

Communication

Exploration of the Native Plants from the Biodiversity of United Arab Emirates for Conservation and Reintroduction Efforts: Collection, Verification, Design, and Implementation of UAE Flora Database

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Abstract: The introduction of exotic plant species in the UAE poses substantial environmental challenges. Both poorly and well-adapted species can be detrimental to the local ecosystem by outcompeting native species and disrupting ecosystems. Native plants play a critical role in maintaining the ecological balance of any region. In the United Arab Emirates (UAE), native plants face significant threats due to habitat loss, climate change, and invasive species. Despite their ecological importance and potential benefits, a comprehensive and accessible database of native plant species for the UAE is currently lacking. Our review paper aims to address this gap by presenting an in-depth analysis of the native plants in Fujairah and the UAE. Our work covers almost all the native plants reported to date, which have been verified and added to our database. We provide valuable insights into the type, nature, physiology, habitat types, and other key aspects of these native plants. By presenting this information in a comprehensive and accessible manner, we hope to facilitate efforts toward biodiversity conservation and sustainable ecosystem management in the UAE. To address this issue, we have developed UAE Flora: The Native Plants Database of Emirates. This Web-based, virtual database contains over 760 plants identified from more than 400 published articles, online resources, and books from national and international authors. Each entry in UAE Flora includes over 50 data fields representing various ecological, biological, and pharmacological properties that have been manually extracted from the literature. This review paper will serve as a valuable resource for researchers, policymakers, and the public interested in promoting the conservation of native plants in the UAE. Flora will serve as a plant data repository that is the first of its kind in the United Arab Emirates.

Keywords: UAE flora; Fujairah; native plants; salt resistance; Wadi Wurayah; sabkha



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1. Introduction

1.1. Hydro-Geological and Weather Conditions in UAE

The United Arab Emirates (UAE) accommodates three main geological zones. There are mountains from Dibba in the northeast to Al Ain in the southeast. Coastal lowlands are located along the eastern coastline, which extends from northeast to southeast along the Gulf of Oman, and the western coastline, which stretches the length of the country along the Arabian Gulf. These comprise the central desert as well as the dune plains to the south and west [1]. The eastern coast also accommodates Wadi Wurayah National Park, which is declared a Man and Biosphere Reserve by UNESCO. Situated in the Shimayliyah mountain range of the Emirate of Fujairah, Wadi Wurayah contains more permanent surface water

than any other section of the Hajar Mountains in the UAE, which provides a suitable habitat for a substantial proportion of the mountainous environment's plant and animal species [2].

Taking a comprehensive view, UAE has habitats that host species that show unique physiological, behavioral, and morphological features to survive under harsh environmental conditions. The climate of the United Arab Emirates is characterized by minimal precipitation, high temperatures, and high relative humidity. The country's yearly mean temperature is 27 °C. The highest air temperature during the summer months can exceed 48 °C, while the minimum air temperature in the interior can drop to 3 °C from December to March. The month with the lowest average minimum temperature is January, with an average of 12 °C. These features have enabled plants species found in the UAE ecosystems to cope with higher levels of salinity and high temperatures that may reach up to 50 °C during summers [3].

1.2. Nutritional, Micro and Macro Mineral Values in Native Plants

These native plants not only have the ability to withstand extreme conditions such as salt and drought, but they also provide significant nutritional and mineral benefits. One study found that the amount of potassium in *Vachellia flava* was higher than that of wheat, rice, soybean, and chickpea, all of which are staple foods. *Vachellia flava* was shown to be an agro-economically beneficial plant with nutritional contents comparable to, and mineral values higher than, commonly used staple food crops [4]. Similarly, the nutritional content of these natural plants has been evaluated to show that they provide a healthier diet for Arabian tahr [5]. The analysis found that the Arabian tahr may acquire an average of 400 mg/100 g of K, Ca, P, and Mg from *Vachellia flava* and 174 mg/100 g of *Acacia tortilis* (Tables 1 and 2).

Table 1. Proximal (%) composition of nutrients in *Vachellia flava*, *Acacia tortilis*, *Ziziphus spina-christi*, and *Prosopis cineraria*.

Nutrients	<i>Acacia ehrenbergiana</i>	<i>Acacia tortilis</i>	<i>Ziziphus spina-christi</i>	<i>Prosopis cineraria</i>
Dry matter	81.29	86.99	75.92	59.65
Crude Protein	7.42	7.08	6.08	6.36
Crude Fat	>0.1	<0.1	<0.1	<0.1
Crude Fiber	23.97	30.92	16.82	14.52
Ash	3.65	3.99	4.38	4.66
Total Sugar	2.23	1.84	2.11	1.53
TDN	67.64	63.11	73.15	74.23
References	[4]	[5]	[6]	[7]

Table 2. Mineral contents analysis of *Acacia ehrenbergiana*, *Acacia tortilis*, *Ziziphus spina-christi*, and *Prosopis cineraria*. Values are in mg/100 g.

Minerals	<i>Acacia ehrenbergiana</i>	<i>Acacia tortilis</i>	<i>Ziziphus spina-christi</i>	<i>Prosopis cineraria</i>
Calcium	375.62	282.85	444.26	650.21
Phosphorus	122.94	133.31	171.49	63.43
Sodium	17.11	5.48	41.30	94.53
Potassium	982.37	124.59	109.95	552.32
Zinc	1.16	1.31	1.13	0.69
Copper	0.72	0.5	0.44	>0.1
Manganese	1.30	0.79	1.77	1.72
Selenium	<0.1	<0.1	>0.1	>0.1
Magnesium	117.9	153.88	139.28	196.14
References	[4]	[5]	[6]	[7]

Ziziphus spina-christi also has a higher mineral and nutrient content than common leafy vegetables such as lettuce and spinach [6]. There is a fascinating correlation between climatic and soil conditions and a plant's nutritional capability, as shown by the comparative analysis. Fujairah-grown *Ziziphus spina-christi* has been found to have greater mineral and vitamin content than its Nigerian counterpart. Leaves of the *Prosopis cineraria* tree are rich in protein and the macro-minerals calcium (Ca), phosphorus (P), and potassium (K). Each part of this tree has value; the fruit is edible, the seeds are nutritious, the stem, root, and bark can be used as medicine, and the leaves are a good source of chlorophyll. In addition, the *Prosopis cineraria* from Fujairah origin has been shown to have greater nutraceutical values than the same species from the origin of Pakistan, which has 2.43 percent less Ca and 0.4 one percent less K [7]. Bees and other animals use all these plants for nectar, and the leaves and stems are fed to livestock in the United Arab Emirates (Tables 1 and 2).

Despite the high nutritional value and significance of native plants in the UAE's food, livestock, medicine, and economy, there is currently no extensive and verifiable list of native plants available. It is difficult to obtain accurate information about these plants because it is dispersed across numerous sources, such as books, newsletters, and informal communications.

1.3. Importance of Native Plants in Landscaping

The ideal plant species to choose when constructing a landscape are those that have adapted to the local environment, as they use water more efficiently and require less maintenance overall. Due to their ability to withstand both dry and moist conditions, plants native to the UAE are perfect for landscaping projects in arid lands. There are over 170 salt-tolerant plants identified previously in the UAE. Native or drought-tolerant plants can potentially outperform exotic ones in landscape designs with no need for further irrigation after planting. Native plants contribute to increasing the biodiversity of a particular landscape and restoring the habitat of wild animals by providing food, shelter, and other biological necessities.

Ordinarily, newly planted ornamental plants require a lot of maintenance, are difficult to adapt to, and consume a lot of irrigation water and other resources. Using native plants in landscaping projects can help conserve limited resources, even though local plants are ideally adapted to the climate and soil conditions of the location. Natural landscaping may help restore a diversified native environment while giving parks and gardens a rustic aesthetic that represents national heritage and culture [8].

Despite the vital role that native plants play in landscaping due to their environmental suitability, there is currently no comprehensive and verified list of these plants and their significance in multiple fields available for public and scientific purposes.

1.4. Global Efforts to Journal Important Plant Species

Regardless of the high level of importance of indigenous plants in the UAE, we do not have or have access to a single authentic list of UAE native plants. This motivates us to create a fully referenced, expert-validated data repository of UAE native plants. By compiling an exhaustive list of native plants and highlighting their benefits, we can increase awareness of their significance and promote their widespread adoption. This resource would serve as a guide for selecting native plants suitable for various purposes including fodder for medicinal and landscaping initiatives, thereby promoting biodiversity, conservation, and the overall health of our environment.

The concept of developing a plant repository is not novel. There are databases available that follow the unique purposes of related countries.

Over 4700 plant species, including more than 4300 vascular plant species and nearly 400 bryophyte species, are documented in the Atlas of Florida Plants (excluding plants known only from cultivation). The Institute for Systematic Botany, USF, and the USF Water Institute have collaborated to create a fully searchable database of all the plants in Florida.

The website also allows users to view the approximately 300,000 specimens now housed in the USF Herbarium (about 2/3 of these are databased and available online) [9].

The PLANTS Database is a standardized resource for data on U.S. and territorial vascular plants, mosses, liverworts, hornworts, and lichens. It contains names, plant symbols, checklists, distributional data, species abstracts, characteristics, photos, crop information, automated tools, external Web links, and citations. Use of these data is encouraged not only for academic and instructional purposes but also for general purposes such as promoting land conservation in the United States and its territories [10].

The records in AGRICOLA (AGRICultural OnLine Access), a database created by the National Agricultural Library (NAL), can be divided into two categories. The first is a list of references to publications in scholarly journals that have abstracts. The second category is made up of bibliographic entries that detail books, magazines, films, and websites from all around the world. Library materials are not the only ones included in AGRICOLA. The database comprises more than five million documents and includes printed works dating back to the 15th century. Animal and veterinary sciences, entomology, plant sciences, forestry, aquaculture and fisheries, farming and farming systems, agricultural economics, extension and education, food and human nutrition, and earth and environmental sciences are only a few of the many fields covered by AGRICOLA records [11].

The University of Texas at Austin and Lady Bird Johnson Wildflower Center's NPIN Plant Database features native plant species from across the United States. Nearly 8000 species of North American flora are represented in this database [12].

The World Flora Online (WFO) (precursor source: The Plant List) collects and presents floristic data from around the globe using a consensus classification—the WFO Taxonomic Backbone—a global taxonomic hierarchy of accepted names and synonyms. It is dynamic and constantly evolving, as it is constantly updated as corrections, new names, and revised taxonomies are incorporated. However, many users require a static list of accepted plant names and their synonyms, which the WFO Plant List provides. The WFO Plant List is a snapshot of the WFO Taxonomic Backbone, offering categorization information at a certain time and a stable reference for publications [13].

Digital information on plant life around the globe is accessible through the international project Plants of the World Online (POWO). Data are gathered from several sources, including the Royal Botanic Gardens, Kew, and its partners and collaborators, who provide data and make it publicly available on POWO. This database contains about 40,600 descriptive photos and 371,600 images of plants.

There are enormous databases for specific purposes for specific countries including native plant species and biodiversity conservation. It is worth mentioning that no such effort has been made for the native plant species of Emirates. The UAE has made huge efforts creating green spaces across the country including afforestation and urban landscaping by mostly introducing exotic plants species that do not reconcile with the environmental conditions of the UAE. This intensive use of exotic species in artificial vegetation has resulted in endangerment and/or extinction of many plant species in the last few decades as well. Several native plant species are imperiled and require special care. The government must develop plans and severe regulations to protect native flora from urbanization and overgrazing, which are degrading the ecosystem. The impact of this erosion in plant biodiversity, high water requirements for UAE greenery, alongside water shortages, salinity, overgrazing, and urbanization are causing major environmental and ecological challenges, which subsequently trigger the need of conservation of plant resources.

The proposed database will serve as a centralized repository for authentic lists of native flora and can be used to make decisions for various projects.

2. Results and Discussion

Features and Applications

Development of a secure, evolving, virtual database, supporting entries of textual (different languages supported), numerical, and pictorial type, follows various steps to reach

the outcome [14]. Requirement establishment is the core part where we have identified our needs for the system as mentioned in the project phases (Figure 1). Each entry in UAE Flora contains over 50 data fields, including common name, Arabic name, biological name, type, habitat, categories, and biological and medicinal properties. Our technical requirements involved databases with different levels of access and authorization, where admins have whole access and subsequent team members have partial access. Once approved, data cannot be deleted by anyone except the admin (Figure 2). The Web page language is supported in Arabic and English. Every record added is searchable with different queries, e.g., name, country of origin, Arabic name. Records added are displayed in an easily understandable way as a list, and then when a single record is clicked, the user is directed to another page with a complete display of related records with images and additional information (Figure 3). We require this database to support textual data in Arabic and English language (supported in the same row) and image upload. Various generic sections are part of this database including our Team and Help sections. Full-time backup and maintenance support is assured for the system. Since hands-on training sessions are necessary to train researchers make effective use of this database, our experts are available to train researchers.

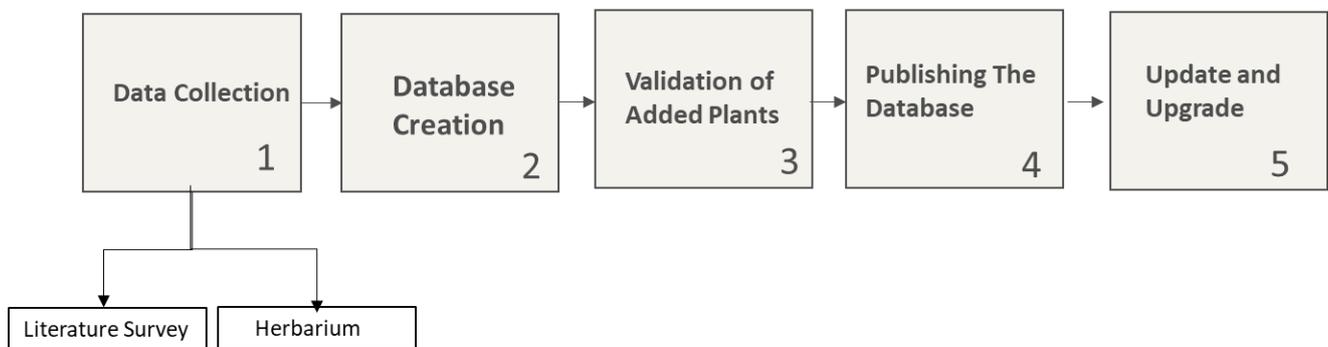


Figure 1. Project phases of database development for the native plants of UAE.

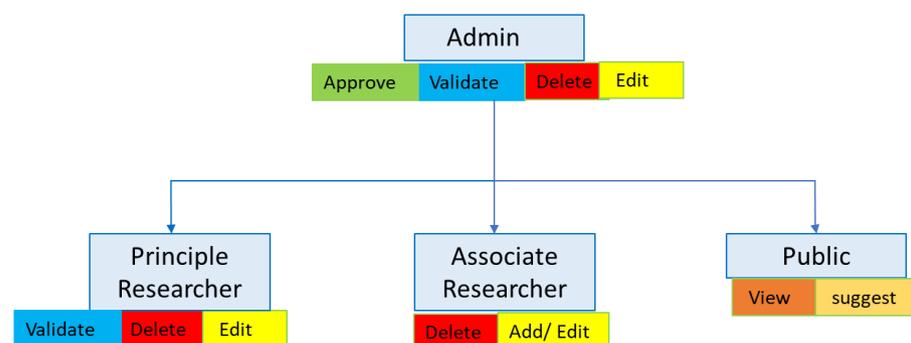


Figure 2. Customized secure database accessibility structure illustration for the dashboard.

UAE Flora: The Native Plant Database of Emirates is freely accessible at www.uaeflora.ae (accessed on 25 May 2023).

Over 625 native or naturalized plant species, including more than 150 cultivated, both common and rare ones, are listed in the database of UAE Flora. According to one of the books largely relied on (Flora of UAE), the UAE's flora consists of roughly 81 families and 350 genera of species (Table 3). The UAE's unique position as the meeting point of four geographical regions is said to be the cause of species diversity. Therefore, the country can be divided into four main geomorphologic regions based on their topography: the mountainous regions in the northeast and east; the gravel plains west of the mountains; the coastal strips (Sabkha), where most of the towns are located; and the vast desert in the interior. The database information annotation indicates that approximately 453 plant species

thrive in sandy environments. The stony to rocky slope is home to between 98 and 186 plant species (Figure 4b). Interestingly, Fujairah provides ideal environmental conditions for the 528 species that make up 70% of the plants listed in the database, following 468 in Abu Dhabi and 328 in Dubai (Figure 4a). The information from the database explains that a major part of the native plants belongs to the herbs category, and fewer are in creeper growth form (Figure 5a). Perennial and annual plants cover 90% of the plants added to the UAE Flora list (Figure 5b). The Remarks section of database makes note of Wadi Wurayah flora since the area is home to several uncommon species that deserve special attention. All the data presented in the database are being verified by national and international experts with vast experience with native plants of UAE. These data are mainly used to promote land protection in the UAE, even though they are recommended for academic, educational, and general purposes.

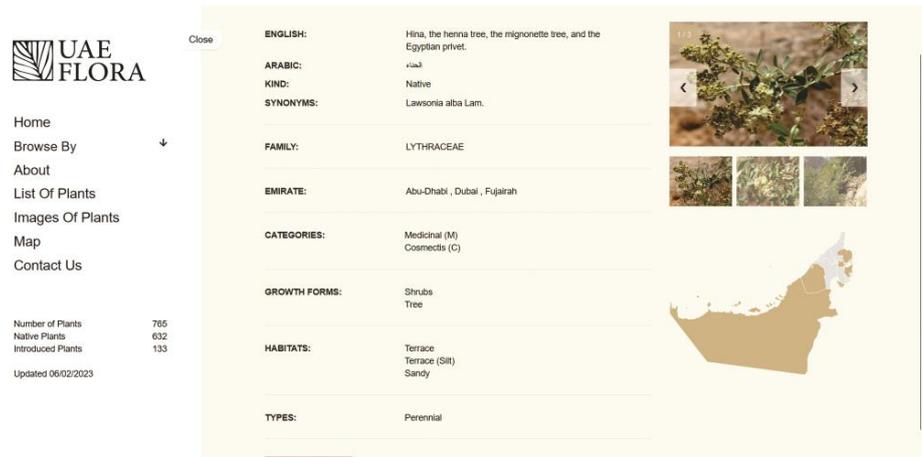
Table 3. Distribution of native plants in UAE Flora based on families.

Family Name	No.	Family Name	No.	Family Name	No.	Family Name	No.
Poaceae	99	Resedaceae	6	Dipsacaceae	2	Frankeniaceae	1
Asteraceae	70	Rhamnaceae	6	Ephedraceae	2	Hydrochartaceae	1
Fabaceae	70	Aizoaceae	5	Gentianaceae	2	Linaceae	1
Brassicaceae	37	Liliaceae	5	Iridaceae	2	Lythraceae	1
Caryophyllaceae	28	Mimosaceae	5	Juncaceae	2	Malpighiaceae	1
Amaranthaceae	26	Moraceae	5	Papaveraceae	2	Meliaceae	1
Boraginaceae	26	Nyctaginaceae	5	Primulaceae	2	Menispermaceae	1
Euphorbiaceae	25	Plumbaginaceae	5	Rosaceae	2	Moringaceae	1
Convolvulaceae	22	Portulacaceae	5	Urticaceae	2	Musaceae	1
Malvaceae	17	Capparaceae	4	Verbenaceae	2	Najadaceae	1
Zygophyllaceae	16	Combretaceae	4	Violaceae	2	Neuradaceae	1
Plantaginaceae	15	Oleaceae	4	Adiantaceae	1	Ophioglossum	1
Chenopodiaceae	14	Orobanchaceae	4	Agavaceae	1	Orchidaceae	1
Solanaceae	14	Pteridaceae	4	Aloaceae	1	Passifloraceae	1
Polygonaceae	13	Tamaricaceae	4	Amaryllidaceae	1	Polygalaceae	1
Cucurbitaceae	12	Acanthaceae	3	Araucariaceae	1	Potamogetonaceae	1
Lamiaceae	11	Anacardiaceae	3	Aristolochiaceae	1	Punicaceae	1
Apiaceae	10	Arecaceae	3	Aspleniaceae	1	Ranunculaceae	1
Cleomaceae	10	Cistaceae	3	Avicenniaceae (verbenaceae)	1	Ranunculaceae	1
Cyperaceae	10	Crassulaceae	3	Balanitaceae	1	Rhizophoraceae	1
Geraniaceae	9	Molluginaceae	3	Balanophoraceae	1	Salvadoraceae	1
Rubiaceae	9	Myrtaceae	3	Campanulaceae	1	Sapindaceae	1
Asclepiadaceae	8	Oxalidaceae	3	Cannaceae	1	Typhaceae	1
Rutaceae	7	Bignoniaceae	2	Caricaceae	1	Umbelliferae	1
Scrophulariaceae	7	Caprifoliaceae	2	Cryptogrammataceae	1	Zingiberaceae	1
Apocynaceae	6	Casuarinaceae	2	Fabaceae (Leguminosae)	1	Total	754

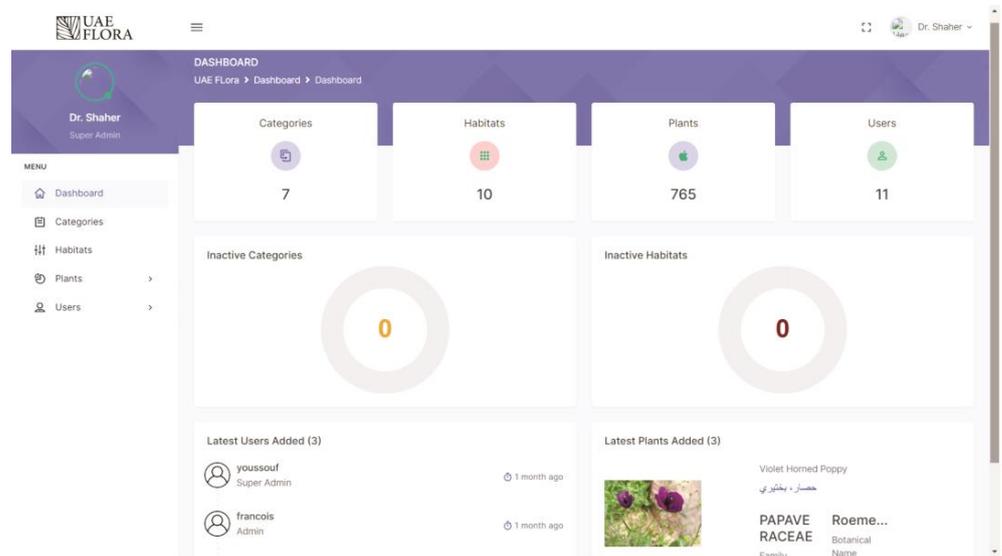


(a) Homepage

Figure 3. Cont.



(b) Detailed information of the specific plants



(c) Dashboard

Figure 3. The screenshots of two pages of UAE Flora website (www.uaeflora.ae, accessed on 25 May 2023) and dashboard. (a) Homepage; (b) detailed information of the specific plants with images and location as responsive map; (c) dashboard where all data are added, annotated, and verified.

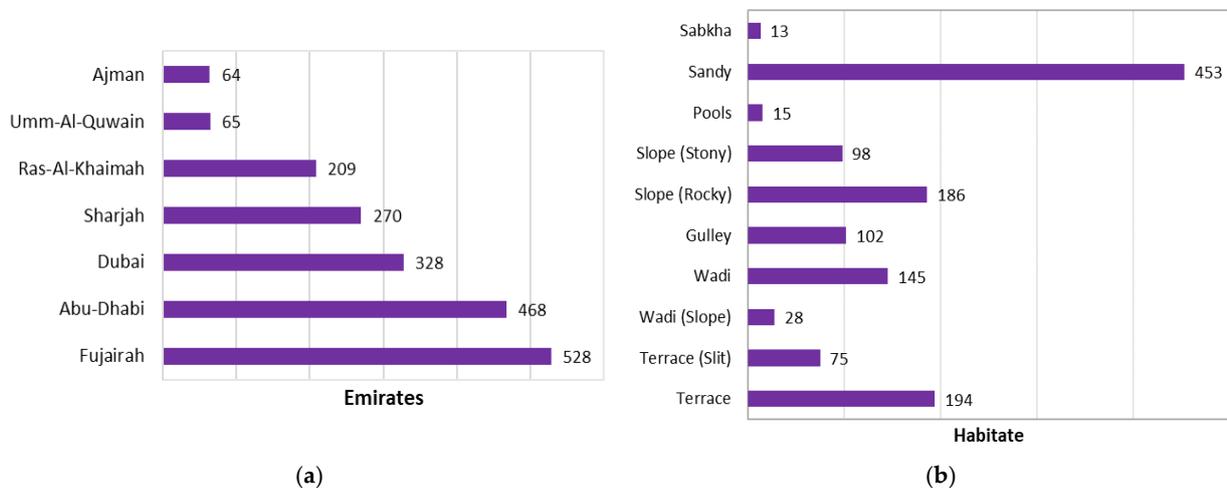


Figure 4. Distribution of native plants in UAE Flora based on (a) Emirates and its (b) habitat types.

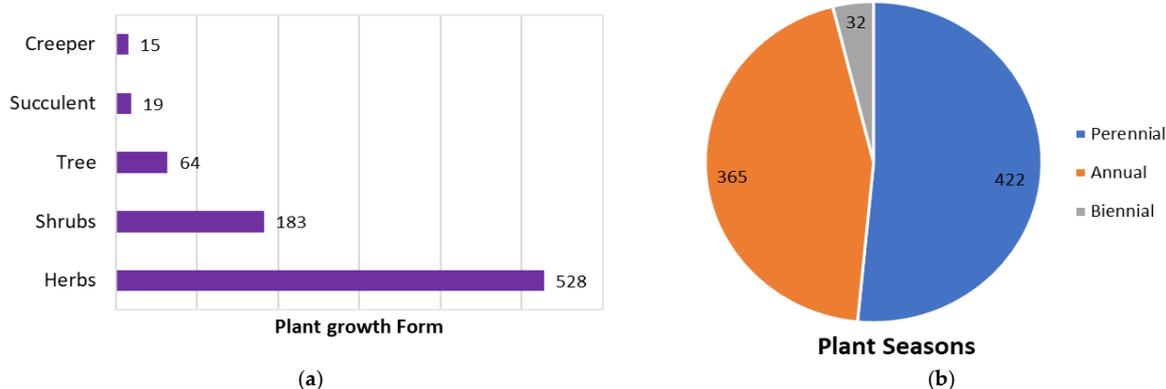


Figure 5. Distribution of native plants in UAE Flora based on (a) plant growth type and (b) plant season type.

3. Methodology

Design and Implementation

Native plants are plant species that have evolved and naturally occur in a specific geographic region, ecosystem, or habitat without any human intervention or introduction. These plants have adapted to the local environmental conditions, including climate, soil types, and ecological interactions, over an extended period, typically thousands of years or longer. Native plants play a vital role in supporting biodiversity, ecosystem stability, and the overall functioning of their native ecosystems.

The project aims at the development of a collaborative and user-friendly GUI and content-based database to publish and display native plants in the Emirate of Fujairah. Moreover, it allows researchers and general users to share their discoveries about new plants and their observations on ecosystem status.

The UAE Flora development project has been divided into three phases. The first phase includes the literature search of more than 400 published articles, online resources, and books that belong to universities only, to identify over 760 native and adaptive plants. The whole literature search consists of two subsets of records. The first contains article citations. Articles used were published between 2012 and 2021. The second consists of bibliographic records describing monographs, journals, audiovisual materials, and online content from around the world. UAE Flora includes but is not restricted to resources available in the library. The database contains printed publications from 2003, 2005, 2006, and 2007 [15].

The second phase includes the careful analysis of information about native plants and its authenticity, which includes correct information about origin, nativity, and availability. The Plants Database presents structured information about native and cultivated plants of the UAE. It includes common names in English and Arabic; botanical names; synonyms; growth form; plant type; area of collection; habitats; categories based on uses; plant description; benefits; remarks; the emirate in which the plant is located; images; and references.

The project required combination of back-end and front-end development tools to establish a customized database. The third phase focuses on the designing and development of the database and dashboard using front-end GUI technologies such as HTML, CSS, Bootstrap, JavaScript, Ajax, and jQuery, and back-end PHP (Laravel) and database in MySQL, ensuring the easy retrieval of all gathered and calculated information [14,16].

4. Conclusions and Future Perspectives

To conclude, the current form of UAE Flora is the start of a long-lasting mega-project, primarily focusing on developing a repository of native plants of UAE diversity with the goal to aid in knowledge sharing, conservation, and ecosystem protection. It is worth noting that the UAE Flora database is managed and maintained by a team of experienced plant

specialists and researchers based at the Fujairah Research Centre. These dedicated experts contribute their extensive knowledge and expertise to ensure the accuracy and reliability of the information provided in the database. Moreover, verification is continuously being performed by pioneers of the previous physical repositories, including experts from the University of Sharjah, Komarov Botanical Institute, United Araba Emirate University, and ICBA, to name a few. Following are the future aims that will be implemented further:

- Extraction of natural products from medicinal native plants of the UAE and creating a data repository for pharmacological purposes.
- Expanding the information available for native plants.
- Identifying the natural compounds or fibers from native plants (or their wastage) for the commercial production of fabric and reusable/biodegradable bags, boxes, and cutlery.

Author Contributions: The authors confirm contribution to the paper as follows: study conception and design: F.L.R., A.A.A. and S.B.M.; data collection analysis: N.A.S.A.A. and A.S.S.J.A.D.; interpretation of results: all authors contributed equally; design and development of front and back end of the database, website, and dashboard: A.G.; draft manuscript preparation: S.B.M. and N.A.S.A.A. All authors have read and agreed to the published version of the manuscript.

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