

Sustainability Assessment of Productive Palm Tree Plantation in Urban Landscapes: A Dubai Case Study

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Abstract

Dubai has imported elegant plants and trees to maintain a green and attractive outdoor atmosphere. However, a substantial proportion of the imported plants are not suitable for the arid climate of United Arab Emirates (UAE) and require intensive irrigation. This poses the potential of replacing all the greenery with date palm trees that are compatible with the region's climate and require more moderate irrigation. The availability and value of reclaimed irrigation water, the local soil quality, the cost analysis of date palm tree plantation, the productivity of palm trees, the appropriateness of types of palm trees, the nutritional value of dates, the required gardening workforce, maintenance schedule, and its positioning in relation to seasonal business activities are also explored. Dubai has the capacity to accommodate sixteen times the number palm trees it currently has.

Keywords: date palm trees, sustainable tourism, seasonal tourism, water scarcity, reclaimed irrigation water, date's nutritional values

1. Introduction

The International Center for Biosaline Agriculture (ICBA) and other institutions have recommended a list of native plants that have been studied and found to be compatible with desertic conditions and high groundwater salinity, to save irrigation water where fresh-water scarcity is the major landscaping challenge. Many of the native species such as Phoenix Dactylifera (the date palm), Delonix Regia (the flame tree), Plumeria (Frangipani), Bougainvillea, Moringa Peregrinaa, Gladiolus Italicus, Prosopis Cineraria (Ghaf), and Ziziphus Spina-Christi (Sidr) are found to be compatible. (Joslin, 2019) These have been studied in landscaping in different countries and have shown good results, including the capability to withstand heat and to thrive on only 60 to 80 liters of water a day, one quarter to one fifth of the water demands of more exotic trees. Despite the adaptability of these plants, unfortunately they are not dominant landscaping plants in arid regions, including UAE, as people are mostly unaware of their variety and beauty (Todorova, 2021).

Palm trees are not listed among the most water-efficient trees. However, as in many countries in arid regions, palm trees are considered as very popular trees in UAE due to their productivity and cultural value. Palm trees in UAE are mainly over-watered up to seven times their needs, which leaches nutrients away from roots and weakens them, making them vulnerable to pests and diseases. While palm trees are indigenous and are very popular plants, they are not the most water-efficient trees and may require up to 300 liters per day. Educating farmers about correct irrigation practices through on-field demonstration, especially those workers who are only familiar with flood irrigation systems, and employing moisture sensors are known to be effective methods for attaining proper irrigation practices country-wide (Abdul Kader, 2018). Hence, sustainable urban productive landscaping that includes plantation palm trees should be accompanied by the training of expat workers to avoid this widely observed over-watering.

Like other major cities of UAE, the metropolis of Dubai has expanded its wastewater treatment plants and reclaimed water distribution system to accommodate almost all green spaces in the city. Maintaining these gardens in an attractive way has always been seen as a vital feature of the city for attracting tourists and offering its residents a sense of well-being. Like some cities with a reclaimed irrigation water distribution infrastructure, the Dubai municipality and other large cities in UAE may not necessarily deal with a tight irrigation water budget and, therefore, may not have a sense of obligation to sacrifice the attractiveness of some ornamental herbs, shrubs and

trees to meet tight irrigation water budgets. (Birge, 2019) Hence, the most water-efficient native trees for arid regions may not necessarily be considered to be the most suitable and visually attractive plants for amenities in such cities. For the city of Dubai, a world-known business and tourism hub, such a focus on the plantation of the most draught-tolerant and water-efficient trees is perhaps not the most appealing strategy. Since these cities can afford higher water budgets for their landscapes, the role of landscapes could hypothetically be elevated to contributing to the nation's food supply chain and bioenergy generation. This research attempts to study the opportunities, challenges, and feasibility of turning urban landscapes into sustainable productive date palm gardens, a development that could potentially serve both the economy and attractiveness of the cities.

2. Objective

The objective of this case study is to assess the feasibility of the redesign of landscapes to serve the sustainability of the nation by food production. This research especially focuses on cities in arid regions possessing reclaimed water distribution infrastructures. The metropolis of Dubai is located in an arid region with poor sandy soil and has been selected in order to evaluate the feasibility of the replacement of various non-productive trees with adaptable palm trees (Shahid, 2008). The research attempts to assess the following aspects of such rearrangement:

- The quantitative and qualitative characteristics of plantation in Dubai's landscapes
- Existing irrigation water quality and quantity and existing irrigation water budgets
- Natural and current soil quality enhancement techniques
- The significance of landscaping in the Dubai economy, including the tourism industry
- The compatibility and productivity of palm trees
- Challenges and opportunities associated with reclaimed irrigation water and nutrient supply for palm trees.
- A cost analysis of palm trees and estimate of date productivity
- The logistics, workforce and facilities required for the redesign of landscapes
- Potential job opportunities and humanitarian activities versus the Dubai vision
- A large-scale farming and harvesting schedule and its integration with Dubai's tourism goals
- An overall cost-benefit analysis of dominant palm tree farming in landscapes.

This multidisciplinary assessment might assist designers and municipalities to determine whether productive tree plantation in public landscapes is a feasible approach to elevate the city's sustainability. The identified characteristics of the local soil, reclaimed water, trees and environment, and their technical and financial impacts on the feasibility of productive landscaping can be considered in further studies in such regions.

3. Literature Review

To assess the feasibility of the redesign of landscapes in the metropolis of Dubai, a thorough review of the UAE climate, the current properties of landscapes including soil quality, current plantation arrangements and the quality and quantity of available reclaimed water irrigation should be conducted. The type of palm trees, their ideal growth conditions, the nutritional value of dates, the required logistics and workforce for gardening and harvesting will be briefly reviewed. Such review will be the backbone of further analysis and discussion regarding the feasibility of redesign of green landscapes to be palm tree dominant.

A section of the review is devoted to Dubai's current vision and goals in tourism and the service sector. The potential of such a city-wide plan to hire seasonal workers and produce local food for poor societies in need will be discussed. The feasibility of planning and holding a humanitarian food festival during the low tourism season of summer will also be discussed. This review is required in order to understand the potential influence of city-wide palm tree gardening and harvesting on these sectors and to ascertain whether the proposed redesign is aligned with the Emirate's vision.

3.1 UAE Climate

UAE's climate is hyper-arid with rare rainfall and less than 100 mm of precipitation annually (Böer, 1997). The north-eastern part of the country, including Dubai, has lower temperatures with a higher chance of rainfall than the southern and western parts of the country. Average daily hours of sunshine in the city is about 9.7 hours. The city's average day temperature is above 25°C for nine months of the year. These high average values, along with high solar radiation over the region, result in high total annual potential evaporation rates from 2.5m in the coastal areas to 4.5m inland, which justifies the perceived high demand for irrigation (Scribd, 2019).

3.2 UAE Freshwater Resource

UAE has an estimated groundwater resource of 757. km³, but only 7.5% of this is freshwater. The major cities of the UAE, including Dubai, are located in the coastal areas, where the water table is mostly accessible at zero to five meters below ground level (Alam, 2017). However, the groundwater salinity is greater than 50,000mg/l. This is known as brine water and is not suitable for most trees. The freshwater shortage in Dubai was mainly caused by excessive pumping of groundwater in the past when Dubai's population and size were small fractions of the current ones. Such shortage of water supply in landscaping was partially addressed by using reclaimed water. As a sustainable practice, the plantation of drought-tolerant native plants, which are adaptable to the environment and require less water, has been implemented in some developments. Apart from the climatic conditions and the natural water table level, the age and type of plants, and the efficiency of implemented irrigation systems, affect the optimum irrigation requirements for plants in different areas of the city.

3.3 Dubai Green Spaces and Vision

Dubai as the most populated city of UAE receives an annual precipitation of 87mm, which is less than the average precipitation in the country (Böer, 1997). As part of the Dubai Urban Master Plan, 60% of the city will be turned into nature reserves to make it the best city to live in by 2040 (Ahmed & Tawfiq, 2021). The government targets 25m² of green area per capita to enhance happiness and quality of life (Arabian Business, 2014). By end of 2018, the total area of green spaces in Dubai was 12,000 hectares, only 3,701 hectares of which are public land, which means that the share for residents is about 10.85m² of public green space per capita (Dubai Statistics Center, 2021). The green areas in Dubai serve as ornamental backdrop to the roads and contribute to the city's attractiveness, which results in more tourists to the city. As in all green spaces, trees contribute to the reduction of the heat island effect and lower the total carbon emissions of the city. In addition, the shade from the trees has been considered as effective protection from direct sunlight, which encourages people to walk and enjoy the environment [9]. The green areas in Dubai are cultivated by 17,600,000 flowers and plants, 21,800,000 ground covers and 7,900,000m² of grass. The rest of the green areas are covered by trees and shrubs (Statista, 2022). By 2017, 98% fruit trees on private and public land in Dubai were palm trees (Gulf News, 2018). According to the official reports, the total number of palm trees was 46,100 in 2019 (The Emirates Center for Strategic Studies and Research, 2003).

3.4 History of the Palm Tree

Date seeds discovered on Delma Island of Abu Dhabi in 1998 evidence that the harvesting and consumption of dates go back about 4000 years. Date palms were very important in the ancient Arab world for consuming and for trading. Nowadays, the date is known as traditional nutrition of middle eastern, including UAE, nationals. With the support of his Highness, the President Sheikh Zayed Bin Sultan Al Nahyan, the cultivation of palm trees became extensively popular through subsidizing farmers (The Emirates Center for Strategic Studies and Research, 2003). Date palm trees were being cultivated in countries ranging from the Indus Valley (now Pakistan) to Mesopotamia (now Iraq), the Nile Valley, Eastern Mediterranean and the Horn of Africa (The Emirates Center for Strategic Studies and Research, 2003). Nowadays, date palms grow from Morocco in the west across the lower-altitude expanses of the Arab countries up to the foothills of the Himalayas (El-Juhany, 2010). In UAE, palm trees are considered to be adaptable to the local harsh environment and require a reasonable amount of irrigation water.

3.5 Irrigation of Palm Trees

The most practical water-conserving irrigation method for the palm trees is drip or micro irrigation, which is 95% efficient rather than the old method of flood irrigation, which is 60% efficient and requires excessive amounts of water (El-Juhany, 2010). Drip irrigation or micro irrigation has other benefits such as low running costs and not requiring intensive labor. Using this technique allows proper monitoring of the amount of irrigation water for each tree and facilitates scheduling irrigation according to wind, temperature and evaporation rates (Liebenberg & Ziad). In Dubai, a date palm typically uses 150 liters of water per day during the middle of summer and about 50 liters per day during the middle of winter (Al-Muaini et al., 2019). For the existing 46,100 palm trees, an average of 4,610,000 liters of water are required per day. An estimate of collected sewage in the city and a comparison between available reclaimed water and water demand will be conducted to determine whether reclaimed water is sufficient for such extensive city-wide plantation.

With the expansion of Jebel Ali wastewater treatment plant and Al Warsan treatment plant, Dubai with a population of 3,400,000, generates a total of 1,000,000m³ per day of treated sewage (Gulf News, 2019). This flow of reclaimed sewage is sufficient for 10,000,000 trees in Dubai. The records suggest that, despite the common perception, the amount of reclaimed water should not be a limiting factor for promoting the cultivation of productive plants and the expansion of green spaces in the city. The soil in UAE is more sandy and granular. It is extremely calcareous and undeveloped, making it poor in organic matter. Dubai has highly saline soil, mostly in

the coastal areas, which becomes less saline or sodic in the inner side of the desert (Rao et al.). With the existing soil properties in UAE, Dubai's current plantation arrangement, with the principle aim of maintaining beauty, serves other purposes such as decreasing soil erosion and restoring a natural plant community (Wisconsin Department of Natural Resources). Freshwater is a scarce resource in UAE, with a quantity of 34m³ per resident per year, while the country is the third highest consumer of fresh water per capita in the world (Al Amimi et al.). About 270,000,000m³ of treated water is delivered to the public gardens annually, using the public irrigation lines (Dubai Municipality, 2021). Utilizing reclaimed water from wastewater treatment plants for irrigation purposes has partially reduced the demand for freshwater. However, the utilization of reclaimed water is mainly limited to public green spaces and is not for agricultural purposes in UAE farms.

3.6 Major Required Nutrients and their Supply

A palm tree requires many nutrients to grow and produce dates successfully.

Table 1 shows the quantities of three major nutrients required by palm trees. The table also presents the concentrations of these nutrients in Dubai's reclaimed water and the Dubai municipality manure that is used as fertilizer in all landscapes managed by the municipality. The contribution of reclaimed water to provide these major nutrients is estimated in the following table according to an irrigation rate of 100 liters per day per tree. The estimated amount of required locally produced fertilizer, Dubai municipality manure, is also presented in the table. The result reveals that the reasonable mass of manure can supply the remaining required nitrogen and phosphorous. However, it is not a suitable source of potassium for palm trees and a different supply of potassium is, therefore, required.

Table 1. Assessment of palm tree nutrient demand

Major Nutrients	Nitrogen	Phosphorous	Potassium	Comments/Reference
Annual demand of palm tree (gram)	1480	140	1250	Africa (The Emirates Center for Strategic Studies and Research, 2003)
Concentrations in reclaimed water (g/L)	0.002	0.0025	0.02	As per reports of Dubai effluent quality
Daily supply by 100 l/day average irrigation rate (g)	0.2	0.25	2	
Annual supply of nutrients by irrigation	72	90	730	
Percentage nutrient demand supplied by reclaimed water	4.9%	64.3%	58.4%	
Dubai municipality manure nutrient content (g/kg)	60 (40 to 80)	2.25 (1.5 to 3)	0.2 (0.15-0.25)	As per labels of the manure in market
Mass of manure required annually to supply remaining plant demand (kg)	23.5	22.2	2600 (Unrealistic, not applicable)	

3.7 Type of Palm Trees

In UAE, normally three types of palm trees are cultivated. Popular types of palm trees cultivated in the country are the Canary Island Date Palm, the Pygmy Date Palm, and the Senegal Date Palm. The Canary Island Date Palm is one of the tallest date palm trees and is one of the most popular, particularly in landscaping. Pygmy Date Palms are used more for commercial purposes as they are beautiful. They are shorter in height and have spiky leaves, which make them unsuitable for public areas. Senegal Date Palms need constant trimming to preserve the beauty of landscaping as their stem is covered in hair and fiber (Baloch, 2019).

3.8 Required Space for Palm Trees

The plantation of date palm trees on existing public green areas and its benefits should be studied thoroughly. The maximum number of palm trees in a certain area depends on the appropriate distance between the trees. The distance between palm trees is contingent on several factors including soil type, climate, and suitable access for laborers for maintenance. In Saudi Arabia, which has a very similar climate, 200 palm trees can be cultivated in one hectare. This means that every palm tree occupies an area of 50 m² (Al-Amoud, 2012). It is noteworthy that for strip planting, including street tree planting, respecting the distance between the plants along the strip is the matter of concern. This implies that, for instance, a garden strip of one-meter-wide and 700 meters long in a boulevard can accommodate about 100 palm trees, so the area for each tree is seven m² of the strip garden, and – in this case - seven meters' distance from the next tree (Aridah, 2016). To examine the applicability of recommended distances in the UAE climate and soil, a group of local existing gardens are studied. According to Table 5, The actual required area for existing gardens is 49 m².

3.9 The Nutritional Value of Dates

During olden times, dates were considered to be a major source of nutrition in Arab countries. They are considered to be very rich in vitamins, amino acids, and fibers. They benefit the body by lowering blood pressure, reducing the risk of stroke and heart diseases. They benefit pregnant women by strengthening uterine muscles, thereby facilitating delivery. Date fruits are low in calories – approximately 20 kcal per date (Gulf News, 2018). Table 2 shows the nutritional information for one average-sized date and how they can benefit the body. As can be seen in Table 2, dates can be a good source of sugar for the body and can partially provide the required carbohydrates and fibers (Al-shahib, 2009). Six dates are sufficient to provide the body's required daily sugar. However, as expected, the consumption of a reasonable number of dates cannot supply all the body's nutrition needs.

Table 2. Nutritional values of dates

Nutrition	In an average date	Average needed per day	Required number of dates per day
Calories (Kcal)	20	2000	100
Total fat (g)	0.03	78	2600
Total carbohydrates (g)	5.33	325	61
Dietary fiber (g)	0.6	35	59
Sugar (g)	4.5	25	6
Protein (g)	0.17	125	736
Vitamin B (mg)	0.012	1.3	108.33
Iron (mg)	0.07	18.9	270
Magnesium (mg)	3	420	140
Potassium (mg)	47	4700	100

3.10 Quantity and Revenue of Date Production

By 2017, UAE with 533,700 metric tons of dates produced was ranked as the world's sixth highest producer of dates (Pariona, 2017). A mature date palm can produce 70kg of dates annually (Peyron, 2000). So, from the existing 46,100 palm trees, up to 3,227 metric tons of dates could be produced. This could reach up to 0.6% of the total production of dates in UAE. A productive plantation can generate a minimum of 48,400,000 United Arab Emirates Dirham (AED) of revenue from Dabbas or Lulu dates with the price of 15 AED per kg, and a maximum of 387,200,000 AED from Majdoor, Ambar and Ajwa dates with the price of 120 AED per kg (Ahmad & Abdul Kader, 2018). As reported in the literature, the planting of an average date palm costs around 1,125 AED (Green Souq). This expense is enormous and most likely beyond the budget of the municipality, if the replacement of non-productive plants were to be accomplished in a short period of time. However, the productivity of a tree shows that devoting more public landscape areas to palm trees would, in the long term, be financially beneficial for the municipality. Additional assessment, including the cost of replacing existing trees, is provided in a discussion section to determine the extent of the plantation's financial benefits, which is only one consideration of productive tree plantation assessment.

3.11 Date Palm Trees and Sustainability

Date palm trees can be a great carbon absorber. A typical tree absorbs 22 kg of carbon dioxide (CO₂), whereas a date palm tree would absorb 200 kg of CO₂ per year (Sharif et al., 2010). CO₂ emissions in UAE are currently 15.7 tons

per capita, which means that the palm tree cultivation plan could compensate for 151,061 tons per year (Sharif et al., 2010). A typical passenger car releases 4.6 metric tons of CO₂ per year, so the total number of palm trees could compensate for CO₂ emitted by 35,500 typical passenger cars per year (Environmental Protection Agency). Basic calculation reveals that to absorb the emissions of one person, 79 palm trees are required, which is not feasible, considering the required resources. Cultivation including palm tree plantation, therefore, can only be considered as part of the plan to neutralize CO₂ emissions.

The temperature under the shade of a palm tree is up to 10°C lower than in the non-shaded area. The date palm trees, like other trees, contribute to reducing temperature and the heat island effect, which can furthermore reduce the energy demand for indoor air conditioning in hot seasons of the region (Ibrahim, 2010).

Furthermore, the waste from palm trees can be converted to biofuel through a process called fast pyrolysis. The raw materials in this method are exposed to 500°C to be converted to gas. Later, the gas is condensed to form liquid oil with enthalpy in a range of typical fossil fuels. According to experimental records, the overall conversion efficiency of the waste is 87%, categorized as “high efficiency” in this technology. The assessment reveals that palm trees generate up to 35kg waste to be converted to a significant amount of readily renewable fuel. In addition, the process also generates a by-product called ‘char’, which is known as a highly effective fertilizer (Sanderson, 2021).

3.12 Labor Required for Date Palm Care

Productive plants, including date palm trees, need additional levels of care to ensure that the expected fruits are produced. For palm trees, steps such as pruning, removal of old fronds, bunches, spines and rachis base, pollination, bagging, fruit thinning, and fruit covering should be conducted at a certain time of year, which makes the production of these trees labor intensive. The required workforce for productive plantation is reduced if date production is fully mechanized. As reported in the literature, an average of seven working days per ton is required (Sonneveld, 2018). Date cultivation is labor intensive and on average needs 170 days labor per year per hectare (Sonneveld, 2018). This is excluding the time required for land preparation, establishment and plantation at the beginning, which is not required every year, and the later stages of date transportation and marketing. Assuming that a palm tree requires an average of 49m² of land, then a hectare of land can accommodate approximately 205 palm trees. Although palm tree care is a full-year occupation, as seen in 错误!未找到引用源。错误!未找到引用源。 not all the harvesting stages are performed throughout the year (Al Mashhadani, 2014). The assumption that the majority of laborers would work for six months per year on average is realistic. Assuming that each laborer works for six months for six days a week and 10 hours per day, then an individual normally works for approximately 1,560 hours per year. Therefore, for Dubai’s current 46,100 palm trees, a total of 247 workers would be required to maintain them.

3.13 Calendar of Date Palm Care and Dubai's Seasonal Tasks

Table 3. The annual calendar of date palm care in UAE year (Al Mashhadani, 2014)

Services	1		2		3		4		5		6		7		8		9		10		11		12	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Irrigation Control																								
Irrigation System Maintenance																								
Palm, Basins & Site Cleanliness																								
Digging, Weeding																								
Organic Fertilization																								
Chemical Fertilization																								
Pruning																								
Old Fronds & Bunches Removal																								
Rachis Base Removal																								
Spine's Removal																								
Offshoots removal and planting																								
Treat wounded areas																								
Collect Mature Male Spathes																								
Pollination & Bagging																								
Fruit thinning																								
Strand's thinning																								
Bunch's Thinning																								
Fruit Bunching																								
Fruit Covering																								
DP Sanitary Care																								
Growth Stages of Palm Fruit																								
Hababok																								
Kimri																								
Bessir (Khalal)																								
Rutab																								
Tamor																								
Fruit Harvesting																								
Pest & Disease Control	Controllable by adoption of this calendar of DP care and by conducting the safe applicable measures of Integrated Pest Control (IPC)																							

错误!未找到引用源。3, depicts UAE's calendar of date palm care for the 12 months of the year. As shown, there are some routine around-the-year tasks such as irrigation of plants and maintenance of pipe systems year (Al Mashhadani, 2014). These are the steps that are monitored and controlled by the Dubai Department of Irrigation and implemented on site by a limited number of workers in charge of monitoring drip irrigation. Digging and weeding are known as a continuous task; however, they can be conducted during workers' lower workload periods to level the manpower required for the project. There are some highly time-specific tasks to be done during a certain month, depending on the type of date palm, such as pollination and harvesting.

Figure 1 shows five growth stages of a date fruit by days post pollination year (Al Mashhadani, 2014). The figure shows that in approximately one month, from day 120 to day 150, the date reaches its last stage, when it needs to be picked as soon as possible. These time-sensitive tasks, including date fruit harvesting, are the tasks for which project managers do not have much flexibility to level the required manpower, and hiring part-time, and in this case seasonal, workers assists the managers in reducing the number of full-time workers. As shown in 错误!未找到引用源。 , fruit covering, bunching, and harvesting are the tasks to be done from May to the end of September, which is known as the hot season in Dubai. Due to the extent of skill required, the hot weather in these months and the lifestyle of UAE residents, relying on local part-time workers does not seem reasonable. It should be mentioned that the laborers in other sectors, such as construction and transportation, are busy with their existing work throughout the year and are not available seasonally. Hiring seasonal and full-time workers familiar with date palm tree care from hot-weather countries therefore seems a practical solution.

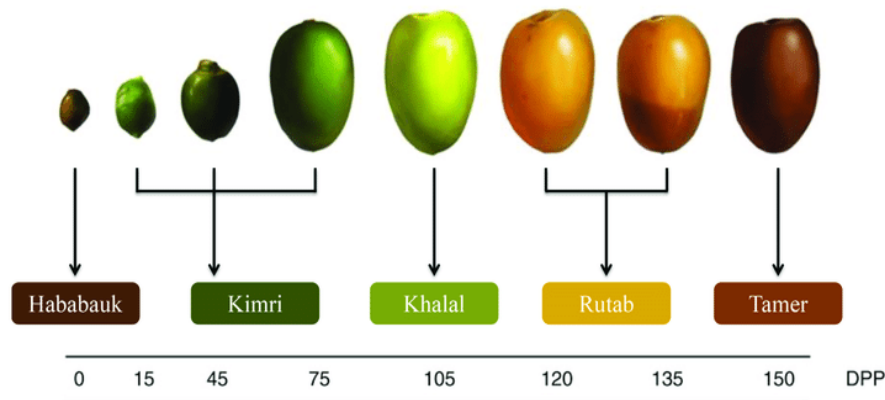


Figure 1. Five growth stages of a date fruit by days post pollination (DPP) year (Al Mashhadani, 2014)

3.14 Feasibility of a Humanitarian Date Festival

Enormous private and public projects have recently been accomplished with a substantial proportion of their areas devoted to green spaces consisting of ornamental trees. These projects play a key role in offering attractive amenities to residents and tourists. Dubai has the seventh highest number of visitors in the world and hosted almost 16 million visitors in 2018 (Maceda, 2018). The planted palm trees, like other trees, provide shade that promotes outdoor activities and enhances the ability to walk in the city (Hayes, 2019). However, during the summer, the number of visitors is less than in winter due to the hot and humid weather in UAE. The private sector and government have implemented tempting plans and offers to attract more tourists. Discounts from service sectors such as the hotel and retail sector, branded as the Dubai Summer Shopping Festival, have been identified as a major summer attraction in Dubai. Aviation industry discounts and recreational locations such as numerous water parks and Ski Dubai are crucial to attract tourists.

The potential to hold a date harvesting festival during the hot season might contribute to improving Dubai’s attractions for tourists if all its dimensions were showcased effectively. In this festival, as a means of showcasing UAE’s cultural heritage, traditional techniques employed by local Emiratis to maintain date palm trees and harvest them could be presented. Hiring seasonal workers from poor countries through a well-organized international program, to assist full-time gardeners through summer date palm tree care tasks, might add unique and unprecedented value to this project. As discussed in other sections, such iconic harvesting tasks can be extended by a week of date packing and a Thanksgiving ceremonial festival to send off seasonal workers with a decent income and packs of UAE dates to their families some time at the beginning of the Fall season.

Although on a smaller scale, the UAE does have similar experiences of date festivals. Abu Dhabi has the Liwa Date Festival, which takes place during the month of July and attracts more than 70,000 visitors. There are different entertainments going on such as puzzles, visits to date museums, date tasting and much more. At the end such a date picking festival, there has been a prize of 6,250,000 AED for the best date harvested (Stewart, 2021). There is also the Abu Dhabi Date Palm Exhibition, supported by the Chairman of the Abu Dhabi Food Control Authority, which happens during the month of December (Abu Dhabi Dates Exhibition). With support from the UAE government, other countries such as Jordan have recently started a date festival. Some other countries including Sudan, Saudi Arabia, the United States (in California), Morocco, Egypt and Oman also have a date festival (Khalifa International Award for Date Palm and Agricultural Innovation, 2021). Drawing on such experience would enhance the proposed Dubai date harvesting festival.

As highlighted before, dates can be a good source of food. Hunger or starvation are a crisis around the world, as approximately 811,000,000 people, about 9.9% of the world’s population, are starving. Unfortunately, this population is growing day by day due to COVID-19, climate change and civil wars (Action Against Hunger, 2021). Hunger and poverty are directly connected, and people on low incomes usually face food insecurity. The most common malnourishment in the world is that of protein-energy when the body has insufficient food for its energy needs. This energy is measured in calories (World Hunger News, 2018). One fifth of people who suffer from hunger are in the African continent and have less than 1.25 US dollars to live on per day. According to Table 4, the 10 poorest countries are in Africa (Ventura, 2021).

Table 4. The 10 poorest countries around the world – gross domestic product (GDP) based on purchasing-power-parity (PPP) per capita (Ventura, 2021)

Rank	Country	GDP-PPP (\$)
1	Burundi	779
2	Somalia	953
3	Central African Republic	996
4	Republic of the Congo	1,203
5	Mozambique	1,338
6	Niger	1,355
7	Malawi	1,503
8	Liberia	1,623
9	Madagascar	1,630
10	Chad	1,637

Malnourishment means that the individual is taking in less than 1,800 calories per day (Action Against Hunger, 2021). In general, the ideal nutrition of dates makes them a healthy food for those suffering from malnutrition (Alireza, 2010). With 15 different minerals, dates are a good source of carbohydrates in terms of sugar, which helps to build a stronger immune system (Aljaloud, 2020). The natural sugar in dates can help in the prevention of cancer. Cultivating date palm trees could help to alleviate this malnourishment issue associated with low income in African countries. The date fruits are easy to pack and transport. They can also be stored at room temperature for a long time. They could be transported to African countries as a humanitarian act, while African farmers could join Dubai's proposed date palm harvesting program to work seasonally, earn an income and gain some experience in a metropolitan city.

The five growth stages of a date fruit by post pollination days are shown in

Figure 1 (Al Mashhadani, 2014). According to the annual calendar of date palm care, the harvesting time of different types of dates mostly from Rutab to Tamor is from March to mid-October, depending on the type of date (Al Mashhadani, 2014). Thanksgiving ceremonies, at which people gather to commemorate the blessings of the past year, are celebrated at distinct dates in western countries. American thanksgiving is held on 24 November, the Canadian ceremony on 10 October, and German-speaking societies' ceremonies in September or October, depending on their harvesting time. The Thanksgiving ceremony in Dubai could be established, at which dates and foods made from fresh dates could be offered, considering that the date fruit is a unique fruit in the Arab world. Thanksgiving usually happens at the end of a harvesting season. Similarly, the Arabic thanksgiving could be at the end of September or beginning of October, when people could come together to celebrate the end of the date harvesting period. Such gatherings are highly appreciated in the Islamic and Arabic culture, whether they are in the form of a public gathering or a private gathering (Indari, 2017).

Such a city-wide festival, including exhibitions of different date products and their historical and cultural aspects, along with parades of the date gardening workforce would add another dimension to Dubai's attractions. The festival could be regarded as a ritual act to offer thanks for the blessings of harvesting dates in a desert city. Thanksgiving has a noble message in the Islamic world, which is "Shukr". Shukr means "thanks to God" and is one of the main concepts in the Quran (Siddiqi, 2020). Celebrating Arabic thanksgiving could also create a great message of social, economic, and environmental sustainability, giving the opportunity for workforces from poor countries, local Emirati citizens, and Dubai's expats from 200 different nationalities to celebrate an event that is founded on multidimensional sustainable landscaping.

4. Discussion

Table 5, reports the results of the assessment of palm tree areas in some local gardens. The results show that palm trees occupy 40 to 50 m², depending on the location and the type of tree. The average dedicated area to each tree is 46.6 m², which is very close to the recommended metrics in the literature. Considering that there is a total of 3,701 hectares of public land in Dubai, Dubai's public green spaces could accommodate approximately 755,306 palm trees. In comparison to the 46,068 palm trees that currently exist on public land, the city could potentially increase the number of palm trees by up to 16 times.

Table 5. Estimate of required palm tree area

Name of the Garden	Area (m ²)	Number of palm trees	Area of a Palm tree (m ²)
Al khazna (Abu Dhabi Al Ain Road, by Al Wathba Marrionette)	286.5	6	47.75
Al khazna (Abu Dhabi Al Ain Road)	300	6	50
A Foah Date Production (Abu Dhabi Al Ain Road)	292	6	48.7
Al Hashmia Date Farm (Al dhaid Sharjah)	240	6	40
		Average	46.6 (m ²)

if such an approach were admitted by the municipality, a total of 6,300,000 hours of labor would be required per year for 755,306 palm trees. Hence, a total of 4,035 workers would be required for 3,701 hectares of public land per year.

As shown in Table 1, the estimate of nutrient supply by local reclaimed water irrigation reveals that the irrigation supplies 4.9%, 64.3% and 58.4% of palm trees' total nitrogen, phosphorous and potassium demands, respectively. Further assessments could be conducted to determine the required amount of fertilizers. The manure produced in the Dubai sewage treatment plants is regarded as the most available and economical supply for plants' nutrient demand. Using manure, a by-product of sewage treatment, for the supply of nutrients for plants that are planted and maintained by Dubai municipality's Public Parks and Horticulture Department might be an excellent example of industrial ecology, regarded as a key sustainability practice. Mass concentrations of nutrients are reported in commercially available packages of Dubai manure and shown in the table.

Table 1 also shows the amount of manure needed to supply the remaining nutrient demands of trees. The results reveal that up to 23.5 kg of manure can supply the total nitrogen and phosphorous demands of a tree. The required manure to supply a palm tree's potassium demand is estimated to be 2,600 kg, which is impractical. This suggests that the municipality needs to address this demand by using other commercially available fertilizers.

The solids production ratio of typical municipal wastewater is between 0.2 and 0.3 kg/m³ of wastewater treated. The average ratio of solids produced from a typical wastewater treatment is 0.24 kg/m³ of wastewater (Turovkiy & Mathai, 2006). Considering Dubai's 1,000,000 m³ per day of sewage, the maximum capacity of manure production of Dubai is estimated to be about 240 tons per day and 87,600 metric tons of manure per year. The estimate provided in Table 1 shows that supplying 23.5 kg of locally produced sewage manure annually is sufficient to provide the required nitrogen and phosphorous for palm trees that are irrigated by reclaimed wastewater. Hence, considering Dubai's maximum capacity of manure production, and the demand of each palm tree, the Dubai municipality can provide manure as a fertilizer for 755,306 palm trees, which are considerably beyond the total number of all trees including palm trees in Dubai. Hence, it can be deduced that the supply of manure as a fertilizer for the trees is not a limiting constraint for such a proposed widespread palm tree plantation project.

A basic estimate revealed that 1.1 workers are needed for every hectare of palm trees. For Dubai's total public land area of 3,701 hectares, approximately 4,035 workers would be needed to maintain date palm tree cultivation if all steps of maintenance are alike in terms of labor intensity. With an estimated date production of 58,280 tons from all public lands, approximately 13,105 kg of dates could be produced by each worker in the project annually. Based on Iraq's date consumption rate of 1.44kg per capita per year and a population of 40,000,000, the harvested dates would be sufficient to supply the demand of a country like Iraq.

Assuming the price range of dates to be from 15 to 120 AED per kg, the harvesting, packing and selling of dates might generate an estimated average of 884,524 AED per individual worker, in the range of 196,600 AED to 1,572,400 AED per year per worker. It should be emphasized that the above-mentioned annual revenue per individual worker would not be the net income of workers, since the revenue should partly be devoted to other expenses, such as project overheads, laborers' accommodation, procurement of fertilizers and pesticides, pipe system maintenance and repair, labor insurance, and transportation fees. However, dedicating one third of the revenue to the salary of workers in such labor-intensive farming projects would facilitate an average total salary of 295,000 AED or 49,140 AED per month of service (assuming six months of work annually), which is near the expected salary of Dubai's laborers with similar skills. Such a calculation does not mean that seasonal workers would have to receive a salary from the municipality or

contractor, as they may opt to harvest, pack and transport dates to their country in return for receiving their salary from that country.

4.1 Initial Case Study of the Workforce

The unemployment rate represents the number of unemployed workers as a percentage of the total workforce of a country. Gross Domestic Product (GDP) is an indicator of the value-added generated by services and the production of goods in a certain country usually in a year. The GDP per capita of a country is a measure of the average per capita economic output of a country. Both unemployment rates and GDP per capita are great indicators of the financial standing of a country's residents. Table 6 and Table 7 present unemployment rates and GDP, respectively, per capita of the poorest African countries (Unemployment Rate - Countries - List | Africa).

Table 6. The 10 countries in Africa with the highest rates of unemployment (Unemployment Rate - Countries - List | Africa)

Country	Unemployment Rate (%) by 2020
South Africa	34.9
Namibia	33.4
Nigeria	33.3
Angola	32.9
Mozambique	25.04
Lesotho	24.7
Swaziland	23.4
Botswana	23.3
Senegal	22.6
Gabon	20.5

To better address the humanitarian aspect of the project, the nations with high unemployment and low GDP per capita should be involved. South Africa is the African country with the highest unemployment rate, followed by Namibia and Nigeria (Unemployment Rate - Countries - List | Africa). As reflected in Table 7, Burundi has the lowest GDP per capita, followed by Somalia and the Central African Republic (Poorest Countries in Africa 2022). In addition to the unemployment rate and GDP per capita, comprehensive research should be conducted to identify the nations that can handle the legalities and organize their workforce for such service. The workforce should be briefed about rules, laws and constraints associated with working and living in UAE, assisted to travel to UAE for such seasonal work, then join this project as an effective workforce, and return to their home country with minimal immigration issues.

Table 7. The 10 poorest countries in Africa

Country	GDP per capita, PPP, current int.\$, in 2020
Burundi	771
Somalia	875
Central African Republic	980
Republic of the Congo	1,131
Niger	1,263
Mozambique	1,297
Liberia	1,428
Malawi	1,568
Madagascar	1,593
Chad	1,603

*For comparison: United States (\$63,544)

The initial assessment revealed that, among many poor African nations, the workforce from Mozambique is a good candidate to join a seasonal workforce for a gardening and harvesting program in Dubai. The country is among the 10 African countries with the highest unemployment rate and the 10 poorest countries in Africa and the world (Kästle). Mozambique, with an unemployment rate of 25% in 2020, located in South East Africa on the coast of the Indian Ocean, may have high motivation to contribute to this program. Its location facilitates mass transportation of the workforce via affordable marine transportation. A person working in Mozambique's agriculture sector, particularly farming or gardening, has an average wage of 380 US dollars per month (1,392 AED per month) (The Complete Guide). The timing of the gardening and harvesting program is complementary to the plantation season in Mozambique, which starts in October, enabling farmers to join the program without missing the plantation season in their own country and thus to return to look after their own farms in a timely manner. Workforces from other East African countries such as Ethiopia, Somalia, Tanzania, Sudan could also join this program with similar strengths and capabilities, such as speaking Arabic languages, and sharing cultural similarities, geographical locations, access to marine transportation, and salary expectations.

Canada had been hiring seasonal workers from Mexico due to lack of sufficient workers (Budworth, 2017). Similarly, Germany has Polish seasonal workers. In addition to job creation, the economic benefits and reduced training costs are some of the advantages of hiring temporary workers. Admitting full-time and seasonal workers from Mozambique would save around 1,620 AED per month for each worker, as a similar job in UAE has an average salary of 3,012 AED equivalent to 820 US dollars per month (Gardener United Arab Emirates – Salary). Employing in this way the total number of 4,035 workers needed to handle date palms in Dubai should save approximately 6,500,000 AED annually.

5. Conclusion

As addressed in this paper, the gradual replacement of the current exotic and unproductive plants and trees in Dubai's public landscapes with productive date palm trees would have many advantages and should be considered as a sustainable plan. Date palm trees are adaptable to UAE's harsh climate and require less irrigation water than the existing exotic plants. Date palm trees can add beauty to the city, act as carbon absorbers to reduce the heat island effects, and be an organic source of waste, which would produce a good amount of renewable energy.

Date palm trees not only have cultural value in UAE, but they have always been an excellent source of nutrition from hundred years ago, as celebrated in existing local date festivals. This study indicates that dates are a good source of sugar, carbohydrates and fiber and could therefore provide nutrition to poor nations struggling with poverty and malnutrition.

By using drip irrigation from reclaimed water, the consumption of fresh water for this proposed plan would be zero. In addition to Dubai's reclaimed water generated and distributed by the Dubai municipality, the manure produced by the municipality would be a sufficient and abundant fertilizer that would supply the phosphorous and nitrogen demand of all proposed palm trees. However, the trees would require additional potassium.

Not only can date fruits be a good source of food, they can also generate substantial income, depending on which type of dates are used. The gradual plantation of 755,306 palm trees in 3,701 hectares of planted public landscapes would increase the current number of palm trees by a factor of 16. This study indicates that approximately 1.1 seasonal workers per hectares would be needed to work for six months of the year. Each worker could produce 13,100kg of date fruits annually and generate an average of 884,500 AED per individual worker, depending on the type of dates. Admitting seasonal workers from a low GDP African country with high unemployment is considered to be a feasible plan. Such employment is expected to save around 629,000,000 AED annually for the UAE government.

Public green spaces in Dubai would not only serve the purpose of producing fruit but attracting more tourists and enhancing the beauty of the city. A city-wide date harvesting festival, along with a ceremony similar to western thanksgiving ceremonies, would provide an additional attraction to the city during the low tourism season.

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