the ornamental and agricultural requirements especially since, at present, there is special emphasis on plantation in the wake of completion of the National Greenery Plan (NGP). This plan calls for greening of additional 20,000 ha within Kuwait City and suburban areas over a 20-yr period. It also identifies large numbers of ornamental and landscape plants to be utilized in greening: 141,000 palms, 3.9 million afforestation trees, 270,000 ornamental trees, 3.0 million shrubs, 3.0 million m^2 of ground cover, 12.4 million m^2 of seeded lawn (KISR 1996a). Future research into new water resources and methods of increasing the productivity of the existing resources are crucial to fulfill the irrigation demands of the landscape projects. Furthermore, the selection for suitable plant palettes, the installation of appropriate irrigation systems, the ultimate landscape water consumption, and suitable ground maintenance practices, will contribute to the enhancement of ornamental landscaping in Kuwait. This paper reviews Kuwait's water resources and their use for greenery development in the country's urban and suburban areas, and will explain various methods of ensuring effective utilization of irrigation water.

Assessment of local water resources

Groundwater

Most of the rainfall in Kuwait either evaporates due to high temperatures or percolates through the sandy-textured soil. It is inadequate to recharge the underground water resources, which, in turn, are continuously declining. The underground water is the only available source that can be used without treatment even though the dissolved salt concentration is relatively high (3000–8000 mg/l) and, therefore, limits selections for the plant palette (ATEN & BERGSTROM 1965).

Over the past few decades, brackish water has been intensively used for agriculture and urban landscaping. Reserves have been reduced considerably, and the quality has deteriorated greatly. Contamination of coastal aquifers by seawater is either due to excess pumping above the safe yield capacity or due to local causes like over-pumping near the shoreline (even without excess pumping for the whole aquifer) or both. This problem is faced frequently if these aquifers are in use mainly for irrigation (ERGIL 2000).

The Ministry of Electricity and Water (MEW) estimated that there will be a total of 1.65×10^6 m^3/d of brackish water with salinities of 3000–5000 mg/l available for landscaping in the years 1996–2005, but it is questionable if this will continue to be achievable in years following to come (AL SAYED et al. 1981) (Table 1).

In 1992, the average daily gross distribution of brackish water was 0.15×10^6 m^3/d. In 1993, this average increased to 0.22×10^6 m^3/d, an increase of 41% in one year. The cost of brackish water accounts only for the capital cost involved with distribution and storage, and the power cost for pumping, estimated at US \$ 0.35/m^3 (ABUSADA 1992).

Desalinated seawater

Kuwait has one of the largest complex desalination units in the world. It operates as a dual-purpose station, producing both power and desalinated water using multistage flash (MSF) technology. The power plants are comprised of six stations distributed at different sites along the Arabian Gulf. They include: Shuwaikh in Kuwait City; Shuaiba and Az-Zour in the south; and Doha East, Doha West and Sabiya in the north. These plants have a total installed capacity of 7398.3 MW of electrical power and 1.15×10^6 m^3/d of desalinated water. Excluding gas turbines and one plant that were severely damaged during the war, the installed capacities are 6934 MW electrical power and 1.02×10^6 m^3/d of desalinated water. The gross maximum water consumption in Kuwait was 0.65×10^6 m^3/d in 1989. In 1992, the average daily water delivery was 0.53×10^6 m^3/d. In 1993, this average increased to 0.62×10^6 m^3/d, an increase of 16.7% in one year. The water is of excellent quality but is very costly. The delivered costs in 1993 were estimated to be more than US \$ 2.47/m^3 (LEITNER 1995).

Table 1. Feasible water quantities available for greenery (x 10^6 m^3/d).

Water resources	1990–1995	1996–2005
Underground water	0.44	0.50
Treated municipal wastewater	0.23	0.23
Industrial wastewater	–	–
Desalination brine	0.01	0.01
Subsurface water	–	–
Reverse-osmosis-desalinated seawater	0.91	0.91
Total	1.59	1.65

Treated municipal waste water

Recycling water, as a strategy for coping with shortages and/or the rising cost of freshwater, may be viable in arid and semiarid regions, and in highly populated metropolitan areas. The public's slow, but increasing, acceptance of using treated municipal sewage water to irrigate plants, including landscape plants, has made this option a reality. In the future, parks, golf courses, cemeteries, and other venues of non-food related, urban horticulture will be better able to compete for reclaimed sewage than for freshwater (HARIVANDI et al. 2000). There are three main plants that process municipal wastewater in Kuwait. There is also a sewage network, a network for effluent discharge, and a center for control and monitoring in a separate area. Treated water can be obtained from the treatment plants, the effluent discharge lines, or the control and monitoring center (HAMDAN et al. 1989). Municipal wastewater in Kuwait is subjected to tertiary treatment. Thus, it is the best source for urban landscaping use as the salinity is relatively low (1000 mg/l) and the quantity is expected to increase as more residential areas are connected to the sewage system due to population increases. However, regulations on wastewater reclamation and reuse are essential. They help protect public health, increase water availability, prevent coastal pollution, and enhance water resources and nature conservation policies (ANGELAKIS et al. 1999).

The major constraint to using treated wastewater for landscaping is the inadequacy of the connecting pipelines. Irrigation pipelines are under construction at present. In 1995, the amount of recycled water available for distribution was 0.3×10^6 m^3/d. The delivered cost in

Table 2. Preliminary estimate of irrigation water demands.

Location and salinity	Zone I (x 10^3 m^3/d)	Zone II (x 10^3 m^3/d)	Zone II (x 10^3 m^3/d)	Zone IV (x 10^3 m^3/d)
Gardens (3000–4500 mg/l salinity)	9.558	168.779	145.863	180.000
Open spaces, major roads and motorways (1500–4500 mg/l salinity)	28.564	172.972	149.869	171.186
Afforestation (4500–6000 mg/l salinity)	–	25.456	95.537	225.250
Total	38.122	367.207	391.269	576.436

1993 were estimated to be only US \$ 0.18/m^3, the least expensive option.

Water requirements

Three types of greenery are included in the landscape enhancement plan. The first includes gardens and play areas, and requires water salinities between 3000 and 4500 mg/l. The second category includes highways, major roads, and open spaces, and requires water salinities of 1500–4500 mg/l. Finally, the third category is designated for afforestation plants and requires water salinities of 4500–6000 mg/l.

The urban landscape in Kuwait is divided into four zones. Each of the four zones has specific characteristics dictated by function, population, size, and location (KISR 1992) (Table 2).

Zone I is the heart of the State, it includes ministries, district offices, shopping centers, banks, headquarters and commercial enterprises. The population intensity within zone I is relatively low in comparison with that in zones II and III. However, zone I is characterized by high traffic volume, especially during working hours. The water demands of this zone are the lowest due to its limited area compared with the other zones. The majority of greenery plans within the zone includes parks, gardens, and public facilities. The plans also include completion of greenery projects along major roads.

Zone II constitutes most of the residential areas with a large number of schools, mosques, major hospitals, and offices. The majority of Kuwait's population resides in this zone. The water requirements are much higher than those for zone I as the greenery in zone II requires afforestation, parks, gardens, and open space landscaping.

Zone III contains schools, mosques, government agencies, and industrial sites. The water demands are primarily for parks, motorways, open space beautification, and afforestation. The population intensity is much lower than that in zone II.

Zone IV is the zone with the lowest population intensity. This zone includes all of the desert areas, including oil fields, military posts, farms, interstat, highways, and open space. Water needs in this zone are for afforestation and windscreens for major roads to support sand control (Table 2).

In summary, the water demands of the four zones are as follows:

- Zone I: 38.122×10^3 m^3/d of water with an average salinity of 3200 mg/l.
- Zone II: 367.207×10^3 m^3/d of water with an average salinity of 3600 mg/l.
- Zone III: 391.269×10^3 m^3/d of water with an average salinity of 3900 mg/l.
- Zone IV: 576.436×10^3 m^3/d of water with an average salinity of 4000 mg/l.

Feasible water resources for greenery

The feasible water resources include groundwater, treated municipal water, desalinated brines, and desalinated water produced by reverse osmosis (RO). RO is a well-established membrane process used for desalination of saline water, where water from a pressurized saline solution is separated from the dissolved salts by means of a water-permeable membrane. The combination of resources reflects the feasible quantities of water available for greenery. This maximum can only be achieved by executing several projects, including expanded groundwater production, expanded installation of wastewater treatment plants, and construction and installation of the RO desalination plants.

There are certain limitations on the use of industrial wastewater and subsurface water. Accordingly, only groundwater, treated municipal wastewater, and RO-desalinated seawater were considered (KISR 1992).

Irrigation techniques

Kuwait makes use of two major methods of irrigation. The first technique is manual service irrigation, resulting in excess use of irrigation water and intense use of the labor force. The second technique is a relatively modern technology. It incorporates an underground system with automated valves and controllers in a drip and sprinkler system. The flaws in the drip and sprinkler irrigation system are manifested in several ways, with major problems in its design, installation, and maintenance. Listed below are some of the deficiencies experienced (KISR 1996b):

- Lack of appreciation of the wind factor.
- Lack of sufficient pump capacity necessary to create a short irrigation window.
- Inappropriate technology use, i.e., obsolete equipment including impact sprinklers and electromechanical controllers.
- Poor uniformity such that many flawed designs lose efficiency by inadequately defining layouts and containing poor or no sprinkler-nozzle specifications.
- Poor plant quality and scheduling in which plant material, soil, weather and irrigation equipment rarely enter into scheduling calculations.
- Over-irrigation, causing loss of water, leaching of fertilizer salts, and root rot.
- Under-irrigation, resulting in stress to plant material.
- Daytime irrigation. In hot and windy weather, more than 20 or 30% of the water is either blown off the site or evaporated as windspeeds usually exceed those of nighttime, and summer temperatures are extremely high in daytime.

Plant palette development

After the liberation of Kuwait in 1991, it was essential that a study was conducted to evaluate those plants that survived the forced neglect, especially, the deficiency of irrigation water. As part of the effort to define a plant palette, that is, a list of recommended species best suited to local conditions, for the NGP, a survey was conducted of the post-liberation status of ornamental plant materials installed before the war. The objective was to identify superior types of plants, based on those that had survived the 12–18 months of the Iraqi invasion and the forced neglect (lack of maintenance and irrigation) associated with it (KISR 1996b). Ornamental plants of different species and varieties were evaluated for growth and survival characteristics at diverse locations in Kuwait (KISR 1994a). Based on field surveys, two distinct areas were identified: an inland zone and a coastal zone. The relative survival potential of the various species was evaluated on a gross observational basis. Qualitative analysis of each species was based on observations of the site conditions and visual comparison of the populations of plant material at each site. The plant material was divided into three groups, based on the estimated number of plants that survived the forced neglect (Table 3). The genotypes that exhibited superior survival abilities and growth during long periods of forced neglect were identified and catalogued for use in future tissue-culture propagation studies.

Approximately 70 species were included in the initial database. The essential condition for selection is that the species thrive in both large and small landscaping projects without special measures being necessary to enhance survival. Additional plant species to the list, there-

Table 3. Relative survival of representative landscaping species in two environmental areas.

	Definition	Representative Species	
		Coastal/North	Inland/South
Group 1	All individuals survived	*Prosopis juliflora* *Washingtonia robusta*	*Prosopis juliflora* *Bougainvillea* sp.
Group 2	Differential success in the populations with some individuals surviving and others showing severe stress	*Nerium oleander* *Hibiscus rosa-sinesis*	*Clerodendron inerme* *Washingtonia robusta* *Eucalyptus microtheca*
Group 3	Most or all individual plants succumbed	*Lantana camara* All turf	*Nerium oleander* All turf

Table 4. Recommended plant list material. Informations derived from KISR (1994b). Salinity tolerance: High > 3200 mg/l; Medium > 640 and < 3200 mg/l; Low < 640mg/l. Irrigation requirement: High Kcrop ≥ 0.5; Medium Kcrop > 0.3 and < 0.5; Low Kcrop ≤ 0.3.

Genus/Species	Characteristics		
	Salinity tolerance	Drought tolerance	Irrigation requirement
Acacia arabica (L.) DEL.	High	High	Low
Acacia ongerup MASLIN	Medium	Medium	Medium
Acacia salicina LINDL.	High	Medium	Medium
Acacia stenophylla A. CUNN. ex BENTH.	High	Medium	Low
Agave americana L.	Medium	High	Low
Agave americana v. Marginata Aurea L.	High	High	Low
Albizzia lebbek (L.)	Medium	Medium	Medium
Alternanthera ficoidea (L.) R. BR. ex R. & S.	Low	Low	High
Atriplex canescens (PURSH) NUTT.	High	High	Low
Atriplex halimus L.	High	High	Low
Atriplex semibaccata R. BR.	High	Medium	Medium
Bougainvillea glabra CHOISY	Medium	Low	Medium
Caesalpinnia gilliesi (WALLICH ex HOOKER) BARTH.	High	Medium	Medium
Caesalipinnia pulcherrima (L.)	High	Medium	Medium
Callistemon viminalis (SOL ex GAERTN.) G. DON ex LOUD.	High	Medium	Medium
Canna generalis L. H. BAILEY	Low	Low	High

Table 4. (Continued).

Genus/Species	Characteristics		
	Salinity tolerance	Drought tolerance	Irrigation requirement
Carissa grandiflora (Ecklon) A. Dc.	Medium	Medium	Medium
Carissa grandiflora var. *prostata* L.	Medium	Medium	Medium
Carpobrotus edulis (L.) N.E. Br.	High	High	Low
Casuarina equisetifolia L.	High	Medium	Low
Catharanthus roseus (L.) G. Don	Low	Medium	Medium
Cericidium floridum (S. Wats.) Sarg.	High	High	Low
Clerodendron inerme (L.) Gaertn.	High	Medium	Medium
Conocarpus lancifolius L.	High	Medium	Medium
Cordia myxa L.	Medium	Medium	Low
Cortaderia selloana (J.A. & J.H. Schultes) Aschers. & Graebn.	Medium	Medium	Medium
Cynodon dactylon (L.) Pers.	High	High	Medium
Dodonea viscosa Jacq.	High	Medium	Medium
Eucalyptus caladulensis Dehnh.	High	Medium	Medium
Eucalyptus microtheca F. Muell.	High	High	Low
Ficus bengalensis L.	Medium	Low	Medium
Ficus benjamina L.	Medium	Low	Medium
Ficus infectoria Willd.	Medium	Low	Medium
Ficus religiosa L.	Medium	Medium	Medium
Ficus retusa L. *fil.*	Low	Medium	Medium
Ipomea palmata (L.) Lam.	Low	Low	High
Ipomea pes-caprea Roth.	High	High	Low
Jasminum sambac (L.) Aiton	Low	Low	Medium
Lantana camara L.	Medium	Medium	Medium
Lantana motevidensis (Sprengel) Briq.	Low	Low	Medium
Lawsonia inermis L.	Medium	Medium	Medium
Leucophyllum frutescens (Berl.) I.M. Johnston	Low	High	Low
Malvaviscus arboreus Cav.	Low	Low	Medium
Melaleuca quinquenervia (Cav.) Blake	Medium	Medium	Medium
Melia azaderach L.	High	Medium	Medium
Nerium oleander L.	High	Low	Low
Olea europea L.	Medium	High	Low
Parkinsonia aculeata L.	Medium	Medium	Low
Paspalum vaginatum Sw.	High	Medium	Medium
Pennisetum setaceum (Forsk.) Chiov.	High	High	Low
Phoenix dactylifera L.	High	Medium	Medium
Phyla nodiflora (L.) Greene	Medium	Medium	Low
Pithecellobium dulce (Roxb.)	Medium	Medium	Medium
Plumbago capensis Thunb.	Low	Low	Medium
Prosopis juliflora (Sw.) Dc.	High	High	Low
Rhoeo discolor Sw.	Low	Low	High
Ruellia californica (Rose) Johnston	Medium	Medium	Medium
Tamarix aphylla (L.) Karst.	High	High	Low
Tecoma stans (L.) A. Juss. ex Kunth	Medium	Medium	Medium
Terminalia catappa L.	Medium	Medium	Medium
Thevetia peruviana (Pers.) K. Schumann	High	Medium	Medium
Vitex agnus-castus L.	High	High	Low
Washingtonia filifera (L. Linden) H. Wendl.	High	High	Medium
Washingtonia robusta H. Wendl.	High	Medium	Medium
Wedelia trilobata (L.) H.E. Robins. & Cuatrec.	Medium	Low	High
Yucca elephantipes Baker	Medium	Medium	Low
Zizyphus jujuba Mill.	High	Medium	Low
Zizyphus spina-christi (L.) Desf.	High	Medium	Low

fore, imply a general ability or adaptation to the rigors of Kuwait's climate, in particular, its high temperatures, low humidity, and fierce winds (KISR 1994b). The use of the selected plants will minimize both water and maintenance requirements (Table 4).

Recommendations

- Develop an underground waterstorage program. Seawater desalination plants are capital cost intensive. Accordingly, these plants are most cost-effective when they operate at peak production for a peak number of hours per year. Unfortunately, this maximum does not correspond with normal demand. If underground storage could be developed, it is estimated that the desalination plants could deliver water to storage during off peak hours at costs of less than US $ 1.09/m^3.
- Use recycled water in the existing brackish water distribution system. The process subjects tertiary treated recycled water to Reverse Osmosis treatment so that it can be distributed in brackish lines for irrigation purposes.
- Implement a Multi-Stage Flash/Reverse Osmosis hybrid system. Kuwait has made a start in testing this technique. The process combines a seawater RO plant with an existing or new MSF plant. With this process, numerous advantages are realized such as lower per-unit costs of product water and use of the excess power generated at the six existing dual-purpose MSF power plants, further reducing the per-unit cost of product water.
- Improve irrigation system designs and specifications. The design quality affects a system far into the future. Good maintenance can rarely alleviate design problems. Moreover, accurate irrigation scheduling definitely improves plant quality. Only by intensive training, especially on the maintenance level, can landscape irrigation be successful over long periods.
- Train manpower in water management by promoting it through advertisements, technical schools, workshops and training courses.
- Select and introduce ornamental plants that can tolerate the existing water quality. Introduced plants must originate from arid countries with environments similar to Kuwait's, to avoid heat-drought-and salinity-intolerance.
- Inject the recommended fertilizer to save resources (time and money) and effort.
- Use different mulches, organic and industrial, to decrease evaporation from the soil.
- Study minor local water resources, and analyze their cost-effectiveness.

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