Developing sea-watered landscapes: a potential way to reduce stress on freshwater resources

Sea-water landscaping can be defined as growing salt-tolerant species for the purpose of landscape. Using sea water could help in mitigating global sea-level rise due to climate change and in removing carbon from the atmosphere and returning it to the soil[1]. In addition, sea-water landscaping would reduce the cost of landscape irrigation, compared to using potable water. Countries with arid land suffer from lack of natural freshwater resources. Over-pumping of groundwater in these countries has resulted in the degradation of water quality, especially increase in water salinity. This is particularly evident in the coastal zones, where sea-water intrusion caused by over-abstraction of coastal aquifers has resulted in the groundwater salinity[2]. In the Arab Gulf countries, for example, the groundwater aquifers are mostly brackish[3]. A good example for deterioration of coastal groundwater quality through sea-water intrusion in Qatar is the expansion of Umm Said Sabkha[4]. In Saudi Arabia, about 80–85% of water supply come from groundwater and excessive use of groundwater has created major problems such as depletion of aquifers and deterioration of groundwater quality[5].

Urban expansion and need for green landscape in arid land cities have increased the demand for irrigation water[6,7]. This puts a great stress on the limited water resources in these countries[8]. Consequently, immediate action is imperative to prevent or minimize the impacts of the depletion of groundwater resources[5]. One way for the sustainable use of the deteriorating limited water resources in the Arab Gulf countries is through the use of native salt-tolerant plants (halophytes) in landscaping coastal zones of urban areas. Halophytes are plants that grow naturally in saline environments and benefit from having substantial amounts of salt in the growth media[8]. These plants could be irrigated directly with sea water. Several halophytes have evolved naturally under the harsh environmental conditions of the arid-land countries. These plants are hardy, as they have adapted to the local harsh conditions[9]. Halophytes could grow in a wide variety of saline habitats, such as coastal regions, salt marshes and mudflats, inland deserts, salt flats and steppes. In order to survive under saline habitats, halophytes have evolved a range of adaptations to tolerate salinity effects. These include the adjustment of their internal water relations through ion compartmentation in cell vacuoles, the accumulation of compatible organic solutes, succulence, and salt-secreting glands and bladders[10,11]. Therefore, halophytes could be perfectly suitable for greening the coastal zone and be irrigated directly using sea water[12,13].

Natural landscaping, which is the use of native plants in landscaping, is adapted to the climate, geography and hydrology and should require no pesticides, fertilizers and watering to maintain; especially native plants which have adapted and evolved to local conditions over thousands of years[14,15]. As sea-water landscaping does not need irrigation with freshwater, natural landscaping would help in the sustainable use of water resources. Once established, halophytes do not need pesticides, fertilizers or watering[16]. In addition, native wild flowers and grasses blooming at different times of the year can beautify the landscapes throughout the growing season. The native plants enhance our connection with nature and provide a beautiful place to relax[17,18]. Native plants are also resistant to most kinds of local insects[19]. Importantly, the use of native plants usually reduces capital inputs[10].

In the Arabian Gulf region, hundreds of terrestrial halophytes grow and complete their life cycles exclusively on sea water or in hyper-saline salt marshes. For example, Böer and Al Hajiri[20] have identified a total of 49 plant species as halophytes in Qatar. In addition, Böer and Gliddon[21] recorded 22 halophytes (9 of them are tolerant to inundation by sea water) in a survey conducted in the coastal zone of Abu Dhabi Emirate, UAE. Many of the halophytes of the Arabian Peninsula are growing even in hyper-saline salt marshes, where salinity becomes several fold greater than the sea-water salinity[22]. It has been reported that many halophytes in several parts of the world could be used as ornamental plants in urban landscaping because of their beautiful flowers and several leaf forms and growth patterns. For example, 172 halophytic plants (34 species from Chenopodiaceae), which naturally grow in the Mediterranean area, were categorized as potential ornamental plants[23]. Khan and Qaiser[24] have identified 34 halophytes of Pakistan as potential ornamental plants. In their review of the potential halophytes that could be used in native landscape, Khan *et al.*[25] reported several other examples in different places around the world. For example, *Paspalum vaginatum* and *Sporobolus virginicus* were considered as suitable candidate species for lawns and golf courses. Other examples of potential halophytes in embellishment and landscaping include *Aster tripolium*, *Limoniastrum monopetalum*, *Batis maritima*, *Tamarix nilotica*, *Tamarix amnicola*, *Cistanche fistulosum* and *Noronhia emarginata*[25].

The use of salty waters in irrigation requires the control of soil salinity by means of leaching and drainage of excess water and salts. To avoid the process of secondary salinization of the soil due to irrigation with sea water, the added salts have to be washed out at least from the upper root zone, which is the most active in the absorption of water and nutrients. The salts dissolved in the percolation water in part can be accumulated in the deeper subsoil, and in part discharged by natural drainage[26]. Using surface irrigation will lead to water logging of the soil. However, installing subsurface drainage systems in waterlogged lands would control the water table level, permit leaching and disposal of the salts and avoid the capillary rise of saline groundwater from the water table[27]. Subsurface drainage system is very simple and cost-effective. It depends on putting pipes with pores around 1–2 m under the soil surface. In sea-water landscaping, it takes the excess water and discharges it back to the sea.

Soil composition and drainage characteristics can also influence the severity of plant damage by saline irrigation water. For example, clay soils and soils with a high percentage of organic matter exhibit faster and greater build-up in concentration of sodium than sandy soils[28]. Generally, the suitable coastal lands that could be grown with halophytes should be less

than 100 m above sea level, have flat topography and a substrate of soil rather than rock or gravel[29]. Duncan *et al.*[30] reported that sea water irrigation on turf grass is feasible in coarse, sandy soil profiles. Most of the lands fringing the coastal zones in the Arab Gulf region could be landscaped with potential halophytic plants that have the features of ornamental plants. However, it is important to adopt sea-water surface (flooding) irrigation strategies that keep salts moving with regular leaching events and keep the soil profile uniformly moist to minimize concentrated salts from rising into the root zone. In addition, proper subsurface drainage designs should be installed to minimize waterlogging and salt accumulation in the upper layer of the soils.

Both sea-water surface irrigation and subsurface drainage that could be used for sea-water landscaping are simple and cost-effective, compared to other irrigation and drainage techniques[31]. Consequently, using sea-water landscaping in arid regions could be a cheaper option for sustainability of the limited freshwater in these regions. In addition, the resistance of the native halophytes to most of the pests and other pathogens will reduce the use of the dangerous chemicals that affect both human and environment health. Furthermore, using native halophytes in landscaping would reduce the cost of maintenances and minimize the use of machines that emit gaseous pollutants, which cause global climate change. To conclude, it is important that countries with arid climate should plan for using their native halophytes as a partial approach for sustainability of their urban areas.

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