CONSERVATION OF NATIVE PLANTS AS A MEANS OF RESOURCE UTILIZATION AND DESERTIFICATION MITIGATION IN KUWAIT

By

Mouza Nassep

A thesis submitted to University of Birmingham for the degree of DOCTOR OF PHILOSOPHY

School Biosciences
College of Life and Environmental Science
University of Birmingham
December 2021

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Abstract

Desertification is “land degradation reduces natural resilience of the ecosystem, destroy vegetation, reduce soil fertility, increase the vulnerability of natural disaster, dust storm; leads to an extension of species.” Environmental degradation and sever ecological condition and many other factors related to human activities leads to severe desertification and deterioration in soil and plant cover in Kuwait. The conservation planning process required various data sources, especially information related to the component and facilitating support. This research project contributes to the conservation of Kuwait plants, development conservation strategy to aid resource utilisation, and desertification mitigation in Kuwait. A priority list of preservation in Kuwait, through developing specific criteria, a total of 118 priority species were identified. The creation of morphological characteristics of the prioritised native plant species and acquired an identification aid. In addition, the development of Red List categorisation to produce a relative estimate of the likelihood of extinction of the prioritised taxon globally and develop the result to the regional threat assessment for the native ones help create high priority native species from the list. The research also follows a design of strategic management and its effectiveness in the Demilitarized zone protected area in Kuwait. The application aims to combat desertification by understanding the actual situation of flora in Kuwait, improving the natural heritage, developing an annual management plan in the future, and help in the development of series of recommendations and use action.

ACKNOWLEDGEMENTS

Special thank and gratitude to my Family for the constant support.

I would like to thank my supervisor Prof. Nigel Maxted for his help, support and understanding, guiding me to develop my research methods and improve my skills through my PhD. I'm also would like to thank Dr. Shahina Ghazanfar, and Dr. Joana Brahm for the help and advice in developing the study areas, and guiding me through my research.

I'm also would like to thank Dr. Raffat Misak From KISR for guiding me in the field work, and reviewing the deferent areas related to the Protected area in Kuwait. Also, I would like to thank Ms Rana From KTUH- Kuwait for supporting during my data collection process. The need for an interactive key to the Kuwaiti flora was apparent following the re-establishment of Kuwait University herbarium, which was destroyed in 1990. I acknowledge assistance from the herbarium expert, and identifying rare and non-protected taxa from the flora of State of Kuwait.

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Chapter 1: General introduction

Kuwait is country at the head of the Persian Gulf, the country is known to be arid, but increased desertification is a growing threat to its specialised flora (Ghazanfar *et al.* 2019). The term desertification is connected with land degradation; this is a highly controversial topic. According to WHO (2020) desertification is sort of land degradation in which desert obtained from the fertile land, due to the various strength such as extreme environmental conditions, human activities and many other factors leads to land degradation. The Global Strategy for Plant Conservation (GSPC; UN, 2010) is composes of targets, including Target 2: "a preliminary assessment of the conservation status of all known plant species, at national, regional and international levels." Many of the 16 targets in the GSPC depend on knowing which plants are threatened in a country. While in particular, Target 5 "protection of 50% of the most important plant diversity areas", Target 7 "60% of the world's threatened species conserved in-situ", and Target 8 "60% of threatened plant species in accessible *ex-situ* collections" (Krupnick *et al.*, 2009) all call for knowledge of a country's flora and its active conservation.

In Kuwait, very severe desertification prevails resulting in increased formation of new active sandy bodies, deterioration of many natural vegetation areas, and limited water resources for large-scale crop and forage production Misak *et al.*, (1999, 2000, 2003, 2009, and 2010). "Loss of natural vegetation in dryland ecosystems creates deserts, dust storms and frighteningly high levels of respiratory disease in cities like Kuwait" (Dudley *et al.*, 2015). To avoid further habitat deterioration, immediate action plans for biodiversity conservation and desertification mitigation needs development. These include identification of vulnerable species, conducting modelling research to improve conservation programs, monitoring key species, *ex situ* conservation using the living collection, ensuring representation in

conservation programs, and *in situ* conservation and enhance management in protected areas.

1.1 Arabian Peninsula

The Arabian Desert, located in southwestern Asia, dominates the Peninsula between latitudes 13° and 32° N and longitudes 35° and 60° E. (Engel *et al.*, 2011). The Peninsula is bordered by the Red Sea, Arabian sea and, Arabian Gulf. Arabian Peninsula occupies about 3,100,000 km^2, consider the largest Peninsula on Earth comprising the countries of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates, and Yemen, as shown in Figure. 1.1 (Mallon and Budd, 2011).



Figure 1.1: The Arabian Desert (http://www.map-library.com)

1.1.1 Topography

Mountains run along the western, much of the southern, and the south-eastern coasts, and shelving more gradually towards the desert interior (Cox *et al.*, 2012). A region called (Tihama) occupies the Red Sea's elongated coast, up to the mountains along the edges. The area is covered by aeolian sands and fluvial sediments. Tihama desert consists of many mountains and valleys ranging from 40-140 m wide, which are expanded parallel to the Red Sea coastal plain. Midian mountains in the north are 1,000-2,000 m asl, and the highest peak is the Jabal Dibbagh which is 2,350 m asl, Hijaz mountain is located in the center with topography up to 1,000m asl, followed by Asir mountains and Yemen highlands which rises up to 3,000 m (Engel. *et al.*, 2011; De Pauw, 2001). In contrast, the Jebel Al-Akhdar mountain in Oman is 3,000 m asl, and Dhofar province in the south part is 1,000 to 2,500 m asl. Limestone mountains located in Musandam area north and east of Ra'as Al-Khaimah of UAE with altitude reach 2,000m asl. Mountains are engraved by flat valleys, which are the most important landscape topography work as drainage system in the Peninsula (Engel *et al.*, 2011). The desert steeps south toward Rub' al-Khali (empty quarter) desert which is covered by sand dunes and continues toward the east plateaued area, which is approximately 72,000 km2 of the Nafud sand desert (Engel *et al.*, 2011).

1.1.2 Climate

The Arabian Peninsula is part of the arid Subtropical Region, which has a fluctuation of aridity, according to the topography and coastal condition. The scarce and sudden rainfall, as well as the extreme high temperatures, dramatically affect the culture and the geomorphological landscape. Historically, population is concentrated in regions with high level of rainfall

(Ghazanfar, 1998). The area has a hot and dry climate in the central region and a less arid climate in the higher altitude regions. The Arabian sea coast endures an atmospheric depression during summer, this is advantageous when it shifts southwards to cover the north part of the Gulf in winter. Regionally, the climatic condition is controlled by the topography (Engel *et al.*, 2011).

The Arabian Peninsula is characterized by a high evaporation rate and, in contrast, low precipitation. The temperature in the daytime fluctuates, at times, to more than 50 °C. This has been previously recorded in Rub' al-Khali and Najd and described as the highest temperature on the planet (Miller and Cope, 1996). The area suffers from warming temperature as it directly affects water resource management, development planning and human settlement in the region (Ellner *et al.*, 2010; Engel, *et al.*, 2011). On the other hand, 'Asir province, Yemen, and the northern high latitude of Oman, has previously had temperatures of less than 0.5 °C recorded, as well as snow (Miller and Cope 1996).

In general, the Arabian Peninsula experiences a cold, dry northeast monsoon winter between December-February. During spring throughout the months of March-May, the weather generally transitions to unstable precipitation with thunderstorm activity. However, in summer, which is through June-September, the Arabian Peninsula experiences thermal lows, which sometimes results in dust storms. Throughout the autumnal season, the peninsula has a period of tropical southwest monsoon storms, in October and November (Miller and Cope 1996; Ghazanfar, 1998). However, although this is the typical climatic condition for the Peninsula, there are some extreme areas where this not the case. In these particular extreme areas, precipitation remains low, at less than 50mm in some regions. These areas remain dry all year long, which consequently impacts the temperature in the region (Fischer and

Memberry 1998). In contrast, Yemen receives an annual precipitation rate of more than 1,500mm which holds the highest precipitation rate in the region.

1.1.3. Biodiversity of the Arabian Peninsula

The climate conditions and aridity of the region result in the low density of biodiversity of Arabian Peninsula. However, the Arabian flora has a high adaptation of its genetic diversity to harsh environmental conditions and abiotic stress resistance. Many vegetation divisions have developed to define the flora of the Arabian. Zohary (1966, 1973), created the flora division, dependent on the geographical locations. The author classified the Middle East flora into two floristic origins: Sahara-Sindian defining the north and central region, and the southern part is defined as Sudano-Deccan (Zohary, 1973). The division was followed by White (1983), who used the endemism zonation which was further extended by Leonard (1989), to southwest Asia. The principal floristic border of the Arabian Peninsula is mainly the Saharo-Sindian region zone, which consists of the Sahara regional subzone, Arabian regional subzone, and the Nuba-Sindian local center of endemism. In the Arabian subzone, the climate and weather have a direct effect on the vegetation presence, which ultimately is impoverished reflecting the adverse conditions for growth. However, the Nuba-Sindian zone includes local endemism borders the coastal belt of the Arabian subzone. The Nuba-Sindian desert habitat contains scattered trees, shrubs, and grasses, dependent on the underground moisture. The Arabian Peninsula vegetation shows that east and southeastern taxa is linked to Iran and Pakistan geographical locations and not connected to the Nuba-Sindian local center (Ghazanfar, 1998).

The open rangeland system and overgrazing deeply effects the vegetation distribution in the Arabian Peninsula. The natural vegetation used to previously be evergreen woodlands,

sclerophyllous and succulent shrublands, and expansive grasslands. The number of native species in the Arabian Peninsula used to be almost 3,500 taxa. However, recently the majority of vegetation areas have been reduced in size and degraded. Ultimately, overgrazing by livestock adversely affects much of the natural vegetation and has led to the rapid depletion of the Arabian Peninsula's flora (Ghazanfar, 1998) and the impact of current climate change has yet to be fully appreciated.

1.1.3.1 Distribution of flora and vegetation in the Arabian Peninsula

Weather conditions and climate are considered the primary factor influencing the distribution of the vegetation in the Arabian Peninsula. The desert's aridity is associated with sparse vegetation including bushes, shrubs, and grasses which are distributed over most of the Arabian Peninsula's landscape. While areas with wadies or where runoff can accumulate result in dense vegetation, whilst area with high elevation forming mountains are associated with more dense overgrown vegetation. The main geomorphological vegetation types (Ghazanfar, 1998; Owen, *et al.,* 2020) in the Arabian Peninsula are:

- **Coastal and Sabkha vegetation** consists of subtidal and intertidal coastal mangroves and halophytic succulent chenopods. In addition, in the eastern coastal lowlands, the habitat mainly contains drought-deciduous thorn woodlands, open shrublands communities, and perennial grasslands (Ghazanfar, 1998). Submerged and coastal vegetation is distinct in the north-south of the Red Sea, as well as in the Arabian Gulf and transitional zone to northern Oman. About 120 species are recorded as halophytes in the Arabian Peninsula (Ghazanfar *et al.* 2019). Halophytes have high survival capability due to their germination potential in the contaminated saline region

(Ghazanfar *et al.* 2019). The main factors that influence growth zonation are: soil salinity, water holding capacity, and their heights above sea level.

- **Desert vegetation zone** covers most of the Arabian Peninsula, the species present are few and very water dependent. The sand deserts rock and gravel deserts extended throughout Rub' al Khali has very low amounts vegetation as a result of the low annual rainfall. In contrast, the great Nafud and Dahna sands are associated with fairly wide-spaced shrubs, perennial grasses, and annual species, which are reliant upon sufficient rainfall (Edgell, 2006). The western and central Desert Arabia zone consists of species influenced by the Iran-Turanian phytochorion (Ghazanfar *et al.* 2019).
- **Shrublands communities** of the transitional zone plateau in the northern and north-eastern and central parts of Peninsula. It consists of scattered vegetation, including bushes, and small woody shrubs which grow in moist regions. Within the coastal low-land, shrubland communities are dependent upon groundwater. The water is not far below the surface, and the area has annual rainfall of 75-140mm (Edgell, 2006).
- **The mountainous woodlands communities** have varieties of regions defined according to the altitude and geographical position of the vegetation. Arabian Peninsula mountains include rich diversified flora communities due to the high average amount of annual rainfall and low temperature (Abbas, *et al.*, 2020). These advantageous conditions allow for an array of vegetation, such as: drought-deciduous woodlands and shrublands, semi/evergreen woodlands and shrubs, mixed shrub and grassland formations, and cold-deciduous woodlands (Osman, *et al.* 2014)
- **The wadies communities** and seasonal water flows play a vital role in the abundance of vegetation of the Peninsula. There are various factors that can influence the density

of the vegetation, in particular, seasonal flooding, sedimentation deposited, and rainfall density (Kurschner, 1998; Osman, *et al.* 2014).

1.1.3.2 *In situ* conservation.

IUCN Protected Areas Programme aims to develop and improve effective models and approaches in the management of protected areas regionally. The IUCN programme also helps in enhancing the reserve management capacity through the development of adequate guidelines and tools. In addition, the organisation provides the support needed to achieve the objectives and outputs for the regional World Commission on Protected Areas (WCPA) network. Protected areas are a significant element in the conservation of biodiversity in the Arabian Peninsula. Within the 7 regions of the Arabian Peninsula, there is approximately 115 established protected sites legally, refer to Table.1.1 UNEP-WCMC, 2021. However, the models for effective management is not fully implemented in many sites.

Bahrain is the smallest region of the Arabian Peninsula countries with approximately 307 vascular plant taxa were identified (Al-Wasmi, *et al.* 2015). Al Areen wildlife reserve covers 5.4 km^2, it represents a botanical garden for species of wild plants and sources of medicinal desert plants that are used in folk medicine. According to the national strategy of Bahrain, protected areas system needs to strengthen implementation of the administration to represent the national natural and cultural heritage (Al-Wasmi, *et al.* 2015; Naser, 2016).

Table 1.1: Arabian Peninsula Total Area Protected and Number of Sites According to UNEP-WCMC, 2021.

Country	Land Area Km^2	Total area protected Km^2	Number of sites
Bahrain	765.3	45	4
Kuwait	17,818	3092	16
Qatar	11,571	1,805	5
United Arab Emirates	83,600	13,724	47
Oman	309,501	7,985	15
Yemen	527,968	3,520	10
Saudi Arabia	2,149,690	92,064	14
Total	**2,470,762**	**122,235**	**115**

In Qatar, there are 371 identified florae plant species. The country has increased the protected sites by designating new reserves, in accordance with the strategic goals established to strengthening the management and conservation of the ecosystem (SCENR, 2007). The government established 5 terrestrial protected areas, covering 18% of the total area of the country. In contrast, United Arab Emirates terrestrial protected areas has a coverage of 19.35%, in which 14.82% are management effectiveness evaluated (SCENR, 2007; Javed, 2015; UNEP-WCMC, 2021). According to the criteria for ratification of the Convention on Biological Diversity and requested that each country conduct management effectiveness evaluations of at least thirty percent of its PAs by 2010 (CBD, 2020). Regular evaluation of the management is a systematic process covering the science, economic and social values obtained from the conserved sites (Stoll-Kleemann, 2010). In Oman, 15 terrestrial conservation sites which are

governmentally designated, cover 2.57% of the total land in Oman (UNEP-WCMC, 2021). The conservation is mainly for sustainability, which covers national and scientific reserves, national parks, natural mountains, and wildlife and landscape sanctuaries (CEIC, 2016). According to UNEP-WCMC (2021), *in situ* conservation in Yemen includes 10 reserves, these are: Jabal Bura Valley Forest National Park, Ras Isa, Zuqur Islands, Socotra Island, Dhamar Montane Plains, Mahjur Traditional Reserve, Bura Community Protected Area, Detwah agoon, Bura'a, and the two areas of Socotra Archipelago. In total, the protected sites cover 0.77% of the land, however, the report mentions that 4 sites have a total of 0.63% of land cover and has been evaluated for management effectiveness. (UNEP-WCMC, 2021). Saudi Arabia, which is the geographically largest region of the Arabian Peninsula, is the richest and most complex floristic division of Saharo-Arabian and Sudano-Zambezian flora (Takhtagan, 1986). The area has a wide range of geomorphological vegetation types in the Arabian Peninsula. There have been over 1,500 taxa identified in Saudi Arabia, in which 242 are endemic and 600 rare and endangered species in the wild (Attia, *et al.* 2017). The existing protected area covers 4.76% of the total area of Saudi Arabia, however, 0.93% (total of 3 reserves) is evaluated for the effectiveness of the management (UNEP-WCMC, 2021). These sites are co-managed by conservation has governmental management and co- management with varieties of environmental agencies and local communities. Although approximately 20.21% of the total area of the Peninsula is under conservation, the level of management does not fully reflect the variation in diversity from in and out of reserves. The numerous environmental threats and harsh environmental conditions of the peninsula have not assisted in the improvement of the diverse habitats (Attia, *et al.* 2017; UNEP-WCMC, 2021).

1.2 Study area: Kuwait

The State of Kuwait is located at the Northeast corner of the Arabian Peninsula, between latitudes 28º, 30' and 30º, 06' North and longitudes 46º, 30' and 48º, 50' East (Figure 1.1). From the east, it is bordered by the Arabian Gulf, Iraq from the north and north-west, and the Kingdom of Saudi Arabia from the south and south-west. Kuwait occupies an area of 17,818 km^2. The average land width from east to west is 170 km, and the distance between the furthest northern locations to the furthest southern sites are approximately 200 km. The borders of the State of Kuwait have a total length of 685 km, of which 495 km are land borders with Iraq and Saudi Arabia. The remaining 195 km constitute to the coastal boundaries of Kuwait along the Arabian Gulf (Environmental 3rd strategy of the State of Kuwait, 2002).

1.2.1 Topography

Kuwait's surface is of low-lying. The maximum height is found in the west and south-westward, where above sea level it reaches 300 m. The minimum height eastward is 0 m toward the sea (Figure 1.2). Kuwait surface is almost flat, for the most part. It mostly has an absence of exposed topographic features; however, it does contain some such as: Jal Al-Zur escapement, Kera'a Al-Maroo, Al-Ahmadi, Al-Leyah, Al-Shegaya, Al-Dibdiba, Al-Huma, Al-Dahzool, Telal Al-Mezeel. Similarly, it also contains depressions and some valleys, such as: Um Ar-Rimum and Wadi Al-Batin. Furthermore, it also contains spits like Ras Al-Ard, Ras Al-Julia (Halwagy *et al.*, 1982; Environmental 3rd strategy of the State of Kuwait, 2002).

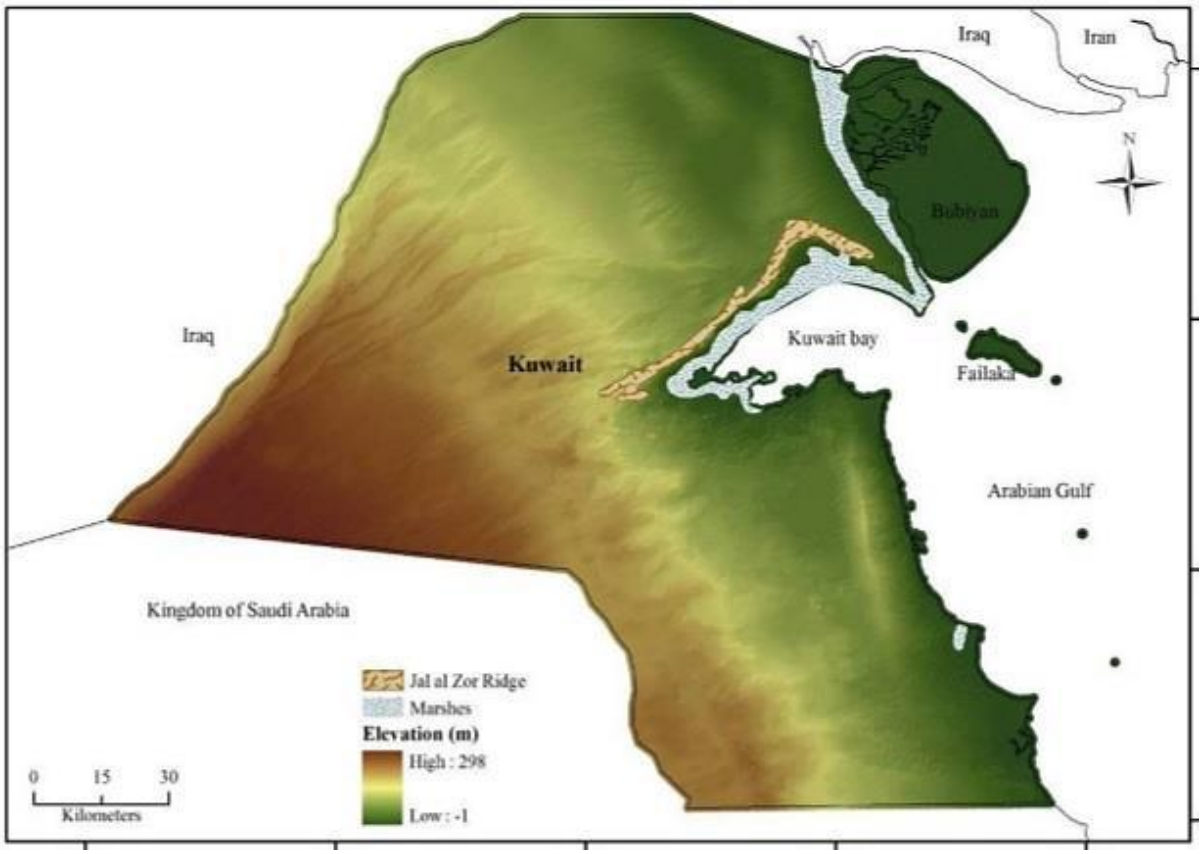


Figure 1.2: Topographical Features of Kuwait (Al-Shehabi, 2012).

The most considerable drainage (wadies) systems in Kuwait is and Wadi Um Al-Rimam. Wadi Al-Batin is considered the primary source of gravel for the upper 'Dibdibba' formation of gravel deposits. Figure 1.3 shows the Wadi Al-Batin location, which occupies a land area of 60,000 km^2. It spreads across the northern part of the Arabian Peninsula, extending from Hafar Al-Batin in Saudi Arabia and covers the western and north-western parts of Kuwait. Wadi Al-Batin area is approximately 250 m above sea level. According to Al-Gurairy *et al.,* (2017) the Wadi Al-Batin area is part of a huge sedimentary delta which extended in Kuwait and Southeastern part of Iraq. The delta is responsible of the transfers of many types of igneous rocks fragments to Iraq and Kuwait. Furthermore, Wadi Um Al-Rimam is located north of the Kuwait bay. It is approximately 8 km wide and 60 km long. It is located within the Jal Al-zor

area, which is the most distinctive geographical landscape of Kuwait and rises to 145 m above sea level.

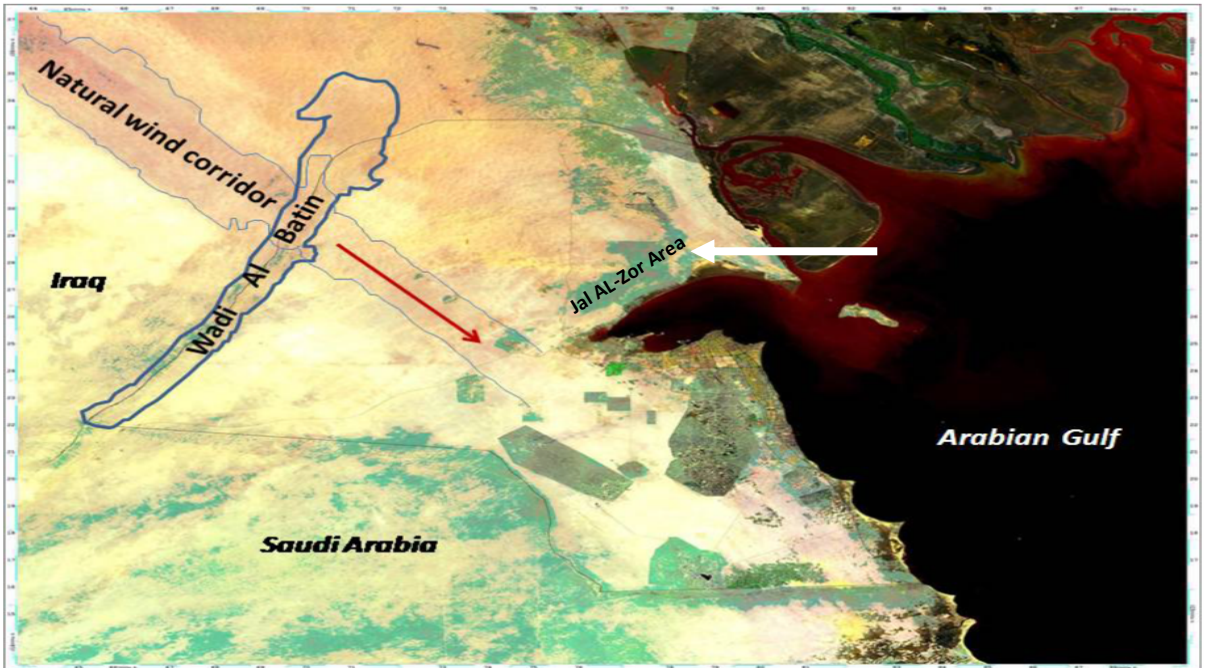


Figure 1.3: Satellite Image of Kuwait Showing Bordering Countries and Wadi Al-Batin Area (Misak, 2012).

1.2.2 Climate

Arabian Gulf region is classified as a desert climate with scarce rainfall, whereby average rainfall in Kuwait decreases from north to south. Throughout the year, Kuwait is saturated with humidity due to it being located near the Gulf waters. However, during May and June, the humidity is contrastingly low due to the dominant high-speed northwestern winds (Misak *et al.*, 2000). Rain in Kuwait is categorized into two types: Cyclonic Rain and Convectional Rain; Cyclonic Rain occurs during the formation of low pressure above the Mediterranean and falls between November and March all over Kuwait. Convectional Rain, falls when the heated air at the earth's surface rises to higher altitudes, forming thick clouds and thunderstorms (Al-Dousari *et al.,* 2007). Depending on the dataset sampled, it is estimated that Kuwait has

approximately 110–190 mm of rainfall annually (Al-Dousari *et al.,* 2007; Marcella and Eltahir, 2008). The annual rainy season occurs from November to April, with double peaks in January to March, as shown in Figure 1.4.

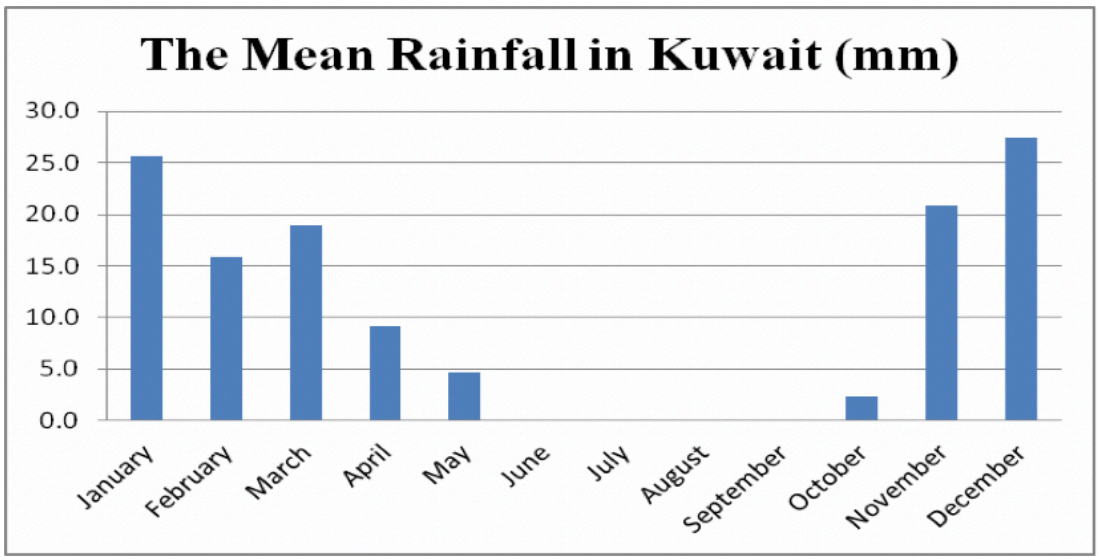


Figure 1.4: Mean Rainfall (mm) in Kuwait from 1980-2013 (Meteorological Department 2010).

Kuwait has a desert climate. The winter endures a cold and humid climate due to the high Siberian winds. The hot, arid, dry climate in summer, is due to the low humid Indian atmospheric pressure belt. Summer is extremely hot, especially in July and August, with midday temperature ranges from 42°C to 50°C (Metrological data from the Kuwait Met Office, 2016).

1.2.3 Soil

Kuwait is covered by arid sandy soils, which is characterised as fragile, due to very low moisture. The soil comprises minimal organic matter and nutrients that sustains less plant growth. Most of the soil is shallow in-depth due to the wind erosion and exposed lower

calcareous layer on the topsoil. Furthermore, overgrazing, rangeland utilization, and vehicle movement throughout the desert ultimately increases soil mobility.

The dominant soil types are sandy, gravelly, and intertidal muddy. The soil texture is classified as mainly sandy or sandy to loamy (Mahdi and Majda, 2002; Ergun, 1969; Abdal and Suleiman, 2002). A detailed soil survey study which covered the entire State of Kuwait was accomplished in 1999 by the Kuwait Institute for Scientific Research (KISR) and the Public Authority for Agriculture and Fisheries (PAAF) in collaboration with international consultants. Through guidance from the United States Department of Agriculture - Natural Resources Conservation Services (USDA-NRCS) (Omar *et al.,* 2001). The project utilized sampling and field mapping. The application identified eight different soil types in Kuwait which are shown in Figure 1.5 and described in Table 1.2

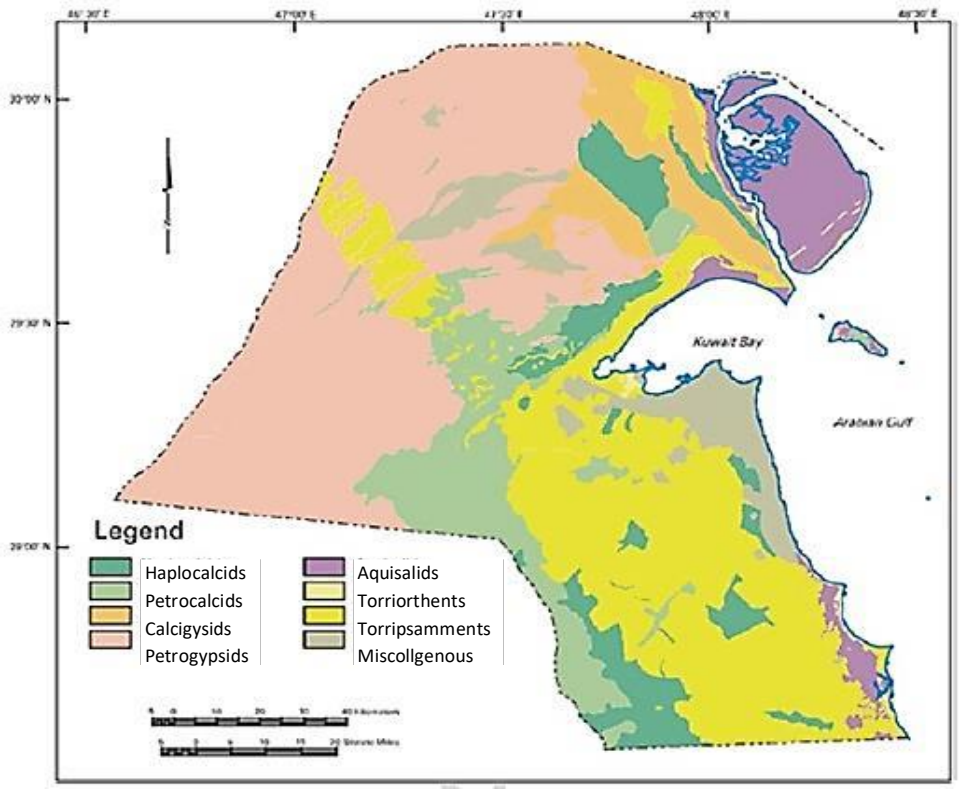


Figure 1.5: Kuwait Soil Group Distribution (Omar *et al.,* 2001).

Table 1.2: Kuwait Soil Unites and Total Area Coverage (Omar *et al.,* 2001).

Map unit	Area (%)	Description
Torripsamments	27	Well to somewhat excessively drained, deep or very deep sandy soils
Petrocalcids	11	Well drained or moderately drained, shallow or moderately deep, sandy to loamy soils overlaying a calcic hardpan. When upper soil is truncated, it may appear at surface
Haplocalcids	8	Well drained, deep or very deep, sandy to loamy soils, which have a layer of carbonate masses and nodules in the profile
Haplogypsids	<1	Well drained, deep or very deep, sandy to loamy soils, which have a layer of gypsum crystals in the profile
Aquisalids	7	Poorly or somewhat poorly drained, deep or very deep, sandy to clayey soils. Within the soil there is a layer of salt accumulation that usually occurs near the surface
Calcigypsids	6	Well drained, deep or very deep, sandy to loamy soils containing a layer of carbonate masses and nodules and a layer of gypsum crystals within the profile
Petrogypsids	33	Well drained, shallow or moderately deep, sandy to loamy soils overlying a gypsic hardpan. Hardpan may to exposed at a surface, when upper soil is truncated
Torriorthents	1	Excessively drained to well drained, moderately deep or very deep, sandy soils. Within the soil profile there is a high content of shell fragments and some gypsum accumulations

1.2.4 Biodiversity in Kuwait

Although Kuwait is not rich in biodiversity, it holds several extraordinarily important marine and desert organisms. About 374 plant species have been identified, most of which are seasonal ephemeral species and are used primarily for grazing (Omar, 2007). More than 350 bird species have been identified and 40 species of reptiles recorded in the area. In addition,

28 mammal's species, of which 5 are considered endangered, the Fennec Fox (*Vulpes zerda*), Common Red Fox (*Vulpes vulpes*), Honey Badger (*Mellivora capensis*), Wild Cat (*Felis silvestris*) and the Grey Mongoose (*Herpestes edwardsii*) (Environmental 3rd strategy of the State of Kuwait, 2002).

According to Halwagy and Halwagy (1974) and Halwagy *et al.*, (1982), the desert plain consists of five distinct vegetation communities, covering the most significant part of Kuwait, as shown in Figure 1.6. Detailed observations of the vegetation in Kuwait carried out by G. Brown, during the period from September 1995 until December 1998, concluded that majority of the southern half of the country was naturally covered by a dwarf shrub community. This was dominated by the Composite *Rhanterium epapposum* Oliv. (local Arabic name: 'arfaj'). Gradually, a community of *Cyperus conglomeratus* Rottb. (local Arabic name: 'thunda') replaced *Rhanterium* as the critical perennial species, probably due to overgrazing (Brown, 2003).

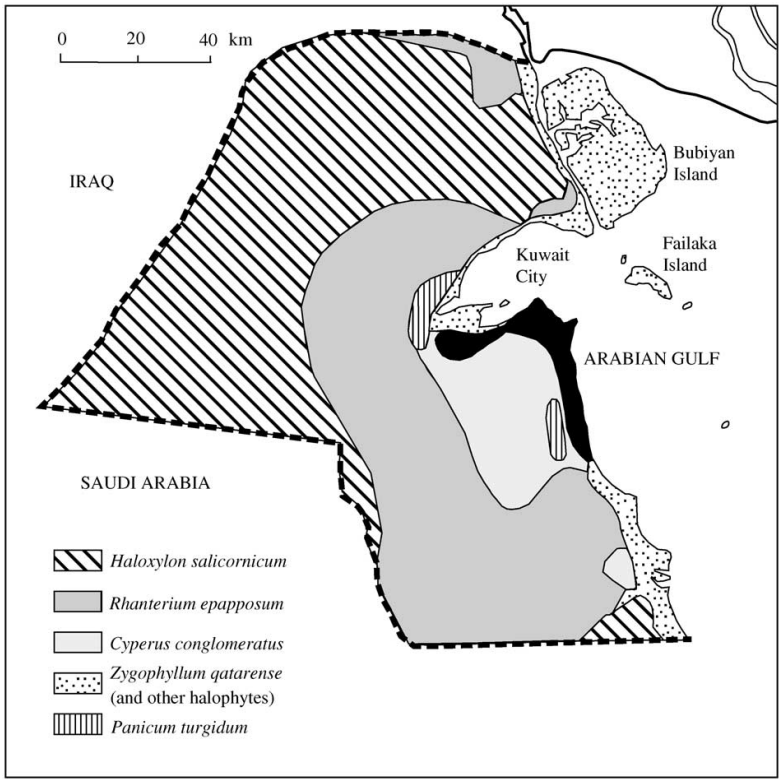


Figure 1.6: Vegetation Map of Kuwait- Halwagy and Halwagy, 1974 Ed. Brown, 2003.

The comparison between species communities within Kuwait desert was carried out by Omar *et al.* (2001) Figure 1.7, which is demonstrated on the distribution map shown in Figure 1.6 created by Halwagy and Halwagy (1974). The main illustrative changes were recorded. *Cyperus conglomeratus* community increased from 10 % to 27 %, with the potential to expand over time. *Rhanterium epapposum* community retreated to 2 %, in open desert. This community has considerably declined in the open desert areas due to overgrazing. And the same effect was recorded for *Haloxylon salicornicum and Zygophyllum qatarense communities,* they decreased from 52 % to 23 %, and from 4 % to 0.3 %, respectively (Omar *et al.*, 2001). The dramatic decrease in plant communities *Rhanterium epapposum* and *Haloxylon salicornicum*) were mainly due to environmental factors related to climate change,

drought, as well as human and military activities (Al-Awadhi *et al.,* 2001; Omar 2007; Brown, 2003).

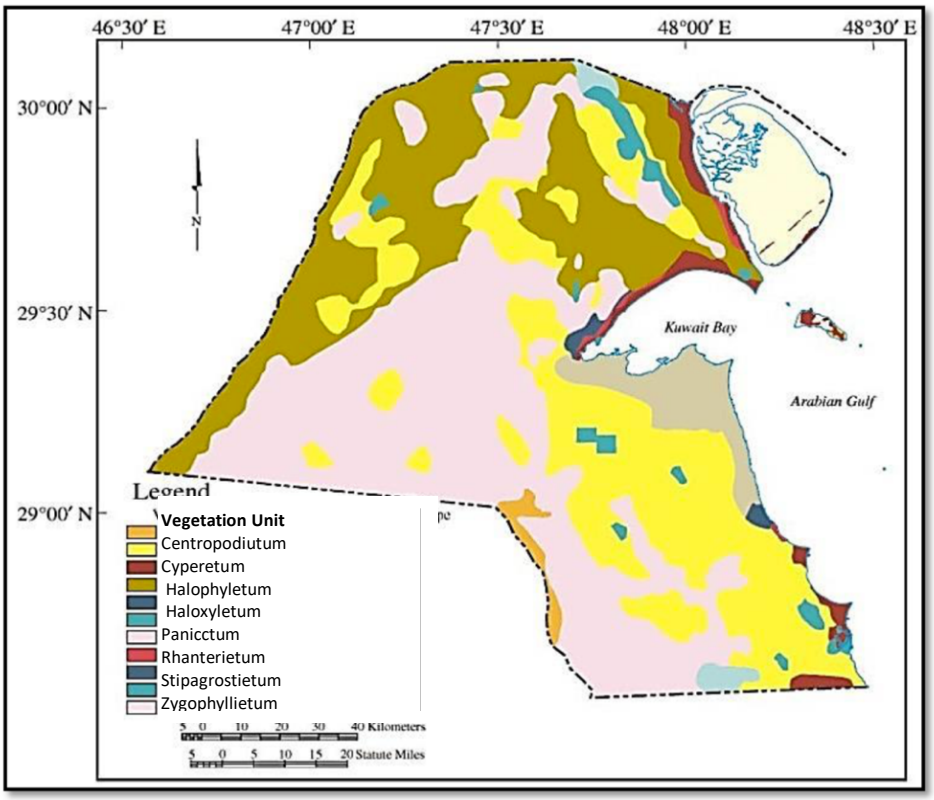


Figure 1.7: Species Communities Associated in Kuwait Desert (Omar *et al.,* 2001)

1.2.4.1 Distribution of Vegetation in Kuwait

Daoud (1976) studied the flora of Kuwait and developed the description of the vegetation of each ecosystem, he divides the area into four categories depending on the habitat, landform, and soil characteristics. The ecosystems are:

1- Dune ecosystems, a part of Umm-Negga in the extreme northeast of the country, extend along the gulf coast from Al-Dbaiyyah southwards. The author gives a detailed description of the soil characteristics. He mentions that the area is dominated by *Zygophyllum coccineum* L and *Seidlitzia romarinus* Bunge ex Boiss., *Atriplex leucoclada* Boiss., *Aellenia*

glauca (M Bieb.). In addition to *Nitraria retuse* (Forssk.) Asch*.,* and *Lycium shawii* Roem & Schult. associated with other species.

2- Salt marsh and saline depression ecosystems

a. Salt marsh fringes on the coast of Kuwait bay and Khor Al- Sabiyah. They are also present in Bubiyan and Warba Islands. In general, this ecosystem is dominated by *Halocnemum strobilaceum* (Pall.) M. Beib*. and Tamarix aucherana* Decne. in associated with other species.

b. Saline depressions occur on either side of the Kuwait- Ras Al-khfji road, west of the coastal dunes. The middle of the depression is covered with *Halocnemum strobilaceum* (Pall.) M. Beib and *Bienertia cycloptera* Bunge Ex Boiss., while the sandy edges are frequently covered by *Zygophyllum coccineum* L., *Tamarix aucherana* Decne*., Aeluropus lagopoides* (L.) Trin. ExThwaites, and *Frankenia pulverulenta* L.

3- Plain desert*,* which occupies the majority of the country and has a variety of soil types which support different communities.

a- *Cyperus steppe*: dominated by *Cyperus conglomeratus* Rottb*.,* which are located in the south and the southwest, as well as the Burgan hills*. Panicum turgidum* Forssk. located in this area around Al-Atraf. However, *Cyperus conglomeratus* has been and continues to be replaced by *Asthenatherum forsskalii* and *Stipagrostis plumose* (L.) Munro Ex T Anders. with other species.

b- *Rhanterium steppe* occurs in the central and extreme northeast of the country. The dominant species are *Rhanterium epapposum* Oliv., *Convolvulus oxyphyllus* Boiss., *Moltkiopsis ciliate* (Frossk.) I.M.Johnston*, Asthenatherum forsskalii, Cutandia memphitica* (spreng.) Benth*., Schismus barbatus* (L.) Thell*.,* and other species.

c- The deep depression area: located nearby the radio station in Kabbed, have the following species: *Gynandriris sisyrichium* Parl. Syn. Iris sisyrinchium L. alongside *Plantago ovata* Forssk., *Plantago ciliate* Desf., *Launaea capatata* (Spreng.) Dandy., *Cynodon dactylon* (L.) Pers. and *Schismus barbatus* (L.) Thell.

d- *Haloylon steppe:* occur in the northern, northwestern, and southern parts of the country. *Chrozophora verbascifolia* (Willd.) A. Juss. Ex Spreng., *Panicum turgidum, and Asthenatherum forsskalii* are all found in this area.

4- Desert plateau ecosystem, located in the extreme west of the country. *Haloylon salicornicum* (Moq.) Bunge. Ex Boiss.Syn. Hammada, salicornica, (Moq.) Iljin. is found within this ecosystem with sand accumulated clumps surrounding it. *Citrullus colocynthis* (L.) Schrad. and *Cistanche tubulosa* (Schrenk.) Wight are also found in this area. In some places within this location, land is covered by annual, biennials, and perennial vegetation, such as, *Asthenatherum forsskalii* and *Schismus barbatus*. Wadi Al-Batin area, which is part of the desert plateau ecosystem is dominated by *Zilla spinose* (Turra) Prantl., *Phalaris minos* r Retz., *Stipa capensis*, *Asphodelus tenuifolius* Cav. Baker. and other species.

Omar (2007) developed a second plant vegetation map of Kuwait (Figure 1.8), with eight botanical family groups which can be compared with the scheme proposed by Halwagy and Halwagy (1974) and Brown (2003). The regions are described as follows:

1. Haloxyletum, covers 22.7% of the total Kuwait area, dominated by *Haloxylon salicornicum* species in the north-west part of the country.
2. Rhanterietum group, consists of *Rhanterium epapposum, Moltkiopsis ciliata*, *Convolvulus oxyphyllus Centropodia*, *Helianthemum lippi*, *Stipagrostis plumosa*, and *S. forsskalii.* The

group is located in the north, the central, and the south part of the country. It is combined with other species, such as *Gynandriris sisyrinchium, Horwoodia dicksoniae, Cornulaca aucheri, Anthemis deserti, Cutandia memphitica, Plantago boissieri, Schimpera Arabicawith*, *Arnebia tenctoria* and *Arnebia decumbens.* The Rhanterietum group covers approximately 2.1% of the total area of Kuwait. According to Omar, 2007 the species has retreated and has been replaced by *Cyperus conglomeratus.*

3. *Cyperetum* group, covers 26.9 % of the vegetation map, extending from the North West to the South East of the country. The area consists of annual species like *Astragalus annularis*, *Brassica tournefortii, Plantago boissieri.* When the Cyperetum species are overgrazed it is replaced by *Cornulaca aucheri,* that are found in the South of Kuwait.
4. *Stipagrostietum* group, dominated by the *Stipagrostis plumose* species, are found in the south and southwest region. Previously, this area was occupied *Rhanterium epapposum,* until it was environmentally destroyed; subsequently it was then replaced by the *Stipagrostietum* group. This species is also found with other taxa such as: *Moltkiopsis ciliate, Centropodia forsskalii, Stipa capensis* located in the North and North West side of the country.
5. *Zygophylietum* group*,* mainly contains *Zygophyllum qatarense* with other annual and perennial salt-tolerant species such as *Salsola imbricate, Cressa cretica, Aizoon hispanicum.* The group covers 0.3% of the vegetation map of Kuwait.
6. *Centropodietum* group, dominated by *Centropodia forsskali* and *St. plumosa* is found in the South-West of Kuwait. The group covers 1% of the vegetation map.

7. *Panicetum* group, with *Panicum turgidum, Aeluropus lagopoides* and *Pennisetum divisum* found in the North-West of the Arabian Gulf and along the South-West coastal area near Umm- ALhayman.
8. Halophyletum group, with salt tolerant species such as *Tamarix aucheriana, Nitraria retusa, Halocnemum strobilaceum, and Seidlitzia Rosmarinus.* Halophyletum group covers 1.9% of the Kuwait plant vegetation map. This group is located in Sulaibikhat bay, coastal and Southern areas, and in Doha which is in the West of Kuwait City.

Omar (2007), identified 374 plant species belonging to 55 families in the Kuwait desert, where 256 are seasonal, 83 herbaceous perennials, 34 shrubs species, and only one native tree species locally known as "Talha"(*Vachilli pachyceras*).

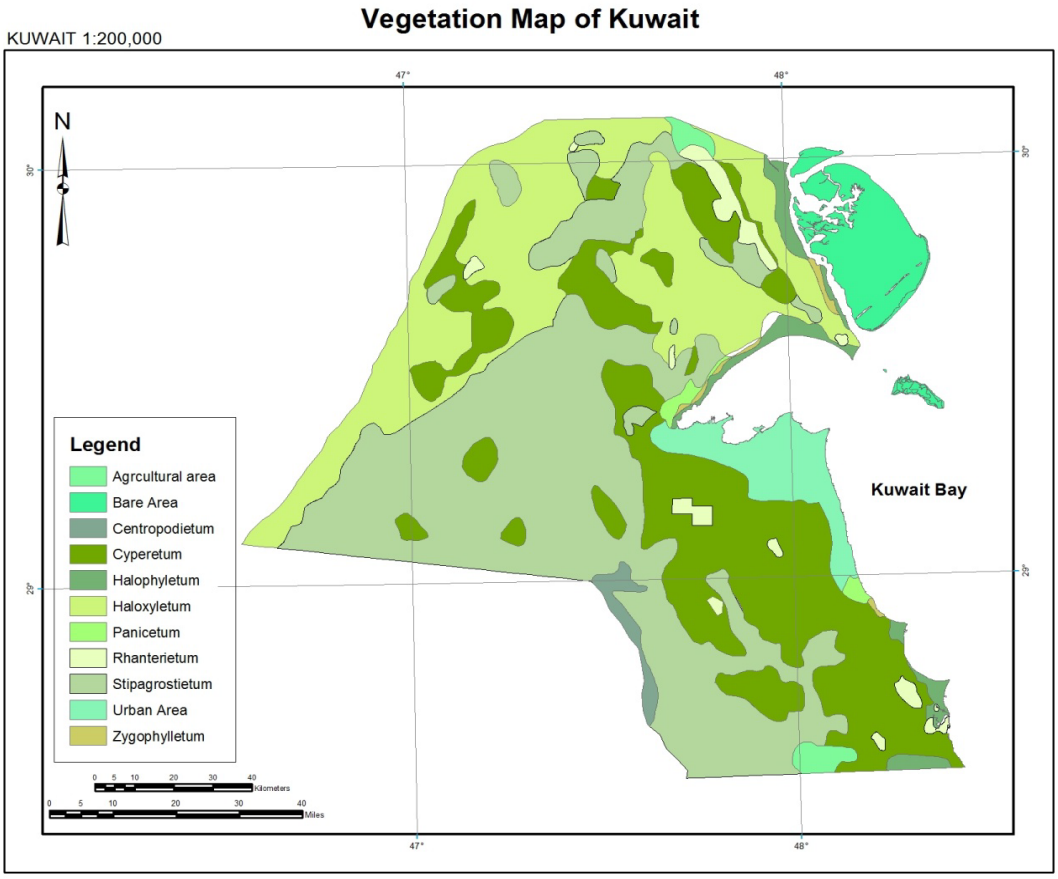


Figure 1.8: Vegetation Map of Kuwait After Omar *et al.,* (2001)

1.2.4.2 Biodiversity Conservation

Brown and Al-Mazrooei, (2003), carried out a study in Northern Kuwait to investigate vegetation recovery. The area has been enclosed and enjoys protection from harmful activities such as camping and overgrazing. Inside and outside of the enclosure, the vegetation cover was compared after Four years. Also, the authors compared the results with another 20 years old protected area in central Kuwait. The study confirms that natural protection by fencing and preventing the harmful practices such as overgrazing, were concluded to be the cheapest and most practical processes for re-habitation which ensures long-term survival. The terrestrial protected areas in Kuwait (Figure 1.9), reached 3.092.15km², representing approximately 17.35 % of Kuwait's total area. Table 1.3 describes the terrestrial protected areas in Kuwait and the managerial responsibility for each

Table 1.3: The Terrestrial Protected Areas in the State of Kuwait- Total Area and Management Responsibility.

NAME	MANAGEMENT	AREA KM²	YEAR
SABAH AL-AHMED WILDLIFE RESERVE (KUWAIT NATIONAL PARK)	(KVWC)	330	1986
AGRICULTURE RESEARCH CENTER (SULAIBIYA) (KABD)	KISR	40	1975
AL-JAHRA POOL NATURE RESERVE	EPA	3.5	1987
DOHA NATURE RESERVE	EPA	4.5	1988
AL-SHAGAYA	PAAFR	1	1989
RAWDTAIN	PAAFR	1	1989
MITLAA	PAAFR	1	1989
MANAGIESH AND MAGWAA	PAAFR	1	1989
SULAIBIKHAT BAY	EPA	0.75	1989
UM-NEGA	KISR, KVWC	222.45	2011
HUWAIMILIYAH,	KISR, KVWC.	273	2011
WADI-ALBATIN,	KISR, KVWC.	601	2011
UM-GUDAIR.	KISR, KVWC.	545.7	2011
DELEE AL-GURAIN	KOC, KVWC.	6.25	2011
AL-ABDALIYAH	KOC, KVWC.	1	2011
THE DEMILITARISED ZONE	Ministry of interior	1060	2001
TOTAL AREA FOR PA		3.092.15	17.35%

(KVWC) Kuwait Voluntary Work Center, (K-EPA) Kuwait Environmental Public Authority, (KISR) Kuwait Institution for Scientific Research, (PAAF) Public Authority for Agriculture Affairs and Fish Resource, (KOC) Kuwait Oil Company.

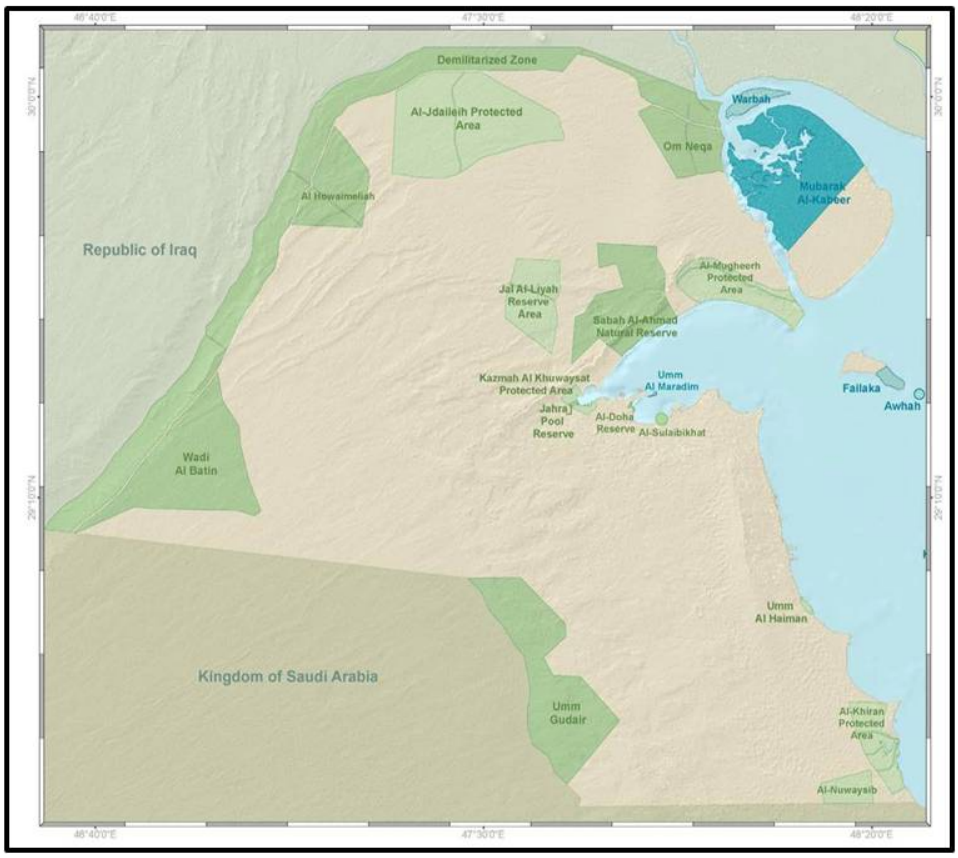


Figure 1.9: Proposed and Existing Protected Areas in the State of Kuwait Proposed by Conservation of Heritage and Natural Biological Diversity (EPA.KU 2011).

Sabah Al-Ahmed Wildlife Reserve (Kuwait national park): Wildlife Reserve located on the North-Eastern part of Kuwait and occupies a total land area of about 330 km^2. Many geomorphological defined ecosystems are observed in this reserve. These include coastal plains, sabkhas-nabkha complex, hilly terrain, *wadis* and depressions, falling dunes, and sandy sheets. The land relief in the reserve ranges from 0 m (at the coastal strip) to about 120 m above sea level (at its western and south-western portions). The reserve area is divided into two sections (coastal and desert), intercepted by AL Subbiyah Road.

Al-Jahra Pool Nature Reserve: One of the non-marine wetlands in Kuwait, is a protected bird sanctuary managed by EPA. The PA was established in 1987 with an area of 2.5km², later expanded to 3 km² in 1998 and then to 3.5km² in 2001 (Evans, 1994). Al-Jahra pool, characterized by the presence of four different environments: the coastal, the marshes, sandy, and freshwater habitats (Alshahabi, 2006). The sandy environment is equivalent to 52% of the protected area, characterized by sand dunes and many kinds of perennials and seasonal plants. The area is a suitable habitat for reptiles and mammals (Figure 1.10). In the early nineties' amendments were made to the drainage pipes, and according to this construction, the drainage water flows through the middle of the protected area and directly into the sea. This resulted in the water level becoming below the level of the pond. The amendments solved frequent flooding in the province of Jahra, hence the pond lost its permanent source of water. However, the pond area reduced until it dried completely, refer to field photos Figure 1.11. The rainwater became the only source that feeds the pond in the rainy season.



Figure 1.10: Al-Jahra Pond Field Photos (2011): A, B part of the flora in Al-Jahra bound *haloxylon salicornicum, Tamarix aucheriana*, *Rhanterium epapposum*; D, E: birds observed in the protected area (Photos: M. Nassep).



Figure 1.11: Field Photos of Al-Jahra Pond: A: The sign of line extension of the oil; B: The drought area (Z) compared with the wetland by sewage (Y) and the location of the drain water Passes in the reserve (X); C: Sand fence area and the urban area; and D: The drain-water passes in the reserve for the transfer of rain water; and E: undeveloped *Tamarix* spp. in the area that turned into a dry area due to the construction of the drain water passes (Photos: M. Nassep, 2017).

Doha Natural Reserve: located on the coastal belt at 29°22'North 47°49'E South Kuwait Bay, established in 1988 by municipality decree No. (LH/28/9/88), about 20-25 km West of Kuwait City center, in the Al- Jahra area. It has an area of 4.5 km² (Evan 1994). The location has a unique importance for the migratory birds. Kuwait municipality allocated the area as a

reserve in 1988 by fencing it and included it within a project of Environmental Public Authority. At least 70 bird species were recorded in the area (Omar, 2008; Evan, 1994).

Sulaibiya Research Station (kabd): one of the oldest protected areas since 1975. The area was 20 km² and later expanded to 40 km² in 2001. It is located Southwest of Kuwait City and managed by the Kuwait Institute for Scientific Research - KISR (Omar *et al.,* 2007). The vegetation in the area is dominated by *Rhanterium epapposum* and *Cyperus conglomerates*. Annuals thrive during each rain season, among the common annuals are *Plantago boissieri, Schimpera arabica, Cutandia memphitica, Lotus halophilus,* and *Horwoodia dicksoniae.* Common perennial species are *Fasetia aegytia, Stipagrostis plumose*, and *Panicum tugidum* (Omar, 2008).

Huwaimiliyah area, was proposed as a protected area by Kuwait Institution for Scientific Research and Environmental Public Authority- EPA. It is located in the Northwest side of the State of Kuwait, with an area of 273 km². Geographically, the region has a series of sandy plains and undulating crescent of heavy vegetation. The site consists of annual plants such as *Horwoodia dicksoniae*, *Fagonia glutinosa*, and *Savgnya parviflora* (Al–Sidrawi, 1985).

Wadi Al-Batin natural reserve: this area is located in the Western corner of the State of Kuwait, away from construction. It has an area of 601 km². The reserve has a unique topography located within the drainage network and sub-valley of Wadi Al-Batin. There is a wide range of vegetation associated and recorded in this area, such as: *Haloxylon salicornicum*, *Koelinia linearis*, *Plantago coronopus*, *Savignya parviflora,* and *Launaea mucronata* (Omar, 1985). The area also consists of rare plant species such as *Astragalus dacylocarpus* and *Arnebia decumbens* (Omar, 2008).

Umm Negga reserve: located in the north-eastern region with an area of 216.2 km². It

extends from the high semi-circular sand dunes and includes salt marshes near the coast. The vegetation consists of *Haloxylon Salicornicum* and *Lycium shawii* which are perennial taxa reaching 3 m (Al–Sidrawi, 1985).

Um-Gudair protected area: located in the South-West of the State of Kuwait, with an area of 545.7 km². The regions importance came from the presence of some unique geological and morphological hills such as: Om-Alfawares hills which produces a rain water collection area, forming (Khabra) of Um-Gudair Khabra and Jalham Khabra. The area contains dense grass vegetation and annual plants in the wet season such as *Anthemis deserti* and *Picris babylonica* (Al–Sidrawi, 1985).

Delei Al-Gurain protected area: managed by Kuwait Oil Company (KOC) in collaboration with the Volunteer Work Center. The main objective of establishing this area is to rehabilitate and resettle organisms that have become extinct from the local environment. The area previously suffered from significant deterioration due to overgrazing, camping, vehicular traffic and human activities. It was a desert environment characterised by a heavy vegetation cover of *Haloxylon Salicornicum*, *Rhanterium epapposum* and many other species. The main objective is to restore the ecological balance of the site which occupies an area of 6.25 km² (Al-Ghanem and Al-Shehabi 2006). Within the re-habitation process, there was a re-plantation project whereby plant seeds were transferred from Sabah Al-Ahmad protected area. This included species, such as, *Polygonaceae* spp*,* Haloxylon *Salicornicum*, *and Rhanterium epapposum* (Al-Ghanem and Al-Shehabi 2006).

Al-Abdaliyah: the environmental project accomplished during the period between January and April 2011. The project's basic idea was to transform Abdaliyah, a part of West Kuwait Operations Group's area, from a camping lot congested with waste to natural oasis.

The project followed by creating suitable habitats for a natural life of plants and wild animals, such as building slopes for water retention. The area consists of species such as *Ziziphus nummularia*, *Acasia tortilis*, *Acasia ehrenbergiana*, *Tamaris aphylla*, *Azadirachta indica*, *Savadora persica*, *Juncos rigidus*, *Rhanterium epapposum*, *Haloxylon salicornicum*, *Atriplex leucoclada*, *Cyperus conglomeratus*, and *Lyceum shawii*.

Demilitarised zone: the border strip between Kuwait and the Republic of Iraq, stretching from Al-Salmi in the Southwest to Umm Qasr in the Northeast for about 212 kms long. The ribbon extends a 5 kms wide area in Kuwaiti territory. The area is a demilitarised zone which was a decision made by the United Nations in 1993-1994, this resulted in the banning of harmful practices of human herding, grazing, camping and many more. This helped to stabilise the soil, increased vegetation and assisted in the growth of rare plant species. Resolution No. 26/2001, further increased the amount of nature reserves, this subsequently brought wildlife to normal in Kuwait.

Other protected areas which endured an ecological study, focussed on research and conserving the natural resources. These areas are managed by the Public Authority of Agriculture and Fisheries (PAAF). The reserves are used for land reclamation and land grazing studies. The classification of the terrestrial protected area proposed by IUCN (Dudley, 2008), and the management objectives proposed by management authorities (Table 1.4), the protection of the terrestrial protected area in the State of Kuwait falls under five categories: I, II, IV, V and VI.

Table 1.4: Classified Terrestrial Protected Area According to the IUCN Classification.

Name	Management objectives	IUCN classification
Sabah Al-Ahmad Nature Reserve,	"Physical and biological importance to conserve and manage natural renewable recourses, recreation, education, and research opportunities to the public".	Category II: ecosystem protection and recreation (National Park).
Al-Jahra Pond,	Non-marine wetland protected as a Nature Reserve and bird sanctuary.	Category IV: conservation through management intervention.
Doha Bay	Consist of a reasonable, significant number of migratory birds.	Category IV: conservation through management intervention.
Sulaibiya (Kabd)	Research and conserving the natural resources	Category I: science or wilderness protection (a) Strict Nature Reserves, and (b) Wilderness Areas
Um-Naga,	Contain a high semicircular dune	Category V: Protected area managed mainly for landscape/seascape conservation and recreation (Protected Landscape/Seascape).
Huwaimiliyah	Existence of a series of sandy plains and undulating crescent by heavy vegetation	Category IV: conservation through management intervention.
Wadi-AlBatin,	Importance unique topography	Category V: Protected area managed mainly for landscape/seascape conservation and recreation (Protected Landscape/Seascape).
Um-Gudair	The unique geology and morphology hills like Um-Alfawares hills, as well as the presence of area of gathering rain water	Category V: Protected area managed mainly for landscape/seascape conservation and recreation (Protected Landscape/Seascape).
demilitarised zone	Preserve of rare plant species and wild animals and stabilize soil- with a low level of human occupation	Category VI: sustainable use of natural ecosystems (Managed Resource Protected Area)

Diele Al-Grean	Rehabilitating environment to what it was in the past, through the resettlement of plants and organisms - controlled to ensure the maintenance, conservation, and restoration of particular species and habitats	Category IV: conservation through management intervention.
Al-Abdalia	Transform area from a camping lot congested with waste to natural oasis.	Category IV: conservation through management intervention.
Ecological studies P.A.	Research and conserving the natural resources, expected to remain in its natural condition	Category VI: sustainable use of natural ecosystems (Managed Resource Protected Area)

Cohen *et al.,* (1991) mention that "e*x situ* conservation acts as a back-up for certain segments of diversity that might otherwise be lost in nature and in human-dominated ecosystems". The Kuwait Institute for Scientific Research (KISR) Herbarium was established during 1970 at the Arid Land Agriculture and Greenery Department (KISR) and developed a database that includes the primary data form (Zaman, 1997).

Restoration of vegetation which assisted with rehabilitation is one of the useful techniques to mitigate desertification (Khalaf *et al.,* 1995; Brown, 2003; Al-Awadhi *et al.,* (2001 and 2005); Misak *et al.*, (1999, 2000, 2003, 2009 and 2010). Suleiman *et al.,* (2007) describe an experimental study in Kuwait's desert to acclimatise plants to enhance the microclimate and periodically assess native flora's status at the site. Desert seed mix planted, and soil and water samples were analysed for various parameters. The authors concluded that the site improved drastically since summer 2005, which led to improved soil conditions. *Ex situ* conservation is currently the most commonly used method for increasing crop genetic diversity, it is source of material for research and ecosystem restoration. However, *Ex situ*

conservation can limit the evolutionary processes of the species within the environment, and interrupts the genetic adaptation with the environmental conditions (Zegeye, 2017).

1. 3 Aims of the Thesis

The research described in this thesis intends to contribute towards the conservation of the Kuwaiti flora, through the development of strategies to aid resource utilization and desertification mitigation within Kuwait.

This study had the following objectives:

1. To establish conservation priority within the Kuwait flora by using a technical tool to manage, analysis, and display the geographically referenced information.
2. The production of an identification aid for the priority flora to assist in field identification and conservation of Kuwaiti plant species.
3. Establish the threatened status and develop a global red list category for the prioritised species from the flora of Kuwait.
4. Evaluation of the effectiveness and most appropriate management of the Kuwait / Iraq border strip protected area (Demilitarised zone), through the application of the IUCN Best Practice Guidelines (2006).
5. Prepare a specific conservation plan for native plant species of Kuwait.

1.4 Thesis Overview

The current chapter gives an environmental and ecological overview of the Arabian Peninsula and the study area, Kuwait. Chapter 2 describes the problem of desertification background, threats, and the importance of the research component.

Chapter 3: The creation of the priority list for further investigation of species in Kuwait by developing specific criteria, using data gathered from Kuwait University, Kew Garden herbarium UK, and the Global Biodiversity Information Facility (GBIF). The data used for predictive species distribution has been modelled with ArcGIS. The analysis focusses on species rarity and protection status at the state level depending on (A) the number of individuals, (B) the time range of specimen collection, and (C) the size of the geographical range: (i) the extent of occurrence (EOO); (ii) area of occupancy (AOO), (D) protection status, and (E) threats affecting the occurrence. Through the use of IUCN threat classification scheme, observations have been recorded using the National Naturalisation Plan Strategy map developed by Council for Planning and Development - State of Kuwait (2016).

Chapter 4 reports the development of an identification aid using morphological characteristics to distinguish the prioritised plant species found in Kuwait. This tool was developed as a scientific aid future fieldwork. It also provides a useful tool for general users to improve their knowledge of the natural heritage of native species.

Chapter 5 established the global and regional Red List categorisation of prioritised plant species in Kuwait

Chapter 6 assesses and evaluates the effectiveness of the management plans of protection to strengthen management of the demilitarised zone protected areas between the State of Kuwait and the Republic of Iraq. The assessment does this by reviewing the existing work on management, reviewing methodologies, finding patterns and common themes in evaluating the results, and investigating the most important factors leading to effective management.

Chapter 7 is the general discussion. The research helps in the development of a series

of recommendations and further action.

Overall, the research discusses the establishment of conservation targets for the priority species and the policy and legislative implementation needed. This gives a clearer vision of the protection and further development of the desertification mitigation plan according to the environmental threats and its effect.

Chapter 2: Background

Biodiversity Conservation and Desertification Mitigation in Kuwait

2.1 Introduction

The application of sustainable land management depends critically on the environmental resources available and the socio-economical value of them. However, it can be challenging to deal with it due to the enormous un-sustainability of resources security, climate change, the increase in population which subsequently effects the biodiversity due to misuse of ecosystem services (Initiative, 2015). In Kuwait, native species are threatened, endangered, or have difficulty germinating under extreme weather conditions. Due to harsh environmental conditions, overgrazing, human pressure, and Gulf War activities, desertification in Kuwait increased in recent years (Suleiman, 2007). Al-Awaadhi (2005), determined the magnitude of desertification and land deterioration in open selected sites in Kuwait. The study concluded that overgrazing is the main factor of land degradation in Kuwait, followed by quarrying and camping. The misuse of land resources, in addition to the growing demands of good and services, leads to rapid and intensive land deterioration and desertification (Initiative, 2015). Many scientists reported the rate of biodiversity loss to be rising at an unprecedented rate (Asem and Roy, 2010). The average annual area of Kuwait's desertified land is estimated to be 285 km^2 (Misak 2009; Misak & Al-Harban, 2013). Additionally, climate change predicted to have an even more significant impact on diversity. The average temperatures are predicted to rise by 2–4°C over the next 50 years and cause considerable disturbances in regional and seasonal precipitation (IPCC, 2007). Also, Safriel *et al.,* (2005) stated that the mean potential evapotranspiration in dryland areas is at least 1.5 times greater than the annual mean precipitation. As a result, the underground water profile of these regions has a high level of

salinity. Kuwait's environmental conditions are classified as dryland that receives low amounts of precipitation, rarely exceeding 100mm. Due to Kuwait being a dryland ecosystem, more effort should be applied to regulatory services for threats and climate control (Yirdaw *et al.,* 2017).

The biodiversity of dryland regions is considered significant biological capital; it represents the crops for long-term food security, active ingredients, and pharmaceutical and cosmetic industries for most people worldwide. However, Yirdaw *et al.,* (2017) claimed that the biodiversity in arid regions is not well documented. The names and number of species that are in danger of extinction are unknown. Arid zone vegetation typically comprises of perennial and annual grasses, herbaceous shrubs and small trees. The adaptations of native species enable them to grow more slowly and survive in the harshest environmental conditions. Some species in arid regions have specially adapted root systems whilst others are characterised by specialised leaves. All of these adaptations allow them to withstand prolonged periods of drought, alongside many other adaptation techniques (Sharma and Tewari, 2011). Biodiversity of dryland ecosystems is an essential aspect of the local cultural identity whereby the species are tolerant of drought.

2.1.1 Socioeconomic Value of Native Species

To maintain a productive ecosystem, it is vital to understand the importance of dominant native species in a variety of ecosystems (Robinson, 2003). Active planning for conservation mostly depends on using native species or carefully introduced ones, especially in challenging conditions (FOA, 2009). Native plant communities have actual and potential value that directly and indirectly provides benefits for humans. The Oman Animal and Plant Genetic

Resources Center (2017), maintains a list of plant genetics of crops and the diversity which is used for other purposes. Some types of useful species are as follows:

- Non-food species with socio-economic value that are used in: the medical industry or directly used as medication, used as ornamental plant species and the species that have recreational value.
- Species with indirect benefits that form the basis for stock harvesting and grassland species

2.1.1.1. Nutritional Native Species

Many of the most important food crops on earth have their origins in drylands. These traditional foods continue to be marketed globally in the era of health awareness (Bonkoungou, 2001). According to the literature, a variety of native desert plant species are considered nutritious food sources. Native plant species referred to in a study carried out by Mandaville (2011) and Tewari (2016), some of which are part of the biodiversity of the Kuwait region. Some of these species' roots, tubers and bulbs can be eaten raw or cooked such as: *Emex spinosa* (L) is juicy and sweet; *Allium sindjarense* Boiss. & Hausskn. ex Regel*, Calligonum comosum* L'Hér*, and Gagea reticulate* (Pall.) have edible bulbs or stems; *Allium sphaerocephalum* L. species are a wild onion species with green leaves. In addition, *Cynomorium coccineum* L. is a parasitic plant with edible fleshy parts. The Authors also mention species used for their green parts which are eaten raw such as: *Anisosciadium lanatum* Boiss, *Aaronsohnia factorovskyi* Warb. &Eig*, Rumex pictus* Forssk*, and Erodium spp* which is used for spicing food. Mandaville (2011) and Tewari (2016), describe the nutrition value of seeds, grains, flowers and fruits for some desert species like *Ziziphus spina-christi (L.),*

Citrullus colocynthis Linn., *Mesembryanthemum forskahlii* Hochst.ex Boiss*., Aizoon canariense* L*.,* and *Panicum turgidum* Forssk.

2.1.1.2 Medicinal Native Plant Species

There are between 35,000 and 70,000 plant species used for medicinal purposes worldwide; approximately 6,500 species occur in Asia (Bhattarai *et al.,* 2010). Deserts because of their extremely marginal conditions for plant growth provide a particular resource for traditional medicinal ingredients which are extracted from leaves, seeds, roots, or even entire plants. Desert species are involved in the treatment of a variety of illness categories, such as dermatological and skin diseases, fever, respiratory illnesses, and malarial diseases. They are also used to treat bile diseases and disorders, diarrhoea and stomach illnesses, wound infections, teeth cleaning and mouth hygiene, headaches and pain in other parts of the body, abdominal and digestive problems, urinary illnesses and many other general health conditions (Bhattarai *et al.,* 2010; Ghazanfar and Al-Sabahi, 1993; Saganuwan, 2010). Species with medicinal and clinical applications include *Thymus serpyllum* L*., Ziziphus vulgaris* Lam*, Salvadora persica* L*., Pistacia lentiscus* L*., Tephrosia apollinea* (Delile) DC*, Curcuma longa* L*., Zingiber officinalis* Roscoe*, Vitis vinifera* L*., Nerium oleander* L. and *Ziziphus spina-christi* (Ghazanfar and Al-Sabahi, 1993). In addition, *Haplophyllum tuberculatum* Juss., *Pulicaria crispa* Sch.Bip*., Ononis serrata* Forssk*.,* and *Achillea beiberstenii* Afan. are used in the control of cancer diseases (Kuete *et al.,* 2013). Rahman *et al.,* (2004) also mentioned a variety of species with antimicrobial activities, such as *Alhagi maurorum* Medik*., Atractylis Carduus* Forssk., and *Mesembryanthemum crystallinum.*

2.1.1.3 Ecological Balance

In order to sustain a habitat, it is vital to maintain the balance of biodiversity within the specific ecosystem, and ensure stability of gradual change to confirm natural succession (WWF, 2020). Suleiman *et al.,* (2007) carried out a study using selected native species aiming to assess flora and fauna status at sites in Kuwait. The study concluded that native plants are highly adapted to the local environment and climate conditions in Kuwait. Regarding the harsh climate conditions with summer air temperatures exceeding 50°C, native plants assist conservation by contributing to genetic diversity. Furthermore, native plants provide a highly efficient mixture of species which are ideal for ecological consequences (Suleiman *et al.,* 2007). Knowledge of the socio-economic value of species can be used to develop a strategy needed for conservation (*ex situ* or *in situ* conservation).

2.2 Plant Biodiversity Threat in the Arabian Peninsula

Land degradation is a severe and widespread threat affecting the livelihoods of 1.5 billion people worldwide, of which one-sixth, or 250 million people, reside in drylands (IPCC, 2019). Globally, it is estimated that 10–20% of drylands are degraded, and approximately 12 million ha are degraded each year (Yirdaw *et al.,* 2017). In the Arabian Peninsula, severe land degradation was recorded in the last five decades (Ghazanfar, 2010). The main reason for the deterioration of land is the increased demand on ecosystem services, housing, tourism and development and livestock overgrazing. In addition, war further intensified the deterioration of land and destroyed a variety of ecosystems. Above all threats, climate change and global warming continues to increase the complexity of the threats and aridity in Arabian Arid region. The combined above threats have led to difficulty in achieving successful conservation

strategies. Furthermore, the low environmental awareness results in a lack of strong implementation of regulations, which has further led to a continuation of degradation and expansion of the desertified land (Ghazanfar, 2010; Al Midfa, 2010). Arabian Peninsula members economically depend on oil exploration. However, oil exploration activities in the desert are not well monitored, even though this area already suffers from a decline in biological diversity. The current processes of the oil industry in the region leads to deterioration of land and desertification. Explorations within the desert ecosystem impacted the conservation of biodiversity, however, the intensity of the impact is not well monitored (Duncan *et al.,* 2014).

The above threat issues affect all countries in the entire Arabian Peninsula region. However, individual regional research indicates that there are other threats affecting the specific area which are dependent on a variety of factors and the conservation response. For instance, in Bahrain, urban expansion intensifies the demand on land area through the application of dredging and infilling operations (A Protected Areas Strategy for the Kingdom of Bahrain, 2015). The application intensely affected habitats and biodiversity in the area (Zainal *et al*., 2012). However, in Qatar, the increase in population developed an increased demand on housing and infrastructure (road and infrastructure improvement) (Yasseen and Al-Thani, 2007). Moreover, the environment in Qatar faced the challenge of development of industrialisation processes (Richer, 2009).

The area of United Arab Emirates (UAE) and Sultanate of Oman has a variety of geographical altitudes. Wadies and valleys can accumulate dense vegetation. The area also has high elevation forming mountains which are associated with more dense overgrown vegetation (Ghazanfar, 1998; Owen, *et al.,* 2020). However, the climate and the harsh

environmental conditions stress biodiversity and make conservation strategies are key in sustaining desert areas. Moreover, the vulnerability and decline of biodiversity, in UAE in particular, resulted from industrialisation, rapid urbanisation, and the introduction of invasive species. While in Oman, 11 distinct habits are currently considered under threat of extinction to different extents. The Oman area has 78 habits with more than 1,204 plant species identified (National Report on the International Year of Biodiversity Sultanate of Oman, 2010). The decline in habitats of Oman, is potentially due to overgrazing, degradation of natural area, and introduction of invasive species.

Saudi Arabia consumes the majority of land mass of the Arabian Peninsula, with a wide range and variety of geographical altitudes. The change in elevation results in variation in biodiversity. Saudi Arabia land cover has coastal, Sabkha, desert, shrub communities, woodlands, mountains and wadies vegetation (Edgell, 2006; Ghazanfar *et al.* 2019). The depletion and deterioration of resources in Saudi Arabia varies and changes geographically. For instance, in the Riyad area the woodlands are under deforestation due to the use of wood for energy and cooking (Al-Subaiee, 2016). The deterioration of the land causes intensive pressure on the vegetation cover and reduces the density of plant species. Also, wetland and coastal land in Saudi Arabia, like other Peninsula coastal regions, has environmental and economic value to human well-being. These coastal regions are threatened by development and tourism. (Abdulkhader *et al.,* 2009; IPCC, 2007, Al-Subaiee, 2016). Sabkha and wetland regions in Saudi Arabia are under severe and strong challenge due to human expansion and coastal development, which leads to habitat degradation and lose of biodiversity (IPCC, 2007, Ahmad Abbasi *et al.* 2010).

The information related to terrestrial biodiversity in the Arabian Peninsula has a

significant gap. The data available is not systematically expressed to cover the baseline of a habitat and particular species associated with it (Javed, 2015; Ahmad Abbasi *et al.* 2010). Also, the principal of strategic terrestrial biodiversity conservation in not clear in most of the Arabian Peninsula (Javed, 2015). The enhancement of microhabitats can be addressed through prioritising threats regionally and sharing experiences for future development strategies (El-Keblawy *et al.,* 2016).

2.3 Impacts and Threats on Biodiversity in Kuwait.

The intensive land degradation in Kuwait is due to many factors. The geographical location of the country is in an arid region, which has intense and scarce rainfall, prevalent drought periods, frequently strong wind, and heavy rain incidents. Primarily, the above environmental climatic conditions lead to desertification in the region (Al-Awadi *et al.,* 2003). However, the intensity of the desertification increases due to other human misuses of land, in addition to the over exploration of oil and economic resources in desert (Al-Awadi *et al.,* 2003; Omar *et al.,* 2016). As mentioned earlier, oil exploration activities in desert are not well monitored. Furthermore, overgrazing, seasonal camping activities and off-road vehicles decrease the level of germination and change the structure and composition of soil (Al-Awadi *et al.,* 2003). The impact of drought on the natural vegetation discussed in Omar, (2007a, b) and Omar *et al.,* (2016), estimated that perennial shrubs cover approximately 27% of Kuwait's surface, while perennial grasses and sedges cover 67.9% of the area. The desert of Kuwait is under severe pressure and is moving towards extreme desertification. Several main interacting factors increases the pressure of land degradation, which has led to a reduction in the natural vegetation that has influenced conservation success (Al-Dousari and Al-Awadhi, 2012). The

loss of vegetation cover has led to potential implications for ecosystem services (Omar *et al.,* 2016).

Habitat conservation is affected by existing threats and the resilience of the ecosystem. However, research related to the understanding of the current status of the adapted native species help in developing strategic biodiversity conservation (Al-Dousari and Al-Awadhi, 2012). Studies related to the change in environment need to be connected to the change in conservation strategies applied, which is implemented according to the new condition. Additionally, intensive land and soil degradation and landscape fragmentation have led to serious and pressing problems (Omar *et al.,* 2016).

2.3.1. Desertification in Kuwait

The term 'desertification' is somewhat controversial and refers especially to the reduction in plant productivity, a decline in species diversity and the loss of soil structure and resources (Brown and Al-Mazrooei, 2003). Brown (2003) mentioned the concept of desertification adopted by Dregne (1986). The idea includes the following features: "(a) reduction in vegetation productivity, (b) decrease in species diversity, and (c) increase in aeolian processes, such as the erosion, transportation, and deposition of sand". As stated by Al-Awadhi *et al.,* (2001, & 2005) and Misak *et al*., (2000, 2009 and 2010), land degradation processes prevail in most of the terrestrial environment of Kuwait, which constitutes to approximately 80% of the country. In the open desert areas (approximately 75% of Kuwait), livestock grazing is the primary land-use type. In agricultural areas (approximately 2.7% of Kuwait), soil depletion productivity, water wells and soil salinisation have been recorded (Misak *et al.,* 2000, 2009 and 2010).

2.3.1.1 Indicators of Land Degradation in Kuwait

Al-Awadhi *et al.,* (2005) discussed the indicators of land degradation recognised in Kuwait; these factors are as follows:

a. **Soil erosion by wind -** Sandstorms are frequent in Kuwait, especially in summer due to the low topography, drought, sparse vegetation, and fragile topsoil. The recurring strong turbulent winds also increases the sandstorm events in the region (AL-Hurban and AL-Osted, 2010; Al-Awadhi and Misak, 2000, Ramadan and Al-Dousari, 2013).

b. **Soil erosion by water -** Rainfall with different intensities impacts Kuwait and it can cause flood events. This has been experienced in February 1993, December 1995, November 1997, March 2002, January 2007, November 2009, January-February of 2011, and September 2018. The erosion in arid areas has increased the severity of soil erosion which reduces soil fertility (Kuwait International Airport 2019; Misak, 2013; Li, 2000).

c. **Deterioration of vegetation -** There has been an intensive decrease and decline in plant communities such as *Rhanterium epapposum* and *Haloxylon salicornicum,* while grass and sedge communities have increased. Al-Awadhi *et al.,* (2001); Omar, (2007); and Brown, (2003) mentioned that the main environmental factors leading to changes in plant communities are climate change and drought, in addition to human and military activities.

d. Soil oil pollution - Oil pollution resulting from the deliberate burning and spillage of oil from oil wells during the First Gulf War impacted air quality, terrestrial ecology, marine ecology, socioeconomic aspects, and public health. Before the liberation of Kuwait in February 1991, 1321 different oil fields were destroyed in Kuwait, and a

total of 608 oil wells were set on fire, which burned 4-6 million barrels of crude oil per day (Al-Damkhi, 2007). Catastrophic events that cause severe damage to the terrestrial environment can be easily observed from TM and SPOT satellite images (Al-Awadi *et al.,* 2005). Studies carried out by Kwarteng and Bader, (1991); Kwarteng *et al.,* (1999); and Omar *et al.,* (2002) described three types of terrestrial oil pollution in Kuwait: oil lakes of 460 million gallons of oil extended 65 km along the coastline of Northern Saudi Arabia. The lakes contaminated 49 km^2 of the Kuwait desert (Issa, N and Vempatti, S., 2018). The second type of oil pollution was tarcrete, a term for the oil rain or oil mist that occurs in the upper layers of unconsolidated soils (Kwarteng, 1998). The third type of contamination was oil trenches, which are holes with different widths and lengths filled with oil along the Southern border zone of Kuwait (Al-Ajmi *et al.,*1998) and the Northern coastal plain (Omar *et al.,* 2001).

e. **Soil Compaction, Crusting and Sealing: Biological soil crusts -** Al-Awadi *et al.,* (2005) mentioned that soil compaction, crusting and sealing detected in rangeland in the Southern part of Kuwait, leads to soil degradation in the Kuwait desert. It is caused by low structural stability due to trampling by livestock and off-road vehicles. Biological soil crusts lack proper documentation in Kuwait and the Arabian Peninsula (Eldridge, 2000; Schulz *et al.,* 2016). It has important effects on vascular plants in the topsoil layer. This is because they retain soil moisture for more extended periods of time, increase nutrient uptake through nitrogen fixation and reduce erosion of the soil surface from wind and water (Belnap *et al.,* 2001). According to Misak *et al.,* (2001), soil compaction reduces the infiltration capacity of soil by 40-100% and increases the bulk density of the soil to 50% compared to that of uncompacted soils.

At least 65% of Kuwaiti soil are affected by some degree of compaction. Soil compaction leads to surface runoff, soil erosion by water, natural vegetation deterioration and sand drift becoming more frequent all over the Kuwaiti desert.

f. **Salinisation -** As a result of the climate conditions and high temperatures, which reach more than 50 degrees in Kuwait, the evaporation increases which leads to dry sand and leaching of salt into the soil profile (Shahid *et al.,* 1999). Brackish water used in the irrigation of the agricultural areas further increases the problem of salinity. KISR (1999) mentions that 23,000 ha from the 785,000 ha of agricultural land in Kuwait is irrigated by brackish water.

2.3.1.2 Factors Influencing Land Degradation.

Research of rehabilitation on drylands is considered less common (e.g., Dorrough and Moxham 2005; Ravi *et al.,* 2009, 2010). Rehabilitation often uses protected areas in dryland due to complex socio-political, ecological, geographical, and economic factors (Dudley *et al.,* 2014; Sankey and Draut 2014). Yirdaw *et al.,* (2017) claimed that effective ecological restoration in drylands can enhance biodiversity and ecosystem services and, as a result, contribute to sustainable development. Furthermore, the successful application of ecological restoration in drylands has improved the local community and the ecosystem's resilience by improving biodiversity. The main part of the rehabilitation in drylands is to identify the driving forces of degradation. The rehabilitation process focuses on specific sites, taking into consideration environmental factors. This includes soil data, climate conditions, landscape, and water profile, in addition to the diversity of the site (Yirdaw *et al.,* 2017; Puigdefábregas, 1998; Schiappacasse *et al.,* 2012)

Land degradation threatens the environment and also causes social effects (Warren,

1992; Reynolds *et al.,* 2007; Whitfield *et al.,* 2012; Torres *et al*., 2015; Wiesmeier, 2015). The desertification phenomena can be understood by viewing the interaction between several causal factors, as well as the direction of many processes and spatial variability (Grainger, 2009; Schwilch *et al.,* 2012). Desertification is influenced by unsustainable land use, human activities, population increases, and climatic conditions such as extended or recurrent droughts (UNEP 1997; Msangi, 2004; Mganga *et al.,* 2015).

Wiesmeier (2015) discusses environmental indicators of dryland degradation, including primary productivity and prioritising plant species as an indicator species for land degradation. The author considered the indicators of soil organic matter, including chemical and physical soil properties. Factors of the desertification early stages and land degradation include the vegetation/bare soil pattern (Wiesmeier, 2015). Drylands are easily degraded due to their sensitivity to environmental conditions, such as water and wind erosion. They are also affected by chemical degradation, such as acidification, salinisation, and the decrease in retention capacity (Reynolds *et al.,* 2007). Dryland is also physically sensitive and is affected by changes in crusting, compaction, hard-setting, biological degradation including reductions in the total biomass of carbon and declines in land biodiversity (Sivakumar, 2007).

2.3.1.3 Desertification and Climate Change

Greenhouse gases causes warming of the Earth's atmosphere and have resulted from the long-term climate change that constitutes to three main variables: elevated carbon dioxide (CO_2), altered rainfall patterns and temperature ranges (Bachman *et al.,* 2010). The rise in temperature has resulted in dramatic alterations in ecosystems, droughts in arid and semiarid regions, in addition to dramatic weather events, such as heatwaves, wildfires, storms, and

flash floods (Omar *et al.,* 2001). Land degradation is recognised as a major threat to human wellbeing and the environment due to the resulting loss in biodiversity, soil degradation, and significant contributions to greenhouse gas emissions (UNCCD 1994). The dynamic effects of climate change are accelerated by environmental degradation, pollution, and biodiversity depletion. A variety of models have been developed to predict climate change impacts on vegetation cover and biodiversity (Willis and Bhagwat, 2009; Randin *et al*., 2009; Luoto, 2008; Lapola *et al.,* 2009). In light of these predictions, precautionary strategies must be implemented. Climate change affects biodiversity globally at the ecosystem level and species level. Research proves that the changes in species adaptation which might affect the rate of expansion and occurrence. The change in species adaptation is related to the difference in temperature, the increase in flooding, and the change in rainfall which leads to the change in habitats (Reid and Swiderska 2008).

The effects of desert environmental constraints on plants in arid lands have been well documented (Malagnoux, 2007). However, the links of these constraints to climate change have been poorly studied (Asem and Roy, 2010). The atmospheric CO_2 concentrations have changed from 280 to 379 parts per million compared to pre-industrial levels (IPCC, 2007). The IPCC has predicted that global temperature will increase between 2.5 $^{\circ}$C and 4.8 $^{\circ}$C higher than pre-industrial levels by 2100. Bonkoungou (2001) stated that simulation models predict that "dryland biomes such as savannahs, grasslands, and Mediterranean ecosystems will be among the biomes experiencing the largest biodiversity change and will be affected significantly by the combination of land use change and climate change".

The climate change impact on the vegetation in Kuwait has not been well-documented or well-studied. The changes in Kuwait's annual and seasonal rainfall and strong dust storms

have changed the vegetation dynamics and soil in Kuwait, in addition to changing the plant communities (Omar, 1991). *Rhanterium epapposum* community distribution decreased from 30.6% on the vegetation map in 1974 to almost 2.1% of the map developed in 2001 (Omar, 2007). The change in community was replaced by *Cyperus conglomeratus* in rangelands. Due to human pressure on the communities of *Rhanterium epapposum*, *Haloxylon salicornicum*, and *Panicum turgidum,* they were the first species influenced by climate change (Omar, 2007). Their distribution has been confined to smaller areas. Long-term drought due to climate change will continue to severely affect plant cover leading to wind erosion and sand encroachment (Asem and Roy, 2010). On the other hand, stabilising vegetation cover will reduce the effects of erosion and sand encroachment that appear in protected areas (Omar 1991). However, the fragmentation of protected areas surrounded by multiple use areas might affect species long-term survival capacity and the adaptation to their habitat (Asem and Roy, 2010).

2.4 The Current Status of Biodiversity Conservation

Suleiman (2007) mentioned that many of Kuwait's native plants are either threatened, endangered or have difficulty germinating in extreme weather conditions. Land degradation is exacerbated by the soil's inherent fragility and the loss of native vegetation cover in the Kuwaiti desert. IUCN (2020), mentions that in 2019, Environment Public Authority of Kuwait (EPA) co-operated with Regional Office for West Asia (ROWA) to implement a project aiming to document and analyse the biodiversity in Kuwait. Part of the project's objectives were to expand the knowledge of staff through the organisation of a technical workshop. The training programs uses a Geographical Information System and Remote Sensing in addition to the Red

List categorisation assessment. However, none of the flora in Kuwait is regionally assessed for the IUCN red list threat categorisation yet (see Chapter 5).

Kuwait Institute for Scientific Research (KISR), conducted several research projects regarding rangeland management in Sulaibiya Research Station (Kabd). The activities resulted in the successful conservation and protection of several species planted in the expanded area (20 km^2), which was previously a grazing area before expansion. *Rhanterium, Helianthemum, Iris, Stipa, Cyperus, Plantago,* and *Panicum* were the genera used in the projects. Also, several other ecological studies are conducted by the Public Authority of Agriculture and Fisheries (PAAF) in Kuwait. The studies were established by fencing areas to prevent overgrazing and increasing vegetation cover (PAAF, 2010). The sites were then used to evaluate the possibility of reclamation of grazing lands, where most fenced areas experienced deterioration of vegetation cover due to overgrazing. These areas are Al-Shegaya, Al-Rawdatain, Al-Mutla'a, Al-Manaqeesh, Sulaibikhat Bay, and Al-Muqwa'a Reserves.

Kuwait's environmental issues are serious, according to the UNDP environment programme for Kuwait (UNDP 2011). The UNDP report reviewed various critical factors in the environment and consulted widely within government organisations, the private sector, and NGOs. Protected areas in Kuwait cover 20% of the land in Kuwait, with 17 terrestrial protected areas of different categories. According to the criteria of ratification of the Convention on Biological Diversity, they requested that each country conducts management effectiveness evaluations on at least thirty percent of its PAs by 2010 (CBD, 2020). Regular evaluation of the management is a systematic process covering the science, economic and social valuability obtained from the conserved sites (Stoll-Kleemann, 2010). According to the revision of the periodic biological national strategic report, prepared by the Environmental Public Authority

of Kuwait (2010-2019), none of the protected areas follow the process of management evaluation. UNDP (2011), summarised a list of environmental problems, including all forms of pollution, low levels of public awareness, loss of biodiversity, the need to prioritise the most critical areas for conservation, unclear regulations, inadequate monitoring, weak organisational structures, and low institutional capacity.

2.4.1 Status of Environmental Awareness in Kuwait

Before the exploration of oil in Kuwait, people who lived in the desert understood the relationship between human beings and conservation of their own environment. The old community appreciated the native species and they understood their value. They utilised it for their stock, medicinal sources and many other purposes (Abdal and Khalil,2002). Thereafter, exploitation of the natural resources occurred. This was due to oil exploration, urbanisation, industrialisation, and the accompanying community and entertainment services. The increased development and demand for oil resulted in deteriorated the soil properties over the last several decades (Abdal and Khalil, 2002). From the previous literature review about threats on conservation and vegetation in Kuwait, the harmful activities destroyed the ecosystem, causing direct and indirect deterioration. This is due to overgrazing, urbanisation, and tourism and coastal development.

The State of Kuwait signed the Convention on Biological Diversity CBD legislation in 1992. The commitment of the agenda requires the understanding of the management of the resources by local communities (Njoroge *et al.,* 2010). Experts of the biodiversity sub-groups discussed the efforts from the scientific community, environmental societies, relevant authorities and their responsibility to increase public awareness about biodiversity (PIED, 1995). UNESCO (2005), reported that formal education of biodiversity is a priority at all

academic levels. It has been suggested that pupils should be empowered to work in ways that protect and conserve biodiversity (Lindemann-Matthies et al., 2017). Biological studies and botanical knowledge can significantly help in educating local communities. In particular, the scientific conservation helps in the achieving a higher level of environmental awareness (Njoroge *et al.,* 2010).

Kuwait University is the main educational agency in Kuwait. The scientific knowledge of plant biodiversity is applied and studied in the Department of Plant Biology – Faculty of Science. The Department aims to study plant life forms, including its external and internal structure, classification, the functions of plants, plant growth and propagation, plant tissue culture and hybridisation. The Department was established in 1966, however, the study of the environmental technology and science was not applied until 2018-2019. According to the annual report of the University, the environmental Department consists of the lowest number of members compared with other Departments in the faculty (KU, 2020). Part of the Department objectives is to educate students on environmental management and protection in order to achieve sustainable development.

In Kuwait, there are a variety of environmental and conservation-based societies: Kuwait Environmental Public Authority (KEPA), Kuwait Institution for Scientific Research (KISR), Public Authority for Agriculture Affairs and Fish Resource (PAAF), Kuwait Voluntary Work Center (KVWC), and Kuwait Oil Company (KOC). However, the main governmental institutions are: K-EPA, KISR, and PAAF. The Environmental Public Authority K-EPA is responsible to prepare and develop an annual report of the strategic plan on the environmental goal achievement. This has to be done through coordination with the relevant authorities in the State. Moreover, the society is concerned with controlling and monitoring

biological diversity (K-EPA, 2020). KISR is another scientific research society in Kuwait who have conducted a variety of research related to the restoration of ecosystem. This society is represented by the Environment and Life Sciences Research Center. KISR develop research related to the preservation of natural resources (KISR, 2020), however, these studies and their findings are part of the Institute's internal reports, and most of which are not available for publication. In addition, for both societies, the significant participation in educating the local community and environmental public awareness is unclear.

The governmental environmental societies and education sectors need to reflect on their participation levels within civil society to improve the conservation strategy. The low awareness of land vegetation in the arid region, is the main reason that this ecosystem is not receiving enough attention and consequently deteriorating (Lindemann-Matthies *et al.,* 2017). Understanding the role of biodiversity in maintaining the balance of the dryland ecosystem, helps in limiting the impact of threats (McNeely, 2003, Duchelle, 2007; Njoroge *et al.,* 2010; Initiative, 2015; Lindemann-Matthies *et al.,* 2017). Furthermore, the concerned societies and education sectors need to exchange successful experiments between similar Arabian Gulf environmental parties. They also need to develop a practical network which will assist in meeting the needs of future education.

2.5 Desertification Mitigation and the importance of the research outcomes

In the many studies discussing desertification, the research concentrated on the problem rather than the practical and successful approaches to solutions. The studies were carried out either by Social or Natural Scientists. As a result, landscape studies have revealed little scientific information regarding landscape processes (Schwilch, 2012). Monitoring and

evaluation indicators must exist in desertification research. Also, the identification of vegetation cover is a crucial research tool in the degraded desertified land (Abdelfattah, 2008). Changes in dryland rehabilitation can be implemented through the better understanding of the natural and social components of landscapes. However, there are still significant gaps in our knowledge and overall understanding of the terrestrial biodiversity. Yirdaw *et al.,* (2017) claimed that the biodiversity in arid regions is not well documented. The names and number of species that are in danger of extinction are unknown. Ghazanfar (1998) studied the vegetation cover in the Arabian Peninsula and emphasised that overgrazing by livestock adversely affects much of the region's natural vegetation. The uncontrolled grazing led to the rapid depletion of the Arabian Peninsula's flora. In Kuwait, native species are threatened, endangered, or have difficulty germinating due to harsh environmental conditions, overgrazing, human pressure, and Gulf War activities (Suleiman, 2007; Al-Awaadhi, 2005). The research reviews and discusses many gaps related to the requirement for conservation planning such as: lack of systematic baseline data, which is also discussed in the re-establishment of the National Herbarium of Kuwait. Also, there is an absence of a clear terrestrial biodiversity conservation strategy with a presence of different environmental and scientific bodies. Furthermore, there is an absence of development of comprehensive and representative protected areas network (KEPA, 2018).

The applied research, discuss individual tests which may help in the development of the desertification mitigation and conservation plan. Through the research, a series of combined criteria were developed for selecting the most relevant factors to be used for the prioritised species. The used trail helps in the understanding of the natural landscapes and threats. The rare and threatened species that were recorded in research deserve high priority

for conservation (El-Keblawy *et al*., 2016). However, the identification tool for the most threatened and rare species may help in developing and enhance the social understanding of the components of the natural vegetation (see Chapter 4). Understanding of natural vegetation and threats can help in developing a proper conservation strategy. In addition, the identification tool may help in the enhancement of awareness and educate society about natural resources. This tool can be developed further as a scientific application for use in fieldwork in the future, and it can also be provided for general users to improve their knowledge of our natural heritage of native species.

Through the research, the threatened and rare species were assessed using the IUCN Red List. The developed assessment is a comprehensive description of global and regional threat status for species. The assessment helps in providing information for future implementation of conservation and planning. However, the application can be expanded in the SIS network to cover all Arabian Peninsula flora. Threat categorisation applied for individual taxa in specific regions help in understanding the threat status for the species in Arabian Peninsula. The application is organised to facilitate and share spatial data for individuals and countries. The application reviews extinction risks and considers other factors, such as ecological, phylogenetic, historical, and cultural preferences that affect some taxa and so highlight conservation priorities (Miller *et al.,* 2006 and 2007).

Species conservation planning needs to consider many other aspects such as: the increase of protected areas with periodic assessment of management effectiveness. Moreover, the evaluation of protected areas helps in the implementation of new categories of protection, which can be applied according to the environmental conditions and the development of new strategies. In Kuwait, 17% of the land has protected sites, in which

management effectiveness is not evaluated (KEPA, 2018). Also, the application of the evaluation can be knowledge utilised by protected and environmental agencies in Kuwait. The societies may move forward and use the management effectiveness evaluation applied as a base line for the implementation of evaluation of other sites in the country. The application may help in the achievement of the strategic objectives and targets defined in the environmental vision. The research evaluated the management effectiveness and protection applied to one of the most critical protected sites in Kuwait, the Demilitarised Zone.

Rehabilitation of the environment is possible, not only by the enforcement of laws but also through the use of advanced technologies. The application of scientific technology helps to enhance research methodologies. The scientific tools provide systematic information to assist policy makers in implementing actions. Using GIS technology with different variables can increase conservation knowledge and hence utilisation of land. Furthermore, managing geographical data is an ideal tool for the assessment of long-term conservation strategies. Figure (2.1) describes examples of the services provided from the geographical mapping tools in research.

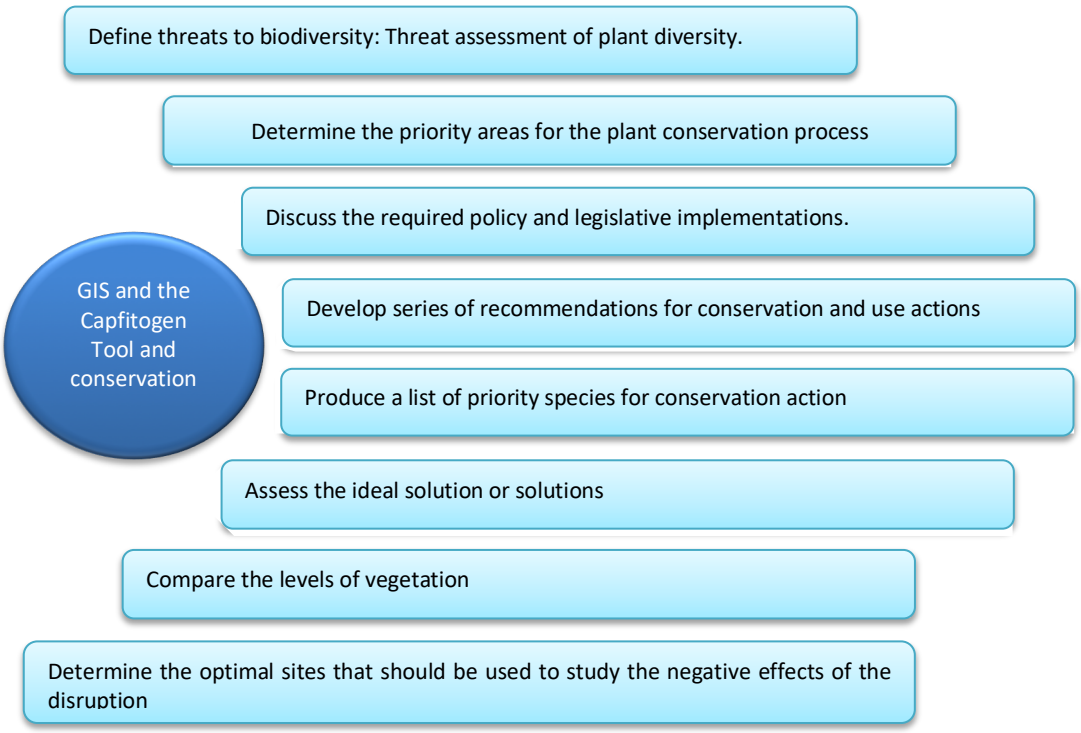


Figure 2.1 Examples of the Benefits from the Application of Geographical Mapping Tools in Research (Advanced GIS Training Manual (2013); Capfitogen version 1.2).

In general, this assessment helps in the development of a series of recommendations and usage action. This includes the establishment of conservation targets for priority species and required policies and legislation implemented. The assessment obtains a clearer vision of the native species status and level of protection and development.

Chapter 3

Assessing Conservation Priorities for the Flora of Kuwait

M. Nassep[1] and N. Maxted[1]

[1] School of Biosciences, University of Birmingham, Birmingham B15 2TT, UK.

Abstract

For effective multi taxa conservation, we need conservation planning which includes the scientifically justified prioritisation of species. The primary objective of this research is to create a priority list of plant species for preservation in Kuwait. Data was gathered from Kuwait University Herbarium and Science Museum, Royal Botanic Gardens, Kew Herbarium (UK), and the Global Biodiversity Information Facility (GBIF). The prioritisation criteria applied were species rarity and protection status at the state level depending on (A) the number of individuals, (B) the time range of specimen collections, and (C) the size of the geographical range: (i) extent of occurrence (EOO); (ii) area of occupancy (AOO), (D) protection status of provenances, and (E) threats affecting the occurrence. This is according to the IUCN threat classification scheme, which were observed using the National Naturalisation Plan Strategy map developed by Council for Planning & Development State of Kuwait (2016). According to this research, 8,267 accessions were used to develop a working list of 315 species. The application of score ranking examines the combinations of criteria used. The scoring scheme determined that 121 species of Kuwait flora can be potentially prioritised for further investigation and conservation. This research also discusses the ecological distribution of the prioritised species and the highest prioritised list of 43 species which are with low number of specimen collections (less than ten samples) collected more than 25 years ago. And additional

list of 50 species with no record of protection status were defined. Methodological issues, conservation recommendations are discussed providing conservation targets for the priority species.

Keywords: Prioritization, species rarity, conservation, geographical range

3.1 Introduction

In Kuwait, natural sparce vegetation covers a large area of the desert habitat but it was severely degraded by the early 1990s during the Iraqi invasion (Khalaf and Al-Ajmi 1993) and became a global exemplar of human deliberate land degradation (Al-Awadhi *et al*., 2003). Natural vegetation now covers less than 10% of the land surface of Kuwait (Al-Awadhi *et al.,* 2005) and intensive human activities related to annual camping, combined with fragile ecological conditions have accelerated the environmental degradation. The rate of desertification is approximately 285 km^2 per year (Al- Awadhi *et al*., 2014) and the annual sand drift is 20 m^3 per metre (Khalaf and Al-Ajmi 1993). Both present a significant threat to plant diversity. Therefore, the need for a national plant species conservation strategy is crucial to mitigate these threats in order to sustain plant diversity and native habitats.

Related studies in Oman and Saudi Arabia focus on vegetation concentrated of plant family distribution, presenting the main landscapes and their vegetation (Patzelt *et al*. 2014; Miller & Cope 1996; Miller & Morris 2004). This is due to the higher floral concentration in these regions. However, the other countries in the Arabian Peninsula (Kuwait, UAE, Qatar and Bahrain) have considerably lower numbers of plant species (Miller & Cope 1996). According to Daoud, (1985), Al- Rawi (1987), Dickson and Macksad (1973), Halwagy and Macksad (1972) the flora of Kuwait is relatively depauperate and is composed of 374 plant species from 55

families.

One of the first steps in conservation planning is the prioritisation of taxa for immediate conservation action (IUCN, 2017). Sakkir *et al.* (2012) conduct a research related to prioritisation aiming to conserve medicinal species in United Arab Emirates (UAE). The categorisation included information gathered through literature surveys and field trips related to the traditional knowledge of species' medicinal value, aiming to complete a list of medicinal plants within the region. A total of 132 plants, nearly 18% of total medicinal species, were found to possess medicinal properties in the UAE traditionally, but it is highly probable that the medicinal properties of the remaining 82% have not been yet discovered or documented. The Sakkir *et al.* (2012) study describes the species present, their ecological distribution, and major threats impacting each species, as well as the conservation measures applied. The Authors strongly recommend further research and investigation through the application of the Red List assessment, in addition to *ex situ* and *in situ* conservation.

Another prioritisation study applied in Qatar also related to medicinal species carried out by Phondani *et al.* (2019) and included a literature review, field survey and sharing learning approaches. The study described 58 medicinally important plant species through the identification of: botanical and Arabic name, habit, habitat and distribution pattern. The prioritisation was based on their use value, feasibility to local climatic conditions for long-term survival and the fulfilment of criteria measures of global sustainability assessment system. However, both sets of research concentrate on developing a priority list of medicinal species in arid region with the aim to describe species distribution and uses.

The research reported here discusses the prioritisation process for the Kuwaiti flora, as a step forward for conservation action planning. In addition, the research discusses the

threats affecting the occurrences of plant species. It reviews natural habitats in Kuwait using the third master plan map applied between 2005-2030 (State of Kuwait, 2005). The master plan map discusses and reviews the actual and future land uses in the Northern, North-Eastern, Southern and South-Western parts of the country (North Al Mutla, Al Abdali, Subiya, North Subiya and Al-Bohaith). This includes the Iraqi border and in the South-Eastern part (Arifjan, Az-Zour, and Wafra) the Saudi Arabia border area – (State of Kuwait, 2005). The aim of the Master Plan was to allocate the total land area of the country for different uses, new urban and rural settlements, conservation, recreation and tourism areas, industrial areas and service center, national/international roads, dry ports, oil fields, water fields, military installations and bases, agricultural and animal husbandry areas, and fishing areas.

Saterson (1995), argued that there is no precise or agreed methodology for prioritising taxa or populations for *in situ* conservation. A general methodology would always need to be adapted to meet local requirements and circumstances. Historically, many criteria have been used in prioritisation taxa for active conservation, including current conservation status, socioeconomic use, the threat of genetic erosion, genetic distinctiveness, ecogeographic distribution, biological importance, cultural values, cost, feasibility, and sustainability, as well as legislation, ethical and aesthetic considerations and institutional priorities of the conservation agency (Maxted *et al.,* 1997). Later they extended this initial set of criteria to include: population status, quality of habitat, intrinsic biological vulnerability, human impact, and the taxon's ability to speciate into new environments (Kell *et al.,* 2011). A combination of a subset of these criteria is normally applied based on the data available to make the assessment (Mace *et al.,* 1993; Maxted *et al.,* 2013). Commonly applied criterion are economic value and threat affecting the occurrence, threat is normally assessed using the IUCN red list

criteria (Maxted and Kell 2009; IUCN, 2001). By contrast Brehm *et al.,* (2010) proposed a more complex prioritisation procedure using eight criteria for the prioritisation of Portuguese Crop wild relatives (CWR) and wild-harvested plants (WHP).

Once the criteria are selected, they may be applied using a rule-based system scoring scheme or ranking system (Magos-Brehm *et al.*, 2017). The rule-based system proposed by UNEP (2001) consists of rules related to the extinction risk. Areas containing taxa that are most threatened become a priority area for conservation. This method has the advantage that is completely explicit about what features of a species lead to it being listed as threatened (Mace *et al.*, 1993). Whereas scoring schemes include multiple criteria where each taxon is scored, and the summed highest scoring taxa areas become the priorities. Kale *et al.,* (2004) applied a scoring scheme to prioritise medicinal plants using criteria such as endemism, use value, and rarity status. While Robertson *et al.,* (2003) used a scoring scheme to prioritise active control of invasive species' in South Africa. The scheme used seventeen criteria which are grouped in five modules. The modules have confidence score which describes the uncertainty and availability of data for each approach. The lower the confidence score is, the higher the certainty of the data.

In Kuwait, the choice of prioritisation criteria was limited by the data available. The main source of information has been provided by the Kuwait University Herbarium (*Index Herbarium* code – KTUH), the national herbarium of the state of Kuwait. In the late 1980s, the herbarium contained approximately 22,000 specimens. but during the Iraqi invasion of Kuwait in 1990 the entire herbarium and the attached library were moved to Iraq. Following liberation of Kuwait, the herbarium staff were forced to start collecting again to rebuild the herbarium. From the total of 374 species from 55 families observed in Kuwait, according to Daoud, (1985),

Al- Rawi (1987), Dickson and Macksad (1973), Halwagy and Macksad (1972) and Omar *et al*., (2007), only 315 species were relocated and collected by the Kuwait University herbarium team and museum over the last 25 years. Although some species may have been lost, many of the 59 species not thus far relocated are believed to exist and surveying to discover their presence is still active.

The aim of the research is to develop a prioritisation scheme for the flora of Kuwait and subsequent use *in situ* and *ex situ* conservation of the flora. The application of a well-set priority ranking scoring system based on the available data, is an aid to improve the restoration of threatened native species. It also assesses the protection status as part of desertification mitigation plans. This will be achieved using a scoring scheme based on multiple criteria. Research also provides significant information about threats impacting the prioritised species, helping validate the national naturalisation plan strategy in accordance with the third master plan map which was reviewed and applied between 2005-2030 (State of Kuwait, 2005).

3.2 Materials and Methods

The prioritisation of the Kuwaiti flora used data collected by the Kuwait University herbarium and museum over the last 25 years. In addition to data preserved by the Royal Botanic Gardens (Kew) herbarium (UK) and Global Biodiversity Information Facility (GBIF) as shown in Table 3.1.

Table 3.1. Source of Data Collection and Number of Specimens Collected.

Data source	GBIF	Kuwait university herbarium (KTUH)	Royal Botanical Garden (Kew) herbariums (UK)	Total Data
Number of specimens	587	8986	689	10262

The scoring scheme used multiple criteria where each taxon is scored, and the summed highest scoring taxa areas become the priorities. The ecogeographic data recorded, collection date, collection location, and description enabled them to identify the specimen. The prioritisation criteria included: (a) species rarity based on the absolute number of individuals recorded, (b) the time range of specimens collections, (c) total area occupied by collected specimens used the GEOCAT (http://geocat.kew.org/), to calculate the geographical information to determine the (i) extent of occurrence (EOO, minimum convex polygon containing all points of occurrence), and the (ii) area of occupancy (AOO, area estimated by superimposing a grid onto occurrence points and calculating the cumulative area of cells occupied by a species), (d) whether the taxon is present within five areas which would determine the taxon as having levels protection, (e) known number of threats identified as threatening the species using the IUCN threat criteria (IUCN, 2001). The data types were then recorded for all specimens using the scoring system shown in Table 3.2. Distribution map layouts were created using GIS software (ArcGIS version 10.4.1).

Table 3.2. Prioritisation Criteria Categories Used in the Scoring Scheme.

Criteria		Score				
		5	4	3	2	1
Species rarity	Number of known individuals	1-10	11-20	21-30	31-40	41 ≥50
	Year of last collection	1970-1980	1981-1990	1991-2000	2001-2010	2011-2017
	AOO	<10 km^2	<500 km^2	<2000 km^2	NT	LC
	EOO	<100 km^2	<5,000 km^2	<20,000 km^2	NT	LC
Protection status	Protection status	Not protected	Present in 1 site	Present in 2 sites	Present in 3-4 sites	Present in ≥5 sites
Threats	IUCN Threats Classification Scheme (Version 3.2)	4-8	3	2	1	0 threats

3.3 Results

The total number of Kuwaiti floral specimens available was 10,262. However, not all specimens had sufficient data to permit inclusion in the prioritisation process. The written information is sometimes not entirely legible; some samples have inconsistencies between site descriptions and written numerical data. In addition, duplicate specimen collections were identified and deleted from the dataset. Ultimately 80.5% or (8,267) unique specimens of the full dataset were used in prioritisation. Specimens were collected from a range of habitats including urban areas (45%), roadsides (12%), tourism areas (5%), as well as 38% being recorded from protected areas. All species were scored using the 6 criteria.

3.3.a Score values

The scores obtained for the specimens included were divided into nine groups, as shown in Figure 3.1. According to the criteria used, the scores were individually reviewed for each of the 315 species. The revision revealed that the species that scored between (10-15) represented by 31%, with a total of 96 individuals considered stable. This is due to their recent observation whereby a relatively high number of specimens were collected and had stable geographical distribution. Also, there were still individuals contained within the threatened areas according to the IUCN threats classification used; however, they were also observed in more than three protected sites. Scoring with the criteria used in the application resulted in eliminating them from the Prioritisation List.

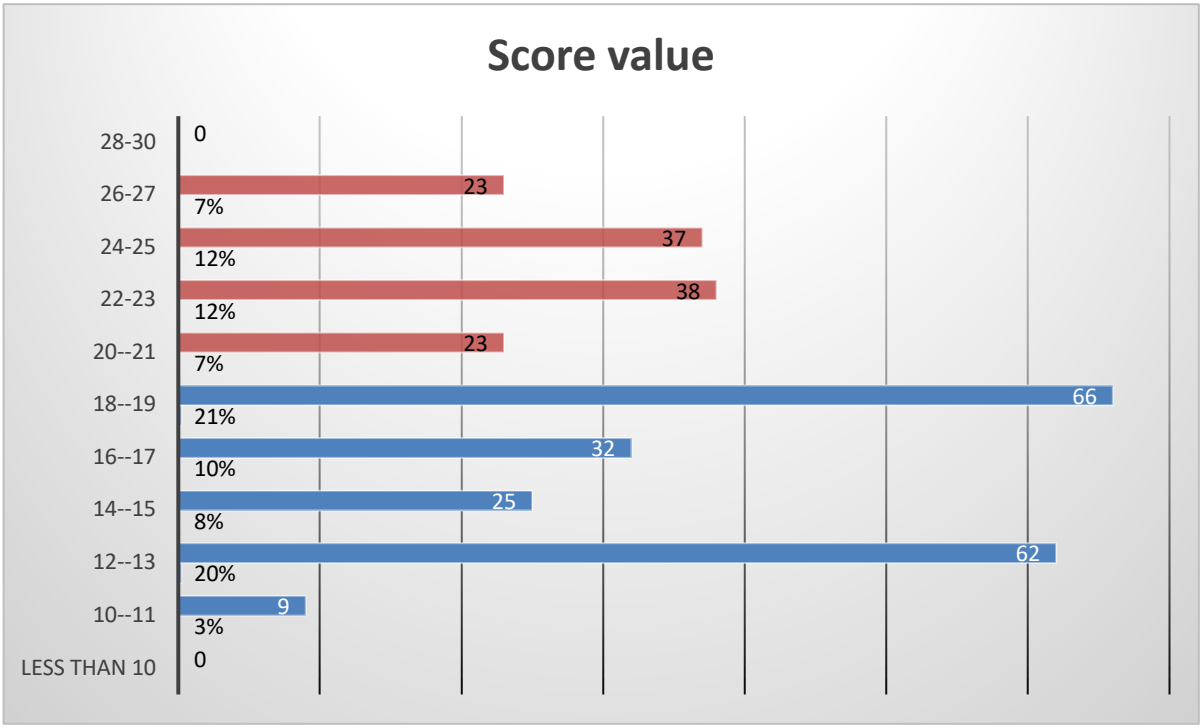


Figure 3.1. Scoring Percentage of the Selected Criteria.

There were 32 species in the next group scoring within the range (16-17). This groups consist of species that have moderate distribution. They were recently observed in its area of distribution. The majority of species in this scoring range has an area of occupancy range between Vulnerable to Least concern with average score of approximately 16, as shown in Table 3.3. The revision of species observation in relation to the criteria used resulted to eliminate them from prioritisation. The species related to this group consider stable according to the protection status and recent collection, observation and number of specimens. However, further investigation is applied for the species with score range of (18-19), with average score of approximately 18.09, with an increase from the previously tested group of approximately 2 points. However, few of the species with categorised endangered, this includes literature revision of the species distribution and data observed in the score. The research concluded that the individuals with several specimens recently observed in their distribution area. In addition, the reviewed species were found protected in more than three reserves. According to the previous revision they were excluded from the prioritisation list, while few of them were re-scored and were later determined to have a higher score, considering mainly species geographical distribution and threat might affecting their occurrence and literature individual revision.

Table 3.3: The Average Score for Tested Species

Number of species	Values	Number of specimens	Time range	Protection	AOO	EOO	Threat	Average score
9	**10 -11**	1.00	1.00	1.00	1.00	1.67	5.00	**10.67**
62	**12 -13**	1.08	1.05	1.18	1.12	2.82	4.84	**12.10**
25	**14-15**	1.80	0.96	1.64	1.92	3.12	4.64	**14.08**
32	**16-17**	3.00	1.34	2.06	2.03	3.03	4.56	**16.03**
66	**18-19**	3.98	1.54	2.76	2.33	3.06	4.41	**18.09**
23	**20-21**	4.26	2.00	3.61	3.30	4.13	3.60	**20.92**
38	**22-23**	4.84	2.26	4.21	3.32	4.32	3.95	**22.89**
37	**24-25**	5.00	2.97	4.54	3.84	4.84	3.70	**24.89**
23	**26-27**	5.00	4.09	4.87	4.39	5.00	3.61	**26.95**

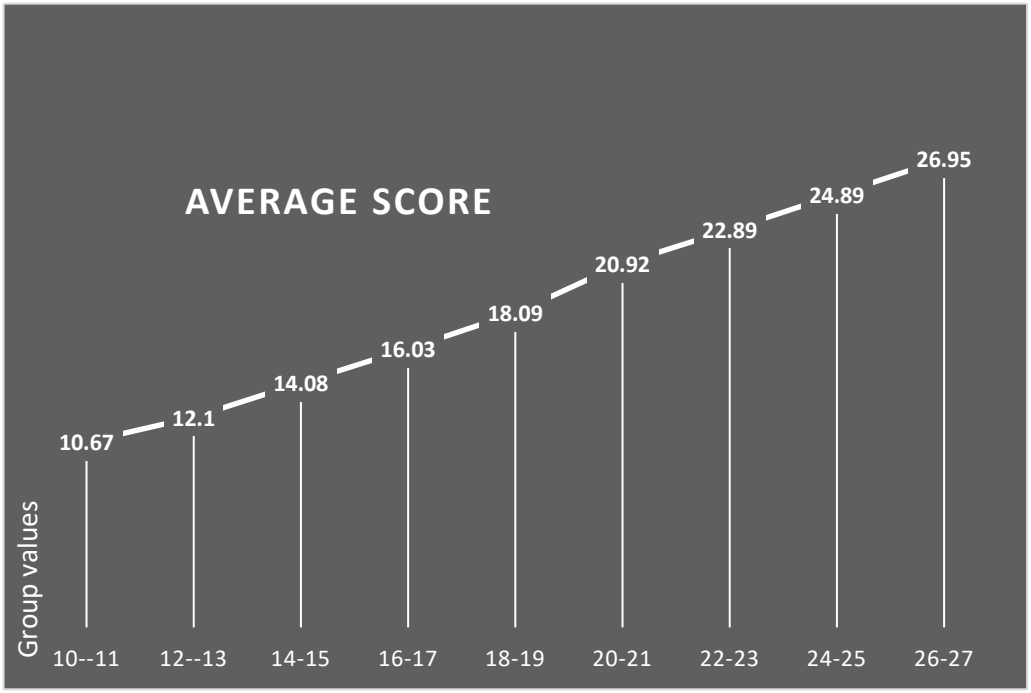


Figure 3.2. Scoring Group and the Average Values.

The revision for the next 4 groups observed that most of the species were categorised with high scores (3-5) for most of the criteria used. These species expressed the highest value

of the criteria used in the application, with average score of approximately range from 21 to 27, as shown in Table 3.3 and Figure 3.2, with a highest increase from the previous tested group of approximately 3 points. The analysis indicated these were species with a low number of specimens collected, were not observed in the last 15 years, or more than 15 year for most of them. According to the criteria used, the species are distributed within an area of occupancy of less than 500 km^2 and is categorised as endangered or critically endangered. The individuals in these groups included non-protected species or were observed in one protected site, with relatively old record. Also, they were contained and in risk from more than four identified threat, therefore, they were selected for further investigation.

One hundred and twenty-one species (38% of total species) had scores of 20 or more points, as shown in Figure. 3.1, and as a result, were selected as priority species for further investigation, because there was an increased rise between the 18-19 and 20-21, there being a stable rise between 10-19 and after 20-27. According to the data collection, 498 specimens from the total specimens observed and collected are considered for the prioritised species. Appendix 3.1 consists of the list of the scoring process for 121 priority species related to 31 taxonomic families, from the total of 315 species of the flora of Kuwait. Their distribution is shown in Figure 3.3 and largely mirrors the distribution of all taxa.

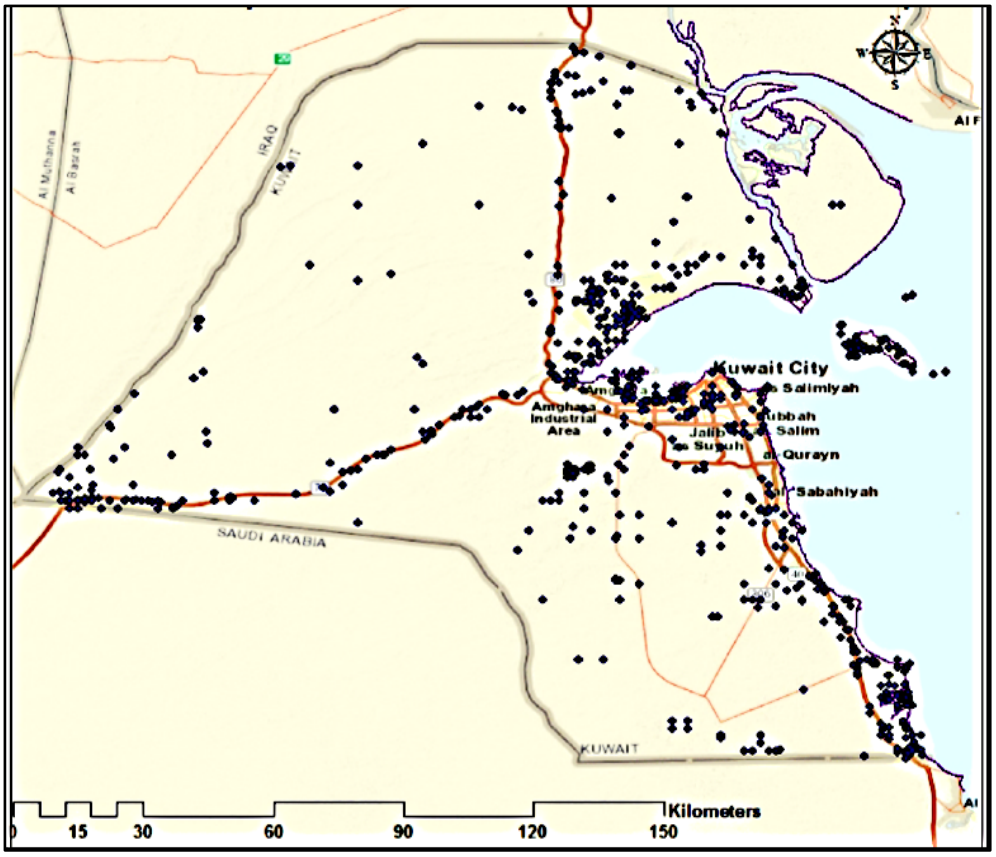


Figure 3.3. Distribution Map for 8,267 Localities for all 315-Plant Species in Kuwait- based map (ArcGIS 10.4.1, KWT_adm1, 2007).

3.3.b. Ecological distribution

Kuwait's surface is low-lying. The maximum height is found in the West and South-Westward, where above sea level it reaches 300 m (Al-Sarawi *et al*. 1995). The distribution map is reviewed in Figure (3.4) in order to revise the distribution of the species scores between 20-27 in the main ecological zone.

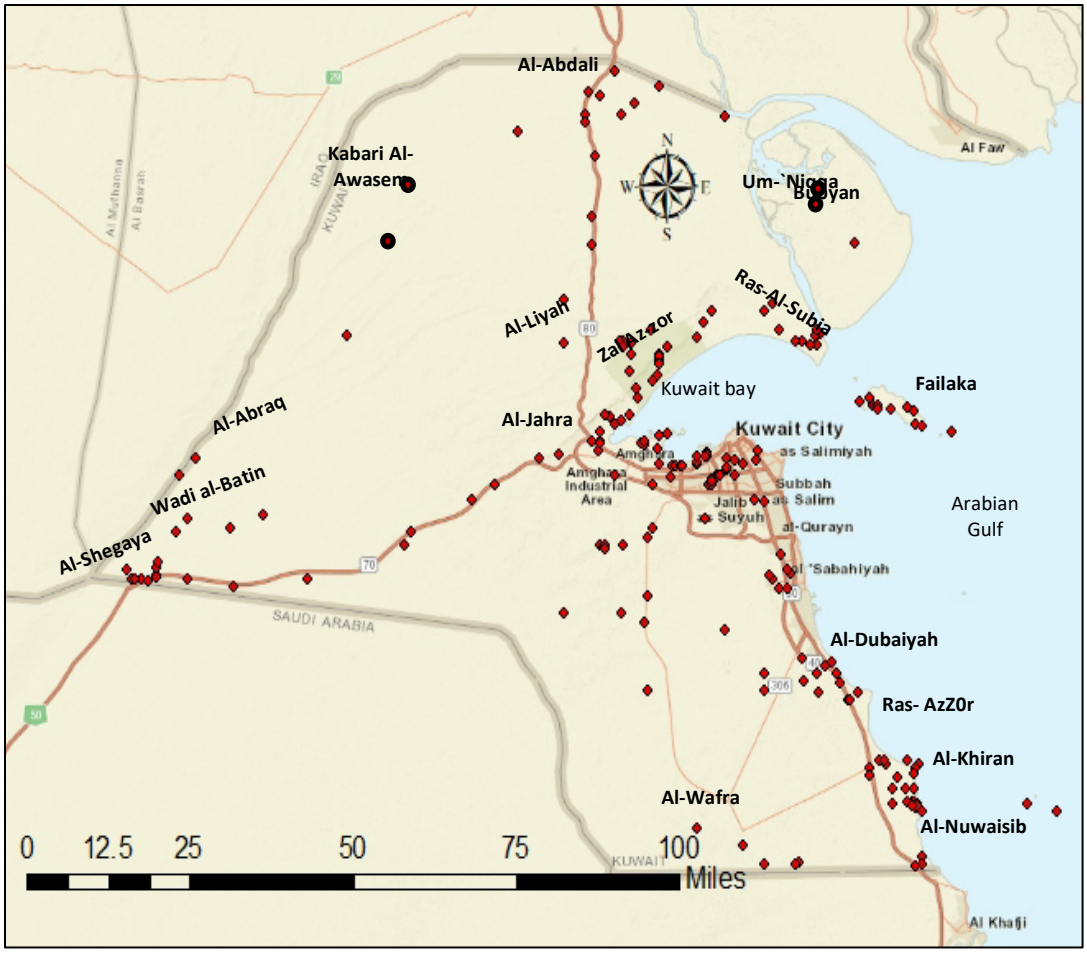


Figure 3.4 Distribution of the Species Scored Between 20-27 and Ecological Valued Areas - based map (ArcGIS 10.4.1, KWT_adm1, 2007).

The observation shows that the data collection is concentrated in protected sites and area associated with, however, the collections were also made in open desert, and coastal region and residential areas. Specimens were collected from: low coastal dunes extending from Al- Dubaiyah to Al-Khiran. Also, they were collected from salt marshes fringe and saline depressions from Kuwait Bay to Ras Al-Subiyah. Few collections were made on Bubyan Island, while more collections were made on Failaka island. The most specimens were contained in the West and South-West area of Al-Shegaya, Wadi Al-Batin, Jal- AzZor, Um- Al-Rimmam,

inside and outside the protected sites which were associated within these locations. Few groups were made from the west plateau ecosystem, which is predominantly a gravel desert. Moderate specimens were collected from Al-wafra and Al-Abdali private farms. Appendix 3.3 reviews the data collected in the research in association with different ecological zones.

3.3.c. Rarity and protection status

Further assessments were made on the relatively small numbers of specimens collected during the 25 years since liberation. The test resulted in 43 species (36%) being determined a further priority, out of the 121-priority species. In addition, another priority assessment made based on the protection status, resulted in 50 species (41%) of the 121-priority species. The two-tests resulted in 68 plant species from the prioritised list shown in Appendix 3.2, having the priority consideration for conservation action plans and *in situ* conservation. The 68 species of the further priority list should potentially be used for further monitoring purposes to get a precise vision of the species status.

The protected terrestrial area in covers 17.5 % of Kuwait's land area, totalling 3,048 km² of the total 17,418 km² land area. There are over nine terrestrial protected areas, managed by multi-stakeholder committees: The Environment Public Authority (EPA), the Public Authority for Agriculture and Fish Resources (PAAF), the Kuwait Institute for Scientific Research (KISR), and the Kuwait Volunteer Center (KCVW). In addition, the protected areas co-managed by government agencies: Kuwait Municipality, the Ministry of Interior, and the Ministry of Defence. Figure 3.5 shows data accessions on the distribution map of the prioritised species and terrestrial protected areas of Kuwait. According to the map, most of the collections were in the Sabah Al-Ahmad protected area, Al-Mugreerah, Failakha Island, the Demilitarised zone and the Wadi Al-Batin areas.

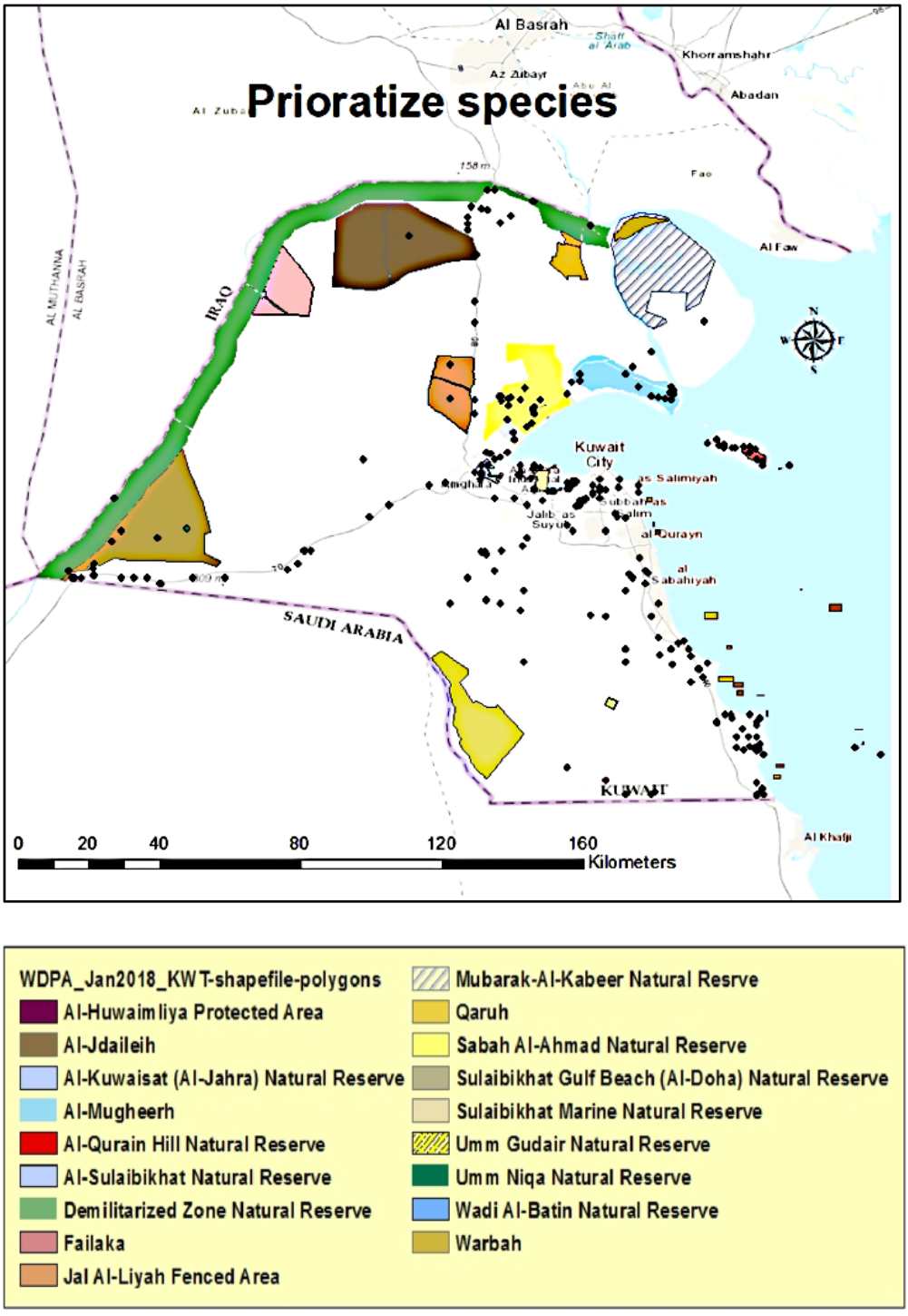


Figure 3.5. Distribution Map for 121 Priority Species and Protected Sites-(ArcGIS 10.4.1, WDPA_Jan2018_KWT- shapefile, KWT_adm1, 2007).

3.3.d. Threats affecting species occurrence

The application of ArcMap geo-reference converts a photo to a map, which assists in the restoration of the land use. In the application we use a map reviewed in the Third Master Plan of the State of Kuwait which is shown in Figure 3.6. The georeferenced map describes the locations of collected specimens and the list of features, such as: agricultural areas, residential areas, rangelands, oil fields, sabkha, areas proposed for tourism development, residential areas, water wells, agricultural areas, and other features. The revision connected the map features to the IUCN threats classification related to each of them. Figure 3.7 descries the major threats affecting the occurrence of plant species in Kuwait.

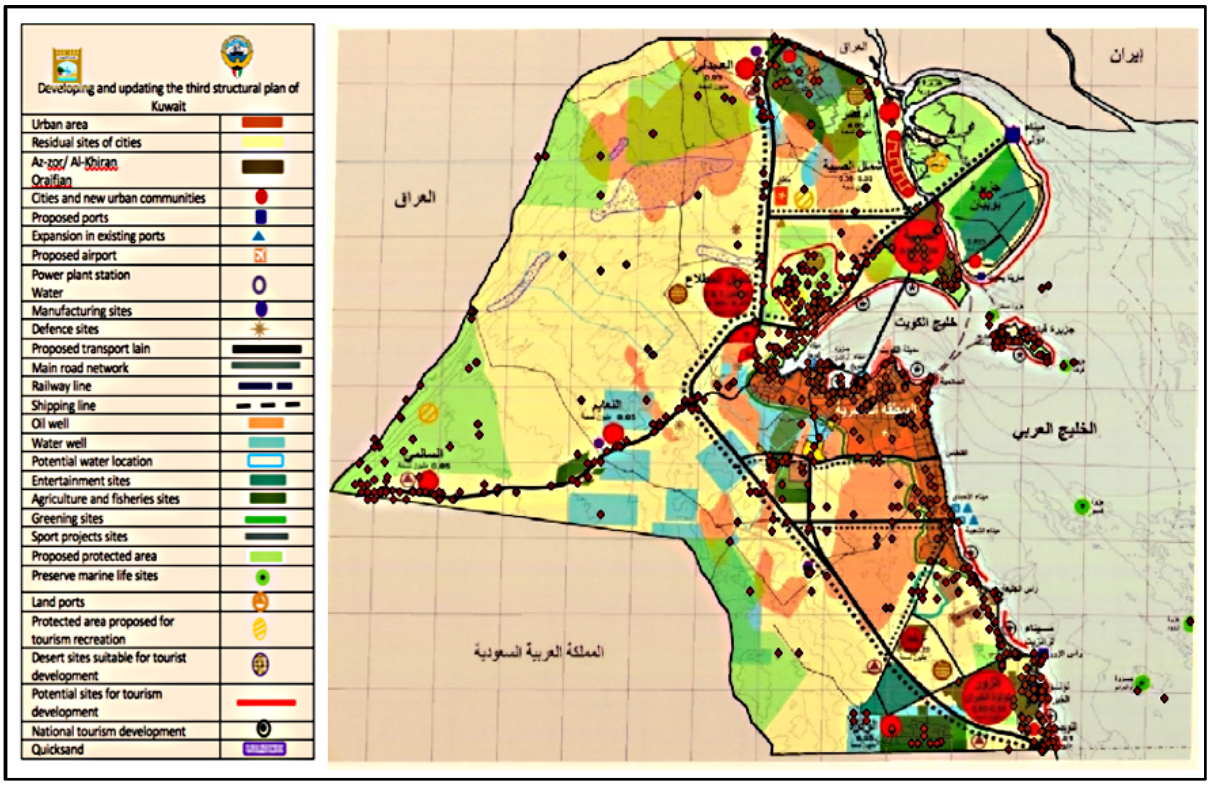


Figure 3.6. Georeferenced Third Master Plan of the State of Kuwait Map, (.) Describing the Locations of Collected Specimens, Kuwait Based Map (State of Kuwait, 2005).

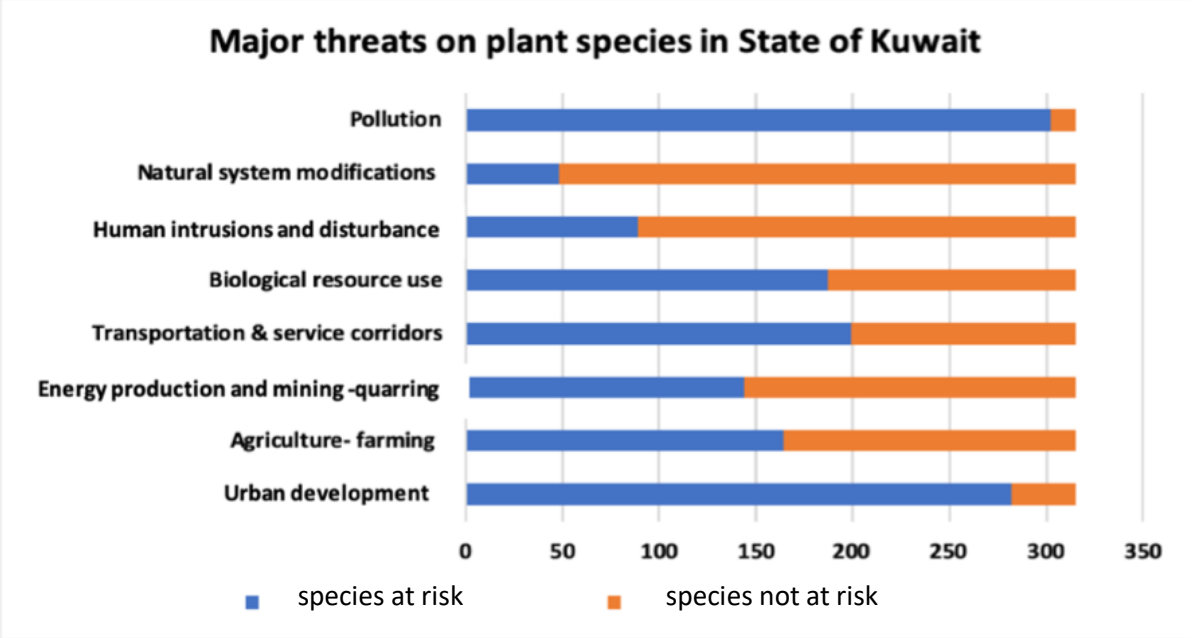


Figure 3.7 The Major Threats Affecting Plant Species in Kuwait.

3.4 Discussion

The prioritisation applied in the assessment depend on scoring scheme of specific criteria related to the available information associated with species, representative specimens and data recorded in herbaria. However, in practice a variety of institutional factors also impacted the result. The observed distribution of vegetation related to the scoring criteria values used in the application concluded that the total 8,267 specimens used in the research, 498 specimens of almost 6% represented the 121 prioritised species. However, the average of score for the priority groups is range from approximately 22-27, while the average score for the non-priorities categories is between approximately 10-17.

The result related to the recorded scores of the threats which might affecting the species distribution are consider high in all the assays taken, as shown in Table 3.3. The average score related to the threat among all scoring groups range between more than 3 to

5. However, the data observation was affected by a variety of factors, such as: the number of specimens observed for the species and the protection status. In addition, the smallest area essential for survival of existing populations of a species- AOO and the parameter measured the spatial spread of the species EOO, both are affected by the threat, which influenced by many factors such as number of specimens collected, ability of species to grow under different ecological and biological variable and its ability to survive. It is recommended to study species distribution in all areas, in particular the distribution of native species. Native plants' have "capacity to adapt to adverse local environmental conditions" (Franco *et al.*, 2006), in addition to the food benefit they have for humans and animals, and traditional medicines. These native species are also used in desertification mitigation, and they are connected to many factors such as: vegetation density, functional, ecological, and ethno-botanical values (Helfand *et al*., 2006; Lamb, 2009; Larson *et al.*, 2009; Reid and Oki 2008; Uren *et al*., 2015). These factors need to be studied before selecting individual species for landscaped environment and conservation. In contrast to Oman, where native plants are often overlooked as landscape species due to a preference for heavy flowering, fast growing exotic species, as they are used in developed landscapes of residential and commercial areas (Hopkins and Al-Yahyai, 2015).

Our research found that different ecosystems were associated with different vegetation cover. The collected specimens from many ecological features in Kuwait are shown in Figure (3.4) and Figure (3.6). The collections are related to the exposed topography in the Jal-Az Zor and Al-Shegaya area and are associated with the lowland zone, ridges, and valleys of Um- Al-Rimmam and Wadi Al-Batin. The specimens collected represent a variety of salt-tolerant species / halophytes from the coastal zone, as well as species typically found in urban areas, industrial locations and open desert.

The region of Wadi Al-Batin, associated with the demilitarised zone, and Al-Shegaya area are both represented by dry desert climate and seasonal water flows, which plays a vital role in sustaining the abundance of vegetation in the two wadis (Al-Sarawi *et al.*, 1995, Kuwait National Adaptation Plan, 2019). There are various factors that can influence the density of the vegetation, particularly seasonal flooding, sedimentation deposited, and rainfall density (Kurschner, 1998; Osman, *et al.* 2014). This area has a unique topography located within the drainage network and sub-valley of Wadi Al-Batin. Geographically, the site is part of geographical structure extended in the region. The valley extends throughout Kuwait, West and Northwest highlands of Saudi Arabia and Southeastern Iraq. The vegetation cover is primarily annual herbs which are reliant on the rainy season to supply sufficient moisture content and improve soil fertility in the valley. Most of the natural vegetation are medicinal and fodder plants. The area is geographically associated with Hafr Al-Batin area in Saudi Arabia. However, the adjacent region's floristic composition and vegetation diversity have not received much attention, except a few studies of the desert vegetation of the Eastern and Central part by Vesey–Fitzgerald (1957) and Mandaville (1990). The Authors made an illustrated guide of the flora of Eastern Saudi Arabia. In contrast, of the total 8,267 specimens used in the research data, 1,152 specimens were associated with Wadi al-Batin, Al Salmi and Al-Shegaya area, representing more than 13% from the total data collection. Appendix 3.3 reviews the data collected in the research associated with different ecological zones. The specimens contained 173 species from which 31 species were identified as prioritised ones according to the criteria used in this study.

Mohammed–Ibtisam and Doka (2018) studied the area of Hafr Al-Batin from the Saudi Arabia side and produced a list of 83 plant species in association with Hafr Al-Batin area. The

study found rare species within Saudi Arabia, such as *Artemisia* sp*, Haloxylon salicornicum, Calendula tripterocarpa* and *Acasia tortilis* to be present in this area. However, there were also a variety of species observed in Wadi Al-Batin and collected in Hafr Al-Batin Saudi Arabia area such as, *Aaronsohnia factorovskyi*, *Astragalus* spp., *Chenopodium* spp., *Chrozophora* spp., *Launaea nudicaulis*(L)Hook, *Zilla spinosa*, *Scorzonera tortuosissima* and *Plantago boissieri*. However, some of these have not been observed or collected in Kuwait for more than two decades. The observation also contained some species which have only been collected in Kuwait from this site and associated with vegetation described in Saudi Arabia, such as *Arnebia tinctoria, Agathophoa alopecuroides, Scorzonera papposa, Zilla spinosa, Diplotaxis acris* and *Alyssum homalocarpum*. The studies related to Wadi Al-Batin region associated with Iraq mostly concentrated on the geological description of the rocks and sand distribution (Al-Gurairy, 2017; Sissakian, 2014). On the other hand, the literature observation of species within Oman, also contained species that were prioritised in Kuwait; these are newly recorded in Oman 2014, such as *Leptaleum filifolium* (Patzelt *et al.* 2014).

The protected site of Wadi Al-Batin is adjacent to: Al-Abraq, Khabary Al-Awazim and Al-Huwaimliyah reserve, reaches the North-Eastern region of Um-Negga protected area. According to the data collected in this research, few collections were made from Al-Abraq and Khabari Al-Awasem area. About 28 specimens were reviewed in this area which represents 24 species, all are not assigned within the prioritised category. The area supports very water dependent desert species and the dominant soil types are sandy and gravelly. The observation is similar in Al-Liyah and Al-Huwaimliya protected area. Moderate collection was made from these reserves. Only 41 specimens were collected from these sites which represent 32 species, and 5 species are considered prioritised. Al-Dosari *et al.* (2018), mention

that the Al-Liyah area is mostly lacking vegetation. The area was subjected to a plantation project from June 2011 to May 2015. This was a field assessment to reintroduce native plants in order to reduce dust and sand encroachment. The projects focus on the most vulnerable native species such as *Lycium* sp. *Haloxylon* sp. and *Nitraria* sp, in which all are not prioritised in this research.

On the other hand, Sulaibiya Research Station (kabd) protected site has a high ecological value which assists in conserving the native desert vegetation. It is one of the oldest protected areas, existing since 1975. It is located South-West of Kuwait City, in the desert plain, and consists of water dependent species. A total of 656 specimens of 152 species were observed in this site. 18 species are considered priority species, such as: *Horwoodia dicksoniae, Launaea capitata,* and *Farsetia aegyptia*. The area contained species that were observed as rare in Saudi Arabia (Wadi Hafr Al-Batin) such as: *Artemisia herba-alba*, *Haloxylon salicornicum* (Mohammed–Ibtisam and Doka 2018); in contrast, these species are observed in this site.

Moving to the North-Eastern region towards the Um-Negga reserve, which extends from the high semi-circular sand dunes and includes salt marshes near the coast. 91 specimens were collected from this site representing 60 species. However, 5 species were prioritised according to the criteria used in this research, such as: *Allium sphaerocephalon, Stipagrostis drarii* and *Aegilops kotschyi.* The dune ecosystems in Um-Negga extends to the extreme North-East of the country along the Gulf Coast and salt marsh fringes.

Further specimens were collected from the salt marsh and saline depression ecosystems of Bubiyan, Al- Doha protected area and Ras Al- Subiyah. The data collection consists of a relatively high number of specimens observed in Ras Al- Subiyah. 948 specimens

were collected which represents 171 species, totaling 11.46% of the data collection. The number of specimens used in the prioritisation assessment in Ras Al-Subiyah and Al- Doha protected area were 32 specimens representing 21 species, such as: *Aegilops kotschyi, Aeluropus littoralis, Lolium temulentum, Atriplex dimorphostegia, Suaeda vermiculata,* and *Launaea angustifolia*. However, few collections were made in Bubiyan Island and the adjacent shore site whereby only 7 species were observed. The observed data since 1961 to 2001 shows that only 2 are considered a priority according to the criteria used in this research.

Sabah Al-Ahmad Natural Reserve is considered another ecological valued site. It is located on the North-Eastern part of Kuwait with many geomorphological defined ecosystems, including: coastal plains, Sabkhas-Nabkha complex, hilly terrain, Wadis and depressions, falling dunes, and sandy sheets. The area is one of the oldest protected sites in the country, extending from the Kuwait Bay and Kathma to Southern desert of Al-Dibdibah. Which support Sabkhas ecosystems that are a high saline area and consist of plants that are adapted to grow in these conditions. The protected site associated with Um-Al-Rimmam depression is one of the largest depressions located in the Northern part of Kuwait. According to the data collection, there were 197 species from a total of 978 specimens, which represents almost 12% from the data collection. These species have been observed in this area since 1971, it represents more than 52% of the flora of Kuwait. According to the data revision, the non-saline depressions and salt marches communities had higher species richness in the site, which extended from Kathma to Ras Al-Subiyah. The prioritisation assessment summarised 33 species in and outside of the protected site associated with the area, includes species that were only observed in this site such as *Acacia pachyceras.* However, in Oman, *Acacia pachyceras* is an indigenous tree which develops a microclimate due to their potential of

cooling the soil under their canopies (Hopkins and Al-Yahyai, 2015). In addition, the area includes species' which have an extremely narrow range of distribution in Kuwait, such as *Stipagrostis spp., Valerianella dufresnia, Cynomorium coccineum and Helianthemum kahiricum.* The latter is considered a characteristic species in the Oman high-montane zone steppe communities (Patzelt *et al.* 2014)

Nature Reserve of Al-Jahra Pool is another ecologically valued zone. It is part of the non-marine wetland containing coastal salt marches. The area is ecologically characterised by the presence of four different environments: the coastal, the marshes, sandy, and freshwater habitats (Alshahabi, 2006). A total of 718 specimen were collected from Al- Jahra Reserve and Al-Khuwaisat area included in this research. These specimens represent 141 species from which 11 are classified as prioritised species, such as *Oligomeris subulate, Aeluropus littoralis* and *Eragrostis minor.*

There are areas of the salt marsh fringe and saline depressions within Al-Zor port, Al-Dubaiyah Al-Khiran and Al- Nuwaisib. The sites are unprotected arid regions close to the coast which are subjected to arid climatic conditions (Al-Ateegi 2007). The coastal Sabkhas extends along the coastline from Kuwait through Saudi Arabia to Oman. About 4% of the total flora of the Arabian Peninsula are considered halophyte species, which have high survival capability due to their germination potential in the contaminated saline region (Ghazanfar *et al.* 2019). The data revision of specimens observed in Al-Zor port, Al-Dubaiyah Al-Khiran and Al-Nuwaisib has a total of 1156 specimens for a variety of species distributed according to the data presented in Appendix 3.3. These species are observed within the deserts and the Sabkha, making up almost 14% of the data collection. However, the prioritised species observed in this area is 37 species including: *Traganum nudatum, Ducrosia anethifolia,*

Salicornia europaea, Centaurea mesopotamica, Aeluropus lagopoides and Valerianella dufresnia. The area is an open site exposed to a variety of threats such as: industrialisation, urbanisation, overgrazing and tourism. The site supports vegetation which is highly salt tolerant, facultative halophytes in addition to grasses and sedges. A recent study developed by Ghazanfar *et al.* (2019) describes the coastal vegetation in the Arabian Peninsula. The author mentions that the variation in the distribution of vegetation is dependent on the climatic conditions and the geographical topography of the coastal zone. A variety of species included in the data observation is associated with the region of Saudi Arabia and Oman coast, such as *Limonium* spp., *Salicornia perennans* Wild, *Seidlitzia rosmarinus* Bung ex Boiss, *Suaeda* spp. Furthermore, grasses and sedges include species such as *Aeluropus lagopoides.* Also, the area contains one of the most important facultative halophytes, *Suaeda vermiculata* which is observed in the flat sandy beaches and coastal sabkhas of Saudi area. The area also contains *Caroxylon* spp in the inland sandy saline plains, which are also observed in Saudi Arabia. In addition, *Suaeda aegyptiaca* grows in narrow beach with rocky shores in areas of Oman, and were also associated in the data collected in Kuwait. The previously mentioned species are considered part of the prioritisation test; with low observation rate and threat status within the area of distribution. However, further investigation is a priority considering the species adaptation related to the growth rate in the contaminated zone. Coastal areas are increasingly under threat by development and urbanisation.

A variety of factors might affect the result related to the sources of data collection and ecological observation. Although Kuwait University Herbarium and Museum are the main national base for collecting information on vegetation cover in Kuwait, however, temporal and spatial factors may affect the availability of rarity and distributional data used in the research.

This is due to the national university's educational requirements, which result in student data collection being focused at specific times of the year and in areas such as protected sites and valued ecological zones. In addition, vegetation in a small country like Kuwait exhibits accentuation of biotic factors such as: overgrazing, urbanization, human destruction, oil exploration, climate change, and industrialization (Al-Awadhi *et al.*, 2003; Al- Awadhi *et al.*, 2014; Khalaf and Al-Ajmi 1993). The distribution also depends on the ability of individual species to overcome all threats mentioned and species adaptation. Furthermore, the scoring result for the annual prioritised species also may be affected. Vegetation in Kuwait annually bears a direct relationship to the rainfall (Halwagy and Halwagy, 1974, Al-Sarawi, *et al.*, 1995, Kuwait national adaptation plan 2019). According to the research result, 58% of the annual prioritised taxa are considered rare species. There have been low numbers of specimens seen throughout the collection made in the past 25 years, even more so, these species were collected less than ten times prior to the year 1990. However, other data resources can improve the validity of the information used. In our research, Royal Botanic Gardens, Kew Herbarium (UK), and the Global Biodiversity Information Facility (GBIF) provide useful additional data that enhances information related to the scarcity factor, especially for the period before the invasion of Kuwait. In addition, there could also be discrepancies between the environmental agencies collecting the data and the rate of research visit in each protected site.

Institutional research for multi-threatening dryland ecosystems is a functional aspect in the conservation strategy (Dudley *et al.,* 2015). This strategic approach is needed to present to develop the prioritisation for preservation of the region. The institutional strategy may depend on inventory research, developed socio-economic value, and species adaptation to

drought. Furthermore, the working list is not yet assessed using the IUCN Red List criteria, and the biodiversity in arid regions is not well documented (Yirdaw *et al.,* 2017). However, the data available from the design test provided significant material for wide range research projects related to species geographical distribution and conservation in Kuwait. In addition, the available data used showed the geographical occurrence of most of the plant species in Kuwait, that can be use in the global threat assessment using the IUCN Red List global criteria. However, a conservation plan should focus on native species distribution and adaptation factors. The native plants provide a highly efficient mixture of species adapted to the niches available in that country (Suleiman *et al.,* 2007). Thus, in Kuwait the conservation strategy has to focus on taking account of desertification aspects in the region and consider long-term impact of climate change, using the individual digitalised data developed in this research.

According to the research results, 36% of the 121-priority species are considered rare species, due to the low numbers of specimens collected over the past 25 years. However, the country has not been surveyed systematically and it is likely that many unobserved species are yet to be added to the national list. Those rare or hidden plants that were missed in observation in the last 25 years, need verification to determine whether they have disappeared from the Kuwaiti environment or had just been missed since Kuwaiti liberation. A strategic conservation and determination of the causes of their scarcity should be part of the plan to rehabilitate the vegetation. In addition, the revision of the checklist of the accepted taxonomic names used by Angiosperm Phylogeny Group (APG IV, 2016) should be applied to the national floristic checklist. The Angiosperm phylogeny reflect the systematic botanical taxonomy and DNA sequences related to the new knowledge. This revision was fundamental in improving the understanding of the actual situation of the flora in Kuwait, classifying the

native, non-native wild, cultivated, and weedy species.

The available data used in this research should raise awareness for Kuwait University herbarium and Museum which is currently being re-established. The Kuwait herbarium should consider many factors when interpreting and analysing the saved data and the type of vegetation cover in Kuwait. The institution should cover all aspects of plant physiology and adaptation, especially for annual plants that depend on periods for germination. In addition, the herbarium needs to pay more attention to identifying the plant species found in protected areas, then working with reserves site managers to develop a strategic plan for conservation.

The revision of IUCN threat for all prioritised species listed in this research, are affected by variety of factors, such as: the area of collection and field survey, the quality and quantity of threats and the resilience of the environment of species. Overall, pollution and urban development have the highest score of risk on species. This is related to its connection to other threat categories uses. The range land area considers open area for a variety of activities such as: grazing, camping, gathering species with unknown value and target. These activities affect almost 187 of the total 315 species used in this research.

Follow up research which aims to study possible conservation targets is beneficial in field surveys for the land cover in Kuwait. According to a research and analysis presented here, the protection status of all species needs to be reviewed to inform the plans followed by the environmental authorities to achieve their protection target. According to the Kuwait Master Plan map (Figure3.5) some of the protected areas are subject to future oil exploration and oil mining projects, in particular: Al-Judaylia, Al Mugeera, and Um-Nigga protected areas and these should rebalance the economic versus conservation priorities of the sites.

Acknowledgements

We acknowledge assistance from the herbarium expert, and identifying rare and non-protected taxa from the flora of State of Kuwait.

Chapter 4

Interactive identification of prioritised species of Kuwait

Mouza Nassep[1], Shahina Ghazanfar[2] and Nigel Maxted[1]

1. School of Biosciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK.
2. Herbarium, Royal Botanic Gardens, Kew, Richmond, Surry TW9 3AE, UK

Abstract

The preparation of identification aids can help enhance knowledge of valued taxa and in the education of biodiversity. The production of a Kuwaiti Identification tool can achieve both purposes. The keys presented cover 232 plant species, 62% of the flora of Kuwait. The working set consist of the priority list of 121 rare and threatened Kuwaiti species plus a further 111 species relatives of priority species found in the same genera. The primary goal was to develop an interactive multi-entry key for the priority and related species from the flora of Kuwait, through (a) following a strategy to differentiate groups of families within the same order and, (b) creating of a list of characteristic key features for families, genera, and species. The interactive identification aid was produced using the interactive identification program Lucid ver. 3.1. 88 morphological characters and 348 states were selected for plant habit, stems, leaves, flowers, and fruits. The features and states used were developed from the literature and personal observation of specimens. It is expected that this interactive key will facilitate further conservation and floral studies, and will be periodic updated with additional taxa as taxonomic information becomes available.

Keyword

multi-entry key, prioritized plant species, identification aid, morphological characteristics, terminology, description.

4.1 Introduction

The importance of biodiversity is unquestioned, they reflect variety of values such as: economical, ecological life support, recreational, cultural, and scientific value. UNESCO (2005), reported that formal knowledge of biodiversity is a priority at all academic levels of education. It has also been suggested that all citizens should be empowered to work and act in ways that protect and conserve biodiversity (Lindemann-Matthies *et al.,* 2017). On the other hand, there is clearly a lack of familiarity with the identification of biodiversity among the general population and educating them might not be easy task (Pretty *et al.*, 2009). Education of species identification and their taxonomy, especially in plants, is neglected or not well used in the educational process in universities and schools (Stagg and Donkin, 2013). The Swiss Academy of Sciences (2006), reported that there was a significant reduction in the systematic biology teaching at European universities. Moreover, in the UK there has been a significant decline in botanical and zoological knowledge (Leather and Quicke, 2010). Studies concluded that the industrialised countries consider taxonomic knowledge as useless when determining the sustainability of communities (Pilgrim *et al.,* 2008; Leather and Quicke, 2010; Stagg and Donkin, 2013; Bilton, 2014). Meaning that, there has been a decrease in the utilization of natural resources in close proximity, which leads to a further decrease in interest in local biodiversity knowledge (Pilgrim *et al.,* 2008; Bilton, 2014).

Understanding the value and uses of the Arabian flora demonstrates the importance of taxonomic and identification skills in conservation planning. This is in part due to functional adaptation of the species to the local climatic conditions. The marginal growing conditions of the Arabian Peninsula have led to the evolution of plants with an unusual chemistry that play a fundamental role in the medicinal industry (Ghazanfar and Al-Sabahi, 1993; Saganuwan,

2010; Kuete *et al.,* 2013). Van Weelie and Wals (2002), confirms that identification of plant species is also of value to the general public, especially for the environmental and conservation sector of education. The challenge the Arabian Peninsula is that the majority of vegetation areas have been reduced in size and degraded. Ultimately, overgrazing by livestock adversely affects much of the natural vegetation and has led to the rapid depletion of the Arabian Peninsula's flora (Ghazanfar, 1998). Moreover, the invasion of Kuwait by Iraqi forces and the ecological damage caused by departing troops further damaged native biodiversity. This instigated a scorched earth policy, spilling oil and setting fires that devastated Kuwaiti biodiversity, and the loss of biodiversity data and the national herbariums. Since then, the country has been attempting to rehabilitate its biodiversity and re-establish its systematic conservation of its biodiversity.

Correct specimen identification provides access to the wealth of information available for the species and enables communication of novel information to others without confusion (Davis and Heywood, 1964). The traditional tools used to identify specimens use some form of key, usually dichotomous keys found in flora in the region or country where the specimen is found. Keys are commonly based on morphological features: the characteristics that are readily seen and recorded in the field, laboratory, museum or herbarium (Maxted and Crust, 1995). However, traditional dichotomous keys have their disadvantages, notably forcing the user to go through the character set in a specific pre-ordained sequence. Whereas multi-access keys permit the user to select whichever characteristics in whichever order they choose, even ignoring individual characteristics. In some cases, these individual characteristics may be absent on the specimen, however, an identification can still be obtained. There are several interactive identification programs now available, including 'Lucid'

(www.lucidcentral.com).

Basically, the identification of species is used to improve knowledge and understanding of the biodiversity (Randler *et al.,* 2005). Stagg and Donkin (2013), carried out a study relating to a science project which aims to teach adults the identification process of native plant species. The project used a dichotomous key, word association exercises and pictorial card games. The study concluded that the establishment of the dichotomous key and the use of it in plant species identification is a useful tool. The study emphasize that the dichotomous key is transferrable and an easily adapted tool within the identification process. While the other tools such as: word association exercises and pictorial card games can stimulate initial interest (Stagg and Donkin, 2013).

The urgent need of identification of plant species in Kuwait is for educational purposes to increase the awareness of biodiversity in the country. Therefore, the aim of this research is to construct a learning tool which simplifies the identification process and assists in the understanding of biological diversity within communities. According to the previous studies, the prepared interactive identification aid can contribute the enhancement of valuable species knowledge, in particular those in danger that can then aid their conservation (Stagg and Donkin, 2013; Randler *et al.,* 2008). The tool produced for priority Kuwaiti plant species will also aid conservation planning and field recognition by conservationists.

4.2 Materials and Methods

A recent priority list of 121 rare and threatened Kuwaiti species from 32 families has been established (Chapter 3). These species were prioritized for Kuwait using (a) species rarity estimated on the number of known populations per species, the regularity of collection, the

IUCN defined Area of Occupancy (IUCN, 2001); (b) protection status estimated by occurrence of population in protected areas; and (c) IUCN Threat Classification (IUCN, 2001). The priority set are considered as a priority for conservation and include taxa that are endemic or near endemic, rare and those threatened by development. To these a further 111 species related to the priority species and found in the same genera were added. Furthermore, Asteraceae and Poaceae families observed in assessment to have the highest number of threatened and rare species. Asteraceae and Poaceae families have a high economic value in several fields, as food plants and as in medicine (Mohamed *et al.,* 2010). The plants of the two families demonstrate consider tolerance to saline conditions, which is likely to be an advantage with the present trend in global warming and climate change (Ghazanfar *et al.,* 2014). Accordantly, assessment includes the rest of taxa from the flora of Kuwait of both families to ensure the ability to differentiate the rare ones from their relatives in the same families. Which meant the identification working set contained a total of 232 plant species covering 62% of the flora of Kuwait.

The classification of species families and class were named according to the APG IV system of classification (Angiosperm Phylogeny Group IV, 2016). Lucid software ver. 3.1 (https://www.lucidcentral.org) was used to produce the interactive key. It is based on a step-by-step elimination of characteristics of multiple plant features and states connected to species, genera, and families. The identification process depends on the following:

- Choosing a key relative to the super orders, orders, and families.
- Developing a list of features to distinguish families.
- Developing primary key features derived from the distribution chart

- Applying structural morphological characteristics from a variety of references that describe plant features for each family, genus and species.

4.3 Results

The working list of 232 species (62% of the flora of Kuwait) includes both Monocot and Eudicot species (APG IV, 2016). The working set is listed in Appendix 4.1. To identify the prioritised species and the provided working set, a morphological characteristic list of 88 feature and 348 states were developed for the included taxa, presented by plant habitats, stem, leaf, flower, fruit and seed characters (Appendix 4.2). The features and states were used to generate dichotomous keys for the seven monocotyledonous and 24 dicotyledonous families present in Kuwait, the key was made using the program *Lucid* 3.5 *Builder* http://www.lucidcentral.com). see Figure 4.1 and 4.2 respectively.

Figure 4.1. Dichotomous Keys to the Seven Monocotyledonous Plant Families Found in Kuwait

1	Perianth distinct, blue, white or pink (in Kuwait)	2
	Perianth absent or indistinct……	4
2	Flowers arranged in umbels	Amaryllidaceae
	Flowers in umbellate cymes, panicles or spikes……	3
3	Each flower subtended by 2 bracts; the upper tepal largest arching over 3 stamens; capsule splitting at top	Ixioliriaceae
	Flowers subtended by spathe-like bracts; tepals more or less un equal, free; capsule splitting into 3……	Iridaceae
4	Marine aquatics; leaves grass-like; apex tapering with minute teeth	Cymodoceaceae
	Terrestrial or in marshy areas; leaves various; apex various……..	5
5	Leaves consisting of sheath, ligule and blade; inflorescence of numerous spikelet's ..... ……	Poaceae
	Leaves usually narrow flattened or circular in cross section; inflorescence a dense spike with upper flowers usually male and the lower usually female or flowers bisexual and clustered in cyme……	6
6	Flowers with 6 perianth segments; flowers bisexual.....	Juncaceae
	Perianth absent; flowers surrounded by hairs or forked scales; flowers unisexual……	Typhaceae

Figure 4.2 Dichotomous Keys to the Eudicots Plant Families Found in Kuwait.

1	Parasitic plants without green leaves or green stems.....	2
	Plants not parasitic; leaves and stems green ……	3
2	Flowers zygomorphic; perianth of calyx and corolla; corolla 2lipped; stamens 4	Orobanchaceae
	Flowers actinomorphic; perianth of linear to lanceolate segments; stamen1…	Cynomoriaceae
3	Flowers grouped into heads (capitula), heads arranged in various inflorescences	Asteraceae
	Flowers not grouped in heads……	4
4	Flowers arranged in umbels; ovary inferior; fruit splitting into 2 mericarps	Apiaceae
	Flowers solitary or in cymes, thyrsus, spikes or racemes; ovary superior, semi-inferior or inferior; fruit not splitting into 2 mericarps ……	5
5	Gynoecium (pistil) of 2 or more separate or nearly separate carpels with separate styles and stigmas	6
	Gynoecium (pistil) of 1carpel or 2 or more united carpels; styles free or united……	8
6	Petals free……	7
	Petals more or less united……	Crassulaceae
7	Leaves alternate, not fleshy or connate at base; petals 2-8, unequal, superior petal usually larger; 3 or more times divided; capsule dehiscing at apex	Resedaceae
	Leaves opposite or verticillate, fleshy and connate at base; petals 5, stamens up to 15; follicle dehiscing along the carpel suture.....	Crassulaceae
8	Flowers unisexual, Petals absent or rudimentary, Plants with	Urticaceae

	rough stinging hairs……	
	Flowers bisexual, Petals present, Hair not stinging…….	9
9	Ovary with 2 or 4 carpels, style 1 or 2 or 4 ……	Boraginaceae
	Ovary with 1 or 3 carpels, style 5 ……	10
10	Ovary with one ovule, fruit indehiscent; capsule 1-celled	Amaranthaceae
	Ovary with many ovules; capsule 2–5-celled or cluster of 5 achenes……	11
11	Plants with a white latex; involucre bracts frequently fused to form a cup-like structure (cyathium in Euphorbia); fruit a 3-lobed capsule	Euphorbiaceae
	Plants without latex; involucre bracts absent or if present not fused into a cup-like structure; fruit not a 3-lobed capsule …	12
12	Plant often succulent……	13
	Plant few are succulent; sepals 3-8, free; capsule dehiscent, 2 ovules in each locule of the ovary…….	Phyllanthaceae
13	Sepals 3-6, free or fused capsule loculicidal or septicidal (4-celled) capsule.....	Aizoaceae
	Sepals are persistent fused into tube circumscissile capsule……	14
14	Thin-walled capsule with many seeds……	Portulacaceae
	Seeds in rows, divided by a thin wall ……	15
15	Petals free from each other	16
	Petals united, at least at base……	21
16	Leaves opposite; petals 4; stamens 6, tetradynamous (4 long +2 short); petals not falling early;	Brassicaceae
	Leaves alternate or all leaves basal; petals 5 or more; stamens not tetradynamous ……	17
17	Calyx ribbed with 5–15 ribs; fruit 1-seeded achene or utricle,	Plumbaginaceae

	usually enclosed by calyx .....……	
	Calyx not ribbed; fruit various, but not a 1-seeded achene or utricle……	18
18	Stamens many, grouped with free or fused filaments forming a tube around the style; petals not fugacious……	Malvaceae
	Stamens 5–10; not grouped together……	19
19	Sepals unequal, the inner three distinctly wider that the outer two which are narrow; petals fugacious ……	Cistaceae
	Sepals equal; petals not fugacious ……	20
20	Nodes of stem not swollen; carpels fused by their styles to a central column elongating in fruit ……	Geraniaceae
	Nodes of stem swollen; carpels not fused by their styles……	Caryophyllaceae
21	Ovary inferior or semi-inferior; sepals 4–5 fused, persistent	Caprifoliaceae
	Ovary superior ……	22
22	Petals 4–5 petals, 2-lipped or funnel-shaped, scarious	Plantaginaceae
	Petals 5, cup-shaped or tubular, not scarious.....	23
23	Sepals fused, persistent and often enlarging in fruit; petals united to form a tube; often lobed above; carpels 2–5; style 1; stigma 1	Solanaceae
	Sepals free; ……	24
24	Petals fused funnel-shaped or cup-shaped, often plaited; carpels usually 2, each topped with 1– 2 (rarely 5) free or partially joined styles, fruit can be a capsule, berry, or nut……	Convolvulaceae
	Petals five free, usually cup-shaped, Leaves pinnate or bipinnate, inflorescences raceme, corymb, spikes, or heads, ovary with single carpel, fruit pod (legume)…	Fabaceae

The interactive key for all taxa can be downloaded from https://keys.lucidcentral.org/keys/v3/priority_plant_species_in_kuwait/

As well as enabling interactive, multi-access identification the key also provides diagnostic photographs of: the whole plant, flowers, fruits of the preserved specimen, and distribution maps. Lucid can also be used to assess the usefulness of individual characteristics via use of the features unscored report. The characteristics that are not used in the identification process can then be deleted or kept for use in production of full descriptions.

The key resulted in the development of identification for Asteraceae and Poaceae species observed and collected in Kuwait. Interties and features develop to creates the descriptive part of the identification process. However, within the identification tool, list of feature and interties specially use to differentiate Asteraceae family taxa from the rest of the working set. The list details with examples of taxa provided in Table 4.1

Table 4.1: Character list of the Rare Species Related to Asteraceae from the Flora of Kuwait

Features	States
1. Indumentum (both in stem and/ or leaves)	A, Plants with stinging hairs (*Launaea anggustifolia*); B**,** without stinging hair (*Scorzonera papposa*)
2. Thorn availability	A, with thorn (*Luanaea sp.)*; B, without thorn (*Scorzonera sp.*)
3. Plant secretion	A, Plants with white latex (*Scorzonera* spp*)*; B, Plants without latex (*Senecio* spp)
4. Phyllotaxy	A, alternate (*Xanthium strumarium*); B, opposite (*Flaveria trinervia*); C, whorl (*Filago pyramidata*); D, decussate (*Flaveria trinervia*); G, rosette (*Leontodon laciniatus*)
5. Leaf apex	A, Acute (*Sonchus* spp); B, obtuse (*Scorzonera papposa*); C, tapering (*Scorzonera tortuosissima*); D, truncate (*Lactuca serriola*)

6. Blade margin	A, entire (*Gymnarrhena micrantha*); B, lobed (*Senecio* spp); C, dentate-teethed (*Urospermum picroides*); D ciliate (*Aster squamatus*); E, undulate (*Scorzonera papposa*)
7. Inflorescences type	A, racemose; B, cyme; C, cone; D, spikelet; E, umbel; F, cyathium (Asteraceae spp)
8. Inflorescences function	A, unisexual (Gymnarrhena micrantha); B, bisexual (*Launaea* spp)
9. compact head a structure shape	A, radiate (*Xanthium strumarium*); B, ellipsoid (*Carduus pycnocephalus*); C, oblong (*Artemisia scoparia*); ovoid (*Carthamus oxyacantha)*; D, cylindrical (*Ifloga spicata*); E, discoid (*Senecio spp*); F, conical (*Seriphidium herba-alba*)
10. Inflorescence arrangement	A, cymiform (*Iflago spicata*); B, disciform (*Echinops acantholepis*); C, dichasiform (*Filoga trinevia*); D, corymbiform (*Urospermum picroides*); E, racemiform (*Koelpinia linearis*); F, paniculiform (*Lactuca serriola*)
11.Flower or Spikelet's pedicel	A, without pedicel- sessile (*Pallenis hierochuntica*); B pedicelled (*Arvillea garcinii*)
12.Bracts size	A, equal (*Pallenis hierochuntica*); B, unequal (*Atractylis spp)*
13.Phyllaries series	A, 1-2 (*Koelpinia linearis*); B, 3-5 (*Luanaea nudicaulis)*; C,7-12 or more (*Launaea capitata)*
14.Phyllaries (bracts)-glumes- lemma texture	A, rough-rigid (*Echinops* spp.); B, nerved (*Filago trinevia)*; C, membranous (*Anthemis* spp.); E, chartaceous-thin, dry, papery (*Filago trinevia)*; F, herbaceous (*Arvillea garcinii)*
15.Bracts or involucre Shape	A, cup- shape (*Lactoca serriola*); B, spathulate like bracts (*Flaveria trinervia*); C, campanulate (*Calendula* spp.)
16.Receptacle surface	A, glabrous or without scale like ridges (*Calendula spp)*; B, hairy (*Ifloga spicata*); d, spiny (*Echinops* spp); E, with scale like ridges (*Centaurea mesopotamica*)
17.Receptacle shape	A, flat (*Senecio* spp); B, convex (*Leontodon lacineatus*)
18.Petal or tepal color	A, blue (*Echinops polyceras*); B, pink (*Centaurea mesopotamica*); C, white (*Echinops acantholepis*); D, yellow (*Rhanterium epapposum*)*;* E, green (*Artemisia scoparia*); F, purple (*Filago pyramidata*).

19. Fruit Shape	A, ovoid (*Gymnarrhena micrantha*); B, oblong (*Urospermum picroides*); C, ovate (*Artemisia scoparia*); D, lanceolate (*Erigeron bonariensis*); E, globose (*Ifloga spicata*); F, ellipsoid (*Picris babylonica*)
20. Fruit external features	A, compressed (*Sonchus* spp); B, beaked (*Urospermum picroides*); C, angled (*Launaea angusifolia*).

The character list also develops features and states for sub families to identify Poaceae (Andropogoneae, Aristideae, Eragrostideae, Panicaea, Bromeae, Aveneae, Poeae, Triticeae). The traits suggested below are contribute in defining Poaceae species from the rest of the group and similar entities. The list created according to the use of the following features and state listed in Table 4.2.

Table 4.2: Character list of the Rare Species Related to Poaceae, Typhaceae and Juncaceae from the Flora of Kuwait

Features	**STATES**
1. Ligule margin	A, line of hairs (*Cenchrus* spp); B, membranous (*Digetaria sanguinalis*)
2. Inflorescences type	A, racemose (*Dichanthium* spp); B, spikelet (*Bromus* spp); C, Panicle (*Stipagrostis* spp.).
3. Compact head a structure shape	A, ellipsoid (*Lolium temulentum*); B, oblong (*Lolium rigidum*); C, ovoid (*Panicum turgidum*); D, cylindrical (*Imperata cylidrica*); E, lanceolate (*Hordeum spp*); F, orbicular (*Eremopyrum bonaepartis*)
4. Flower or spikelet's pedicel	A, without pedicel- sessile (*Lolium temulentum)*; B pedicelled (*Lolium rigidum*)
5. Spikelet's disarticulation	A, persistent (*Avena sativa*); B, as a unit (*Paradoxa* spp); C, separately (*Avena fatua)*

6. Spikelet's separate disarticulation position			A, below each floret (*Bromus* spp); B, between all florets (*Avena fatua*)
7. Spikelet's cover			A, with hair (*Cenchrus* spp); B, without hair (*Eragrostis* spp); C, ciliate (*Stipagrostis* spp)
8. Glumes size			A, equal (*Aegilops* spp); B, unequal (*Aeluropus* spp)
9. Glumes – lemma texture			A, rough- rigid (*Dichanthium annulatum*); B, nerved (*Stipagrostis* spp.); C membranous (*Poa infirma*); D, glossy, shiny (*Echinochloa colona*); E, chartaceous- thin dry, papery (*Phalaris minor*); F, herbaceous (*Bromus madritensis*).
10. Glumes and lemma	Upper glumes	Shape	A, ovate *(Stipagrostis ciliata*); B, elliptic (*Dinebra retroflexa*); C, lanceolate *(Stipagrostis obtuse*); D, oblong (*Bromus tectorum*); E, linear (*Eremopyrum distans*).
		Features	A, Pubescent (*Hordeum* spp); B, hairy (*Digitaria ciliaris*); C, membranous (*Avena* spp); D, hyaline (*Rostraria cristat*); E, gibbous (*Melinis repens*); F, chartaceous (*Bromus* spp); G, coriaceous (*Lolium* spp); H, shorter (*Bromus catharticus*)
		Keels	A, with keels (*Bromus* spp); B, without keels (*Lolium* spp.)
		Glumes veins	A, 0; B, 1 (*Cenchrus setiger*); C, 3 (*Poa annua*); E,4 (*Parapholis incurve*); F, 5 (*Melinis repens*); G, 6 (*Schismus barbatus*); H, 7 (*Aegilops kotschyi*).
	Lower glumes	Shape	A, ovate (*Imperata cylindrica*); B, elliptic (*Dinebra retroflexa*); C, lanceolate (*Stipagrostis* spp.); D, oblong (*Melinis repens*); E, linear (*Eremopyrum distans*).
		Features	A, hairy (Hordeum spp); B, membranous (*Avena* spp); C, hyaline (*Imperata cylindrica)*; D, gibbous (*Eremopyrum bonaepartis*); E, chartaceous (*Phalaris* spp); F, coriaceous (*Aegilops* spp); G, shorter (*Schismus* spp)
		Keels	A, with keels (*Bromus* spp); B, without keels (*Melinis repens).*

		Glumes veins	A, 0 (*Sphenopus divaricatus*); B, 1 (*Eremopoa persica*); C, 3 (*Echinochloa colona*); E, 5 (*Imperata cylindrica*); G, 7 (*Aegilops triuncialis*); I, 9 (Panicum turgidum).
	Lemma nerve counts		A, 1 (*Pennisetum divisum*); B, 3 (*Eremopoa persica*); C,5 (*Ammochloa palaestina)*; D, 7-13 (*Avena* spp); E, 9-11 (*Aeluropus littoralis*)
	Lemma apex		A, awned (*Bromus* spp); B, awn less (*Echinochloa colona*)
	Awn counts		A, 1 (*Eremopyrum bonaepartis*); B,3 (*Stipagrostis* spp)
11. Receptacle surface			A, coriaceous-leathery (*Bromus* spp); B, glabrous, or without scale like ridges (*Avena* spp); C, pubescent (*Phalaris minor*); D, hairy (*Digitaria ciliaris*); E, spiny (*Cenchus* spp.).

An example of the use of the identification process for two species from **Geraniaceae family - *Erodium cicutarium* and *Erodium ciconium*** is as follow

1	Nodes of stem not swollen; carpels fused by their styles to a central column elongating in fruit ……	2
	Nodes of stem swollen; carpels not fused by their styles to a central column elongating in fruit ……	Other included families
2	Inflorescence umbel……	3 (Geraniaceae)
	Inflorescence not umbel……	Other included families
3	Stamens 7-10, Fruit beaked……..	4 (*Erodium* Sp.)
	Stamens 5, Not beaked…….	Other included Sp.
4	Fruit beak length 2.5-3.5 cm long……	***Erodium ciconium***
	Fruit beak length 4.5-5 cm long…….	***Erodium cicutarium***

4.4 Discussion

To help identify part of the Flora of Kuwait, an interactive multi-entry and dichotomous keys are presented. The identification process follows a procedure whereby the user selects specific characteristics from the list of features available. In the provided key there are specific taxonomic features to start with. However, the Dichotomous family keys (Appendix 2, and 3) have suggested characteristics to start with, and this will minimise error in the elimination process. The application process is followed by use of genera and ends with species features and a subset of entities. In addition, the application also follows the use of dependency scoring to determine the logical relationships between features. The state of one feature controls the presence (or absence) of another feature. For instance, the selection of the option 'leaf development' followed by 'reduce to scale' will only display features of species without leaf. The same procedure is implemented for 'indumentum' followed by 'without indumentum' as a result of these selections, the designed program will not display any features related to 'plant indumentum type or shape'. The use of dependencies results in a reduction in states of specific feature, and makes the identification process become simpler.

In the research, there are numerous characteristics of features and states developed in the key, due to lack of taxonomic relationship among family and genera used. This is taken into consideration when improving the key score value. However, the creation of identification aids if or the flora of Kuwait, means they can be used for education purposes and field research, can be expanded to cover all the taxa of the flora of Kuwait. However, if an expanded key is to be created, it will require significant novel research because the taxa are poorly documented. Furthermore, overgrazing by livestock adversely affects much of the natural vegetation and has led to the rapid depletion of the Arabian Peninsula's flora

(Ghazanfar, 1998). The lack of existing morphological datasets and the rarity of the taxa mean there are difficulties when creating identification aids, a full floristic inventory requires development.

The provided identification tool cover for 62% of the flora of Kuwait allows the user to identify the rare and threatened taxa in Kuwait and compare it with species from the same genera found in Kuwait. However, the process of assigning states to taxa leads to uploading a large amount of information related to features and states to differentiate genera from different families. On the other hand, developing key features related to genera from different sub-families reduces the characteristics used in the identification process. For example, the created list of features to identify Asteraceae (Gymnarrhenoideae, Gnaphileae, Carduoideae, Cynareae, Anthemideae, Inuleae, Astereae, Senecioneae, Cichorieae, and Heliantheae subfamilies) and Poaceae (Andropogoneae, Aristideae, Eragrostideae, Panicaea, Bromeae, Aveneae, Poeae, Triticeae subfamilies). The suggested identification tool for Poaceae species found in Kuwait consists of 19 floral characters, reviewed in Table 4.2. However, the main features used in the identification and differentiate entities related to this group is the glumes and lemma, in addition to the compact head a structure shape. Whereas, the suggested tool developed through variety of features used to differentiate Asteraceae species found in Kuwait (Table 4.1) such as: compact head a structure shape, flower or spikelet's pedicel availability, spikelet in paired or not, spikelet's disarticulation, disarticulation position, spikelet long and cover. However, the rest of interties and features is used in the designed program to creates a full descriptive illustration in the identification process.

The score analyser tool is part of the Lucid program, used to analyse the process of differentiating entities used in the key and separating taxa. In addition to the numeric analysis,

the programme provides the information graphically. In the case of our research, all of the taxa are separated by more than two states, with an average of 39 different separation point. The result changes according to the relation among genera and the number of characteristics listed.

To minimise observations errors, it is recommended and necessary to review the written information with live material, which can help in using the correct identification process. This means that the preserved specimens lack some specific characteristics which have a key difference (e.g. indumentum, petal colour). The application provided a map image of the possible location (in Kuwait) of species used in the research, according to the accessions of preserved specimens. It is expected that the interactive key will facilitate future periodic updates. Subsequently, this will benefit all those interested in identifying listed taxa and uploading more data to expand research.

Acknowledgements:

The concept discussed here stimulated by the re-establishment of Kuwait University herbarium, which was destroyed in 1990. We acknowledge assistance from the herbarium expert, Hope expand research, and identifying rare and non-protected taxa from the flora of State of Kuwait.

Chapter 5

Red Listing Assessment for the Flora of Kuwait

Mouza Nassep[1], Joana Magos Brehm[1] and Nigel Maxted[1]

[1]School of Biosciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK.

Abstract

The aim of the research is to establish threatened status and develop a Red List Category for the prioritised species of the flora of Kuwait, understand the global situation of the priority list, and contrast with the National Red List Category for the native ones. The working list is the priority taxa of 118 rare and threatened Kuwaiti species from 32 families. The assessment followed the design application of the International Union for the Conservation of Nature (IUCN) - Species Information Service SIS, providing information on status, trends and threats. Through the application, the global threat categorisation for the priority working list was assigned. Global IUCN Red List criteria reveals that among all taxa, there is a high priority list of only (1) Vulnerable (VU) taxa, (3) species of Near Threaten (NT) species were identified, 111 are considered to be of low risk and assigned as Least Concern (LC), and (3) are Data Deficient (DD) consider under further investigation, to place them in any category. There is a correlation between geographical range and threat categories, which is related to the decline in habitat. The threatened species mentioned is native to Western Asia and Arabian Peninsula. Subsequently, an assessment applied on the Kuwaiti native (N) taxa and native weed (NW), excluding the non-native weeds and cultivated plants which considered Not Applicable (NA). The working list consists of 74 taxa of native status. The regional assessment resulted in 17 taxa (23%) threatened; of which 2(3%) are Critically Endangered (CR), 1 (1%) Endangered (EN),

and 14 (19%) Vulnerable (VU). There are 9 taxa (12%) assigned as Near Threatened (NT) species, and 31 (42%) taxa are Least Concern (LC). The assessment also revealed that 17 (23%) species were categorised as Data Deficient (DD) as there are no credible records. The DD taxa' appearing to have a relatively restricted distribution within Kuwait, this is based on unconfirmed relatively old records. Assessment concluded that species with high conservation priority in Kuwait are not generally restricted on a global scale.

5.1 Introduction

5.1.1 Global and Regional Red List

Using the IUCN Red List has many benefits, it is considered the most comprehensive resource as it enables a description of global threat status for species (Rodrigues *et al.,* 2006). It encompasses the use of environmental and taxon population information in the development of the threat assessment (Meynell, 2005). The assessment provides information for activities such as the implementation of planning conservation (Hoffmann *et al.*, 2008) and prioritisation of taxa for developing a national conservation policy (De Grammont and Cuarón, 2006). In addition, the use of IUCN Red List strengthen the sustainable conservation plan according to the discussion result of the workshops during the assessment process. The Red List categorisation is used to establish a list of taxa with high conservation priority (Miller *et al.,* 2007). Categories are assigned on the basis of quantitative criteria, geographical range of distribution and population trends and structure. According to the data obtained, the status will be declared as Vulnerable, Endangered, or Critically Endangered and would result in them being considered as threatened (IUCN, 2001). The regional and global assessment categories are the same except for the fact that there are two new categories in the regional: Regionally Extinct (RE) and Not Applicable (NA), and the former assessed species through part of their range and the latter throughout their entire range (IUCN, 2003).

Conservation threat assessment should be objective and comparable, and it is used to help categorise prioritised species according to the rate of threat and risk of extinction (Nowak *et al.*, 2020). The most accepted species categorisation used to create the red lists at national and international level is the *2001 IUCN Red List Categories and Criteria* (Spain by Bañares *et al*., 2004; IUCN, 2004; Great Britain by Cheffings and Farrell, 2005; Sweden by Gärdenfors,

2005; Luxembourg by Colling, 2005). Nowak *et al.,* (2020) carried out assessment research on global and national threat categorisation of vascular plants of Tajikistan, and he emphasised that the most effective conservation actions, policies and law implementation take place at the national scale, using IUCN criteria and guidelines at regional levels to guide the policies designed and implemented.

5.1.2 Red list in the Arabian Peninsula

The Arabian Peninsula occupies about 3,100,000 km^2, with the Arabian desert being the second greatest desert on Earth. It covers an area of about 2,3000,000 km^2 and is surrounded by mountains which run along the Western, much of the Southern, and the South-Eastern coasts, and shelving more gradually towards the desert interior (Cox *et al.,* 2012). The Arabian flora has highly important genetic diversity and this is due to their adaptation to harsh environmental conditions. In addition, the Arabian flora are genetically heat and water stress resistance. Plants in the desert environment have evolved characteristics that enable them to survive in their environment. This assists with facilitating germination, growth, and reproduction, with each stage showing adaptation to the host environment. Desert plants develop adaptive modifications, such as develop a waxy covering on stem and leaves, spines and hairs to shade plants, and some shallow widespread roots to absorbers maximum moistures. The modification developed to escape un-favourable environmental conditions (Kameswara, 2013; Patzelt, 2008-2018). Kameswara (2013), states that approximately 70 of the flora in the Arabian Peninsula are considered food and forage crops. With over 400 wild relatives of food and forage crops, medicinal plants, ornamental and plant used for industrial purposes, each having natural adaptation to the harsh environmental conditions that are associated with future climate change associated conditions Maxted *et al.* (2020). The species

are an important source of genes for crop improvement being particularly useful in mitigation of climate change. In addition, the Arabian flora have great potential value for the global agriculture (Maxted *et al.*, 2006).

The number of species included in the national floras in Arabian Peninsula is listed in Table 5.1. Some of the details are related to the categorisation of threat assessments at the national level, however, some have not yet been assessed. Research applied to assess the threat categorisation in Saudi Arabia revealed that four plant species that were studied and considered as threatened, have not yet been completely assessed- as shown in Table 5.1 (IUCN, 2020). In Bahrain and Qatar, the IUCN Red List reports an unknown status of plant threat assessment which has been applied (ARC-WH, 2017; IUCN, 2020). On the other hand, the floristic status of Sultanate of Oman and United Arab Emirates is studies with a range of specifications and categorisations. In Oman, the flora has a high degree of endemism with a total of 191 restricted endemic species (Miller and Cope, 1996; Patzelt, 2018). With 15.8% of the flora being range-restricted to Oman (Patzelt, 2008). According to Ghazanfar (1998), 4.6% of the flora in Oman is threatened, with 0.7% of the flora Critically Endangered, 0.2% Endangered, and 2.0% Vulnerable. Patzelt, (2014), mention that 105 plant species are rare and threatened. Another recent threat assessment developed by Patzelt (2018), produced a guideline for the strategic conservation assessment, the focal points to start with, and the botanical survey which used throughout the Sultanate. However, baseline data related to the distribution and population size were lacking. The assessment provided a comprehensive assessment total of 153 threatened and 87 near threatened plant species listed. The assessment revealed that the challenge to the survival is due to the rapid development, industrialisation and urbanisation (Patzelt, 2018).

Table 5.1: Data Record for the Applied Plant Conservation Threat Assessment on the Arabian Peninsula States. (Patzelt, 2018, 2014; IUCN, 2016; UAE Plant Red list, 2016; Shahid and Poa Nanduri, 2015; El-Sheikh and Abbadi, 2004; Omar, 2000).

Country	Land Area Km^2	Identified species	Assessed plant species	Threatened species
Bahrain	765.3	327	Unknown	Unknown
Kuwait	17,818	374	1 globally	28 Threatened (non-systematic)
Qatar	11,571	371	1 globally	1 Threatened Globally
UAE	83,600	809	432	16 Threatened Regionally
Oman	309,501	1200	Regionally assessed	153 Threatened Regionally
Saudi Arabia	2,149,690	2247	4	4 Threatened Globally (not yet assessed)

SSC Medicinal Plants Specialist Group has a keen interest in the Arabian Peninsula. In particular, the Landscape Agency of the Government of Ras Al Khaimah-UAE. In Abu Dhabi-UAE flora has been reviewed regionally and covered the conservation status of 432 plant species (IUCN, 2016). According to the regional conservation assessment applied, eight plant species are listed as Threatened and *Schweinfurthia imbricata* is the only Endangered (EN) species. There are seven Vulnerable (VU) species, such as: *Haloxylon persicum*, *Desmidorchis arabica*, *Nannorrhops ritchieana, Prosopis cineraria* and other three plant species. The assessment by the UAE Plant Red list (2016) concluded that *Acridocarpus orientalis* is Near Threatened (NT), and 402 species are of Least Concern (LC) in the draft UAE Plant Red list, following Table (5.1). Another non- systematic revision of the flora in the UAE resulted in an

additional eight undocumented plant species, that were found growing in different parts of the country. These species are: *Bromus diandrus*, *Lolium multiflorum, Diplotaxis erucoides*, *Alternanthera sessilis*, *Amaranthus lividus*, *Commelina benghalensis, Kickxia elatine,* and *Cyperus eremicus.* All the mentioned species are considered newly-reported species, and have been recorded in only one single location. Thus, all of them are rare in the UAE and appear visually vulnerable (Shahid and Poa Nanduri, 2015).

In Kuwait, the information mentioned in Table (5.1) related to threat categorisation is not systematic and lacks any kind of justification. Most recent research describes the geographical location and the evaluation of conservation measures. It is dependent on information related to the descriptions of the vegetation cover in specific locations. A study carried out in Sabah Al-Ahmad Natural Reserve developed by El-Sheikh and Abbadi, (2004), recorded 28 threatened species. The research categorised them as endangered, rare, exclusively restricted to the park, very restricted elsewhere, and being recorded from one locality only, but not by applying the standard IUCN criteria (IUCN, 2001). The information is having not been reassessed subsequently in terms of data collection and analysis, and was relatively unsystematic and lacked coordination. However, the information is valuable in describing the actual situation for species in specific areas. According to the research, individual species conservation is very rare to find as the research concentrates on developing a general description for taxa in a specific area. The only species assessed and found threatened is *Acacia pachyceras,* which was assessed as being Near Threatened (IUCN, Version 2.3; 1989). This species has only one individual which inhabits Sabah Al- Ahmad Natural Reserve and has an age of about 80 years (Omar, 2000).

5.1.3 Factor Influence the Red List Application

The research aims to investigate the status of the vegetation in Kuwait, in order to mitigate desertification, aid resource utilisation and conservation. In fact, the vegetation cover in the Kuwaiti desert has declined, as discussed in the first chapter. There was a total of 374 species from 55 families observed in Kuwait, according to Daoud, (1985), Al-Rawi (1987), Dickson and Macksad (1973), Halwagy and Macksad (1972) and Omar *et al*., (2007), only 315 species were observed and collected by the Kuwait University Herbarium and Museum over the last 25 years. It is necessary to know the species that may be most vulnerable and threatened. Although some species may have been lost, many of the 59 species may have relocated and are believed to exist. Further research is required in order to discover their presence. The combined criteria used in creating the working list needs further investigation through assessing their status using the Red List criteria. However, many factors may influence the application which are outlined below.

5.1.3a. Data Availability and Uncertainty:

The major obstruction in the assessment of conservation status using IUCN Red List criteria is the lack of basic database and the limitation of its accuracy (El Hadji *et al.,* 2006). However, in arid environments, reaching an accurate assessment is more difficult due to many factors including: the variation in temperature and misunderstanding of the nature and the extent of the threats. Within areas of harsh environmental conditions, the implementation of field surveys is an important factor in the successions of the conservation assessment. However, the stored herbarium data has to consider many factors such as: uncertainty and time scale of herbarium records, seasonal variation of flora germination and restriction of habitat occupancy. Moreover, the field survey emphasises the ecosystem approach, social aspects,

participatory dimension and strengthen the implemented conservation assessment (El- Hadji *et al.,* 2006).

5.1.3b. The Decline in the Quality of the Species Habitat.

Habitat quality affects the access to resources needed for initial survival, which can have an impact on the individual species distribution. The improvement of the result is related to the development of a deeper relation between threat and individual occurrence in the region or country. The extreme fluctuation of data records and seasonal variation, combined with fragmentation of population needs accurate interpretation in arid environments. However, climate change and long-term drought consequences, in addition to sudden floods affects species occurrence. Unstable increase in temperatures and unexpected stormy weather, leads to a high stress response. However, research is needed to confirm the effect of the combined factors related to the fragmentation of populations of individual species (Schleuning *et al*., 2009).

Humans use most of the land surface, and the natural habitat is a fragmented portion of the original space on land. The quality of plant production is dependent on the potential evolution of remaining plant populations in fragmented habitats. This also depends on the species' ability to adapt to the change in the environment (Aguiler *et al*., 2019). Human destruction leads to fragmentation or loss of habitat, decrease in original area which leads to the increase in isolation (Lindenmayer and Fischer, 2006). Moreover, the human misuse of land and destructive overgrazing changes the structure and composition of soil (Pykala, 2019). These factors might be affected by grazing or other threats which affect the occurrence of the species (Silcock *et al*. 2014). These changes affect the structure and function of remaining habitat, and it is frequently making it difficult to distinguish the relative effects of

habitat loss and habitat fragmentation (Aguiler *et al.,* 2019; Didham *et al*. 2012; Hadley and Betts, 2016).

Habitat fragmentation in the Arabian Peninsula arid region increases the threat due to the narrow range of species distribution. In addition, climate change also leads to a decrease in vegetation due to the stress response in the diverse arid region. In the Arabian Peninsula, habitats are disturbed by: drought, contamination of the oil exploration industry and oil spills. These have resulted in further decline in the quality of species' habitat (Ghazanfar and Fisher, 1998; Hall and Miller, 2011; Ahmad-Adbbas *et al.,* 2020).

5.1.4 Kuwait Biological Diversity

Although Kuwait is not rich in biodiversity, there are still several desert of importance species. There are 374 plant species belonging to 55 families native to Kuwait, where 256 are annual species, 83 herbaceous perennials, 34 shrubs species, and only one native tree species locally known as "Talha"(*Acacia pachyceras*) (Omar 2007; Boulos and Al-Dosari, 1994; Daoud, 1985; Al-Rawi, 1987). The prioritisation criteria applied to species threat assessment include (IUCN, 2001): rarity and protection status at the state level depending on (A) the number of individuals, (B) the time range of specimen collections, and (C) the size of the geographical range: (Ci) extent of occurrence (EOO); (Cii) area of occupancy (AOO), (D) protection status of provinces, and (E) threats affecting the occurrence. This initial assessment involved the priority list of 121 Kuwaiti species identified in Chapter 3 using the 6 criteria to prioritise species which scores of 20 or more points.

5.2 Aim

The aim of this research was to investigate the status of the prioritised species of Kuwait flora and to highlight the threat status of these species at a global and regional level. It also aimed to find out the relation of the particular endangered group to the ecological and climate factors in Kuwait. The International Union for the Conservation of Nature (IUCN) - Species Information Service SIS was used for developing information on status, trends and threats. The information provided in lists can help in the desertification mitigation planning, research and development of conservation strategy.

5.3 Material and Methods

The Global Red List assessment was undertaken for the 121 prioritised species according to criteria developed earlier in chapter 3. Using the Species Information Service SIS (available at: https://sis.iucnsis.org/apps/org.iucn.sis.server/SIS/index.html for data collation. Data was uploaded according to the standard documentation process. The assessment was followed by the creation of national conservation threat categorisation for the (74) native species. According to research applied by Halwagy and Macksad (1972), Daoud (1985); Al-Rawi, (1987); Boulos (1988); Boulos and Al-Dosari (1994); Tropicos (2019); The Plant List (2019); Board of Trustees of the Royal Botanic Gardens- Kew (2019), most of the native plants and naturalised plants should be adapted to the regional climate conditions. The application allows for downgrades and upgrades from global assessments, according to conspecific populations outside the region and the status of regional populations as sinks (Magos Brehm *et al*., 2007; IUCN, 2003). The IUCN Red List categories and criteria: version 3.1 (IUCN, 2001) was applied. The application followed guidelines on the documentation standards and consistency checks

for IUCN Red List assessments and species accounts. Assessments data were compiled using information associated with herbaria, environmental and biological network: Royal Botanical Garden-KEW; Tropics; African Plant Database; Global Biodiversity Information Facility – GBIF, Genesys Gen Bank and other environmental societies, threat-search; and many other data sources refer to standards used for documents and taxonomic information.

5.4 Result

5.5 5.4.1 Habitats and Ecology

The working list consists of 121 plant species, however, species with unresolved names were not added. These are: *Medicago brachyacantha* Boiss; *Convolvulus* buschiricus Bornm, and *Calendula arvensis* Vail L., contributing data sources did not contain sufficient evidence to decide whether they were accepted or synonyms. The 118 - priority list (Appendix 5.1) contains 71% (84) annuals including (2) dependent species living as parasites and 29 % (34) perennials including (2) dependent species living as parasites life form, as shown in Figure 5.1. Data revealed that 37% of the priority list, which are 44 species, were not native flora of Kuwait as shown in Figure 5.2. 63%, represented by 74 species, of the priority list are native and will be assigned national threat assessment.

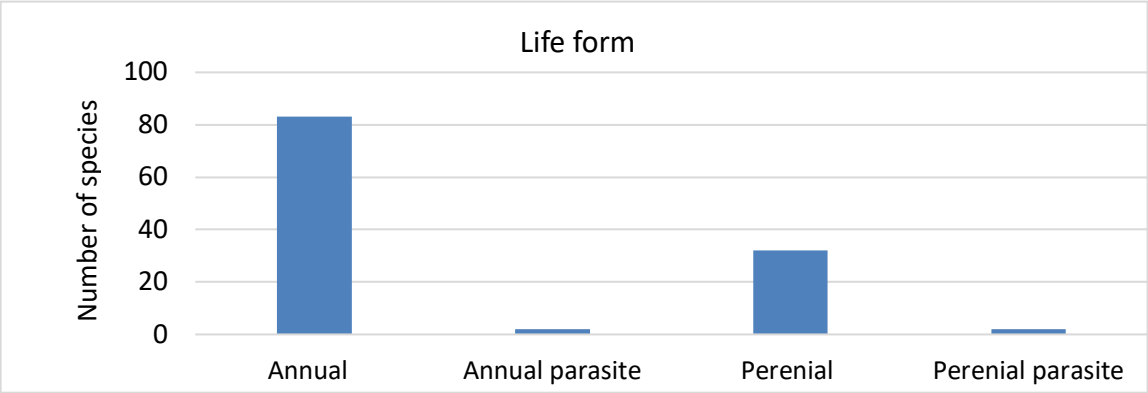


Figure 5.1 The Priority List Defines the Plant Species and Life Form.

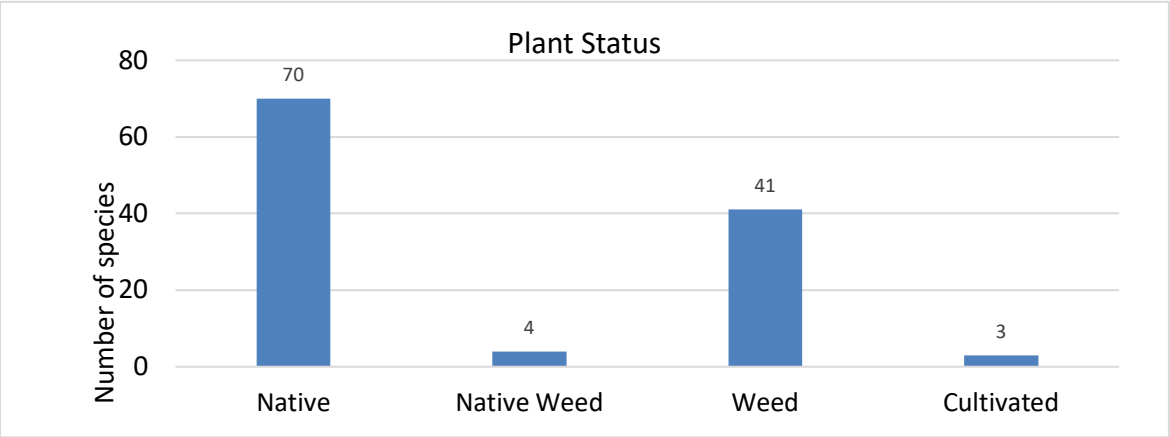


Figure 5.2 The Priority List Plant Status.

5.4.2 Red List Assessment

Global assessment resulted in prioritised Kuwaiti taxa as shown in Appendix 5.1 and Figure (5.3-A). The assessment identified one threatened vulnerable (VU) taxa (*Acacia pachyceras* O. Schwartz var. *najdensis (Chaudhary) Boulos*), the species lacks adaptation to endure prolonged drought due to seed dormancy since the last evaluation assessment in 1998. Three taxa were assigned as Near Threatened (NT), these are: *Centaurea mesopotamica* Bornm; *Aegilops bicornis* (Forssk.) Jaub. & Spach; and *Stipagrostis drarii* (Täckh.) De Winter. The Near threatened taxa were observed in an area with a declining quality of habitat. The decline in

quality is related to variety of threat types such as: industrial, pollution under many categories, development and tourism, and recreational activities. Moreover, the native distribution of them is narrow and they are rarely observed. A total of 111 taxa (94%) of the priority list were evaluated as Least Concern (LC) according to the research information available and standards followed. Three species from the working list were categorised as Data Deficiency (DD), but potentially further investigation and data retrieval would enable more research to be obtained, these are: *Withania somnifera* (L.) Dunal*; Limonium carnosum* (Boiss.) Kuntze; *and Gypsophila Vaccaria* (L.) Sm. The information on these species are with a degree of uncertainty and lack confirmation of severity. In addition, there is conflict among the taxonomic name in different regions.

At the regional level, an assessment was followed for the native (N) and native weed (NW) taxa, excluding the W- weeds, C- cultivated plants which were all deemed as not applicable (NA) at the regional level. Of the working list of 74 native taxa, 17 taxa have been assessed as threatened. Figure 5.3-B, showed that there were 2(1%) Critically Endangered (CR), assigned for: *Acacia pachyceras,* which is with risk of isolation and possible extinction. This is due to the extent of habitat conversion and level of dormancy in extreme prolonged drought. And *Centaurea mesopotamica* also assessed regionally as CR due to the fragmentation of the number of location- individuals are found in small and relatively isolated subpopulations. And the quality of the habitats in continue declined with unknown conservation or remediate measures are taken.

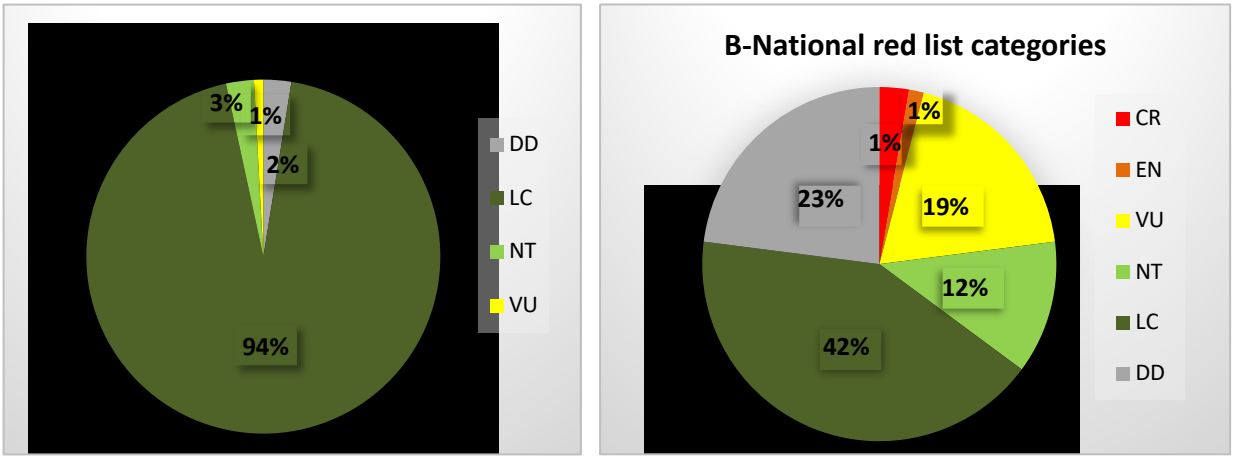


Figure 5.3. Percentage of Species Threat Categories for the Priority Flora of Kuwait A- Global and B- National.

Threatened categories also includes 1 (1%) Endangered (EN) assigned to *Cynomorium coccineum,* which is one of the medicinal valued species (Sdiri *et al.*, 2018). It is estimated that the species is observed in one locality with restricted area of occupancy, with plausible threats from human activities, affecting its habitat. The assessment concluded that 14 (19%) of taxa are assessed as Vulnerable (VU), Appendix 5.1 and Figure 5.6-B. However, VU assessed taxa is under criteria (D2). The criteria applied due to the presence of many factors and threats such as: restricted area of occupancy or number of locations and the continuing decline in the quality of habitat as a result of grazing pressure. In addition, in most cases of the VU applied criteria, species cannot tolerate activities near roads (human disturbance), and prolonged drought. Furthermore, the number of subpopulations of this particular category is continuing to decline. This is occurring with unknown remediate measures, unknown conservation plan, and a relatively old observation record.

The regional assessment applied for the priority native species in Kuwait concluded that 9 (12%) of taxa is assigned as Near Threatened (NT). For instance, *Aegilops bicornis* has

been assessed as Near Threatened (NT), with a possible regional decline in area of occupancy. This is due to the variety of threat on species distribution and the area is severely fragmentated. Some of the species of this category shows intensive decline in plant communities. The species observation is estimated from relatively old data (1935-1981) before the gulf war. In addition, due to the threat on the area of species distribution, there is a possibility of a decline in area of occupancy. However, some of the listed species exhibit a significant adaptation capacity for water limitation and high temperature in arid ecosystems.

The assessment consists of 31 taxa (42%) which are considered as Least Concern (LC), and so not demanding urgent conservation action. A total of 17 species (23%) have been assigned to the Data Deficient (DD) category as there are no credible occurrence records existing. Despite appearing to have a relatively restricted distribution within Kuwait, this is based on unconfirmed old records before Kuwait invasion and Gulf war. The area of species distribution was impacted with oil pollution from 15 oil fields. These oil field were divided into a Southern sector including Burgan and 4 other oil fields in the Northern sectors (Misak, 2001; Omar and Bhat 2008; Omar *et al*., 2009). In addition, the Data Deficiency (DD) category applied for species with taxonomic status was questionable.

5.5 Discussion

5.5.1 Distribution and Occurrence

The assessment revealed that 82% of the list were assessed globally as Least Concern and low risk of extinction, as shown in Appendix 1. This is related to their stable global geographic distribution. However, these species are still a conservation priority in Kuwait, due to a variety of national threat factors discussed, including overgrazing, urbanization and cutting of

woodlands. Moreover, increasing arid geographical distribution due to climate change is likely to lead to the change of individual occurrences and affects the initial survival of species.

Assessment research concluded that globally Vulnerable and Near Threatened taxa are linked to be particularly threatened in Kuwait due to the extremely arid and semi-arid regions. Analysing the area of distribution of the working list revealed 18% (21 taxa) globally occur only in arid regions (Table 5.2). These taxa have a narrow range of distribution and cover parts of the Mediterranean, Arabian Peninsula and slightly extend to cover part of Southwest and Western Asia (Figure 5.4). However, all of them are native species in Kuwait, covering 29% of the native prioritised species. Regional conservation assessment of them revealed that two species were Critically Endangered (CR): *Acacia pachyceras* and *Centaurea mesopotamica*, five were regionally Vulnerable (VU): *Stipagrostis drarii*, *Cuprella homalocarpa*, *Echium rauwolfii, Stipagrostis obtuse, Valerianella dufresnia* and Regional conservation revealed four species were Near Threatened (NT): *Aegilops bicornis*, *Ducrosia anethifolia, Ephedra alata, and Eremopyrum bonaepartis.* The regional assessment also concluded four species were Data Deficient (DD) and cannot be placed in any category, yet they warrant further investigation, these are: *Eremopoa persica, Zilla spinosa, Limonium carnosum.* Most of which are appear to have a relatively restricted distribution within Kuwait, this is based on an unconfirmed old record (1972-1988), before the Kuwait invasion and Gulf war. The invasion of Kuwait in 1990 and the subsequent wars caused increased pressure on the desert ecosystem. This resulted in further degradation of the groundcover and further losses in flora and fauna. In addition, the Data Deficiency (DD) category applied for species with taxonomic status was questionable, which is *Limonium carnosum* (Boiss.) Kuntze.

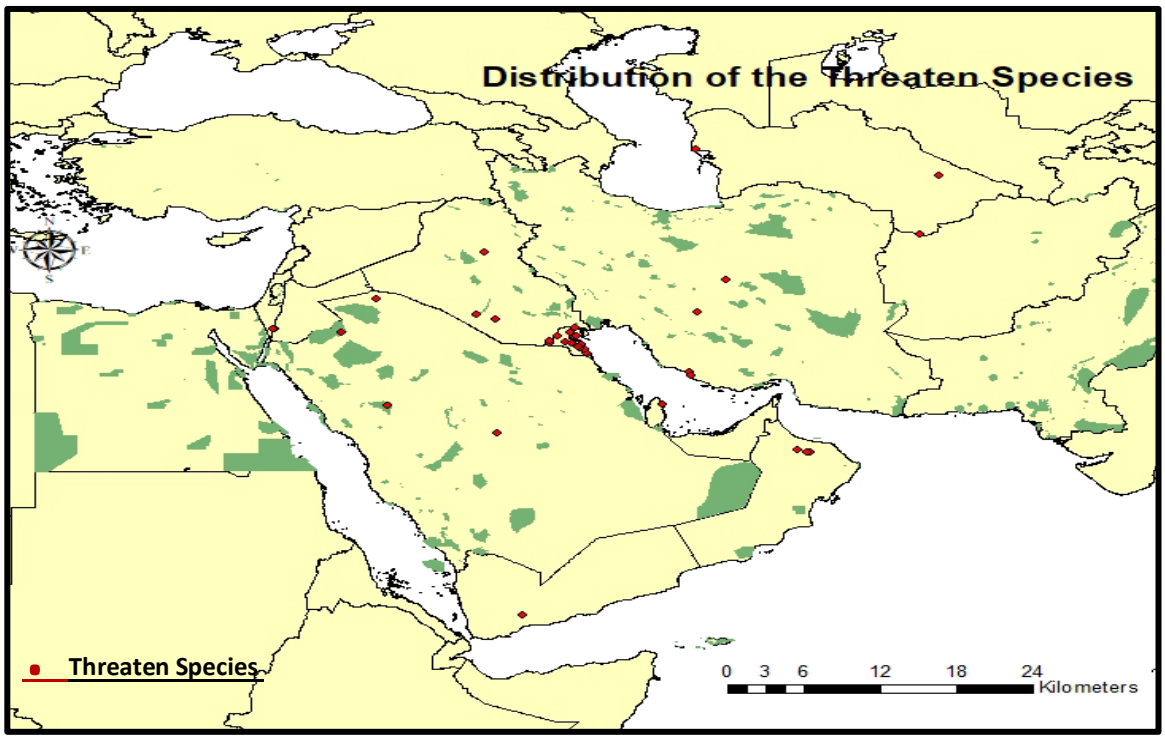


Figure 5.4 The Observed Specimens of the 18% of the Prioritised List Observe Only in Arid Region with Narrow Range of Distribution.

Species distribution in arid regions is estimated to be threaten by habitat loss and degradation. In Southwest and Western Asia deserts, cutting of woodlands and forests for commercial and fuelwood, and overgrazing by domestic livestock is having a direct impact on the conversion of natural ecosystems (USAID, 2001). Furthermore, ~40% of the total area of Iran are rangelands and have been degraded; vegetation cover has declined overtime and has been replaced by less desirable, and sometimes toxic species (Mofidi *et al.,* 2012). In the Arabian Peninsula, grazing in open areas is the main cause of land degradation (ICARDA, 2002). Overgrazing is estimated to be the greatest threat to desert ecosystems and is threatening the Arabian plant biodiversity affecting approximately 3,500 species (Ghazanfar and Fisher, 1998). Native species distribution is threatened by overgrazing as it causes a reduction in vegetation cover, increase in unpalatable species, decrease in species diversity, and alteration of soil

structure and compactness (Mainguet, 1994; Keya, 1998; El-Keblawy *et al.,* 2009; Zhou *et al.,* 2011; Belgacem *et al.,* 2013 and Kairis *et al.,* 2015).

The rare species observed in Table 5.2 has a narrow range of distribution and also threatened by human disturbance and tourism. Coker *et al.*, (2017), claims that urbanisation, resulted from population growth and expansion of cities, which have narrowly distributed taxa of conservation concern, can directly threaten local and regional biodiversity. UNDP (2014), estimated that 2 billion additional urban residents are predicted to be in urban areas by 2030, with the largest forecasted increases to occur in Asia and Africa. The expansion will lead to habitat reduction for species with small ranges that are located near to expanding urban areas (McDonald *et al.,* 2015). In addition, the location of listed species mentioned earlier has been disturbed by industrial pollution, namely from oil contamination and oil spills, particularly since the Gulf war in 1990. Above all threats mentioned, climate change and intrinsic factors are having an effect and predicted to change precipitation patterns and temperature. The area of threatened species is affected by desertification due to a 10 - 20% decrease in rainfall, and a 2 - 3^{o}C increase in temperature by 2050 (Kotwicki and Sulaimani, 2009). In the Arabian Peninsula, droughts occur more frequently and with greater intensity, while flooding also affects the region more often than before (Mooney 1990, Newman *et al.,* 2011, Schilling *et al.,* 2012). In addition, Kaniewski *et al., (*2012) mentions that the worst drought-affected regions were Eastern Syria, Northern Iraq and Iran. All threat categories were discussed for each assessed taxon individually according to the red list category and criteria guidelines and the documentation standards.

Table 5.2: Plant Species with a Narrow Range to Cover Part of the Mediterranean and Arabian Peninsula Slightly Extend the Occurrence to Cover Part of Southwest and Western Asia.

Genus/species	Growth form	Regional assessment	Global distribution
Acacia pachyceras	*P*	CR	Arabian Peninsula and Iraq and Israel
Centaurea mesopotamica	*P*	CR	Southwest Asia, part of Arabian Peninsula.
Stipagrostis drarii	*P*	VU	Iraq to Arabian Peninsula
Cuprella homalocarpa	*A*	VU	Egypt North to Western Asia, Arabian Peninsula and in Pakistan
Valerianella dufresnia	*A*	VU	Central Asia, Afghanistan, Armenia, Iraq, Iran, Pakistan, Syria, Turkey, and USSR. Western Arabian Peninsula.
Echium rauwolfii	*A*	VU	Mediterranean, Saudi Arabia, Kuwait, Sinai, Sudan, Yemen.
Stipagrostis obtuse	*P*	VU	Africa (North tropical and South), Asia temperate, Arabian Peninsula
Aegilops bicornis	*A*	NT	Northern Africa- Mediterranean, Arabian Peninsula and the Eastern Asia.
Ducrosia anethifolia	*A*	NT	Iran, Pakistan, Afghanistan, Syria, Lebanon, Arabian Peninsula
Ephedra alata	*P*	NT	North Africa, West Asia the Arabian Peninsula, Chad, Mali, and Mauritania.
Eremopyrum bonaepartis	*A*	NT	North Africa, Arabian Peninsula, Western Asia, Temperate and

			Tropical central Asia Turkmenistan, Uzbekistan, West Himalaya, up to China.
Arnebia tinctoria	*A*	LC	Libya, Palestine to Iraq and Arabian Peninsula
Caroxylon jordanicola	*P*	LC	Western Asia and Arabian Peninsula.
Cuscuta planiflora	*P*	LC	Mediterranean
Diplotaxis acris	*A*	LC	Part of Mediterranean region. Kuwait, Palestine, Saudi Arabia, and Sinai.
Diplotaxis harra	*A*	LC	Extends from Morocco to Pakistan through the Arabian Peninsula, Somalia, and Yemen
Strigosellla grandiflora	*A*	LC	Sahara- Arabian region, Afghanistan, Iran, part of West Asia.
Suaeda vermiculata	*P*	LC	Mediterranean region from the Western Sahara, North Africa, Arabian Peninsula, Socotra, Eastwards to West and central Asia -India.
Eremopoa persica	*A*	DD	Egypt Sinai, across the Northern Middle East, to West Asia
Limonium carnosum	*P*	DD	Iran, Jordan, Arabian Peninsula
Zilla spinosa	*P*	DD	North Africa, Arabia peninsula

5.5.2 Population

In arid and semi regions, baseline data related to plant species distribution and population size is often lacking for most of the working list. According to the research, the distribution of the Threatened and Near Threatened species (globally and regionally) mostly occurs in arid and semi-arid regions. Earlier global assessments since the 1970s concluded that desertification ranges between 4% and 70% in arid land regions, the research results are based on qualitative and expert evaluation (Safriel, 2007). The estimation depends on the distribution of vegetation, structure of species occurrence, drought-tolerant plant species, and many other factors, such as: climate condition, human development, and industrialisation (Maestre and Escudero 2009; Kéfi *et al.* 2010; An *et al.*, 2007). The mentioned factors used in the estimation of the vulnerability of desert vegetation (Salvati *et al.,* 2009). Further research on the severity of desertification varies according to the missing and/or unreliable information (Gibbs and Salmon, 2015). The population research needs to depend on definitive baseline data with ground observations and modelling approaches. Prince (2016) and Cherlet *et al.,* (2018), discuss the complexity and multiplicity of the quantitative measurements, as the desertification makes it more difficult to estimate threat. The need to establish a baseline population data has to be observed and developed systematically for each individual taxon in arid regions. The study of population diversity and distribution is influenced by many factors, such as: environmental factors, the capacity of species to change and respond to environmental conditions, and the interaction among plants and other organisms (Maestre and Escudero 2009; Kéfi *et al.,* 2010).

5.5.3 Use and Trade

Data revision of the working list of the 118 species assist in Red list categorisation describes 30 taxa as crop wild relative species listed in Table 5.3. These species are used in the improvement in tolerance to abiotic adaptation in economically important crops (Gairola *et al.*, 2018). Conservation assessment concluded that *Aegilops bicornis* assessed as NT, while the rest of the list with the regional and global evaluation of LC. From the listed species in Table 5.3, ten CWR taxa are native to Kuwait. These species are *Diplotaxis harra, Euphorbia densa, Euphorbia serpens, Bromus tectorum, Heliotropium kotschyi, Diplotaxis acris., Aegilops bicornis, Aegilops triuncialis, Dichanthium annulatum*, and *Cenchrus ciliaris.*

For instance, *Aegilops bicornis* is a secondary wild relative of and potential gene donor to bread and durum wheat, as well as several other cultivated wheats, including emmer, einkorn, spelt, and sanduri (van Slageren, 1994). *Aegilops triuncialis* L., according to the interpretation of the bread wheat gene pool of van Slageren (1994), are a secondary wild relative of Bread Wheat, *Triticum aestivum* L. subsp. *aestivum, Durum* Wheat, *T. turgidum* subsp. *durum* (Desf.) Husn., and other cultivated wheats. However, *Dichanthium annulatum* is another member of the Poaceae family used in the crop research studied to understand the mechanism of apomixis to transfer this trait to crop plants (Bhat *et al.*, 2011). *Avena fatua, Avena sterilis,* and *Avena barbata* are also related to the same family, are a primary genetic relative of Oats (*Avena sativa* L.) (Jellen and Leggett 2005, USDA – ARS - National Genetic Resources Program 2013). *Cenchrus ciliaris* part of the prioritised species, high tolerance to drought and use in research for understanding the ability stress-responses and to withstand heavy grazing (Marshall *et al.*, 2012). *C. ciliaris* consider an economically important crop. It is classified in species Group 4, following the definition of Maxted *et al.* (2006).

Table 5.3: Reviewing the CWR Taxa from the Priority List (CWRSG RLA)

No	**Genera and species**	***No***	**Genera and species**
1.	*Aegilops bicornis* (Forssk.) Jaub. & Spach.	2.	*Aegilops triuncialis* L.
3.	*Avena barbata* Pott Ex Link	4.	*Avena fatua* L.
5.	*Beta vulgaris* L.	*6.*	*Bromus catharticus* Vahl
7.	*Bromus moeszii* Pénzes	*8.*	*Bromus tectorum* L.
9.	*Cenchrus ciliaris* L. a synonym of *Pennisetum ciliare* (L.) Link	*10.*	*Chenopodium album* L.
11.	*Chenopodium glaucum* L.	*12.*	*Chenopodium opulifolium* L.
13.	*Convolvulus arvensis* L.	*14.*	*Dichanthium annulatum* (Forssk).
15.	*Digitaria sanguinalis* (L.) scop.	*16.*	*Diplotaxis acris* (Forssk) Boiss.
17.	*Diplotaxis harra* (Forssk) Boiss.	*18.*	*Eragrostis minor* Host.
19.	*Euphorbia densa* Schrenk.	20.	*Euphorbia hirta* L.
21.	*Euphorbia peplus* L.	22.	*Euphorbia serpens* Kunth.
23.	*Heliotropium kotschyi* (Bunge) Gurke.	24.	*Lepidium sativum* L.
25.	*Limonium carnosum* (Boiss.) Kuntze.	26.	*Lolium temulentum* L.
27.	Malva nicaeensis All.	28.	Portulaca oleracea L.
29.	Setaria verticillata (L.) P.Beauv	30.	*Sorghum halepense* (L.) Pers

The working list of 118 taxa consists of 44% (52 taxa) of the medicinal value. IUCN-WWF Plants Conservation Programme emphasises that medicinal plants are of significant conservation priority. The 52 medicinal plants consist of 34 species with native status. The global position of the assessed medicinal taxa is considered stable and they are assessed as LC, with only three species assessed as DD. However, the regional Red List categorisation revealed that there are 12 threatened taxa, which are: *Allium sphaerocephalon, Artemisia scoparia*, *Cuprella homalocarpa, Cynomorium coccineum, Scorzonera tortuosissima, Ducrosia anethifolia, Echium rauwolfii, Heliotropium kotschyi, Launaea angustifolia, Malcolmia pygmaea, Traganum nudatum,* and *Valerianella dufresnia*. In Kuwait, it should be a priority to counteract diminishing stocks of medicinal plants through conservation programs, as the medicinal native species currently have unknown conservation or protection action and significant potential commercial value.

Research has enabled descriptions of the physical and environmental adaptations of the working list taxa. The adaptation of native species to the desert environment enables them to reduce growth to survive in the harshest environmental conditions. They inhabit deserts that experience low rainfall and high temperatures. Research revealed that a total of 40 species of the working list of the 118 were considered drought or salinity tolerant species (Figure 5.5), with 28 of these being native species. Furthermore, research inputted into the database features adaptations of some arid region species, such as adaptations related to unique root systems. The list consists of 11 native species with particular root adaptations suited for harsh environmental conditions through the root distribution, morphological features, and anatomical adaptation. For instance, *Convolvulus arvensis* has a long-lived root system. *Traganum nudatum* has old branches forming a dense tussock. It roots from the

lowermost habitat in sandy and rocky soils. Also, *Helianthemum kahiricum* stabilises sand dunes through their excellent root system development, improving organic soil matter content. *Acacia nilotica* is a legume species with Mycorrhizae nodules that fix nitrogen, and *Alhagi maurorum* has roots extending six to seven feet into the ground. Research inputted also provides information related to Ammochloa palaestina which stabilises dunes, and *Stipagrostis drarii* which produces new shoots from the axillary buds of the leafy culm. In addition, the native species' enable them to adapt to the environment through seed dormancy for favourable conditions. This is found in *Cuscuta planiflora* Ten., *Ducrosia anethifolia* (DC.) Boiss., and *Horwoodia dicksoniae* Turrill.

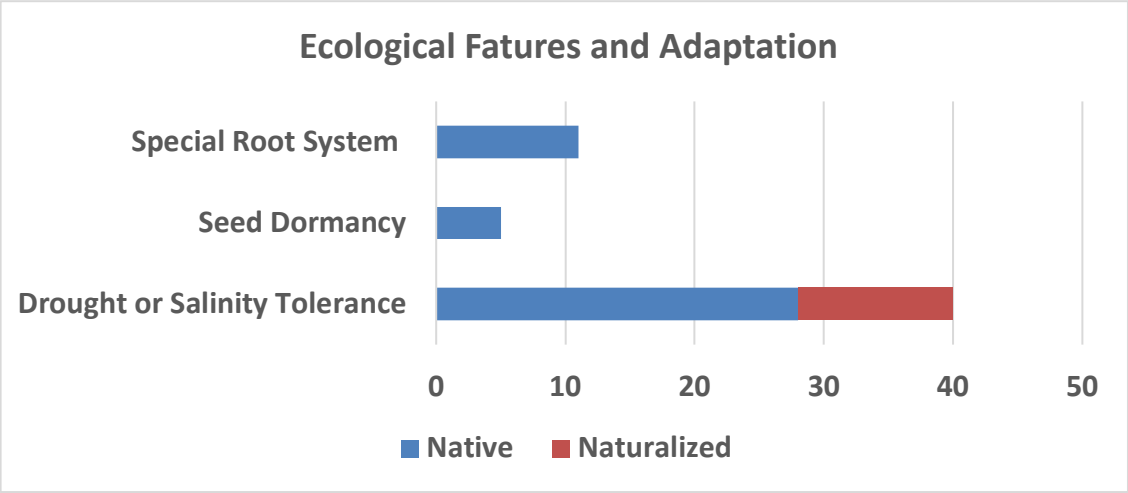


Figure 5.5 The Physical and Environmental Adaptations of Species from the Priority Taxa.

The Red list assessment for the 118 taxa also describes their tolerance to salinity, such as *Heliotropium Kotschyi* and *Artemisia scoparia*, which prefer dry or moist soil can tolerate drought. Also, *Centaurea mesopotamica* grows in saline depressions in sandy areas, *Halothamnus iraqensis* with seeds that can germinate under varying salinity levels. The

working list also alerted the need to conserve other species' according to their adaptation of highly saline soils, such as *Strigosellla grandiflora*, *Aegilops bicornis*, and *Horwoodia dicksoniae.*

The adaptation features can be used for conservation improvement and assist in developing the desired environment and climate change mitigation plans. Urgent conservation of the native flora is needed because of their natural and anthropogenic value. Species adaptations are used in research for understanding the molecular mechanisms of stress response for salinity and temperature adaptation to improve tolerance.

5.5.4 Threats

According to the IUCN threat scheme, 53% of the priority species were revealed to be located in one or more threat category. While when applying regional assessments, the native priority species are assessed as being under increased threat, 89% of the priority native taxa are located under one or more threat categories. Which affects the categorisation of taxa according to the Red list standard followed at the regional level. However, the DD taxa represented by 11% has unknown levels of threats. The disappearance of the species in the wild, estimated from old records, is considered a threat of all levels. Figure 5.6 (A-B) describes the major threat categories affecting the priority taxa at the A-global level, B- regional (= national) level. All threat categories related to the individual species assessment are counted in the analysis, even if the threats are not enough to assess the species as threatened or Near threatened ones. Globally, research revealed that climate change, drought and extreme temperatures; pollution, industrial & military effluents, oil spills; biological resource use related to gathering species; and energy production & mining from oil & gas drilling are the

major threats acting on the priority list species at a global level. In addition, agriculture including livestock farming and grazing also threaten almost 30% of the priority species at the global level.

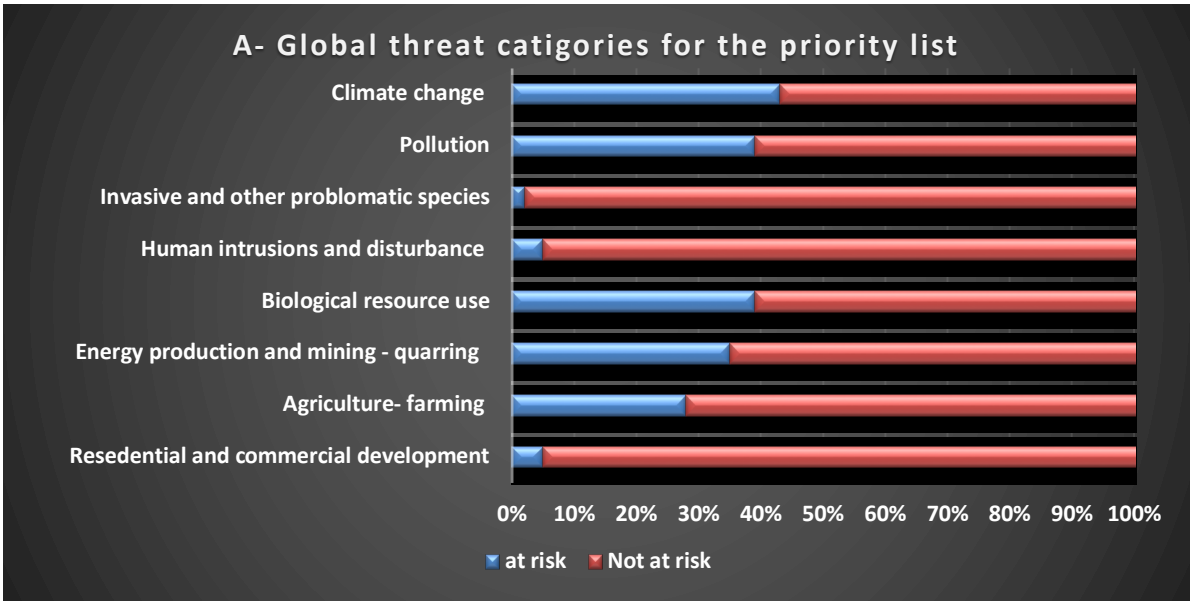


Figure 5.6-A: Major Global Threats Affecting Priority Taxa.

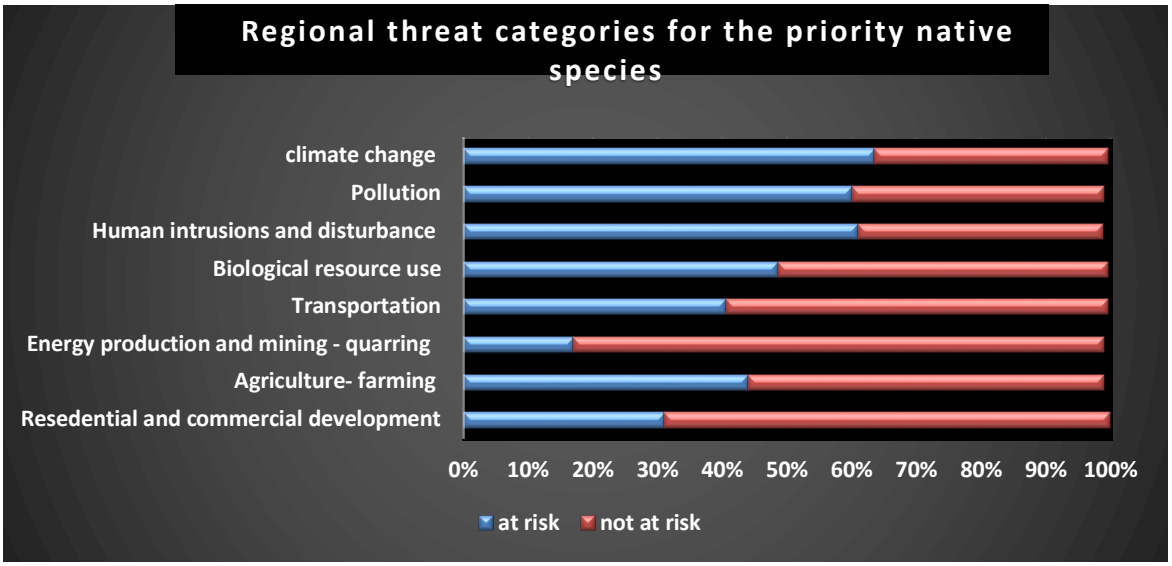


Figure 5.6-B: Threat Categories According to the Regional Threat Assessment.

Regionally, research revealed that the threatened categories are more developed whereby the descriptors go into more depth when describing the environmental threats on native species in Kuwait. Assessment revealed that Climate change (drought and temperature extreme) is having the highest impact on species in Kuwait, however, the information is inferred from research related to changes of the adaptation of native species. Pollution, such as garbage and solid waste, human intrusions and disturbance, recreational activities, such as transportation and service corridors off road, livestock farming and ranching such as nomadic grazing and biological resource use related to gathering species, are the major threats on the priority list species at a regional level. In addition, residential and commercial development such as tourism and recreational areas also threaten almost 30% of the priority species at the global level. In Kuwait, intensive land degradation has resulted in less vegetation and therefore shown a decline in plant communities. This is caused mainly by environmental factors (e.g. climate change and drought) and human interference such as the uprooting of shrubs, gravel quarrying, spring camping, off-road driving, livestock over-grazing, military activities and oil exploration (Al-Awadhi *et al.* 2001; Omar 2007; Brown 2003; Yirdaw *et al.* 2017; Issa and Vempatti, 2018). The detailed information outlined above can be found in the Species Information Service SIS (available at: https://sis.iucnsis.org/apps/org.iucn.sis.server/SIS/index.html.

5.5.5 Conservation

The global conservation measures for each prioritised taxon concentrates mostly focus on whether the taxa are found in a protected site or not and/or the germplasm accessions are sampled and placed in a gene bank collection. In which case then determined whether it is

from wild origin within the native range or not. Also, conservation of species depends on the global distribution of taxa and whether it is within a wide range of distribution or not. However, the species, such as CWR or the medicinal species, have a variety of conservation measures regionally. In Kuwait, conservation by protection of native species is described individually for each taxon. 28%, which is 21 species, of the native taxa were observed and collected from at least one protected site and are considered under conservation measures. Even so, some of them were assessed as threatened regionally due to other factors, such as seeds that exhibit physical dormancy, fragmentation, restricted area of accupancy and continue decline in sub-population, which affected their criteria assessment and categorisation, such as: *Acacia pachyceras, Ducrosia anethifolia, Traganum nudatum*. In addition, information related to site area management or *ex situ* conservation is unknown for all prioritised native species of our working list.

5.6 Conclusion

IUCN Red listing provides the best tool for the prioritisation of species; it is essential in the development of a conservation plan (Schmeller *et al.*, 2008). The assessment helps in identifying species at risk which can then be given early conservation action. In our research, species threat assessment at the global scale covers the whole range of distribution. However, regional Red Lists can determine the national range of distribution, which can help in developing the conservation programme by national authorities. Although, most of the species (84%) were assessed as having lower risk of extinction due to their stable geographic distribution, these species are still a conservation priority in Kuwait.

In our research the prioritised taxa reported in chapter 3, include: rarity and protection status at the state level depending on (A) the number of individuals, (B) the time range of specimen collections, and (C) the size of the geographical range: (Ci) extent of occurrence (EOO); (Cii) area of occupancy (AOO), (D) protection status of provinces, and (E) threats affecting the occurrence, applied to the species at the regional level. The use of the IUCN Red list enables an expansion of each category and criteria for each taxon individually. The significance of plant diversity assessment allows for a further development of detail related to threat, conservation, used, and geographical distribution of the Kuwait prioritised list. Comparison between priority data in Chapter 3 and Red list data related to the threat category, concluded that in both cases threat categorisation does not consider details related to climate change. Also, urban development is not well documented.

The criteria used in chapter 3 [include (IUCN, 2001): rarity and protection status at the state level depending on (A) the number of individuals, (B) the time range of specimen collections, and (C) the size of the geographical range: (Ci) extent of occurrence (EOO); (Cii) area of occupancy (AOO), (D) protection status of provinces, and (E) threats affecting the occurrence] was used to develop the list of 121 species which are currently under further investigation, from which 3 species are not included in the research as they considered to have an unresolved name (section 5.4.1). The main factor that influenced the 118 species being further investigated is the status of reduction of vegetation in Kuwait. The Red List assessment includes an in-depth literature review which describes a wide range of threats in Kuwait, and can also assist with conservation strategies.

The IUCN global assessment revealed that there is 1 threatened species, which is *Acacia pachyceras*. The species scored 24 according to the prioritisation chapter 3 due to its

rarity. Although the species is observed as protected, the Red List threatened status is related to a biological factor, as the species has physical dormancy due to the presence of the hard and impermeable seed coat which prevents water imbibition-physical dormancy in viable seeds (98% viability). In addition, since the last evaluation assessment in 1998, there has been no higher category which has been met for more than five years. The species area of distribution is an arid region and has severely declined in recent years as a result of prolonged drought, severely impacting the relatively isolated sub-populations.

The globally Nearly Threatened species are *Centaurea mesopotamica* and *Aegilops bicornis*, they scored regionally 25 and 26 respectively according to the criteria used in prioritisation in chapter 3. Both have a low observation rate in threatened regions and an extremely narrow range of distribution. *Centaurea mesopotamica* lacks any update in the available information of the occurrences from its native distribution, the species is considered rare in its distribution and is classified at risk of extinction (Thomas, 2019) with unknown record of protection or conservation, it is found in small and relatively isolated subpopulations, occurs at less than 10 locations. The global assessment applied for *Aegilops bicornis* meets the area requirements under IUCN threat criterion B (AOO less than 500 km^2) and is declining. In addition, the coastal subpopulations species are possibly at higher risk and severely fragmented. Although *Aegilops bicornis* is recorded from protected area, only one specimen has been observed since 1981 regionally. Similar observations were found for *Stipagrostis drarii*, which scored 21 from the criteria used in chapter 3. However, it should be considered that there is a discrepancy in the research size and comparison. This global Nearly Threatened species is native to Western Asia and the Arabian Peninsula, both areas are arid regions and vegetation is clearly suffering reduced patterns of rainfall and temperature. In the

Arabian Peninsula, droughts occur frequently and with great intensity, while flooding is also a growing problem for vegetation. This affects the annual and perenial species range of distribution in the regions (Mooney 1990, Newman *et al*., 2011, Schilling *et al.*, 2012).

According to the red list criteria, the IUCN regional assessment on the 74- native species from the prioritised ones in chapter 3 revealed 26 threatened and nearly Threatened species. However, the mentioned species' priority scoring status is varied as follows in Table (5.4) and Appendix 5.1-B. Research revealed that some of the observations related to the prioritised species are from relatively old recorded data, which was before the Gulf war and the Kuwait invasion. In addition, some of the species were observed by a single occurrence. Further research based on the previous studies developed the estimation of most of them, meant the estimate was not based entirely on samples found in the herbarium. However, a list of 17 species from the prioritised list is assigned to the Data Deficient (DD) category as no credible occurrence records are an existing priority score of approximately 25. Despite appearing to have a relatively restricted distribution within Kuwait, such as, *Euphorbia densa* which has single occurrence found in 1981. The species is missing within the native distribution range from Khiran, Al adaami, Al-Dbaiyyah, Um Al-Rimam, Jal Az zor, Mina Abdullah, Al-Mutla'a along the road of subbiyah, Basra road, al-Sobiyah, and Al-Wafra (Daoud 1985; Abdullah 2017). The recorded data is based on unconfirmed single old records before the Kuwait invasion and Gulf war. The score for the regionally assessed species is shown in Appendix 5.1 B. More information is needed on the species distribution and confirmation of its occurrence. In addition, the Data Deficiency (DD) category applied for the species has questionable taxonomic status.

The Regional IUCN threat assessment Critical Endangered category was applied for *Acacia pachyceras* and *Centaurea mesopotamica*. However, they scored 24 and 25, respectively, as shown in Table 5.4. As mentioned earlier, the Red List assessment for *Acacia pachyceras* is connected to the status of the species' biological factor, related to the species seed dormancy level. In contrast, the regional level of Red List categorisation for *Centaurea mesopotamica* is related to the increasing fragmentation of the number of locations. Individuals are found in small and relatively isolated threatened subpopulations, with a possible decline in the quality of its habitats, and unknown conservation or remediate measures are taken. However, low observations and a narrow-threatened range of distribution used in chapter 3 assisted in developing an in-depth Red List assessment, which considers the ecological, conservation, distribution, and use-values.

The estimation considers research based on the individual's previous studies, as well as using data of samples found in the herbarium, which led to an assessment of EN. The medicinal valued *Cynomorium coccineum* species is observed as protected, but the determination is based on the old recorded data. The literature review of the species revealed that *Cynomorium coccineum* found in the Jal az-Zor protected area in Kuwait is considered an Endangered species and very rare according to research followed by Malallah *et al.* (2001) and Omar *et al.* (2008), in addition to the fragmentation of the number of locations. The species is parasitic on the roots of *Zygophyllum coccineum* and collected from the Al-Khiran area only. However, the site is relatively high threated and no remediate measures are currently planned. The species has an unknown occurrence status in the Al-Khiran area, considering the literature related to the biological, uses and ecological data (Omar *et al.* 2008).

According to the research, the prioritisation scores help develop the Red List categorisation research and estimation obtained for the regional assessment. For instance, *Traganum nudatum* and *Crassula alata*, *Stipagrostis obtuse*, *Scorzonera tortuosissima*, *Cuprella homalocarpum*, *Stipagrostis drarii*, and *Malcolmia Pygmaea* has a priority score as shown in Table 5.4, categorised as Vulnerable according to the criteria used in the Red List assessment. The application depends on specific criteria, which concluded that the individual habitat is declining. Some of them need to be protected from grazing, as they are edible for domesticated and wild animals. In addition, the research revealed that these species have no active conservation measures in place. These single occurrences have a plausible threat from a variety of human activities. They occupy a restricted area with likely threats from drought, off-road traffic, and spring camping, affecting its habitat within a concise period, and their future is uncertain (Omar *et al.* 2008; El-Sheikh, *et al.* 2010, Abdullah 2017).

The average priority score for the species assessed as VU, and the NT is approximately 24. Some are considered rare species (El-Sheikh *et al.,* 2010). In Addition, the previously mentioned species distribution in the Arabian Peninsula, which is arid and has severely suffered in recent years from prolonged drought, has ultimately caused a decline in soil and plant productivity, resulting in further desertification (El-Sheikh *et al.*, 2010). Furthermore, some species considered part of the coastal vegetation has declined as a result of intensive land degradation, such as *Stipagrostis drarii*, with a priority scoring of 24. It is estimated that the restricted area of occupancy is now less than 10 km^2, and they are considered rare species (El-Sheikh *et al*., 2010).

There is a decline in coastal plant communities mainly due to environmental factors and human interference such as the uprooting of shrubs, gravel quarrying, spring camping,

off-road driving, livestock over-grazing, and military activities (Omar *et al*. 2008; El-Sheikh, *el al.* 2010; Valadbeigi and Lemraski, 2018). A similar observation was concluded for *Eremopyrum distans* with a priority scoring of 25 and assisted as VU. The regional statement shows an intensive decline in plant communities (estimated from data taken in 1978-1981). In addition, the species shows environmentally enforced low soil moisture, which causes the delay of germination (Wang *et al*. 2010). *Eremopyrum distans*, used in wheat improvement (Clayton and Renvoize, 1986), and *Heliotropium kotschyi* are also assessed as VU, and it has a priority score of 27. The Red List assessment revealed that although *Heliotropium kotschyi* is not ideal for stock grazing (Oatham 1997), the harsh desert conditions result in limited flora availability leading to camel and antelope grazing, further reducing the observation of species (El-Keblawy 2018). However, the combined criteria are discussed in-depth through the Red List assessment obtained from various research.

Table 5.4. The IUCN Regional Assessment Status and the Priority Score.

Genus species	Growth form	Threat category	Criteria Score
Acacia pachyceras O. Schwartz var. najdensis (Chaudhary) Boulos Syn. Acacia gerrardii.	P	CR	24
Centaurea mesopotamica Bornm. Beih.	P	CR	25
Cynomorium coccineum L.	P/P	EN	23
Allium sphaerocephalon L.	P	VU	21
Anthemis pseudocotula Boiss	P	VU	27
Crassula alata (Viv.) A. Berger	A	VU	25
Cuprella homalocarpa (Fisch. & C. AMey.) Salmerón-Sánchez, Mota & Fuertes	A	VU	23
Echium rauwolfii Delile.	A	VU	23

Eremopyrum distans (K. Koch) Nevski	A	VU	25
Heliotropium kotschyi (Bunge) Gurke.	P	VU	27
Launaea angustifolia (Desf.) Kuntze.Revis.	A	VU	23
Malcolmia pygmaea (Delile) Boiss. Syn. and Hesperis pygmaea Delile	A	VU	23
Scorzonera tortuosissima Boiss.	P	VU	23
Stipagrostis drarii (Täckh.) De Winter	P	VU	24
Stipagrostis obtuse (Delile) Nees	P	VU	23
Traganum nudatum Delile.	A	VU	25
Valerianella dufresnia Bunge Ex Boiss.	A	VU	23
Aegilops bicornis (Forssk.) Jaub. & Spach.	A	NT	26
Aeluropus littoralis L.	P	NT	25
Ducrosia anethifolia (DC.) Boiss.	A	NT	23
Ephedra alata Decne.	P	NT	23
Eremopyrum bonaepartis (Spreng.) Nevski	A	NT	25
Dichanthium annulatum (Forssk).	A	NT	27
Stipagrostis ciliate (Desf.) De Winter	P	NT	25
Typha domingensis Pers.	P	NT	23
Eragrostis minor Host	A	NT	25

Some of the mentioned species have medicinal and other values. For instance, *Scorzonera tortuosissima* is a traditional medicinal species, and *Cuprella homalocarpum* is used as an active packaging material for packaging industries. In addition, *Echium rauwolfii, Launaea angustifolia, Ducrosia anethifolia, Stipagrostis ciliata, Eremopyrum bonaepartis, Aegilops bicornis,* and *Valerianella leiocarpa* has many potentials uses in the pharmaceutical industry. The native prioritised species are listed in Appendix 5.1-B. However, individual research revealed that it is unknown whether the wild harvesting of these species is sustainable or is causing a significant threat to the species abundance (Ashtari *et al.*, 2013,

Alyemeni *et al.*, 1999, Abdullah, 2017). These species are part of the stony desert habitats found in dry arid and semi-arid regions. All of the above species are observed in threatened areas with a low protection score. Their habitat is in the open desert, which has declined in quality due to development, human disturbance, off-road traffic, spring camping, and recreational activities. In addition, the species are threatened by camel and sheep overgrazing, with limited growth of some of them due to their low seed germination (Ashtari *et al.*, 2013, Alyemeni *et al.*, 1999, Abdullah, 2017; Ghasemkhani *et al*., 2008). Regionally, the disappearance of these plant communities in the open desert might result from adaptation mechanism failure due to climate change or anthropogenic phenomena such as war activities, camping or overgrazing.

The Red list estimation for the prioritised species revealed a list of 31 species as Least Concern (Appendix 5.1-B). The average priority score for the species assists as LC is approximately 22. Undoubtedly, the essential evaluation of the assessment relies on further in-depth research on the status of the species based on many factors, such as distribution, occurrence, habitat, ecology, threats, and conservation status. Although they are classed as prioritised according to the criteria used in chapter 3, the literature research concluded to assess them as LC. For instance, some were estimated as LC species based on their adaptation to harsh environmental conditions. *Aegilops kotschyi, Oligomeris linifolia, Aegilops triuncialis, Horwoodia dicksoniae, Caroxylon jordanicola, Halothamnus iraqensis, Artemisia scoparia, Salicornia europaea, Pallenis hierochuntica,* and *Farsetia aegyptia* species are highly adapted to the local environmental and climatic conditions. The adaptation features vary among the listed species. Some of them grow in many habitat types, including disturbed areas and saline soil, while other germinate from seeds that can recover after alleviating the salt stress,

irrespective of photoperiod, and some of are drought tolerant species and used in rehabilitation of arid and semiarid habitat (Parr *et al*. 2014; Neffar *et al.* 2019; Ahmed *et al.* 2016; Abdullah, 2017; Bhat *et al.* 2019). In addition, research revealed that some species have the ability to grow in oil contaminated areas, such as *Gymnarrhena micrantha*. A study of the regions of Kuwait conducted by Brown and Porembski (2000) states that an area covered by oil or by tar tracks is largely sterile; *Gymnarrhena micrantha* was one of the few taxa found in this area growing in the controlled sites and in areas where the sand has blown out from under the tar tracks. The species grows more frequently on micro-Nebkas than in plots and inhabit dry, primarily bare, sandy areas (Gutterman, 1993; Funk and Fragman-Sapir, 2009).

Herbarium data indicated that some species had a relatively restricted distribution within Kuwait, but active environmental conservation program were promoting their existence. Some of the Least Concerned listed species are protected yet suffer an unknown direct threat that affects their occurrences, such as *Arnebia tinctoria, Aegilops triuncialis,* and *Suaeda vermiculata* Although research considers the species as rare, the Red List assessment has not met any further criteria to be considered as threatened or nearly threatened. Also, *Launaea capitata* was recorded between 1982-1990, but with a low observation frequency. The species was subjected to research in the Jal az Zor protected area (El-Sheikh and Abbadi, 2004). Similar observations were recorded for *Chrozophora tinctoria*, *Aegilops kotschyi*, although their population were not found in protected areas, research revealed that they were recently observed growing along roadsides and around farms (El-Sheikh and Abbadi, 2004, Abdullah 2017).

From the mentioned values, 58% of the working list has unknown conservation status in Kuwait and should be investigation further. Details related to the regional conservation for

the working list can be used in the estimation of the conservation measures of the Arabian Peninsula flora. This data can be compared to other countries located in other biodiversity hotspots. The natural heritage in Kuwait is under severe threat from habitat fragmentation and degradation caused by intensive grazing, population growth and unsustainable use of natural resources. The un-sustained human activities reflect the threat status of the flora, which leads to raising the numbers of endangered and vanished species in Kuwait.

Over-grazing in open areas is considered a major factor on land degradation in Arabian Peninsula. It is estimated to be the greatest threat to desert ecosystems threatening the Arabian plant biodiversity, affecting approximately 3,500 species (ICARDA, 2002; Ghazanfar and Fisher, 1998). According to the regional range of species distribution in open range land, nomadic overgrazing is impacting native distribution and resulting in a reduction of up to 40% of the native priority list.

Special research is required to understand the adaptation mechanisms of native desert species. This research can subsequently help in predicting the effect of changes in climate in the Arabian Peninsula and West Asia. Research related to species adaptation requires the development of modelling research to study the impact of climate change on biodiversity. The research relies upon high level of factors and information related to the distribution of species, climate data and the effect it has on individual species distribution. The research can be further improved if there was a development of a scale stating the degree of adaptation. In addition, the factors also depend on the availability of the effect of climate data on threatening processes, ecological processes and interaction between species (Omar and Roy 2018).

According to our research, it is recommended to follow the regional threat assessment for the flora in Kuwait, rather than applying the prioritisation from the criteria which is dependent on herbarium data sheets, which might have a degree of un-certainty due to many factors such as: time range of observation, human and overgrazing threats and climate condition. However, the research highlighted almost 31% of the flora of Kuwait with unknown status. Moreover, detailed information in the research considered a baseline for conservation of species and further investigation should be undertaken. The adaptation research must be developed individually for each taxon. This has to be done over a prolonged period of time, due to constantly changing factors and the need a life-long observation. Species adaptation relies on different factors and interaction of taxon with other species. In addition, this kind of research is fundamental in developing a conservation plan in Kuwait. It is important to encourage research on species listed as threatened by IUCN. Previous assessment has resulted in an improved understanding of the biology and conservation needs of the priority list. The conservation of threatened prioritised species can be through the development of a special programme of *in situ* conservation of the listed species. *In situ* conservation-based propagation for medicinal prioritised species at risk is one of the strategic solutions. As well as habitat rehabilitation associated with endangered species in its geographical zone within reserves and protected areas. The establishment of a wild nursery and the *ex situ* conservation for the endangered medicinal plant species, through seed sampling and seed banking, along with the establishment of medicinal botanical garden are all options being investigated.

Acknowledgements

We acknowledge assistance from the SIS expert and the Arabian group for reviewing data, and develop the threat categorisation for rare and non-protected taxa from the flora of State of Kuwait.

Chapter 6

Management Effectiveness Evaluation for the Demilitarised Zone between The State of Kuwait and the Republic of Iraq.

Mouza Nassep[1], Rafat Misak[2] and Nigel Maxted[1]

[1]School of Biosciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK.

[2]Kuwait Institute for Scientific Research, Environment and Life Science Research Center, Kuwait.

Abstract

This research aims to evaluate the management and its effectiveness in the Demilitarised zone (protected area) between Kuwait and Iraq. A scheduled program is developed to cover different parts of the study area. The analysis was done according to the methodology of the IUCN Management Effectiveness Evaluation (Best Practice Guideline 1), which consists of three main themes: the design issues related to the context and planning of the protected site, followed by the appropriateness of the management process which reviews input and process, and analysis of the output and outcome delivered from the management process applied on the site. The assessment is then followed by the Management Effectiveness Tracking Tool (METT). The METT framework consists of 3 data sheets: the general description of the site, the threat information sheet, and the 30-question evaluation report covering all components of IUCN-WCPD (World Commission of Protected Areas) elements. The application discusses many aspects of ecological, educational, social, and environmental perspectives. The investigation concluded by developing a list of aspects recommended in the development of the annual management plan for the future.

Key word: Demilitarised zone, output, outcome, Management, evaluation, Effectiveness.

6.1 Introduction:

The establishment of the Protected area network was agreed by the Convention on Biological Diversity (CBD) parties in 2004 ‘‘a global network of comprehensive, representative and effectively managed national and regional protected area systems’’ for the terrestrial protected areas by 2010. Convention on Biodiversity (CBD) aims to encourage the establishment of an effective Management Protected area covering 10% by 2020 (CBD, 2010). However, according to worldwide evaluations, robust data is fundamental for the assessment of status and effectiveness of the management applied towards the CBD targets (Wood *et al.,* 2008). To strengthen the implementation of the CBD targets, cooperation is needed from regional and sub-regional conventions. The development of such targets needs a strategic guideline for technical networks and other partners, developed by IUCN Global Committee of Protected Areas. The main objective of the IUCN Protected Areas Programme is to guide and enhance the development of adequate regional approaches and models for effective protected area management. The application needs to focus on community participation and involvement at all levels. Another objective is to build the regions capacity in protected area management, including the development of sound, as well as regionally adequate guidelines and mechanisms.

A variety of different tools have been developed to assess the evaluation of protected areas and the effectiveness of its management, which have been utilised since the 1990s (Rivero Blanco and Gabaldon, 1992; Cifuentes *et al.,* 2000; Hockings *et al.,* 2000; Hockings, 2003; Stolton *et al.,* 2003, 2007; Staub and Hatziolos, 2004; Leverington *et al.,* 2010). Most of the applied methods use in the evaluation of the management of protected areas develop a theme consisting of three main categories, which are the design, appropriateness and

delivery. However, each of the categories required different components related to the data and financial input (Hockings *et al.,* 2000).

According to the research, following the IUCN management effectiveness (Best Practice Guideline 1) for conservation processes provides a broader understanding of its sense. The concept of management effectiveness is applied and discussed by IUCN- World Commission on Protected Area WCPA; Cifuentes and Izurieta Valery, (1999); Ervin, (2003); Stolton *et al.,* (2003); Hocking *et al.,* (2006); and Leverington *et al*., (2010). It evaluates protection management effectiveness which strengthens conservation communities as it enables them to share good work and recommend ways to improve. Protected Area Management Evaluation (PAME) is defined as *"the assessment of how well the protected area is being managed – primarily the extent to which it is protecting values and achieving goals and objectives. The term management effectiveness reflects three main themes: design issues relating to both individual sites and protected area systems, adequacy and appropriateness of management systems and processes, and delivery of protected area objectives including conservation of values."* (Hockings *et al.,* 2006, xiii; Anthony, 2014). Management effectiveness evaluation aims to support the adaptation and approach of the management which assists them in allocating resources in an effective way. The implementation has to continually focus on liability and transparency. The accountability developed from the involvement of the community in protection implementation, builds constituency and enhances the value of protected area. Moreover, the reporting of the evaluation improves the relation between managers and stakeholders and with that supports the protected area requirements (Hockings *et al.,* 2006, xiii; Anthony, 2014).

Each component of the evaluation process consists of specific details which outlines

how to approach the evaluation (Hockings *et al.,* 2006, xiii):

- **Design** of the planning of the protected area such as its dimensions, surrounding activities and spatial perimeter of its buffer zones, which affects the achievement of the objectives. The design also describes details related to the failure of the ability to adapt to the change in the environment. The design describes the existence and adequacy of the planning process to develop the protected site.
- **Appropriateness** of the available resources, covering both the sufficient and insufficient management or supply of the resources. Management failures span from in completed implementation of input to strategic errors in defining the priorities or how management is to be conducted.
- **Delivery** of the planned objectives and the achievement of the stated aim of the implementation of the protection. The measures cover biological and social aspects. Social elements such as: recreational or local human activities connected to the achievement of protection targets.

The evaluation assessment is subsequently followed by tools or methods; many of these tools are developed and modified globally according to the elements used in the design. Some of them combine elements of the components of the PAME categories. However, the different methodologies used to examine effectiveness of the protection process, identify influencing factors and determine intensity of threats and their seriousness (Stoll-Kleeman, 2010). Wright *et al.,* (2017) summaries and describes the tools and their limitation features. For example: Rapid Assessment and Prioritisation of Protected Area Management (RAPPAM) is designed for broad level protected areas, however, this will control and restrict the individual outcome measures. Enhancing our Heritage (EoH) management tool consist of 12

means that identifies main site values of the IUCN WCPA elements, and it is considered very general and time-consuming. The author also describes the structure of Management Effectiveness Tracking Tool (METT) which consists of 30 questions covering all components of IUCN-WCPD elements, in which all questions are assigned equal weight. The New South Wales – State of The Parks (SOP) management assessment tool is also applied for the qualitative and quantitative management assessment, which needs a significant adaptation on contexts. According to Wright *et al.,* (2017) and Coad *et al.,* (2013) the most widely used tool is the Management Effectiveness Tracking Tool (METT), which has been driven by several vital institutions: IUCN WCPA, CBD, GEF, World Bank, and WWF (Dudley and Hockings, 2016). In addition, University of Queensland develop a database on Protected Area Management Effectiveness, which now managed by UNEP WCMC (UNEP WCMC and IUCN WCPA, 2016). Database implementation aims to encourage the application of the evaluation following CBD's decision related to improvement of protection management evaluation using a variety of national and regional tools (UNEP WCMC and IUCN WCPA, 2016)

According to Dudley *et al.,* (2007) METT is the most used methodology, being used in over 300 protected sites. The methodology is used to understand the correlation between biodiversity and many factors such as: law enforcement, control of access, resource management, monitoring and evaluation, maintenance of equipment, budget management and the existence of annual work plans. Workshop research applied by Seddon *el al.,* (2009) aims to evaluate the management of prioritised protected areas in the Arabian Peninsula. The workshop includes experimenting with a variety of evaluation tools such as: Trans Boundary Conservation Areas (TBCAs), Rapid Assessment and Prioritisation of Protected Area Management (RAPPAM) and Management Effectiveness Tracking Tool (METT). However, by

comparison the METTs came out with more details which were obtained from the threat working sheets and the questionnaire. Field revision and interview with managers provides a friendly communication. In addition, the designed assessment of the site-specifics helps in monitoring progress towards improving management effectiveness of protected areas. The application of METT can help in providing consistent information on achieving protected area objectives necessary for tracking progress across protected area systems. Further research applied by Stolton (2007), on the METT framework utilises data which is literature reviewed for the completion of the questionnaires. The application concluded that METTS is a useful tool in tracking management effectiveness, and could be adapted for specific organisational needs. The METT tool summarised better management plans with explicit links between monitoring indicators and protected areas objectives (Stolton, 2007). Revisions developed for the marine environment by Staub and Hatziolos (2004), is nearly identical to the METT and, as it was developed specifically, it considered the most appropriate of these global tools for assessing MPAs (Van Lavieren and Klaus, 2013).

The data used can be developed by questionnaire-based methods or it can be more complicated if used to cover full management effectiveness evaluations. However, the full management effectiveness evaluations often require the expansion of research and collection of additional field data, and this kind of research is time consuming and requires a considerable financial commitment (Leverington *et al.,* 2010). The application of questionnaires depends mostly on the available literature and informed opinions developed from interviews with site managers or independent assessors (Stolton *et al.,* 2003, 2007; Staub and Hatziolos, 2004). Although the questionnaires and interview data can be affected by many factors (Van Lavieren and Klaus, 2013), the investigation and site visit can develop the depth

of the research, especially if it's done with consultation. Research applied by Van Lavieren and Klaus, (2013) aimed to develop a database of protection within the Red Sea area. The application depended on a comprehensive revision of literature from a variety of resources, and a final consolidated list of all MPAs within the RSA was prepared.

Based on the WCPA framework developed by Hockings *et al.,* (2006), the application varies from a simple questionnaire used for the evaluation of individual PA, to workshop approaches which are used to develop evaluations of protection systems with more thorough detail in monitoring (Mathur, 2016). However, in major studies related to PA evaluations, the failure in the outcomes concerning overall effectiveness are partially contradictory. The failure resulted from the number and type of indicators used in the evaluation, or the context of the PA (Stoll-Kleemann, 2010). The evaluation of PAs helps in the implementation of new categories of protection, which can be applied according to the environmental conditions and the development of new strategies.

6.1.1 PAME in the Arabian Peninsula Region

Development of reserves help to conserve key elements of biodiversity, play a significant role in social and economic development, and embody many practical approaches to participatory and collaborative management (Al Omari, 2010). Environmental changes and threats affect the countries within the Arabian Peninsula differently. This results in variation in the conservation for the wildlife. The management developed in some of the states in the Arabian Peninsula protected networks is extremely evolved. However, some reserves lack the capacity for effective management, while others have recently embarked on difficulties to create a protected site. Approximately 230 protected areas (for all types) have been legally established

in the Arabian Peninsula, comprising of approximately 900,000 km^2. However, this system does not fully reflect the diversity of habitats and species. Also, the level of management greatly varies from one area to the next. Seddon *et al.,* (2009), argued that countries have to share the significant lessons that occur in conservation management; there is still considerable scope for international cooperation to achieve shared goals.

One of the key concerns for the Arabian region is the lack of a rationalised network of effectively managed protected areas. This includes key areas of high biodiversity, endemism, and representative habitats (Seddon *et al.* 2008, 2009). Seddon *et al.,* (2009) and Chape *et al*., (2008), mentioned that the current issues in PA management in the Arabian Peninsula may include: the lack of skilled staff, research and disciplines related to the planning and wildlife management, weak or missing legislation for protected areas, establishment and involvement of local citizens as participants in the management of the protected areas.

Within the 7 regions of the Arabian Peninsula, there is approximately 115 legally established terrestrial protected sites, refer to Table.6.1 UNEP-WCMC, 2021. However, the models for effective management has not been fully implemented in many sites. Although approximately 20.21% of the total area of the Peninsula is under conservation, the level of management does not fully reflect the range of species from in and out of reserves. The numerous environmental threats and harsh environmental conditions of the Peninsula have not assisted in the improvement of the diverse habitats (Attia *et al.,* 2017; UNEP-WCMC, 2021).

Table 6.1: Arabian Peninsula Total Terrestrial Protected Areas and Number of Sites According to UNEP-WCMC, (2021).

Country	Land Area Km^2	Number of sites	Total area protected Km^2	PA %	PAME %
Bahrain	765.3	4	45	6.62%	0
Kuwait	17,818	16	3092	17.4%	0
Qatar	11,571	5	1,805	15.78%	0
UAE	83,600	47	13,724	19.35%	14.82%
Oman	309,501	15	7,985	2.57%	0
Saudi Arabia	2,149,690	14	92,064	4.76%	0.93%
Total	2,572,945	101	118,715	4.60%	24%

According to the UNEP-WCMC (2021) database, Kuwait, Bahrain, and Qatar have no record of evaluation of the management protection applied in the terrestrial sites. On the other hand, in the United Arab Emirates, protected sites comprise of both privately owned and government-designated reserves. UAE terrestrial protected areas have a coverage of 19.35%, in which 14.82% are management effectiveness evaluated (SCENR, 2007; Javed, 2015; UNEP-WCMC, 2021). The country planned to develop a network for the protection system which can be overseen by the Federal Environment Agency (Aspinall 1996).

Although UNEP-WCMC (2021), is lacking any information related to the PAME in Sultanate of Oman, however, the protection status of Oman is comparatively well advanced with their protected areas system. A system of Nature Reserves was proposed in 1986 (Clark, 1986) and a coastal zone management plan was prepared during the period of 1986-1992.

Conservation assessments have been carried out for most of its vascular plant species and areas designated for protection. These designations do not consider the evolutionary uniqueness of the flora or the identification of the conservation processes followed. However, knowledge is also needed for coastal processes to establish techniques for minimising risks. Knowledge is also needed for climate change adaptation, focusing on biotic communities and environmental quality. Clark (1986); Van Lavieren and Klaus (2013), mention that this can be done through increasing the development of protected areas in the region and reviewing the regional guidelines, training of local stakeholders and sustainable funding of these areas.

In Kuwait, 17% of the land is a protected site, in which management effectiveness is not evaluated (KEPA, 2018). The application of the evaluation can be knowledge utilised by protected and environmental agencies in Kuwait. Kuwait's MPAs are under the direct supervision of the EPA and the Public Authority for Agriculture and Fish Resources (PAAFR). Kuwait University (KU) and Kuwait Institute for Scientific Research (KISR). To date, there are no internationally recognised management evaluated PAs in Kuwait. However, the societies may move forward and use the management effectiveness evaluation applied in this research as a baseline for the implementation of evaluation of other sites in the country. The application may help in the achievement of the strategic objectives and targets defined in the environmental vision.

Our research covers the application of a systematic methodology of evaluating the management plan and the effectiveness of the Demilitarised protected area, investigating the ecological, educational and environmental value of the establishment of protection in the zone. According to the research, the site has an ecological and environmental value as it

mentions in the context of the result. Assessment strengthens the protection process by collecting the existing work which has already been done, reviewing methodologies, finding patterns and common themes through evaluating the results. The assessment also investigates the most important factors leading to active management.

Lamb, (1999) analysed the demilitarisation phenomenon. In particular, he studied the various dimensions of reduction of military resource size, increased civilian control, conservation involvement of defence industries, the establishment of research and development, and manufacturing plants. Further research argued that existing conservation and its actual management in the disarmament process will optimize the benefits (Sandler and Hartley, 1995). According to Sandler and Hartley, (1995) conservation has two stages: starting with the establishment of research and manufacturing goods, subsequently, the transferring of resources from the military and armed forces to other economic sectors such as education and health.

6.2 Aim and Objectives

The research aims to evaluate the management and its effectiveness in the border strip protected area (Demilitarised zone) in the State of Kuwait, through the application of the IUCN Best Practice tools or methods for PAME. The evaluation is followed by analysing the PAME component through using the Management Effectiveness Tracking Tool (METT) framework (Leverington *et al.,* 2010; Hockings *et al.,* 2006).

6.3 Material and Methods:

The assessment is following the Environmental Management Effectiveness Evaluation strategy, discussed in the cycle developed by Hockings *et al.,* (2006), which consists of three dimensions. Refer to Figure 6.1: '**Design** issues relating to both individual protected areas and the systems used; adequacy and **Appropriateness** of management systems and processes; and **Delivery** of objectives including the conservation value.'

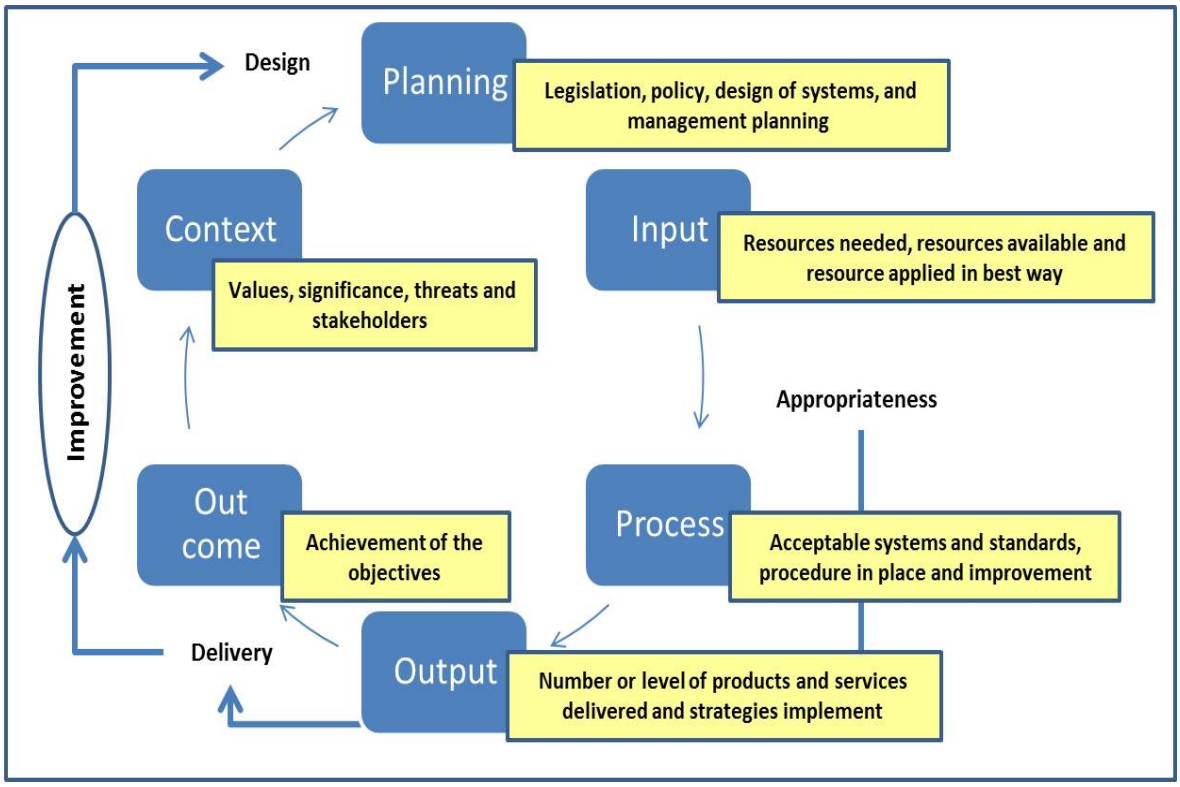


Figure 6.1. Structural Methodology of Assessing the Protected Areas Management Effectiveness (PAME) Developed from Hockings *et al.*2006.

Assessment followed by the creation of the Management Effectiveness Tracking Tool (METT) framework- **Reporting Progress at Protected Area Sites: *Second Edition*** (Leverington *et al.,* 2010; Stolton *et al*., 2016; Wright *et al.,* 2017), which consists of 3 data sheets: the general description of the site, threat information sheet that includes 12 classified dimensions

related to the threats affecting management in the protected area, and the questionnaire which consists of 30 questions covering all components of IUCN-WCPD elements.

Scheduled visits were conducted to review several transects along the DMZ: Al-Sheqaya, Smoud, Al-Abraq, Al-Taawon, Al-Ritqa, Khabary Al-Awazem and Al-Bohaith (Appendix: 6.1.A and B). ESRI ArcGIS 10.4.1 programme (ESRI, 2012) was used for creating the maps involved in the research. Information available from the field survey was used for the details inputted in the management tool, which was applied 2017-2018. Eight permits were obtained in order to visit the Demilitarised area. Registration was compulsory for each visit, in the General Department of Border Security, in Al-Mutlaa area. The purpose of the registration is to review the permission paper and check the identification forms. In the meantime, we met the guards who will accompany us through the visit. Each visit consists of two-part, aiming to cover more employees from different categories:

1- The General Department of Border Security in Al-Mutlaa area.
2- The protected site: Al-Sheqaya, Smoud, Al-Abraq, Al-Taawon, Al-Ritqa, Khabary Al-Awazem and Al-Bohaith.

The questions discussed with managers and staff were designed to meet the research objectives. The Survey and form completed as followed:

A- Reporting progress of protected area sites: discussion with the managers in the General Department of Border security concentrated on reviewing the data sheet of Appendix 6.2.1, aiming to develop the report with information related to:

- Establishment, date, ownership and size (legal status for the protected area)
- Review the official documentation, if possible.

- Managers knowledge related to protected species, habitats, ecological processes and conservation concern.
- Review the site boundary demarcation on the map and important site features.
- Knowledge related to the environmental aspects in general.
- Discuss the extent of understanding the ecological objectives and management directions related to:
    1- Orientated survey
    2- Research work
    3- Resource management
    4- Employment policy, type of training and education planning.
    5- Equipment used for management.

B- The report related to the Protected Areas Threats data sheet was applied for all reviewed threats in the site. Ranked as of high significance for those which are seriously degrading values; medium are those threats having some negative impact and those characterised as low are threats which are present but not seriously impacting values or N/A where the threat is not present or not applicable in the protected area. The data sheet was filled according to the discussion with experts from KISR (details Appendix 6.2.2), depending on the involvement in protected area and previous projects related to earlier consultations regarding the protected site.

C- The report related to Protected Area Management Evaluation Assessment Form. Appendix (6.2.3-A) consist of the details of the discussion with managers and staff in group meeting. The survey was applied twice in each visit, resulting in a total of 16 surveys being conducted. 8 times in the General Department of Border Security with the

available staff and 8 times through the revision with the staff who conducted the site visit tour. The details were produced from the discussion with the reserve staff in the group meeting, whereby there were 3-5 staff members in each meeting. The discussion aiming to cover the report described in Appendix (6.2.3-C), the Protected Area Management Evaluation Assessment Form, with particular focus on context, planning, inputs, processes, output and outcomes.

Throughout the interview, questions were asked which needed to be translated to Arabic, and the required details were written appendix (6.2.3-A). The interview concentrated on ensuring there was a full understanding of the METT component reviewed. In each visit, the group meeting discussed and reviewed the surveyed site, considering the main ecological and environmental issues in each site. The discussion aimed to gather knowledge about implementation and action needed. However, according to the Regional framework design and METT tool, all questions have been designed to be easily answered by protected area staff, without the need for additional research. The detailed explanation determines the level of score achieved which was the desired result from management. The values are connected to each protected element of the evaluation procedures applied. Appendix (6.2.3-B) summarised the revision of scores in 16 surveys in the locations. The questions were in order according to the form designed for the questionnaire of the components of IUCN-WCPD elements of the Protected Area Management Evaluation Assessment Form.

6.4 Result and Discussion

6.4.1 Part 1: Assessing Design: A - Reviewing context

The Demilitarised Zone (DMZ), Figure 6.2, between the State of Kuwait and the Republic of Iraq covers an area of about 1008 km^2. It extends from Salmi to Al Bohaith (Umm Qasr) for approximately 212 km. The width of the DMZ averages 5 km. This zone was established in April 1991(UN Resolution 689,1991). In October 2003, the UNIKOM (United Nations Iraq-Kuwait Observation Mission) was accomplished (UN Resolution 1490, 2003). Geographically, the DMZ is divided into four sectors, extending from NE Abdaly, through Ritqa and Khabary Al Awazem to the SW Abraq.

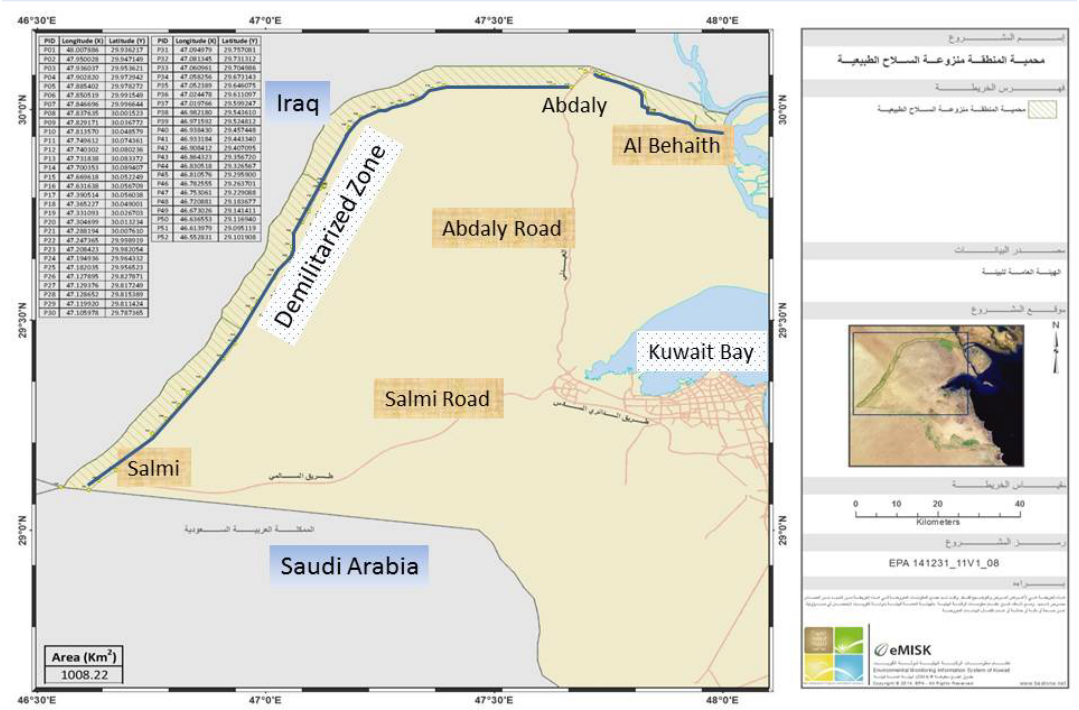


Figure 6.2. Map Showing the Location of the Demilitarised Zone (eMisk).

The site is managed by the Ministry of Interior - General Department of Border Security, Environmental Public Authority-Kuwait (EPA). However, for research and projects with special requirement, they are cooperative with Kuwait Institution for Science Research (KISR), Public

Authority for Agriculture and Fish research (PAAF). The objectives for protection from the environmental point of view are to manage natural renewable resources in the reserve and conservation of the site. Based on the Border Zone Authority, the DMZ consists of three main components which are: border trench, electric fence and outer fence (Figure 6.3). The cross-section consists of 2 zones with different types of restrictions.

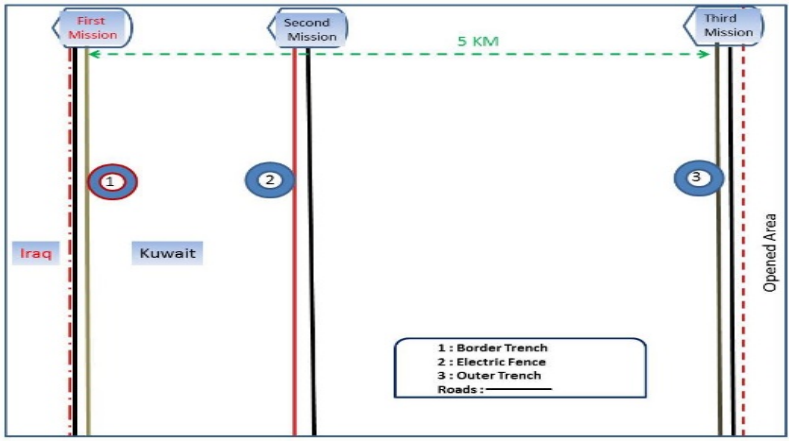


Figure 6.3. Sketch Showing the Main Components of the DMZ (Demilitarised zone).

The area is surrounded by many protected sites as shown Figure (6.4), which make the outer section of the DMZ a buffering zone for the adjacent protected areas. Stakeholders construct a porous outer fence to control the Kuwaiti side entrance, and banned grazing and camping in the area. They also provided access roads to enable vehicle movement inside the area. In addition, full-time guards have been assigned by the Ministry of Interior - General Department of Border Security. Visitors carrying out scientific research or technical development need to submit a request outlining full details of the program which needs to be approved by the Ministry of Interior. From the physical point of view, the site includes a wide variety of landforms and surface sediments. The landforms include: wadis or cannels that is dry except in the rainy seasons, playas of flat dry areas, cliffs of rocky faces, long narrow hilltops of ridges, terraces, desert pavements surface of angular gravels and boulders in arid

areas, sand dunes and nabkas hills formed by winds and sabkhas which result in the accumulation of aeolian clays, evaporites, and salts. In addition, several types of surface sediments are observed. These are differentiated into two main groups: consolidated that is currently experiencing its highest stress of about 20% and unconsolidated soil of about 80%. The first group includes gravels, aeoilan sands, silt and clays of fluviatile origin and evaporates (only in Al Bohaith Area). The consolidated group includes calcrete (calcium rich duricrust), limestone, calcareous sandstone and clay. The site ecosystem covers hilly terrain, wadies, depressions, failing dunes, and sandy sheets. The protected area is associated with the Wadi Al Batin area with an average width of 7 to 10 km, relief as high as 57m.

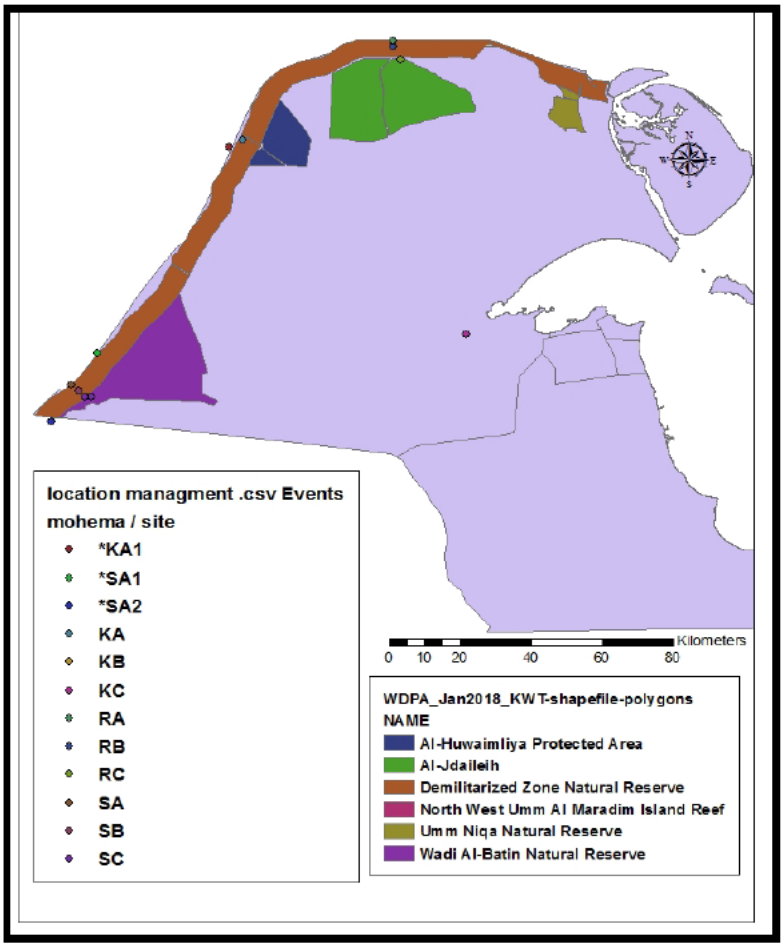


Figure 6.4. Locations of the Site Visits, Details Appendix: 6.1A, Assessing Protected Areas Context (ArcGIS 10.4.1).

Wadi Al-Batin valley extends over a distance of 75 km wide from the South-West to the North-East. The topography of the valley is associated with low lying sandstone, isolated irregular hills and small cuestas, stream terraces covered by gravels, aeolian depressions, and Khabrat sandstone plain wadi (Al-Sarawi, 1980; Misak, 2010). Wadi Al-Batin area is approximately 250m above sea level. According to Al-Gurairy *et al.,* (2017) the area is considered responsible for transferring many types of igneous rock fragments and sediment to Iraq and Kuwait.

New vegetation and wider varieties of species has been observed at the site (Appendix 6.1.B - Plate 1). The natural recovery in the demilitarised zone (DMZ) were examined through a preliminary field survey which took place in June 2009. The survey aims to study plant and soil conditions inside the DMZ and compare it with conditions in the open rangeland (simply grazed and disturbed). The investigation revealed that by avoiding the drivers of disturbance, species became more diverse. A total of 74 plant species of annual and perennial life form were recorded, and the vegetation cover varied from 35-47% across the DMZ. *Haloxylon salicornicum* community were dominant (Kuwait National Focal Point, unpublished data; Abdullah, 2017). The site is dominated by *Haloxylon salicornicum* species, *Rhanterium epapposum,* associated with *Astragalus spinosus* (Forssk.) Muschl, and *Chrozophora* spp. The observation of newly grown species like *Zilla spinose* is associated with *Phalaris minos*, *Stipa capensis*, *Asphodelus tenuifolius,* and other species. The substantial growth of annual species associates with *Moltkiopsis ciliata*, *Convolvulus oxyphyllus Centropodia*, and *Stipagrostis plumose*.

Revision of specimen's and data collected and gathered from Kuwait University Herbarium and Science Museum, Royal Botanic Gardens, Kew Herbarium (UK), and the Global

Biodiversity Information Facility (GBIF) (Chapter 3). Aiming to review the biodiversity observed in the DMZ or the adjacent protected site. The revision concluded that 196 species (61%) from a total of 322 species were observed in the area or in adjacent protected sites. The comparison applied from specimen's data reviewed in 2017-2018.

- Threats

The area experiences an intensive defensive system consisting of a belt of crude oil trenches (Figure 6.5, a-b), as a result of the Iraq invasion of Kuwait, detailed information is discussed by KISR, (2012) and Misak, (2010). The trenches developed severe soil contamination in the Wadi Al-Batin area. Another oil contamination from a pipeline rupture incident happened in the Al-Taawon area resulting in another oil spill.

The protected site experience activities related to oil exploration, miner grazing of un-controlled Camels grazing in the Al-Retga area. However, grazing has previously been banned unofficially by the managers within the Ministry of Interior. Moreover, across the border through Khabary Al-Awazem site there is passage of heavy machinery. In addition, Political design aimed to destruct border trench led to an environmental threat in the protected zone. The ground trench was established by Kuwait in 1993-1994 and is about 3-5m wide and 2-3m deep.

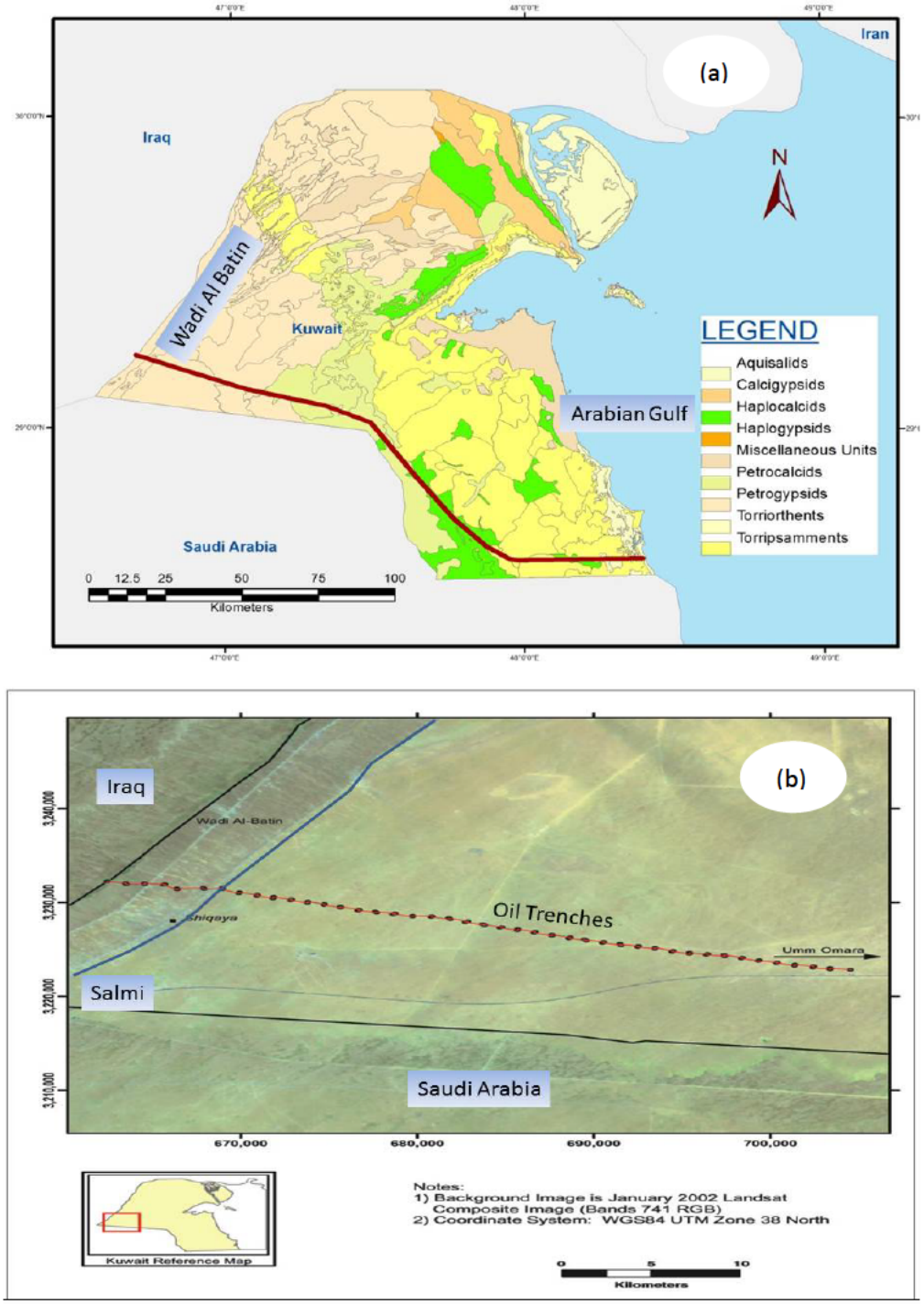


Figure 6.5: (a) Soil Map Showing the Line of Oil Trenches in Kuwait Linked to Wadi Al-Batin (Misak, 2012). (b) Image Showing the Oil Trenches in Wadi Al-Batin and in Shaqayah.

The removal of sand along the border trench using heavy machinery led to sand encroachment. Detailed photos are shown in Appendix 6.1.B Plate 2: a, and b. Misak (2012),

discussed the application of border trench and what resulted from it:

1- Land degradation from the loss of topsoil.

2- Soil crusting, and the loss of soil productivity.

3- Vegetation degradation due to new sand being placed over old vegetation.

4- Hydrological disruption which resulted in the natural flow of rain-water in the valley being disturbed.

5- Blocking of runoff water and outwash sediment leading to hydrological drough (Figure 6.6).

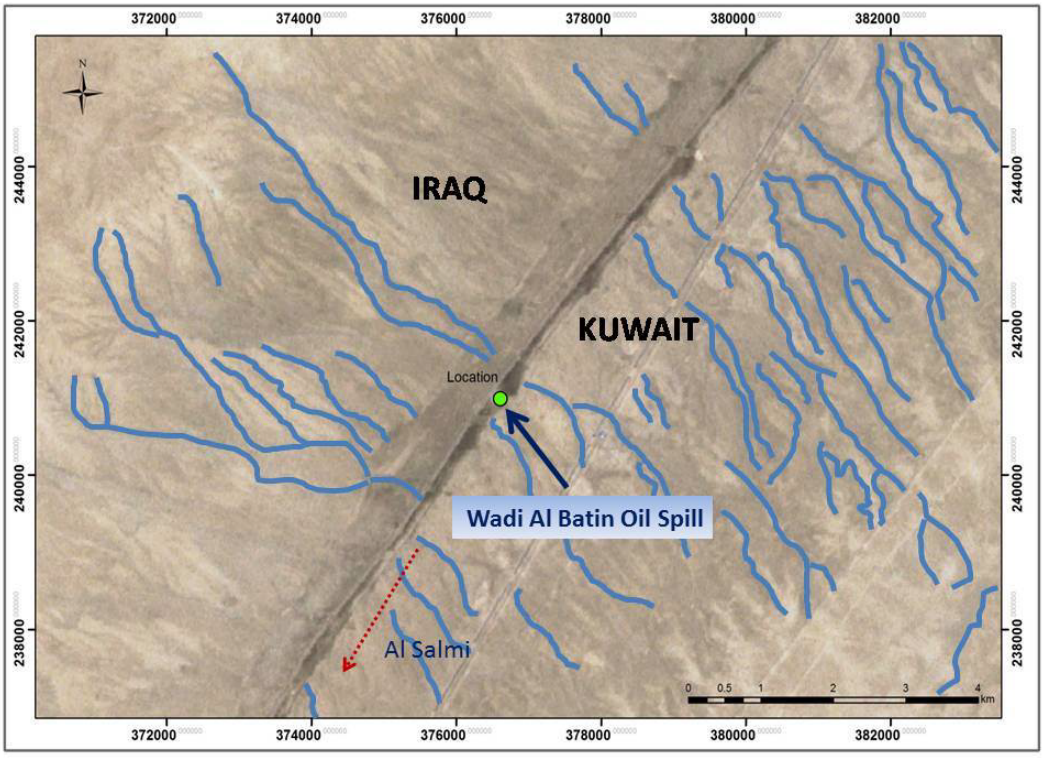


Figure 6.6: Hydrological Disruption and Disturbing of the Natural Flow of Rain-Water (Misak, 2012)

B- The Planning

The protected area design helps in the achievement of the objectives to some extent. The information related to the protection design and geographical location was discussed earlier in the context. The protected site managers develop regulations for controlling land use and activities in the protected area but there are some weaknesses or gaps. The activities related to oil exploration, observation of miner grazing in one part of the DMZ are considered weaknesses in the application of the site protection. In addition, the passage of heavy machinery across the border through Khabary Al-Awazem site, disturbs the ecological balance of the mentioned site. The non-environmental managers society makes it unlikely to achieve the goals and objectives of protection, leading to un-ecological decisions being made to maintain security.

The evaluation and discussion with managers concluded that there is no management plan for the protected area. Preparation of an environmental management plan should mainly consider: conservation of natural resources and biodiversity restoration, financial plan and designation of skilled employees and a well-developed training plan (IFC, 2019; IUCN Financial plan 2017-2020). Moreover, threat conservation assessment needs to be applied as the planning process is developed according to accidental threats. There is also no monitoring and evaluation of biodiversity conservation of protected area. The application needs to be annually re-evaluated after applying the management plan.

The adaptation of the genetic reserve management plan content elements focuses on the relevant parts summarised by Maxted *et al.,* (1997c). The research identified the planning process in which specific details were developed (Table 6.2). The adaptation describes the main indicators within the context of the planning process. It also describes the present

conservation activities, site management, monitoring, and feedback.

Table 6.2: The application of the genetic reserve management plan content elements, focus on relevant parts summarized by Maxted *et al.* (1997c) provided to identify the planning process.

Main target	Title	Plan content
Conservation context	National Conservation strategy	The primary objectives of environmental protection in Kuwait are: "Supporting the necessary ecological operations, maintaining the ecosystems, and biological and genetic diversity and rational use of the ecosystem".
	Present conservation activities	- Banned the harmful practice of human activities and camping. - Buffering zone, for the entire zone, and the adjacent protected areas (Wadi Al-Batin reserve, Al-Huwaimliyah protected area, Al- Jdailiah, and Umm Niqqa natural reserve). - CO_2 reduction as a result of increased vegetation. - Restoration of biodiversity and soil stabilisation by the deep root system. - Soil erosion prevention which assists in vegetation survival
	General threats of genetic erosion	- Sand encroachment along the border trench. - Land degradation from loss of topsoil. - Soil crusting and decrease in soil productivity - Vegetation degradation - Hydrological disruption

		- Oil contamination - Soil contamination
Site abiotic description	Geology, geomorphology	- Wadi Al-Batin extends over a distance of 75 km, and is mainly responsible for the transfer of many types of igneous rocks fragments and sediment from Iraq and Kuwait. - Isolated irregular hills and small cuestas which are covered by gravels and aeolian depressions. Referred to locally as Khabrat with sandstone plain wadi.
Site biotic description	General vegetation cover	196 species (61%) from a total of 322 species collected and observed in the area or in the adjacent protected area.
	Flora	Reviewed in PAME context.
Site anthropogenic description	Effect of the local human population	No interaction
	Land use	-Historical use (oil exploration, and open area uncontrolled grazing). -Border security, ministry of defence -Heavy machine passage to Iraq (Khabary al-Awazem site).
	Cultural significance	Reviewed in PAME context.
	Public interest	Lack of community participation, limited to educational and recreational activities.
	Scientific research	Participation is limited.
Site management	Control human intervention	Lack of community participation and interaction.

policy	Allowance harvesting by local	Not applied
	Educational use	Not applied
	Application of material transfer agreements	Not applied
Prescription – management interventions	Details (timing, frequency, duration)	The area is used by the Guard Department. Details are in PAME context.
	Impact assessment	Management assessment for oil trench contamination. Management assessment for border trench to study the mechanical solutions.
	Staffing requirement	Staffing only applied for the Guard Department in the Ministry of Interior -
	Projects needed	- Vegetation cover, taxonomical level research and frequent monitoring plan. - Environmental monitoring devices, such as: electrochemical devices for sampling, dust monitoring devices for desertification control. - Soil and border trench physical assessment. - GIS mapping support - Threat assessment.
Monitoring and feedback	Genetic monitoring plan	Studying the legal framework for the future schedule monitoring plan. Methodology not discussed during the visit.

	Feedback resulting in context.	-Co-operation with the environmental and research community for solving incidents to improve the result. -Biodiversity restoration of non-food species (medical, ornamental, and recreational). -An increase in land cover results in a reduction in desertification which leads to the improvement of human health

6.4.2 Part 2 Appropriateness:

A- Reviewing Input.

In order to achieve the planned objectives, a list of resources needs to be applied.

Staffing: There are major deficiencies in staff capacity and resources to enforce protected area legislation and regulations. The employment concern is security issues, they are lacking skills related to ecological and environmental support. Ministry of Interior guards distributed at each point in order to patrol for security purposes. Empower the environmental sectors and increase the number of employees, taking into consideration the need for upskilling within specific environmental specialisms of staff in different sectors according to the future management plan.

Equipment: very few of the requirements for active management were implemented in the protected site. According to the research, the environmental and ecological management plan depends on available resources, which are provided and controlled by the Ministry of Interior and are required incidentally. The incidental resource is implemented based on the expertise of the scientific community and engineering communities, which is determined according to the size of the project required. Resources and equipment need to be developed according a proposed threats assessment and annual management plan should be developed. There is also a need to provide environmental monitoring devices, such as: Electrochemical devices for field-based and *in situ* environmental monitoring which allows for auto sampling rather than the traditional way of bringing the sample to the laboratory. In addition, dust monitoring devices for desertification control should be distributed on the site.

Research: according to the revision of the demilitarised zone, natural resource management projects were applied to improve field vegetation of *Rhanteriom and haloxelon*.

The project was developed by Kuwait institution for scientific research, but the result is unknown. In addition, research followed by KISR related to water patterns in Wadi Al-Batin area. The projects aim to develop strategies related to the contamination of oil spills and border trench. Moreover, the development of strategies to improve land cover are essential to overcome contamination.

Information on the critical habitats, species, ecological processes and cultural values of the protected area is sufficient to some extent for most key areas of planning and decision. Information on species distribution is available from Kuwait University herbarium and museum (2018). Administration of the information depends on the data results of research carried out by the scientific community which have been unofficially published. The available information is the baseline for reviewing the protection process, which is likely not developed to the protection management standard. A wide range of research is needed to develop a proper management plan. For instance, the threat assessment for a variety of threats mentioned in the context related to the oil exploration and contamination and hydrological processes, research related to vegetation cover inventory and soil. Scientific research on soil and border trench and physical solutions used is also needed. In addition to many ecological researches for maintaining the ecological value of the protected site related to climate change and Carbon dioxide capture.

B- The Process

According to the context design, the site manager developed an engineering solution to protect the cultural value of the reserve. This was through the construction of an outer fence to control the entrance to the area and prevent camping and grazing. This resulted in determining the boundary of the protected area by the management authority and local

neighboring land users. Protection objectives and design banned the involvement of ecotourism, local community use, social networking and indigenous people. In addition, they also have no input in decisions relating to the management of the protected area. There is no contact between managers, neighboring officials and corporate land owners.

Protection systems are moderately effective in controlling access and resource use through the development of roads and division of the protected site to three sections according to the security control. However, access can be allowed for other non-environmental sectors such as oil exploration or other societies which makes it unlikely for them to achieve the goals and objectives of protection. Moreover, there is a small amount of survey and research work related to the hydrological processes and the vegetation investigation, but it is not directed towards the needs of protected area management. In addition, monitoring and evaluation of the protected area has not been applied.

The management depend on the governmental sectors for economic issues. The financial and economic plan developed by the Ministry of Interior have not accounted for ecological and environmental requirements. A wide list of requirement processes such as: monitoring ecological processes, developing environmental testing tools, maintenance of equipment and facilities, educational awareness, research and development of the management plan needs to be implemented.

6.4.3 Part 3 Delivery:

A- Assessing Output

Protection adaptation leads to the improvement in vegetation cover in most of the protected site. Enhancing the restoration of biodiversity can improve soil stabilisation by the deep root system. The site decreases soil erosion to some extent and facilitates plant recruitment and survival. The protected area design and location is ecologically valuable. The protection adaptation leads to the reduction of CO_2 from the species continuing to grow in the area, preserves cultural value and improves wildlife. The protected area design has allowed for the development of a buffering zone, as the cross-section consists of 2 zones with different types of restrictions; and also, there is a buffering zone for the adjacent protected areas. However, the field revision concluded that there is no co-operation with adjoining the protected areas, according to managerial discussions. Also, there is no regular work plan being implemented. In addition, protected area design and context does not allow for the involvement of ecotourism, local community or social networking.

B- Assessing Outcomes

"Clearly, however good management is, if biodiversity continues to decline, the protected area objectives are not being met." (Stolton *et al.,* 2007).

The primary environmental protection objectives of the Kuwait National Conservation Strategy have been achieved in the DMZ to some extent. Our research was applied for a sector which was evaluated for the first time. The main focus was to concentrate on achievement of the objectives of protection from the environmental point of view. The protection systems

are moderately effective in controlling access. The site managers also developed accessibility roads to reduce the vehicle destruction of vegetation and prevention of harmful activities resulting from camping, and nomadic grazing. However, the access can be from other non-environmental sectors which makes it unlikely for them to achieve the goals and objectives of protection.

The value of the protected site has improved in comparison to when it was first designated. This can be observed from the decision to stop the practice of human harmful activities, construction of an outer porous fence to control entry, prevention of grazing and camping in the area. The field survey reviewed the application of ecological operations by observing threat management which involved consultation of the environmental parties. This leads to improved results of the reserves biological and ecological value.

The protection and conservation of the biological genetic diversity, socio-economic and cultural value of the protected site was achieved through the restoration of the non-food species (medical, ornamental, and recreational). The increase in the land cover reduces desertification which leads to the improvement of human health. The improvement of landcover maintained physical and biological importance to assists in conserving and managing natural renewable recourses. The co-operation with some environmental societies (EPA-KW, KISR, and PAAF) occurred for monitoring and research of the contaminated areas which helped in the restoration and investigation of the vegetation cover. However, the protected area is not providing economic benefits to local communities. The site is considered not been institutionally evaluated since its establishment. In addition to the absence of an environmental management plan within the site, which resulted in deficiencies in carrying out researches and providing its necessary integrated environmental tools for monitoring.

The management has limitations in the following aspects:

- Clear management plan to follow and evaluate.
- Legal framework for management inquiries.
- Trained staff for the implementation of the management plan.
- Research and education such as:

  - Limitation of vegetation cover research.
  - Threat assessment research.
  - limitation in information related to climate change.
  - Monitoring and evaluation research.
  - Limitation of the sustainable resource use.
  - Limitation of environmental monitoring equipment and devices.

6.4.4 Management Effectiveness Tracking Tool METT

Respond and Framework details are specified on the Tracking Tool sheets as follows:

Appendix 6.2.1 represents the sheet which states the general description of the study site which outlines details from the literature review and the discussion with the managers. The applied sheet concluded that the context of the PAME framework is officially applied and the management has the authority to develop a conservation management plan. The main value and objectives of the designation of the protected site is determined from the environmental sector.

The threat evaluation form was subsequently followed by the threat information sheet which includes 12 classified dimensions related to the threats affecting the protected site. The information sheet was completed through site observation and consultations from experts from KISR, details in Appendix (6.2.2). The consultation was required due to the lack of

competence of the security members and guard about the possible threats related to the planning activities applied. Specialists from KISR were requested to complete the data sheet 2 utilising their knowledge and opinions from previous projects applied in the protected site. Experts agreed on most threat component and ranking values. However, the discussion concluded that the main significant threat categories resulted from production of non-biological resources through oil and gas drilling and energy generation, including hydropower dams. The human intrusions and disturbances within the protected area has only been observed from the war and civil unrest and military exercises. This was overcome and is currently in the process of being resolved. However, the modifications of the natural system resulted in a variety of threats related to the hydrological natural flow, increased fragmentation within the protected area and isolation from other natural habitats has also resulted in a moderate threat. Moreover, the threat related to the development of utility and electricity cable services. The mentioned threats lead to different categories of pollution such as: industrial, mining and military effluents, and ecological fragmentation. The long-term threat consequently might be linked to a wider natural variation in habitat shifting and alteration, temperature extremes, droughts, storms and flooding events.

The sheet within Appendix 6.2.3-C consists of 30 questions which covers all components of IUCN-WCPD elements. It provides detailed information of the PAME component. The questionnaire is filled according to the discussion with staff and managers through the 16 surveys detail in Appendix (6.2.3-A and 6.2.3-B).

The top score value of the questionnaire is 99, which is the optimum score to receive. Our results scored 25 out of 99, from the applied questions. There are two non-relevant questions which are related to the current budget and the security of the budget. They can be eliminated

from the assessment in calculating the final value. Out of a maximum score of 93 the protected area scores almost 26.9% which represents the PAME component score. The METT evaluation tool concentrates mostly on details related to planning, input, and the process stages, in contrast with other stages of the evaluation as shown in Table 6.3. and Figure 6.7. However, the process stage has details connected to output and outcome stage, which will not neglect the importance of any stage of the assessment. These details allow for the future improvement of the management plan.

Table 6.3: Details Value of the Score from the Assessment Process Appendix 6.2.3-C

Detail	Context	Planning	Input	Process	Outputs	Outcome	Total
Actual assessment value (total 25)	3	6	5	8	1	2	25
Optimum assessment value (93)	3	21	18	36	6	9	93
% of the stage from the actual value (25)	12.00%	24%	20.00%	32%	4%	8.00%	100%
% of stage from optimum score value (93)	3.23%	22.58%	19.35%	39%	6.45%	9.68%	100%
% of the actual score from the optimum value	3.23%	6.45%	5.38%	9%	1.08%	2.15%	26.88%

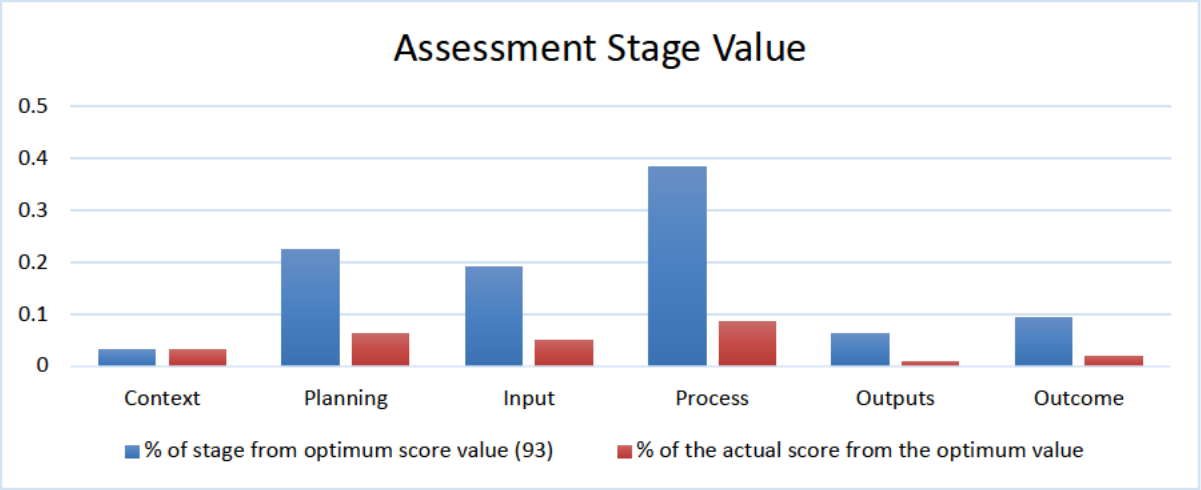


Figure 6.7: Details Value of the Score from the Assessment Process Appendix (6.2.3-C) Comparison Between % of Stage from Optimum Score Value (93) with the % of the Actual Score from the Optimum Value.

In general, implementation of PA evaluation summarised as: effective to some extent in meeting the Kuwait objectives for conservation of nature, and the application addressing threats. In addition, the observation presents the ecological processes of the biogeographical region. The legal structure, size and shape of the protected site was sufficient to maintain ecological processes, however, details in METT Appendix 6.2.3-C need a deep revision from managers of the protected site for future plan.

6.5 Conclusion

Due to the continuous ecological, social and environmental changes in Kuwait, many issues focus on sustainable improvement Leverington *et al.,* 2010) related to education, health, conservation of regional habitat and the relation between resources and activities. (Even though the PA assessment result was so poor the evaluation process helped point to needed PA management improvements. Within the evaluation element, each part plays a role with

obtaining specific information in the final result. For instance, the context design covers the descriptive part of the site, discusses the appropriate input tools required for the future improvement of the management needed to achieve the outcomes. Increased attention must be paid to the regular monitoring of activities in the protected site. The systematic analysis of the economical and socio-cultural value has developed further indicators for management outcomes. However, the outcomes of management and its effectiveness in the field of economic issues are difficult to access, and they are not widely shared among conservation community (Stoll-Kleemann, 2010). The application must go beyond the simple asserting whether PAs are effective or not. The information provided from the evaluations can help in the future development of the protected site. Nagendra (2008) mention that in most scientific professional evaluation research, most of the protected sites are successful in controlling human threats, in particular, effective mitigation in response to hunting, fire and overgrazing. However, in many instances, implementation and enforcement are given insufficient attention (Chape *et al*., 2008).

The threat datasheet and assessment provide information from field surveys which have already been conducted, and the results reveal general patterns that are considered easy to follow within the evaluation and can assist with future improvement. The discussions with the experts focused on the extent of the impact of the threats, despite the agreement on their existence. For instance, utility and service lines require routine maintenance and operation, also, the construction needs further research to confirm the use of herbicides to control vegetation. Furthermore, the maintenance may require access roads to be placed in the protected site, which may disturb natural areas. The discussion also confirms the fragmentation of the border site (Mohema A) which is related to the destruction of land

trenches leads to the isolation of habitats, especially in Wadi Al-Batin area. The construction increase fragmentation within the protected area and cause isolation from other natural habitats, this may affect gene flow and migration. However, the discussion related to the intensity of the threat needs further research.

In summary, the main purpose for the protection is to guard against misappropriation and misuse, preservation of genetic resources and cultural goods, and protection against unfair utilisation. However, the framework tracks the development of the protected area, but the questions are qualitative and depend ultimately on human opinion. The qualitative inquiries might limit the evaluation output and outcome and, in some cases, might develop general information with less specification. On the other hand, the descriptive part of multiple-choice questions can help to improve knowledge of the management responsibility on achieving goals.

The information is designed according to the PAME framework and is discussed in detail through the METT guideline. The application of the METT evaluation tool has limitations in the detailed evaluation of outcomes. Knights *et al.,* (2014), mentions that assessing the relationship between the evaluation tool and components of PAME can be done through the use a variety of independent datasets. The individual datasets developed according to the management plan applied and objectives. In addition, the further investigation dataset can be developed according to the limitation aspects from the outcomes. For instance, outcome can be discussed in more details within separate sheets. The PAME application concluded that there is limited information related to climate change, which would appear particularly relevant in Kuwait and whether the evaluated site managed to adapt to climate change, or if the protected area managed to prevent carbon loss and to encourage further carbon capture.

However, in both cases, there have been no efforts to consider adaptation to climate change, carbon storage or capture, which can be represented through a separate data sheet which allows the covering of all aspects for future implementation. This has not been considered in the management plan of the study site. The limitation in terms of outcomes is not stopping researchers criticising the tool (Nolte and Agrawal, 2012). In fact, the improvement of the result can be developed using suitable data from re- analysing PAME over time. In addition, it can be improved from further investigative research of the study site and its relation to the surrounding area (Dudley *et al.*, 2016). It would be ideal if the evaluation is repeated over time to track the progress of the site using the final score as an indicator, and the details can be used to compare the percentage of the stage score from the optimum score value. The data represents the management evaluation process, and reports must be followed for the future improvement of the management strategy.

6.5.1 Future Directions

Ways of improvement PA management to achieve the establishment objectives of the protected site can be through the improvement of the implementation and the cooperation between the environmental, scientific, and political bodies in the country. In addition, the involvement of the Center for Volunteer Work - NGOs. Valued results can be obtained through the creation of a management plan that covers all aspects of protection. The managers can improve the achievement of the objectives by analysing the ecological, environmental, and social factors that influence the indicators investigated in the site. Also, through the development of a systematic monitoring strategic plan, which must be followed by environmental bodies studying the systems implemented and standards met. Also, the

improvement of objectives achievement can be done through reviewing the recommendations for the improvement of the assessment, and the identification of the IUCN category according to the developed evaluation. It is important to develop transparent funding for successful management correlation to ensure the achievement of the national strategic objectives in this site. Moreover, it is essential that the application is annually re-evaluated after applying the management plan. The site needs surveying to observe the vegetation cover in detail and the creation of a baseline vegetation database for monitoring and identification of biodiversity. The observation can assist in: sampling studies, improvement of vegetation cover and restoration of biodiversity, soil stabilisation, prevention of soil erosion and in facilitating plant recruitment and survivor. A study should be developed to discuss the relation between adjacent protected sites and buffering areas. More observational research must be conducted in order to achieve the planned work program, especially for threat prevention, and for solutions that develop planning outputs. The METT can thus be a useful contributor to a range of datasets, rather than providing the sole dataset, to help practitioners assess conservation outcomes. The current rationale for PAME is focused on facilitating effective management rather than building a scientific evidence base, therefore, it helps in understanding the impacts of protected area management (Forrest *et al.*, 2011 and Henschel *et al*., 2014).

The evaluation assessment must implement the recommendation for data collation and storage to improve the protected site. The planning process needs to cover wider issues to improve the achievement of the protection target and this can be applied through the Develop annual management plan assessment consist of (Middleton and Julie, 2003; Hocking *et al.* 2006; Knight *et al.* 2011):

A- Review the structure and develop management approach and goals

- Identify key issues and significance area within the protection system
- Define targets and formulation of the objectives.
- Set indicators for improvement measures.

B- Framework

- Develop the zoning system for protection connected to specific ecological value of the protected site. Zoning can be according to:
    1- Environmental zone related to natural, cultural or landscape
    2- Services and development zone according to facilities main access and required services.
    3- Natural wild reserve zone related to earth and biodiversity distribution.
- Improvement of the implementation of protection legislation and ecological measures through the empower the environmental sectors to ensure success in the new laws applied.
- Define budget required for protection management implementation, covering important aspects such as:
    - Technical advice and support.
    - Scientific application tools for scientific research implementation equipment (GIS mapping, soil sampling and analysis, environmental technical monitoring tools, etc.

- Set out policy for protection and resources and attributes with engagement of the environmental and scientific sectors in Kuwait and facilitate communication with environmental organization.
- Provide significant monitoring aspects of protected area development and improvement, such as:
    1- Conserve endangered, endemic and remaining species, as well as species of special ecological value.
    2- Conserve economic and cultural value through the application of research to improve data input.
- Develop ecological and biodiversity monitoring programmes and implementation of ecological restoration measures.
- Develop monitoring research such as:
    1- vegetation condition assessments research.
    2- Research address the impacts of climate change, particularly through developing landscape-level initiatives that link protected areas with other land uses.
    3- Sampling studies related to soil structure.
    4- Threat assessment.

C- Applied protection over a specific period of time - time frame for:

- Preparation of the plan and consultation process.
- Implementation of the protected area planning
- Monitoring process for the key aspects applied in the framework

- Study the time frame for each individual target developed in the management plan.

Acknowledgements

Special thank and gratitude to Prof. Raffat Misak for guiding me in the field work, and reviewing the deferent areas related to the Protected area in Kuwait.

Chapter 7. Discussion

Research in the previous chapters contributes to improving the conservation of natural heritage. The application helps in the development of a desertification mitigation plan and series of recommendations that will benefit the plant species of Kuwait. This can be implemented through conservation planning in Kuwait, data collection research, application of Red list assessment- especially the regional assessment. The research helps in the improvement of knowledge and conservation process of prioritised species and contribute the environmental educating of the communities through identifying aid. Moreover, using the evaluation of the protection and conservation measures to improve the management process of the *in-situ* conservation.

Rehabilitation of degraded arid region in most research's started with identifying and addressing the drivers of the degradation (Le Houérou, 2000; Reynolds *et al.*, 2007, Maxted *et al.,* 2020). The research identifies future working prioritised list of species, maintains re-habitation, and assesses threat taxa identification. Ecolqogical and environmental information improves knowledge related to species and the abundance in the study region. The application of ecological prioritisation research develops the understanding of the threat and analysing the destruction and evaluating the consequences, which is not difficult to find (e.g., Drescher 1995; Yang *et al.* 2006; Sternberg 2008; Le Polain de Waroux and Lambin 2012; Zhang *et al.* 2014). Researchers also often prioritise conservation within protected landscapes (Dudley *et al.* 2014), which can be through the conduction of management evaluation in PA.

Our research considers part of conservation planning for the re-habitation process. Data collection can help understand the actual status of the vegetation community in Kuwait, marking natural vegetation fluctuation when describing rarity level, protection, threat status

on each species, and developing a list of priority actions. In addition, the application provides baseline data for conservation from the red listing categorisation and identification of literature related to threats. The adaptation of the Red List category and criteria strengthens the understanding of the actual situation of the threatened species globally with contrast in the regional conservation for priority species. Moreover, adapting the evaluation of the protection status of one of the protected areas in Kuwait (The demilitarised zone), in which the evaluation considers the best solution of re-habitation of degraded land (Dudley *et al.,* 2014) in Kuwait. The research evaluate conservation in one of the essential sites of protection. The applied research also develops identification aids that can help in expanding the knowledge of taxa conserved and used for the future, which can help local communities in understand their natural heritage. The application of robust conservation strategies will help protect plant diversity using the knowledge available.

7.1. Why Prioritise Species for Conservation?

The reduction of plant populations is considered an early warning indicator of species threat. Kuwait is often a sign of desertification (Savory 1989, Bertiller *et al.* 2002; Manzano and Navar 2000; Seghieri *et al.* 1997). The data collection process for the priority species started with the presence/absence of indicative plant species, which is applied according to the flora of Kuwait listed by previous researches. The specimens used collected from many regions, and the Kuwait University herbarium and museum is one of them. The university collection is considered new (almost 30 years), which can develop the understanding of the presence or absence of species. In the research, the presence data used in the prioritisation analysis is 316 from 374 native species, depending on the data provided by the Kuwait University Herbarium

(Index Herbarium code – KTUH), the *de facto* national herbarium of the state of Kuwait. The research also depends on other resources such as GBIF and Kew garden data London. The specimens from other resources are mostly related to Kuwait university as it's the national museum.

The preserved specimens are relatively new collections made after the invasion by Iraq in 1990, but we have observational data collected before invasion of Kuwait found in GBIF and KEW London. The comparison between data observed and collected from the different resource can explain species population history. The comparison gives high priority to further research of structure and composition of the flora of Kuwait and develop a checklist of the vascular plants of Kuwait. However, according to many aspects, this has to be done considering threat status in Kuwait, change in structure distribution and combined flora related to each other which helps in the improvement of the priority list. In addition, not all taxa are available now in Kuwait according to university collection, which is also affected by many other factors related to the observation and collection, due to temporal and spatial differences. In addition to the combined threat in Kuwait related to overgrazing, human destruction activities and industrial work.

According to the research, criteria used in the prioritisation process for Kuwait flora species depend on the rarity factor, which related to the number of specimens, year of collection, and geographical distribution observation (Gaston 1994). The number of specimens collected might be affected by seasonality and timing of collection. The university collection mostly depends on the collection during the coarse period, which is carried out mostly by students applying the herbarium specimen's observation standard. The collection was also adapted according to particular ecological research. The ecological studies cover the

specific area, and the variety of taxa observed might be affected by the number of samples collected. The collection variation has to be discussed with the university and study in-depth the prioritisation process. On the other hand, individual taxa research, data collection, and observation for each species help in understand the relationship between the number of collection and rate of observation for each species, which can develop the relationship among taxa and improve the rarity factor.

The prioritisation process also depends on other criteria associated with geographical distribution, IUCN (2001) extent of occurrence (EOO), and the area of occupancy (AOO). However, the combined characters describe rarity in a simple way and this might ignore the habitat specificity of the species. for instance, observation not considering residential, industrial, or rangeland threats. This leads to developing the other criteria, which are threat observation. Threat observed according to the area of distribution compared with the information related to the land use in Kuwait. However, conservation strategy can also depend on species adaptation in the improvement of the planning process. Prioritisation helps in re-habitation through the development of a list of targeted native species to rehabilitate and develop a conservation strategy. It also reduces threats that accelerate the desertification problem and destruction of vegetation. Identification of threats contributes ways of improvement of species and re-habitation process.

From the mentioned values, 69% of the working list has unknown conservation status in Kuwait and should be under further investigation. Details of regional conservation can be used to estimate the conservation measures of the Arabian Peninsula flora. The significance of plant diversity assessment allows for a further development of detail. The information from the assessment are related to a threat, conservation, used, and geographical distribution of

Kuwait's prioritised list. According to threats and protection status, discussed in chapter 3 and 5, 38% of the working list are considered a target for the conservation plan. However, the research also highlighted almost 31% of the flora of Kuwait with unknown status. Moreover, detailed information in the study considered a baseline for the conservation of species and further investigation.

The priority species listed can be the starting point in the conservation plan. The reduction of the risk of using undesirable tools, assessment can depend on the species' natural adaptation to harsh environmental conditions, which can help in the improvement of the conservation plan. Using them to maintain the species at risk, searching for more locations and the actual situation in sites mentioned, develop a recovery plan to rescue them from the threats in the areas through particular in situ conservation actions. Research provides essential information about the plant communities, helps in understanding the composition and structure of the vegetation of the degraded land. The prioritisation helps in the development of the proper mitigation according to the outcome of the defined result. It uses unique native biodiversity as a critical element of re-habitation and conservation in the dry region.

7.2 Aspects Related to Desertification Mitigation Planning

7.2.1 Nature of Desertification and Threats

The revision of threat categorisation implemented in the research in two ways. The first one was applied through the revision of human activities and practices in the map of the Third Master State of Kuwait. the application uses the scoring scheme of the collected data related to the species distribution with the georeferenced map of the Master plan of Kuwait (Chapter

3). The revision analysis the threats affecting the vegetation occurring in the country. The second threat revision applied according to category and criteria of the Red List (IUCN, 2001). The application depends on the species abundant, distribution and literature review of each individual taxa (Chapter 5). In both analysis, connection of the species distribution and abundance features to the IUCN threats classification is applied for 11 classes and sub-categorisation of each threat. Both applications develop the understanding of threats affecting each prioritised taxon. And in both cases, the threat affecting the occurrence of the vegetation in Kuwait is a combination of human development, intrusions and disturbance, recreational activities, pollution, overgrazing- biological resources use, and land use. The main difference between the two applications is that threat categorisation discussed in the Red Listing assessment revealed that climate change-drought is part of Kuwait's primary threats, depending on individual research. However, the application needs further surveying of each taxon to develop a direct link between the species coverage and climate change. In most cases climate change considers a factor that increases the effect of vegetation degradation thought to aggravation land degradation (Wiesmeier, 2015). Land and vegetation changes happened due to other physical characteristics such as grazing, which resulting in the decline of the quality of the species habitat. However, the individual research assessed in Red listing consists of physiological and biological data related gens and species adaptation if founded, which explain and connect the relation between the different class of weather condition to the growth form structure of the species.

Grazing in the open area is the main factor of land degradation in the Arabian Peninsula. Overgrazing is estimated to be the greatest threat to desert ecosystems and threatens the Arabian plant biodiversity (ICARDA, 2002) of approximately 3,500 species

(Ghazanfar and Fisher, 1998). Urbanisation caused by population growth and expansion of cities is another deleterious factor for plant health. According to the research result, pollution-garbage and solid waste, human intrusions and disturbance, recreational activities, transportation, and service corridors off-road are the major threats on the priority list species at the regional level. In addition, many areas of Kuwait threatened by industrial pollution, namely from oil contamination and oil spills, particularly since the Gulf war in 1990 (Issa and Vempatti, 2018). Moreover, the change in the precipitation patterns and temperature is estimated to aggregate the above-listed threats. With the decreased rainfall by 10 - 20%, Kuwait is frequently affected by desertification. An increase in temperatures is likely to rise between 2 and 3oC by 2050 (Kotwicki and Sulaimani, 2009). The changes produce extreme weather events such as: drought, heavy rain, heat, and cold waves.

In the Arabian Peninsula, droughts occur more frequently and with greater intensity, while flooding also affects the region more often than before (Mooney 1990, Newman *et al.,* 2011, Schilling *et al*., 2012). In Chapter (5), assessment revealed that Climate change, drought, and extreme temperature are the highest categories threatening species in Kuwait. However, the information is inferred from research related to changes in the adaptation of native species. Above all, individual reports discuss the disappearance of species or become vulnerable, which might be due of the change in weather conditions. However, research information considers general conclusion as it describes the threat that combined with other factors such as grazing, oil contamination, and human disturbance.

In general, the level of threat to the region's biodiversity is unclear, especially in arid areas. Threat categorisation can be affected by many factors such as: physiological adaptation, the severity of the threat, and species mixture in the specific area. Moreover, the information

related to individual species distribution and habitat does not reflect the relationship between hazard and regional plant distribution. Moreover, the knowledge of the species native distribution is missing georeferenced occurrence in many regions. The geographical distribution does not reflect the actual occurrence for many taxa studied in this research. Globally: the missing information might be due to the unpublished research, missing georeferenced occurrences, or/ and cannot be reached. In addition, the political factors related to the poor or war, especially in the Mediterranean region is also reflect the species distribution and observation results.

In most of the Middle East region, biodiversity distributional data in missing or even incomplete (Radford, 2011). The Red list assessment for the prioritised species restricted in the native range of distribution (arid region) was challenging to estimate. This was due to the lack of information and/or the taxonomic nomenclature of species recorded an unresolved name. In Kuwait, data collection depends on the Kuwait university herbarium and museum. It is confined by time limit related to the time, of course, specific area to collect. The information pertaining to the protected area collection is not well documented and not georeferenced in some cases. In addition, gathering data depends on the environmental society responsibility and their research capability. Regionally, most data occurrences need to be updated to reflect the actual occurrence and real direct threat. According to that, taxa are found too often to be data deficient (DD). Information is not enough to create a clear understanding of the level of threat on species, using the IUCN red list criteria and categories standers (IUCN.2001). However, the Red Listing assessment information can help in develop the understanding of the regional situation of the priority taxa in Kuwait. The information used in the application also highlighted the economic and ecological value of the active list for the *in situ*, and *ex situ*

conservation plan for the desertification mitigation plan and reflect the actual relation of biodiversity lost and future conservation planning.

7.2.2 Recovery Plan and Management Example

Protected areas help in addressing and mitigate the impact of desertification through maintaining and restoring natural habitats. Reserves can in providing a safe space in drought time from other threats related to human activities and maintain healthy ecosystems with rich biodiversity. Extent protection in Kuwait reached almost 20% of the land protected under a different category, discussed in Chapter 1. In Kuwait, the percentage of total vegetation in open sites decreased by 6.1% compared to protected sites (Al-Awadi *et al*., 2003). The assessment method described in Chapter 6 shows an example of management conservation evaluation of one of the protected sites in the country. The application is easy to follow, starting with literature review and data collection, site visits, interview the managers responsible, and follow the creation of the Management Effectiveness Tracking Tool (METT) framework. The site is first evaluated and isolated from any environmental research studies or assessment.

The application describes qualitative information develop to get a scoring scheme, dependent on human subjective scoring of criteria. This might limit the usefulness of the evaluation output and outcome. The application provides general information of management success with less specification. The quality of the service difficult to measure, and it reflects personal opinion. However, the discussion with the KISR expert and the people who work in the DMZ - PA develop the thinking and reduce the un significant opinion. The application considers an example in evaluating management in protected areas in Kuwait and

addresses threats affecting the management and vegetation conservation. The schemes help in the improvement of reserved land management. Moreover, future development can be achieved by the comparison with the previous year annually, which can use to measure the value of change and determine the pros and cons in site management. METT forms consist of specification related to environmental, ecological and financial aspects which can improve the logical thinking of the workers even if they are not scientists or experts and can help in the future discuss the action implementation.

7.3 The Process of Desertification Mitigation for Kuwait

The actual conservation aspects discussed in Chapter 2 indicate many factors that influence land degradation. According to Yirdaw *et al.* 2017, the critical processes of rehabilitation in dryland ecosystems can be applied through conservation of unique native biodiversity and improving natural ecological settlement in the vegetation cover. Research data of Kuwait considers baseline data, governed by primary source of data. However, gathering the information and using of technology in data processing (Excel, ArcGIS) added a new dimension to the applied criteria. Starting with the data correction process and study the range of species distribution creates a valuable tool of identification. In addition, the technical tools connecting data assessed with the global and regional situation of the threatened native species in Kuwait.

The core efforts towards the conservation process of nature are the protected area. The research provides a critical element of conservation evaluation. Assessment strengthens the protection process by collecting the existing work on control, reviewing methodologies, finding patterns of management of protected sites, and discusses the common themes in

evaluating the results. However, according to the literature review in PA management in Kuwait, the protection development and management correction process is developed randomly. The environmental and scientific society are not fully involved in the management process. This was discussed by investigating the most important factors that lead to active management in the country. However, METT provides information related to the quality of services that can help managers choose a desired environmental decision. The application is valued in aiding the conservation of vegetation cover in Kuwait and improve education aspects related to the natural heritage in the country.

7.4 Biodiversity Conservation

The Flora in Kuwait faces high levels of risk and even extinction in its geographical range of distribution. For some species, estimating risk consider difficult due to the lack of baseline biological information. The documentation process is the central part of the conservation plan in Kuwait, which might be developed through inventory research. In most cases, data resources used in arid region researches lack electrical access. They are gathered manually from herbarium specimens, which are, in our case, collected from the national herbarium in Kuwait University (KTUH). However, collectors of such data need to follow a strategic plan to cover different sites in the country. Gab analysis research needs to be implemented as part of the long-term conservation plan, improving the quality of the result and covering various sites.

Loss of natural vegetation in dryland ecosystems creates deserts, dust storms, and frighteningly high levels of respiratory disease in cities like Kuwait. (Stolton *et al.,* 2015). The process of the development of a broader vision of native heritage in Kuwait is considered a

priority. Conservation is the strategy resulted from a defined vision and range of goals, depending on biological and ecological facts (Breitenmoser *et al.,* 2011). Setting an efficient conservation plan required a substantial source of information such as species distribution and landscape analysis, threat categorisation, defined morphological characteristics, and ecological formulation such as potential adaptation. Concentrating on combating desertification in Kuwait, the improvement of land cover and strategic replantation process developed by determining what to plant, when, and where. Research develops targeted species of high priority for conservation. Part of the Red List Assessment in chapter 5 establishes the threat level for prioritised species under different categories identified. The processed information can contribute to desertification mitigation through:

- The potential distribution data points related to preserved specimens and giving priority for further research. The geographical distribution of the priority working list describes the protected status of 50 taxa, while the rest consider unknown protection status.
- The application considers the native species' adaptation to harsh environmental conditions for the replantation process. Ex-situ conservation aims to ensure the continued survival and sometimes to produce large quantities.
- In our research on the Red List, we assessed almost 50 species from the priority list of the flora of Kuwait with medicinal value. Improve research outcome can be through the understanding the uses of flora in the country and other ecological information. Although Kuwait has limited pharmaceutical manufacturing capacity, all herbal medicines are imported, and consumption in Kuwait is unknown. Published studies around this area are few (Alostad *et al*., 2017).

- The disappearance of vegetation because animals are the primary indicator of overgrazing. The rangeland in Kuwait is severely degraded. Enactment of laws and binding legislation for land use reliance on the distributed sources from relevant authorities.
- Identification and plant taxonomy consider a daunting task, according to the vast taxa varieties and plant properties.

For this reason, there is a significant need to apply the automatic electrical system for identification. Virtual plant data help in using a high number of defining features, considering the ability to continues uploading new features, contributing to the determination of plant species. The application helps detect the relations and change of species among its community in the same family. In addition, it can be used to educate the community about the native species, e.g., the production of application for species features and identification of taxa in the wild, which helps educate communities. Moreover, the electrical data consider easy to deal with for further research and to develop new identification aid from the primary data; for instance, using family taxa group, create weed of Kuwait group, medicinal plant, or any research group needed in the future.

7.5 Limitations of Research

Research depends on georeferenced data collected from the herbarium. However, not all specimens had sufficient information to permit use in taxon prioritisation or research development. Observation and data analysis resulted in finding information with un-define location and duplicate location for many taxa. Meaning that the taxa might be there, but it's not well documented, which might change the scoring value. In addition, most of the data

used in the research were created from raw data of specimens stored in the herbarium. However, the correction process from specimens, if available online, can be through a continual herbarium visit. It was time-consuming and economically insufficient to travel to correct data. The lack or complete absence of good quality data for herbarium specimens was a significant limitation. The data was available to review in the herbarium - University of Kuwait (KTUH), but it's better to develop an electrical website to use data for researchers. The application considers a step forward to improve knowledge of the species conservation process in Kuwait.

The study revealed that many corrections of the data collection process, *Chrozophora verbascifolia* is a synonym of *Chrozophora tinctoria* (L.) A.Juss. *Alhagi grunum* is synonym to *Alhagi maurorum* Medik. Also, data observation identified unresolved names such as: *Medicago brachyacantha* Boiss; *Convolvulus* buschiricus Bornm, and *Calendula arvensis* Vail L., contributing data sources did not contain sufficient evidence to decide whether they were accepted or synonyms. Taxonomic correction may affect the research by subsequently re-correcting analysis results.

Red list data distribution of priority list revealed species not native in Kuwait, such as *Bromus catharticus* native distribution in South America, naturalised elsewhere in South Europe (Stewart, 1996; Omar, 2007; Bisby et al. 2010; Maslo, 2013; USDA -ARS, 2020). The well-known checklist for species name and synonym is an essential source of information to develop sufficient data. Addressing species categorisation according to the criteria and category according to the IUCN framework in the arid region to maintain quality result in research.

7.6 Future work

- Digitalising the Arabian Peninsula flora and establishing a regional online threat assessment should be the priority; exchange information is considered a priority.
- Systemic inventory, which developed in cooperation with environmental societies, is required to update data for new information and contribute the change in structure and composition of flora in Kuwait. The study enhances the prioritisation categories, conservation plan, threat status and develops the genetic erosion and climate change studies.
- Overgrazing contributes to land degradation and leads to the spread of invasive alien species. It changes the structure of the vegetation cover. In this case, future study of the vegetation structure is considered necessary to determine the actual ecological value before the investigation and prioritisation process.
- Developing management plan and policies to review protection status and develop medicinal genetic reserve as a new category for a protected area in Kuwait.
- There has been much research to identify indicators, drivers, and factors to improve the ecological situation in Kuwait. However, the long-term impact of climate change needs further investigation and analysis of the observation and predicting changes in vegetation cover. This kind of research needs to be government-funded in the long term and requires various research resources.
- Extending the working in features of the families and genus for the interactive identification of species develop a series of characters and states better to be designed for all flora of Kuwait with consideration of developing unique interactive multi-entry key for the medicinal plant, prominent family in Kuwait like Amaranthaceae, and

Asteraceae (Compositae). It is also considered a priority to develop a unique multi-entry key for Weeds species in Kuwait and the Poaceae family, part of the conservation research.

- Information related to the genetic research of crop wild relative in an arid region and study stress responses for salinity and temperature adaptation and improving tolerance of abiotic stresses.
- It is recommended to follow the planning process needs to improve the achievement of the protection target which discussed in details in Chapter 6.

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Appendix 3.1: Scoring of Priority Species for Conservation.

Family Genus / species Specimens no.	Score	Time range	Score	Protection	Score	AOO	Score	EOO	Score	Threat	Score	Total
Boraginaceae												
Arnebia tinctoria Forssk.												
2	5	19930423-19950323	3	0	5	450	4	0	5	2	3	25
Arnebia linearifolia A.DC.												
2	5	19930402-19960321	3	0	5	450	4	0	5	0	1	23
Echium rauwolfia Delile												
9	5	19760418- 20050406	2	1	4	900	3	744	4	4	5	23
Heliotropium kotschyi (Bunge) Gürke												
2	5	19760411-19900308	4	0	5	450	4	0	5	3	4	27
Ogastemma pusillum (Coss. & Durieu ex Bonnet & Barratte) Brummit												
3	5	19850307-19900417	4	1	4	675	3	356	4	3	4	24
Cruciferae												
Maresia pygmaea (Delile) O.E. Schultz												
7	5	19720313-20010124	3	2	3	1,350	3	744	4	6	5	23
Asteraceae												
Seriphidium herba-alba (Asso) Soják												
1	5	19810419	4	1	4	225	4	0	5	0	1	23
Artemisia scoparia Waldst. & Kit.												
10	5	19790308-20120506	1	0	5	900	3	5560	3	3	4	21
Anthemis pseudocotula Boiss.												
1	5	19820313	4	0	5	255	4	0	5	2	3	27
Pallenis hierochuntica (Michon) Greuter												
7	5	19870120-20000405	3	2	3	1,125	3	9450	3	3	4	21
Centaurea mesopotamica Bornm.												
2	5	19830421-19970424	3	0	5	450	4	0	5	2	3	25
Erigeron bonariensis L.												
1	5	19820615	4	0	5	225	4	0	5	3	4	27
Gymnarrhena micrantha Desf.												
3	5	19810330-20130309	1	0	5	750	3	744	4	4	5	23
Launaea angustifolia (Desf.) Kuntze												
4	5	19810224-19850301	4	1	4	675	3	12,1	3	3	4	23

Launaea capitata (Spreng.) Dandy												
2	5	19820415-19900408	4	1	4	450	4	0	5	2	3	25
Launaea nudicaulis												
5	5	19820327-20130303	1	1	4	900	3	529	4	3	4	21
Matricaria aurea (Loefl.) Sch.Bip												
4	5	19810305-19930309	3	1	4	459	4	65	5	3	4	25
Scorzonera tortuosissima Boiss.												
3	5	19820404-19900417	4	1	4	450	4	0	5	0	1	23
Scorzonera papposa DC.												
1	5	19820329	4	1	4	225	4	0	5	0	1	23
Senecio vulgaris L.												
1	5	19891216	4	0	5	225	4	0	5	3	4	27
Sonchus tenerrimus L.												
1	5	19720320	5	1	4	225	4	0	5	3	4	27
Urospermum picroides (L.) Scop. ex F.W.Schmidt												
10	5	19920505- 20010217	2	1	4	1,350	3	4,084	4	5	5	23
Xanthium strumarium L.												
1	5	19911020	3	0	5	225	4	0	5	2	3	25
Solanaceae												
Datura innoxia Mill.												
6	5	19951001- 19980517	3	0	5	675	3	38	5	2	4	25
Hyoscyamus pusillus L.												
2	5	19350208-19850321	4	0	5	675	3	4,338	4	3	4	25
Withania somnifera (L.) Dunal												
1	5	19900417	4	0	5	225	4	0	5	3	4	27
Convolvulaceae												
Convolvulus arvensis L.												
13	4	19820528- 20070315	2	0	5	1,125	3	2,319	4	4	5	23
Convolvulus buschiricus L.												
2	5	19810406	4	0	5	225	4	0	5	3	4	27
Cuscuta planiflora Ten.												
8	5	19720320- 20010131	2	2	3	2,350	2	3,455	4	5	5	21
Orobanchaceae												
Orobanche minor Sm.												
1	5	20010121	2	0	5	225	4	0	5	3	4	25
Orobanche ramosa L.												
2	5	19980527- 20030403	2	0	5	450	4	0	5	3	4	25
Plantaginaceae												
Plantago notata Lag.												

1	5	19740327	5	1	4	225	4	0	5	3	4	27
Caprifoliaceae												
Valerianella dufresnia (K.Koch) Kuntze												
6	5	19720308- 20010129	2	1	4	50	4	0	5	2	3	23
Apiaceae												
Ducrosia anethifolia (DC.) Boiss.												
18	4	19820422- 20010413	2	0	5	900	3	420	4	6	5	23
Plumbaginaceae												
Limonium carnosum (Boiss.) Kuntze												
9	5	19810422- 20010329	2	2	3	900	3	996	4	3	4	21
Psylliostachys spicata (Willd.) Nevski												
1	5	19820419	4	1	4	225	4	0	5	2	3	25
Portulacaceae												
Portulaca oleracea L.												
19	4	19870424- 20100320	2	0	5	1,575	3	6,967	3	4	5	22
Caryophyllacaea												
Silene conoidea L.												
1	5	20040401	2	1	4	225	4	0	5	3	4	24
Stellaria media (L.) Vill.												
6	5	19930408-20070301	2	1	4	675	3	114	4	4	5	23
Vaccaria hispanica (Mill.)												
4	5	20070422- 20100315	2	1	4	900	3	4,736	4	5	5	23
Amaranthaceae												
Atriplex dimorphostegia Kar. & Kir.												
1	5	19810504	4	0	5	225	4	0	5	3	4	27
Beta vulgaris L.												
7	5	19710506- 20060323	2	1	4	1,125	3	2,625	4	2	3	21
Chenopodium album L.												
10	5	19931102- 20101124	2	0	5	1,350	3	3,617	4	5	5	24
Axybasis glaucum L.												
7	5	19621103- 19899309	4	2	3	1,350	3	11,238	3	2	3	21
Chenopodium opulifolium Schrad. ex W.D.J.Koch & Ziz												
2	5	19920528- 20010224	2	0	5	450	4	0	5	3	4	25
Halothamnus iraqensis Botsch.												
9	5	19710105- 20041124	2	1	4	1,125	3	1,889	4	6	5	23
Salicornia europaea L.												
5	5	19890323- 20101020	2	2	3	675	3	297	4	3	4	21
Caroxylon jordanicola (Eig) Akhani & Roalson												
9	5	19811201- 20041125	2	1	4	1,350	3	2,820	4	5	5	23
Suaeda vermiculata Forssk. ex J.F.Gmel.												
10	5	19820308- 20080504	2	2	3	1,575	3	3,908	4	3	4	21
Traganum nudatum Delile												

1	5	19930401	3	0	5	225	4	0	5	2	3	25
Agathophora alopecuroides												
1	5	20170416	1	1	4	225	4	0	5	0	1	20
Aizoaceae												
Aizoanthemum hispanicum (L.) Klak												
10	5	20010217- 20130309	1	0	5	1,350	3	1,897	4	4	5	23
Cynomoriaceae												
Cynomorium coccineum L.												
3	5	20000302- 20120311	1	1	4	450	4	35	5	3	4	23
Crassulaceae												
Crassula alata (Viv.) A.Berger												
1	5	19980305	3	0	5	225	4	0	5	2	3	25
Malvaceae												
Malva nicaeensis All.												
1	5	19930408	3	0	5	225	4	0	5	2	3	25
Cistaceae												
Helianthemum kahiricum Delile												
6	5	19710118- 20010121	2	1	4	225	4	7,567	3	2	3	21
Brassicaceae												
Diplotaxis acris (Forssk.) Boiss.												
2	5	19760314- 20130303	1	0	5	225	4	0	5	0	1	21
Diplotaxis harra (Forssk.) Boiss.												
5	5	19810224- 20130303	1	1	4	900	3	735	4	3	4	21
Farsetia aegyptia Turra												
4	5	19810330- 20130220	1	1	4	675	3	29	5	4	5	23
Horwoodia dicksoniae Turrill												
7	5	19350208- 20120206	1	1	4	900	3	527	4	5	5	22
Lepidium sativum L.												
1	5	19850328	4	0	5	225	4	0	5	3	4	27
Leptaleum filifolium (Willd.) DC.												
3	5	19760314- 19820329	4	1	4	675	3	200	4	2	3	23
Strigosella grandiflora (Bunge) Botsch.												
7	5	19780120- 20130309	1	1	4	900	3	1,445	4	4	5	23
Notoceras bicorne (Aiton) Amo												
1	5	19820421	4	0	5	225	4	0	5	1	2	25
Zilla spinose (L.) Prantl												
3	5	19720401- 20170117	1	1	4	225	4	0	5	1	2	21
Alyssum homalocarpum (Fisch. & C.A.Mey.) Boiss.												
2	5	19820404	4	1	4	450	4	0	5	0	1	23
Meniocus linifolium (Stephan ex Willd.) DC.												
1	5	19760314	5	1	4	225	4	0	5	1	2	25
Malcolmia pygmaea (DC.) Boiss.												
1	5	20010224	2	1	4	225	4	0	4	3	4	23

Resedaceae												
Oligomeris linifolia (Vahl ex Hornem.) J.F.Macbr.												
1	5	19970410	3	1	4	225	4	0	5	3	4	25
Phyllanthaceae												
Andrachne telephioides L.												
5	5	19810305- 20130225	1	0	5	900	3	1,076	4	4	5	23
Euphorbiaceae												
Chrozophora tinctoria (L.) A.Juss.												
2	5	19800721- 20040506	2	0	5	450	4	0	5	3	4	25
Euphorbia densa Schrenk												
1	5	19810224	4	1	4	225	4	0	5	2	3	25
Euphorbia hirta L.												
1	5	19891228	4	0	5	225	4	0	5	3	4	27
Euphorbia peplus L.												
2	5	19980525- 19990413	3	0	5	450	4	0	5	3	4	26
Euphorbia serpens Kunth												
12	4	19711206- 20000420	3	1	4	1,575	3	3,387	4	6	5	23
Geraniaceae												
Erodium ciconium (L.) L'Hér.												
4	5	19740318- 20010224	2	2	3	675	3	1,699	4	3	4	21
Erodium cicutarium (L.) L'Hér.												
3	5	19760425- 19990324	3	2	3	675	3	736	4	2	3	21
Fabaceae												
Vachellia farnesiana (L.) Wight & Arn.												
2	5	19851125- 19870616	4	0	5	225	4	0	5	2	3	26
Acacia nilotica (L.) Delile												
2	5	19831031- 19840612	4	0	5	450	4	0	5	3	4	27
Acacia pachyceras O.Schwartz												
2	5	19890316- 20110119	1	1	4	225	4	98	5	4	5	24
Alhagi maurorum Medik.												
2	5	19810527	4	1	4	450	4	0	5	2	3	25
Ononis reclinata L.												
8	5	19930318-20010406	2	1	4	675	3	849	4	4	5	23
Vicia sativa L.												
3	5	19900405- 20100301	2	0	5	450	4	0	5	3	4	25
Urticaceae												
Urtica urens L.												
5	5	19950228- 20070315	2	0	5	450	4	159	4	2	3	23
Iridaceae												
Gladiolus italicus Mill.												
2	5	19820325- 20130225	1	1	4	450	4	0	5	2	3	22
Poaceae												
Aegilops bicornis (Forssk.) Jaub. & Spach												

3	5	19810321	4	1	4	450	4	0	5	3	4	26
Aegilops kotschyi Boiss.												
10	5	19460310- 20010320	2	1	4	1,575	3	3,576	4	4	5	23
Aegilops triuncialis L.												
4	5	19870429- 20070308	2	1	4	900	3	2,385	4	4	5	23
Dichanthium annulatum (Forssk.) Stapf												
4	5	19860327- 19900402	4	0	5	225	4	0	5	3	4	27
Digitaria sanguinalis (L.) Scop.												
7	5	19850927- 19981107	3	1	4	675	3	1,881	4	4	5	24
Echinochloa colona (L.) Link.												
12	4	19860928- 20010722	2	0	5	675	3	559	4	3	4	22
Aeluropus littoralis (Gouan) Parl.												
4	5	19970410- 20010331	2	1	4	450	4	0	5	4	5	25
Ammochloa palaestina Boiss.												
1	5	Na	5	0	5	225	4	0	5	2	3	27
Avena barbata Pott ex Link												
3	5	19820419- 19960316	3	1	4	450	4	18	5	3	4	25
Avena fatua L.												
4	5	19890323- 20070301	2	2	3	675	3	610	4	3	4	21
Avena sativa L.												
2	5	19900417- 20140318	1	0	5	450	4	0	5	4	5	25
Avena sterilis L.												
3	5	19740320- 19960321	3	0	5	675	3	1,037	4	4	5	25
Bromus catharticus Vahl												
1	5	19890323	4	0	5	225	4	0	5	3	4	27
Bromus moeszii Pénzes												
1	5	19810416	4	0	5	225	4	0	5	3	4	27
Bromus tectorum L.												
3	5	19971220- 20000228	3	2	3	675	3	1,378	4	2	3	21
Cenchrus ciliaris L.												
8	5	19530501- 20050224	2	2	3	1,350	3	2,102	4	3	4	21
Dactyloctenium aegyptium (L.) Willd.												
9	5	19850927- 20010722	2	1	4	900	3	1,682	4	4	5	23
Eragrostis minor Host												
3	5	19980309- 19990304	3	1	4	450	4	0	5	3	4	25
Eremopoa persica (Trin.) Roshev.												
1	5	19880128	4	0	5	225	4	0	5	3	4	27
Eremopyrum bonaepartis (Spreng.) Nevski												
4	5	19720309- 19960328	3	0	5	450	4	52	5	2	3	25
Eremopyrum distans (K.Koch) Nevski												
2	5	19780210- 19810315	4	1	4	450	4	0	5	2	3	25
Diplachne fusca (L.) P. Beauv. ex Roem. & Schult.												
1	5	19850117	4	0	5	225	4	0	5	3	4	27

Lolium temulentum L.												
1	5	19890323	4	1	4	225	4	0	5	2	3	25
Setaria verticillata (L.) P.Beauv.												
12	4	19850911- 19981206	3	1	4	1,125	3	2,663	4	5	5	23
Sorghum halepense (L.) Pers.												
1	5	19870522	4	0	5	225	4	0	5	3	4	27
Stipagrostis ciliate (Desf.) De Winter												
5	5	19350501- 19970501	3	0	5	900	3	1,106	4	4	5	25
Stipagrostis drarii (Täckh.) De Winter												
3	5	19930928- 20050402	2	1	4	225	4	1,079	4	4	5	24
Stipagrostis obtuse (Delile) Nees												
1	5	19820421	4	1	4	225	4	0	5	0	1	23
Juncaceae												
Juncus rigidus Desf.												
5	5	19820317- 20090508	2	1	4	675	3	1,091	4	2	3	21
Typhaceae												
Typha domingensis Pers.												
2	5	19990427- 20010131	2	1	4	450	4	0	5	2	3	23
Ixiolirionaceae												
Ixiolirion tataicum (Pall.) Schult. & Schult.f.												
1	5	19820325	4	1	4	225	4	0	5	2	3	25
Amarylliaceae												
Allium sphaerocephalon L.												
2	5	20110402	1	1	4	450	4	0	5	1	2	21
Ephedraceae												
Ephedra alata Decne.												
1	5	20130311	1	1	4	225	4	0	5	3	4	23

Appendix 3.2. Assess Low Numbers of Specimen's Collection <10 (36% of the 121priority Species), and the Protection Status of Priority Species (41% of the 121-Priority Species).

No	Genus	Species	Status	Growth Form	Rare observation	Protection Test
1.	*Arnebia*	*tinctorial*	*N*	*A*		*
2.	*Ogastemma*	*pusillum*	*N*	*A*	*	
3.	*Seriphidium*	*herba-alba*	*N*	*A*	*	
4.	*Artemisia*	*scoparia*	*N*	*A*		*
5.	*Anthemis*	*Pseudocotula*	*NW*	*A*	*	*
6.	*Pallenis*	*hierochuntica*	*N*	*A*	*	*
7.	*Centaurea*	*mesopotamica*	*N*	*P*		*
8.	*Erigeron*	*bonariensis*	*W*	*P*	*	*
9.	*Gymnarrhena*	*micrantha*	*N*	*A*		*
10.	*Launaea*	*angustifolia*	*N*	*A*	*	
11.	*Launaea*	*capitata*	*N*	*A*	*	
12.	*Scorzonera*	*tortuosissima*	*N*	*P*	*	
13.	*Scorzonera*	*papposa*	*N*	*P*	*	
14.	*Senecio*	*vulgaris*	*W*	*A*	*	*
15.	*Sonchus*	*tenerrimus*	*W*	*A*	*	
16.	*Xanthium*	*strumarium*	*W*	*A*		*
17.	*Datura*	*innoxia*	*W*	*P*		*
18.	*Hyoscyamus*	*pusillus*	*N*	*A*	*	*
19.	*Withania*	*somnifera*	*W*	*A*	*	*
20.	*Convolvulus*	*arvensis*	*W*	*P*		*
21.	*Cuscuta*	*planiflora*	*N*	*P*		

22.	*Orobanche*	*minor*	*W*	*P*		*
23.	*Orobanche*	*ramosa*	*W*	*P*		*
24.	*Plantago*	*notata*	*N*	*A*	*	
25.	*Ducrosia*	*anethifolia*	*N*	*A*		*
26.	*Psylliostachys*	*spicata*	*N*	*A*	*	
27.	*Portulaca*	*oleracea*	*W*	*A*		*
28.	*Atriplex*	*dimorphostegia*	N	A	*	*
29.	*Chenopodium*	*glaucum*	W	A	*	*
30.	*Chenopodium*	*opulifolium*	W	A		*
31.	*Traganum*	*nudatum*	N	A		*
32.	*Aizoanthemum*	*hispanicum*	N	A		*
33.	*Crassula*	*alata*	N	A		*
34.	*Malva*	*nicaeensis*	W	A		*
35.	*Diplotaxis*	*acris*	N	A		*
36.	*Lepidium*	*sativum*	C	A	*	*
37.	*Leptaleum*	*filifolium*	N	A	*	
38.	*Notoceras*	*bicorne*	N	A	*	*
39.	*Cuprella*	*homalocarpa*	N	A	*	
40.	*Meniocus*	*linifolium*	N	A	*	
41.	*Chrozophora*	*tinctoria*	N	A		*
42.	*Euphorbia*	*densa*	*N*	*A*	*	
43.	*Euphorbia*	*hirta*	*W*	*A*	*	*
44.	*Euphorbia*	*peplus*	*W*	*A*		*
45.	*Acacia*	*farnesiana*	*C*	*P*	*	*
46.	*Vachell*	*nilotica*	*N*	*P*	*	*

47.	*Alhagi*	*maurorum*	*N*	*P*	*	
48.	*Malcolmia*	Pygmaea	*N*	*A*	*	
49.	*Vicia*	*sativa*	*C*	*A*		*
50.	*Urtica*	*urens*	*W*	*A*		*
51.	*Aegilops*	*bicornis*	*N*	*A*	*	
52.	*Dichanthium*	*annulatum*	*NW*	*P*	*	*
53.	*Echinochloa*	*colona*	*W*	*A*		*
54.	*Ammochloa*	*palaestina*	*N*	*A*	*	*
55.	*Avena*	*sativa*	*W*	*A*		*
56.	*Avena*	*sterilis*	*W*	*A*		*
57.	*Bromus*	*catharticus*	*W*	*A*	*	*
58.	*Bromus*	*Moeszii*	*NW*	*A*		*
59.	*Eremopoa*	*persica*	*N*	*A*	*	*
60.	*Eremopyrum*	*bonaepartis*	*N*	*A*	*	*
61.	*Leptochloa*	*fusca*	*W*	*P*	*	*
62.	*Lolium*	*temulentum*	*NW*	*A*	*	
63.	*Sorghum*	*halepense*	*W*	*P*	*	*
64.	*Stipagrostis*	*ciliate*	*N*	*P*		*
65.	*Stipagrostis*	*obtuse*	*N*	*P*	*	
66.	*Ixiolirion*	*tataicum*	*N*	*P*	*	
67.	*Halodule*	*uninervis*	*N*	*P*		*

Appendix 3.3: Ecological Zone of the Observed and Collected Species

Location	% from the Total specimens of 8,276	total number of specimens in all locations	total Number of species observed	% from the prioritised specimens 0f 564	total number specimens observed in the site	Total number of species prioritised	% of priority species from the observed ones
Wadi al Batin	13.9	1152	173	10.5	59	31	17.9
Khabari al-Awazem and Abraq	0.34	28	24	0	0	0	0
Um-Neqqa	1.1	91	60	1.1	6	5	8.3
Al- Liyah - Al- Huwaimliyah	0.5	41	32	0.9	5	4	12.5
Jal Az Zor, Um Al-Rimam, Sabah Al- Ahmad Natural reserve	11.8	978	197	10	56	33	16.8
kathma	0.7	54	33	0.5	3	2	6.0
Ras Al-Subbiah- Al- Doha	11.5	948	171	5.7	32	21	12.
Al- Sulaibia KISR	7.9	656	152	4.6	26	18	11.8
Al- Jahara Reserve, Al-khuwaisat	8.7	718	141	2.5	14	11	7.8
AL- Dubaiyah - Ras Az Zor	3.2	262	90	4.4	25	15	16.7
Al- Khiran - Al-Nuwaisib	10.8	894	159	11.5	65	22	13.8
AL- Abdali Frams	3.4	279	171	3.4	19	13	7.6
Al- Wafra	5.2	431	114	6.6	37	19	16.6
Failaka Island	5.1	420	123	7.5	41	20	16.6
Bubyan Island	0.2	15	7	0.7	4	2	28.6
Auha and Gharooh Island	0.5	42	30	0.4	2	2	6.7

Appendix.4.1. List of 232 Taxa Used in the Application of Interactive Identification Key for Kuwait Plant Species.

Family	Genus and species	Family	Genus and species
Juncaceae	*Juncus rigidus* Desf	Amaranthaceae	*Suaeda vermiculata* Forssk. ex J.F.Gmel
Typhaceae	*Typha domingensis* (pers.) poir. Ex Steud.	Amaranthaceae	*Suaeda aegyptiaca* (Hasselq.) Zohara. Syn.
Ixiolirionaceae	*Ixiolirion tataicum* (Pall.) Herbert.	Amaranthaceae	*Traganum nudatum* Delile.
Cymodoceaceae	*Halodule uninervis* (Forssk.) Asch.	Brassicaceae	*Alyssum homalocarpum* (Fisch. & Mey.) boiss.
Ephedraceae	*Ephedra alata* Decne.	Brassicaceae	*Alyssum linifolium* Steph. Ex. Willd
Amarylliaceae	*Allium sphaerocephalum* L.	Brassicaceae	*Diplotaxis acris* (Forssk) Boiss.
Urticaceae	*Urtica urens* L.	Brassicaceae	*Diplotaxis harra* (Forssk) Boiss.
Phyllanthaceae)	*Andrachne telephioides* L.	Brassicaceae	*Farsetia aegyptia* Turra.
Cynomoriaceae	*Cynomorium coccineum* L.	Brassicaceae	*Farsetia burtonae* Oliv.
Crassulaceae	*Crassula alata* (Viv.) A. Berger	Brassicaceae	*Horwoodia dicksoniae* Turril.
Portulacacaea	*Portulaca oleracea* L.	Brassicaceae	*Lepidium sativum* L.
Caprifoliaceae	*Valerianella dufresnia* Bunge Ex Boiss.	Brassicaceae	*Lepidium aucheri* Boiss.
Cuscutaceae	*Cuscuta planiflora* Ten.	Brassicaceae	*Leptaleum filifolium* (Willd.) D.C.

Apiaceae	*Ducrosia anethifolia* (DC.) Boiss.	Brassicaceae	*Malcolmia pygmaea* (Delile) Boiss.
Iridaceae	*Gladiolus italicus* L.	Brassicaceae	*Malcolmia africana* (L.) R. Br
Aizoaceae	*Aizoanthemum hispanicum* L.	Brassicaceae	*Malcolmia grandiflora* (Bunge.) Kuntze.
Solanaceae	*Datura innoxia* Mill.	Brassicaceae	*Notoceras bicorne* (Aiton) Amo.
Solanaceae	*Hyoscyamus muticus* L.	Brassicaceae	*Zilla spinosa* (Turra) Prantl.
Solanaceae	*Hyoscyamus pusillus* L.	Euphorbiaceae	*Chrozophora tinctoria* (L.) Raf.
Solanaceae	*Withania somnifera* (L.) Dunal.	Euphorbiaceae	*Chrozophora verbascifolia* (Willd.) A. Juss. Ex Spreng.
Convolvulaceae	*Convolvulus arvensis* L.	Euphorbiaceae	*Euphorbia densa* Schrenk.
Convolvulaceae	*Convolvulus buschiricus* Bornm.	Euphorbiaceae	*Euphorbia hirta* L.
Convolvulaceae	*Convolvulus oxyphyllus* Boiss.	Euphorbiaceae	*Euphorbia peplus* L.
Convolvulaceae	*Convolvulus cephalopodus* Boiss. Syn.	Euphorbiaceae	*Euphorbia serpens* Kunth.
Convolvulaceae	*Convolvulus pilosellifolius* Desr.	Euphorbiaceae	*Euphorbia granulata* Forssk.
Orobanchaceae	*Orobanche minor* Sm.	Euphorbiaceae	*Euphorbia grossheimii* (Porkh.) Prokh.
Orobanchaceae	*Orobanche ramosa* L.	Euphorbiaceae	*Euphorbia helioscopia* L.

Orobanchaceae	*Orobanche aegyptiaca* Pers.	Euphorbiaceae	*Euphorbia indica* Lam.
Orobanchaceae	*Orobanche cernua* Loef	Euphorbiaceae	*Euphorbia maculata* L.
Plumbaginaceae	*Limonium carnosum* (Boiss.) Kuntze.	Fabaceae	*Acacia farnesiana* L.
Plumbaginaceae	*Limonium lobatum* (L.f.) Kuntze	Fabaceae	*Acacia nilotica* L.
Plumbaginaceae	*Psylliostachys spicata* (Willd.) Nevski Syn. Statice spicata (Willd.)	Fabaceae	*Acacia pachyceras* O. Schwartz var. najdensis (Chaudhary) Boulos
Caryophyllaceae	*Silene conoidea* L.	Fabaceae	*Alhagi maurorum* Medik
Caryophyllaceae	*Silene arabica* Boiss.	Fabaceae	*Medicago brachyacantha* Boiss
Caryophyllaceae	*Silene arenosa* C. Koch Linnaea.	Fabaceae	*Medicago polymorpha* L.
Caryophyllaceae	*Silene villosa* Forssk.	Fabaceae	*Medicago laciniata* (L.) Mill. Var.
Caryophyllaceae	*Stellaria media* (L.) Vill.	Fabaceae	*Ononis reclinata* L.
Caryophyllaceae	*Vaccaria hispanica* (Mill). Rauschert.	Fabaceae	*Ononis serrata* Forssk.
Resedaceae	*Oligomeris subulate* (Webb & Berth.) Webb.	Fabaceae	*Vicia sativa* L.
Resedaceae	*Reseda arabica* Boiss.	Poaceae	*Aegilops bicornis* (Forssk.) Jaub. & Spach.
Resedaceae	*Reseda alba* L.	Poaceae	*Aegilops kotschyi* Boiss.

Resedaceae	*Reseda muricata* C.presl.	Poaceae	*Aegilops triuncialis* L.
Resedaceae	*Reseda decursiva* Forssk. Syn.	Poaceae	*Eremopyrum bonaepartis* (Spreng) Nevski.
Geraniaceae	*Erodium ciconium* (L.) L.Her.	Poaceae	*Eremopyrum distans* (C.Koch) Nevski.
Geraniaceae	*Erodium cicutarium* (L.) L.Her.	Poaceae	*Poa annua* L.
Geraniaceae	*Erodium oxyrhinchum* subsp. bryoniifolium (Boiss.) Schönb.-Tem.	Poaceae	*Poa infirma* Kunth.
Geraniaceae	*Erodium glaucophyllum* (L.) Ait.	Poaceae	*Poa sinaica* Steud.
Geraniaceae	*Erodium laciniatum* (Cav.) Willd.	Poaceae	*Eremopoa persica* (Trin.) Rosch.
Malvaceae	*Malva nicaeensis* All.	Poaceae	*Lolium temulentum* L.
Malvaceae	*Malva parviflora* L.	Poaceae	*Lolium multiflorum* Lam.
Boraginaceae	*Arnebia Linearifolia* DC.	Poaceae	*Lolium rigidum* Gaudin.
Boraginaceae	*Arnebia tinctoria* Forssk	Poaceae	*Ammochloa palaestina* Boiss.
Boraginaceae	*Arnebia decumbens* Vent. Coss & Kral.	Poaceae	*Phalaris minor* r Retz.
Boraginaceae	*Echium rauwolfii* Delile.	Poaceae	*Phalaris paradoxa* L.
Boraginaceae	*Heliotropium kotschyi* (Bunge) Gurke.	Poaceae	*Parapholis incurve* (L.) C.E. Hubbard.

Boraginaceae	*Heliotropium lasiocarpum* Fisch. Ex C.A. Mey.	Poaceae	*polypogon monspeliensis* (L.) Desf.
Boraginaceae	*Heliotropium bacciferum* Forssk.	Poaceae	*Rostraria cristata* (L.) Tzvelev
Boraginaceae	*Ogastemma pusillum* (Coss. & Durand Ex Bonnet & Barratte) Brummitt.	Poaceae	*Rostraria pumila* (Desf) Tzvelev SYN.
Asteraceae	*Anthemis pseudocotula* Boiss.	Poaceae	*Sphenopus divaricatus* (Gouan) Reichb.
Asteraceae	*Anthemis melampodina* subsp. deserti (Boiss.) Eig	Poaceae	*Stipa capensis* Thunb.
Asteraceae	*Seriphidium herba-alba* (Asso) Soják	Poaceae	*Trisetaria linearis* Forssk.
Asteraceae	*Artemisia scoparia* Waldst. &. Kit.	Poaceae	*Brachypodium distachyum* (L.) P. Beauv.
Asteraceae	*Matricaria aurea* (Loefl.) Sch. Bip.	Poaceae	*Hordeum marinum* Huds.
Asteraceae	*Aaronsohnia factorovskyi* Warb. & Eig.	Poaceae	*Hordeum murinum* L.
Asteraceae	*Achillea fragrantissima* (Forssk.) Sch. Bip.	Poaceae	*Lasiurus scindicus* Henrard.
Asteraceae	*Anvillea garcinii* (Burm. F.) DC.	Poaceae	*Avena barbata* Pott Ex Link.
Asteraceae	*Aster squamatus* (Spreng.) Hieron	Poaceae	*Avena fatua* L.
Asteraceae	*Atractylis cancellata* L.	Poaceae	*Avena sativa* L.
Asteraceae	*Atractylis carduus* (Forssk.) C. Chr.	Poaceae	*Avena sterilis* L.

Asteraceae	*Calendula arvensis* L.	Poaceae	*Bromus catharticus* Vahl.
Asteraceae	*Calendula tripterocarpa* Rupr.	Poaceae	*Bromus sericeus* Drobov.
Asteraceae	*Carduus pycnocephalus* L.	Poaceae	*Bromus tectorum* L.
Asteraceae	*Carthamus oxyacantha*. M.Bieb.	Poaceae	*Bromus madritensis* L.
Asteraceae	*Glebionis coronaria* (L.) Cass. ex Spach	Poaceae	*Melinis repens* (Willd.) Zizkald.) C.E. Hubb
Asteraceae	*Picris babylonica* Hand. Mazz	Poaceae	*Panicum antidotale* Retz.
Asteraceae	*Pulicaria undulata* (L,) C.A. Mey	Poaceae	*Panicum turgidum* Forssk.
Asteraceae	*Reichardia tingitana* (L.) Roth.	Poaceae	*Imperata cylindrica* (L.) P.Beauv.
Asteraceae	*Rhanterium epapposum* Oliv.	Poaceae	*Pennisetum divisum* (Gmel.) Henrard.
Asteraceae	*Echinops acantholepis* Jaub. & Spach	Poaceae	*Cenchrus ciliaris* L.
Asteraceae	*Echinops polyceras* Boiss.	Poaceae	*Cenchrus setiger* Vahl.
Asteraceae	*Filago pyramidata* L.	Poaceae	*Setaria verticillata* (L.) P.Beauv.
Asteraceae	*Flaveria trinervia* (Spreng.) C. Mohr.	Poaceae	*Setaria viridis* (L.) P.Beauv
Asteraceae	*Ifloga spicata* (Forssk.) Sch. Bip	Poaceae	*Digitaria sanguinalis* (L.) scop.

Asteraceae	*Koelpinia linearis* Pall.	Poaceae	*Digitaria ciliaris* (Retz) Koeler.
Asteraceae	*Lactuca serriola* L.	Poaceae	*Cymbopogon commutatus* (Steud.) Stapf.
Asteraceae	*Leontodon laciniatus* (Bertol.) Widder	Poaceae	*Echinochloa colona* (L.) Link.
Asteraceae	*Erigeron bonariensis* L.	Poaceae	*Eragrostis minor* Host.
Asteraceae	*Pallenis hierochuntica* (Michon) Greuter	Poaceae	*Eragrostis barrelieri* Daveau.
Asteraceae	*Centaurea mesopotamica* Bornm. Beih.	Poaceae	*Leptochloa fusca* (L.) Kunth.
Asteraceae	*Centaurea bruguierana* (DC.) Hand. Mazz	Poaceae	*Dactyloctenium aegyptium* (L.) P.Beaur.
Asteraceae	*Gymnarrhena micrantha* Desf.	Poaceae	*Aeluropus littoralis* (Gouan) Parl.
Asteraceae	*Launaea angustifolia* (Desf.) Kuntze.Revis.	Poaceae	*Aeluropus lagopoides* (L.) Trin. ExThwaites
Asteraceae	*Launaea capitate* (Spreng.) Dandy.	Poaceae	*Dichanthium annulatum* (Forssk) Stapf.
Asteraceae	*Launaea nudicaulis* (L.) Hook.	Poaceae	*Dichanthium foveolatum* (Delile) Roberty.
Asteraceae	*Launaea mucronata*(Forssk.) Muschl.	Poaceae	Sorghum halepense (L.) Pers
Asteraceae	*Sonchus tenerrimus* L.	Poaceae	*Stipagrostis ciliate* (Desf) de Winter.
Asteraceae	*Sonchus oleraceus* L.	Poaceae	*Stipagrostis drarii* (T.) de Winter.

Asteraceae	*Scorzonera papposa* DC.	Poaceae	*Stipagrostis obtuse* (Delile) Nees.
Asteraceae	*Scorzonera tortuosissima* Boiss.	Poaceae	*Stipagrostis plumosa* (L.) Munro Ex T Anders.
Asteraceae	*Senecio vulgaris* L.	Poaceae	*Phragmites australis*(Cav) Trin. Ex Steud.
Asteraceae	*Senecio glaucus* L. coronnopifolius	Poaceae	*Schismus arabicus* Nees.
Asteraceae	*Urospermum picroides* L.	Poaceae	*Schismus barbatus* (L.) Thell.
Asteraceae	*Xanthium strumarium* L.	Poaceae	*Cynodon dactylon* (L.) Pers.
Amaranthaceae	*Agathophora alopecuroides* (Delile)Fenzl Ex Bunge.	Poaceae	*Dinebra retroflexa* (Vahl) Panzer.
Amaranthaceae	*Atriplex dimorphostegia* Kar. & Kir.	Plantaginaceae	*Plantago notata* Lag.
Amaranthaceae	*Atriplex leucoclada* Boiss.	Plantaginaceae	*Plantago ovata* Forssk.
Amaranthaceae	Beta vulgaris L.	Plantaginaceae	*Plantago amplexicaulis* Cav.
Amaranthaceae	*Chenopodium album* L.	Plantaginaceae	*Plantago boissieri* Hausskn. & Bornm.
Amaranthaceae	*Chenopodium glaucum* L.	Plantaginaceae	*Plantago ciliate* Desf.
Amaranthaceae	*Chenopodium opulifolium* Schard. Ex Koch & Ziz.	Plantaginaceae	*Plantago psammophila* Angew &chal. Kabi
Amaranthaceae	*Chenopodium murale* L.	Plantaginaceae	*Plantago coronopus* L.

Amaranthaceae	*Halothamnus iraqensis* Botsch	Plantaginaceae	*Plantago lanceolata* L.
Amaranthaceae	*Salicornia europaea* L.	Cistaceae	*Helianthemum Kahiricum* Delile
Amaranthaceae	*Salsola jordanicola* Eig. Pal.	Cistaceae	*Helianthemum ledifolium* (L.) Mill.
Amaranthaceae	*Salsola imbricate* Forssk.	Cistaceae	*Helianthemum lippii* (L.) Dum. Cours.
Amaranthaceae	*Salsola cyclophylla* Baker, Bull.	Cistaceae	*Helianthemum salicifolium* (L.) Mill.

Appendix 4.2: Characters and character states for priority species A-Family level, B- Genera level, C-species level

A- characters and character states for priority species – family level		
Part	**Features**	**States**
Plant	1. Plant environment	A, terrestrial; B, aquatic
	2. Plant habitat	A, herb; B, shrub; C, tree
	3. Living parasitic or not	A, parasitic; B, non-parasitic
	4. Plant leaves and stem availability	A, without leaves or stems; B, with leaves and stems
	5. Plant texture	A, succulent (fleshy leaves or/ and stem); B, not succulent
	6. Indumentum (both in stem and/ or leaves)	A, with stinging hairs; B, without stinging hair
	7. Plant secretion	A, with white latex; B, without latex
Leaves	9. Phyllotaxy	A, alternate; B, opposite; C, whorl; D, decussate; E, clustered in axils; F, rosette
	10. Plant grass appearance	A, grass-like; B, not grass like
	11. Leaf apex	A, Acute; B, obtuse; C, tapering; D, truncate
	21. Stipule availability	A, absent; B, present
	12. Leaf base connate or not	A, connate; B, not connate
	13. Leaves sheathing	A, sheath; E, not sheathing
	14. Ligule availability	A, with ligule; B, ligule absent
Stem	15. Stem nodes, and leaf base	A, not swollen; B swollen
Inflorescences	16. Inflorescences type	A, raceme- elongated axis bears stalked flowers; B, spike- sessile or unstalked flowers; C, catkin- long pendulous axis; D, corymb- stalked flowers pears almost the same level; E, umbel- flowers arise from one point bears same level; F, capitulum- flattened or convex structure main axis; G, spadix- spike with fleshy axis; H, Panicle; I, cyme; J, cone; K, cyathium- cup shape structure formed by the involucre
	17. Inflorescences function	A, unisexual; B, bisexual

Flower	18. Flower symmetry		A, zygomorphic B, actinomorphic
	19. Flower or spikelet in paired or not		A, paired; B, solitary
	Flower base	20. Base type	A, bracts; B, Glumes
		21. Bracts or involucre Shape	A, cup- shape; B, spathulate like bracts; C, campanulate
	Sepal	22. Sepal count	Range 1,2, 3, 4, 5; > 6
		23. Sepal Length	A, unequal; B, equal length
		24. Sepal connection	A, free; B, fused or connate
		25. Sepal rib	A, ribbed; B, not ribbed
	Petal	26. Petal availability	A, apetalous; B, petaloid
		27. Petal count	Range from 0, 1, 2, 3, 4, 5, 6, 7, 8
		28. Petal Size	A fugacious; B, not fugacious
		29. Petal length	A, unequal; B, equal
		30. Petal connection	A, free, polypetalous; B, united, gamopetalous
		31. Petals Shape	A, tubular; B, campanulate-bell shape; C, funnel form
		32. Petal limp feature	A, lipped; B, lobed
	Stamens	33. Stamens count	A 1,2,3,4,5-6 and 7-10
		34. Stamens quantity	A, numerous; B, few
		35. Stamens length	A, not equal length; B, equal in length
	36. Ovary Position		A, Inferior; B, superior; C, half inferior
	37. Ovules Quantity		A, many ovules; B, 1 ovule
	38. Carpel connection		A, not fused (separate); B, fused (united)
	39. Carpels quantity and count		A, 1-2; B, 2 to many-carpel; C, 3-4; D, 5-6
	40. Style count		Range from 0, 1,2, 3, 4, 5
	41. Style attachment		1- A, united; B, separate styles
	42. Stigma count		Range from 1, 2, 3, 4, 5
Fruit	43. Type		A, achene; B, fruit various; C, legume; D, capsule; E, siliquae
	44. Fruit dehiscence		A, dehiscent; B, indehiscent; C, dehiscent when moist

	45. Capsule lobes or celled	A, 1- celled; B, 3-celled capsule, C, 4- celled
	46. fruit splitting	A, into 2 mericarps; B, not splitting into 2 mericarps
	47. Fruiting perianth segments	A, 5 segments; B, 6 segments
	48. Perianth segments shape	A, linear to lanceolate; B, not linear to lanceolate
	49. Perianth colour	A, blue, white or pink; B, not blue, white or pink
	50. Fruiting perianth Induration	A, indurated to fruit; B, Perianth absent

B- characters and character states for priority genera – list with one genera of family using previous family list. The mentioned taxa are an **example** of feature state used, list was developed in the key according to specimen used

Part	Features	States
	1. Duration	A, annual; B, perennial; C, biennial
	2. Plant hair shape	A, papillose; B, pubescent; C, tubercular hairs; D, stellate- star shape.
	3. Thorn availability	A, with thorn; B, without thorn.
Leaves	4. Leaves development	A, reduced to scale; B, well developed.
	5. Leaf Shape	A, oblong; B, elliptic; C, linear; D, ovate; E, oblanceolate; F, triangular; G, deltoid- ovate; H, lanceolate; I, obovate- spathulate; J, orbicular; K, filiform.
	6. Leaf apex	A, acute; B, obtuse; C, tapering; D, truncate; E, retuse.
	7. Blade margin	A, entire; B, lobed; C, dentate-teethed; D ciliate; E, undulate.
	8. leaf blade margin features	A, crateriform glands; B, papillose hispid; C, tapering.
	9. Ligule margin	A, line of hairs; B, membranous
Inflorescences	10. compact head a structure shape	A, radiate; B, ellipsoid; C, oblong; D, ovoid; E, cylindrical; F, discoid; G, conical; H, ovate; I, lanceolate; J, orbicular; K, scorpioid

Flower	11. Flower or Spikelet's pedicel			A, sessile; B pedicelled.
	12. Flower or spikelet in paired or not			A, paired; B, not in pair (solitary).
	Spikelet's	13. Spikelet's disarticulation		A, persistent; B, as a unit; C, separately.
		14. Spikelet's separate disarticulation position		A, below each floret; between all florets.
		15. Spikelet's cover		A, with hair; B, without hair; C, ciliate
		16. Spikelet long		A, up to 25; B, 26-35; B, 36- 40; C, 41-50mm.
	Bracts- involucre-receptacle	17. Phyllaries series		A, 1-6 series; B, 7-12 or more.
		18. Phyllaries (bracts)-glumes- lemma texture		A, rough- rigid; B, nerved; C, membranous; D, glossy-shiny; E, chartaceous-thin, dry, papery; F, herbaceous.
		19. Bracts or involucre Shape		A, cup- shape; B, spathulate like bracts; C, campanulate.
		20. Bracts -Glumes-lemma leaf shape		A, linear; B, oblong; C, ovate; D, elliptic; E, obovate; F, lanceolate; G, oblique; H, cylindrical; I, orbicular
		21. Receptacle surface		A, coriaceous-leathery; B, glabrous, or without scale like ridges; C, pubescent; D, hairy; E, spiny; F, with scale like ridges
		22. Receptacle shape		A, flat; B, convex; C, epaleate
	Glumes and Lemma	Glumes – lemma texture		A, rough- rigid; B, nerved; C membranous; D, glossy, shiny; E, chartaceous- thin dry, papery; F, herbaceous
		Glumes-lemma leaf shape		A, linear; B, oblong; C, ovate; D, elliptic; E, obovate; F, lanceolate; G, oblique; H, cylindrical; I, orbicular
		Upper Glume	Shape	A, ovate; B, elliptic; C, lanceolate; D, oblong; E, obtuse; F, linear; G, orbicular
			Features	A, Pubescent; B, hairy; C, membranous; D, hyaline; E, gibbous; F, chartaceous; G, coriaceous; H, shorter.
			Keels	A, with keels; B, without keels.
			Glumes veins	A, 0; B, 1; C, 2; D, 3; E,4; F, 5; G, 6; H, 7; I, 8; J, 9; K, 10' L, 11
		Lower Glume	Shape	A, ovate; B, elliptic; C, lanceolate; D, oblong; E, obtuse; F, linear; G, orbicular

			Features	A, Pubescent; B, hairy; C, membranous; D, hyaline; E, gibbous; F, chartaceous; G, coriaceous; H, shorter.
			Keels	A, with keels; B, without keels.
			Glumes veins	A, 0; B, 1; C, 2; D, 3; E,4; F, 5; G, 6; H, 7; I, 8; J, 9; K, 10' L, 11
		Lemma nerve count	A, 1; B, 3; C, 5; D, 7-13; E, 9-11.	
		Lemma apex	A, awned; B, awn less.	
		Awn counts	A, 1; B, 2; C,3	
	22. Petals or tepals Shape		A, tubular; B, campanulate-bell shape; C, funnel form.	
	23. Stamens connection		A, free; B, epipetalous attach to petals	
	24. Style attachment		A, united; B, separate styles.	
	25. Stigma count		A, 1; B, 2; C, 3; D, 4; E, 5	
Fruit	26. Fruit Shape		A, ovoid; B, oblong; C, ovate; D, linear; E, lanceolate; F, globose; G, triangle lens shape; H, star-like; I, ellipsoid	
	27. Fruit external features		A, depressed-flattened at apex; B, compressed; C, horned; D, beaked; E, angled; F, Septicidal.	
	28. Perianth features		A, accrescent inclosing the fruit; B, not hardened; C, developing wing in fruit; D, urceolate; E, flattened apically in fruit.	

C- characters and character states for species level

Part	Features	States
Plant	Plant hair shape	A, papillose; B, pubescent; C, tubercular hairs; F, stellate- star shape
Leaves	Leaf apex	A, Acute; B, obtuse; C, tapering.
	Blade margin	A, entire; B, lobed; C, dentate-teethed; D ciliate; E, undulate.
	Raceme or spikelet's shape	A, elliptic; B, ovoid; C, cylindrical; D, oblong; E, ovate; F, lanceolate; G, orbicular

Flower	Spikelet's separate disarticulation position	A, below each floret; B, between all florets.
	Spikelet's disarticulation	A, persistent; B, as a unit; C, separately.
	Petal or tepal colour	A, blue; B, pink; C, red; D, white; E, yellow; F, pale violet; G, green; H, purple.
	Glumes size	A, equal; B, unequal.
	Glumes -lemma shape	A, linear; B, oblong; C, ovate; D, elliptic; E, obovate; F, lanceolate; G, oblique
Fruit	Fruit beak length	A, 25-34 cm long; B, 35-45 cm long; C, 46- 55 cm long; D, 56-90 cm long.

Appendix 5.1: Red List Assessment of Prioritised Kuwaiti Species The A- Global And B- National Threat Assessment.

A- Global Red List of the native priority taxa Kuwait.

Genus species	Status	Growth form	Global
1. *Acacia pachyceras* O. Schwartz var. najdensis (Chaudhary) Boulos Syn. Acacia gerrardii.	N	P	VU
2. *Aegilops bicornis* (Forssk.) Jaub. & Spach.	N	A	NT
3. *Centaurea mesopotamica* Bornm. Beih.	N	P	NT
4. *Stipagrostis drarii* (Täckh.) De Winter	N	P	NT
5. *Acacia nilotica* (L.) Delile	N	P	LC
6. *Aegilops kotschyi* Boiss.	N	A	LC
7. *Aegilops triuncialis* L.	N	A	LC
8. *Aeluropus littoralis* (Gouan) Parl.	N	P	LC
9. *Agathophora alopecuroides* (Delile)Fenzl Ex Bunge.	N	P	LC
10. *Aizoanthemum hispanicum* (L.) Klak	N	A	LC
11. *Alhagi maurorum* Medik	N	P	LC
12. *Allium sphaerocephalon* L.	N	P	LC
13. *Ammochloa palaestina* Boiss.	N	A	LC
14. *Andrachne telephioides* L.	N	P	LC
15. *Anthemis pseudocotula* Boiss.	NW	A	LC
16. *Arnebia tinctoria* Forssk	N	A	LC
17. *Arnebia linearifolia* DC.	N	A	LC
18. *Artemisia scoparia* Waldst. &. Kit.	N	A	LC
19. *Atriplex dimorphostegia* Kar. & Kir.	N	A	LC
20. *Avena barbata* Pott Ex Link.	W	A	LC
21. *Avena fatua* L.	W	A	LC
22. *Avena sativa* L.	W	A	LC

23. *Avena sterilis* L.	W	A	LC
24. *Beta vulgaris* L.	W	A	LC
25. *Bromus catharticus* Vahl	W	A	LC
26. *Bromus moeszii* Pénzes	W	A	LC
27. *Bromus tectorum* L.	N	A	LC
28. *Caroxylon jordanicola* (Eig) Akhani & Roalson	N	P	LC
29. *Cenchrus ciliaris* L.	W	A	LC
30. *Chenopodium album* L.	W	A	LC
31. *Chenopodium glaucum* L.	W	A	LC
32. *Chenopodium opulifolium* L.	W	A	LC
33. *Chrozophora tinctoria* L. A. Juss.	N	A	LC
34. *Convolvulus arvensis* L.	W	P	LC
35. *Crassula alata* (Viv.) A. Berger	N	A	LC
36. *Cuprella homalocarpa* (Fisch. & C.AMey.) Salmerón-Sánchez, Mota & Fuertes	N	A	LC
37. *Cuscuta planiflora* Ten.	N	P/P	LC
38. *Cynomorium coccineum* L.	N	P/P	LC
39. *Dactyloctenium aegyptium* (L.) Willd.	W	A	LC
40. *Datura innoxia* Mill.	W	P	LC
41. *Dichanthium annulatum* (Forssk.) Stapf	NW	P	LC
42. *Digitaria sanguinalis* (L.) scop.	W	A	LC
43. *Diplotaxis acris* (Forssk) Boiss.	N	A	LC
44. *Diplotaxis harra* (Forssk) Boiss.	N	A	LC
45. *Ducrosia anethifolia* (DC.) Boiss.	N	A	LC
46. *Echinochloa colona* (L.) Link.	W	A	LC
47. *Echium rauwolfii* Delile.	N	A	LC
48. *Ephedra alata* Decne.	N	P	LC

49. *Eragrostis minor* Host.	NW	A	LC
50. *Eremopoa persica* (Trin.) Roschev.	N	A	LC
51. *Eremopyrum bonaepartis* (Spreng.) Nevski	N	A	LC
52. *Eremopyrum distans* (K.Koch) Nevski	N	A	LC
53. *Erigeron bonariensis* L.	W	A	LC
54. *Erodium cicutarium* (L.) L.Her.	N	A	LC
55. *Erodium ciconium* (L.) L.Her.	N	A	LC
56. *Euphorbia densa* Schrenk.	N	A	LC
57. *Euphorbia hirta* L.	W	A	LC
58. *Euphorbia peplus* L.	W	A	LC
59. *Euphorbia serpens* Kunth.	N	A	LC
60. *Farsetia aegyptia* Turra.	N	P	LC
61. *Gladiolus italicus* L.	NW	A	LC
62. *Gymnarrhena micrantha* Desf.	N	A	LC
63. *Halodule uninervis* (Forssk.) Boiss.	N	P	LC
64. *Halothamnus iraqensis* Botsch	N	P	LC
65. *Helianthemum kahiricum* Delile.	N	P	LC
66. *Heliotropium kotschyi* (Bunge) Gurke.	N	P	LC
67. *Horwoodia dicksoniae* Turril.	N	A	LC
68. *Hyoscyamus pusillus* L.	N	A	LC
69. *Ixiolirion tataricum* (Pall.) Schult. & Schult.f.	N	P	LC
70. *Juncus rigidus* Desf	N	P	LC
71. *Launaea angustifolia* (Desf.) Kuntze.Revis.	N	A	LC
72. *Launaea nudicaulis* (L.) Hook.	N	A	LC
73. *Launaea capitate* (Spreng.) Dandy.	N	A	LC
74. *Lepidium sativum* L.	C	A	LC
75. *Leptaleum filifolium* (Willd.) D.C.	N	A	LC

76. *Leptochloa fusca* (L.) Kunth.	W	P	LC
77. *Lolium temulentum* L.	W	A	LC
78. *Malcolmia pygmaea* (Delile) Boiss. Syn. and Hesperis pygmaea Delile	N	A	LC
79. *Malva nicaeensis* All.	W	A	LC
80. *Matricaria aurea* (Loefl.) Sch. Bip.	W	A	LC
81. *Meniocus linifolium* (Stephan ex Willd.) DC.	N	A	LC
82. *Notoceras bicorne* (Aiton) Amo.	N	A	LC
83. *Ogastemma pusillum* (Coss. & Durand Ex Bonnet & Barratte) Brummitt.	N	A	LC
84. *Oligomeris linifolia* (Vahl ex Hornem.) J.F.Macbr.	N	A	LC
85. *Ononis reclinata* L.	N	A	LC
86. *Orobanche minor* Sm.	W	A/P	LC
87. *Orobanche ramosa* L.	W	A/P	LC
88. *Pallenis hierochuntica* (Michon) Greute	N	A	LC
89. *Plantago notata* Lag.	N	A	LC
90. *Portulaca oleracea* L.	W	A	LC
91. *Psylliostachys spicatus* (Willd.) Nevski	N	A	LC
92. *Reseda decursiva* Forssk.	N	A	LC
93. *Salicornia europaea* L.	N	A	LC
94. *Scorzonera tortuosissima* Boiss.	N	P	LC
95. *Scorzonera papposa* DC.	N	P	LC
96. *Senecio vulgaris* L.	W	A	LC
97. *Seriphidium herba-alba* (Asso) Soják	N	A	LC
98. *Setaria verticillata* (L.) P.Beauv	W	A	LC
99. *Silene conoidea* L.	W	A	LC
100. *Sonchus tenerrimus* L.	W	A	LC
101. *Sorghum halepense* (L.) Pers	W	P	LC
102. *Stellaria media* (L.) Vill.	W	A	LC

103. *Stipagrostis ciliate* (Desf.) De Winter	N	P	LC
104. *Stipagrostis obtuse* (Delile) Nees	N	P	LC
105. Strigosellla grandiflora Botsch.	N	A	LC
106. Suaeda vermiculata Forssk. Ex J.F.Gmel. Syn.	N	P	LC
107. Traganum nudatum Delile.	N	A	LC
108. Typha domingensis Pers.	N	P	LC
109. Urospermum picroides L.	W	A	LC
110. Urtica urens L.	W	A	LC
111. Vachellia farnesiana (L.) Willd	C	P	LC
112. Valerianella dufresnia Bunge Ex Boiss.	N	A	LC
113. Vicia sativa L.	C	A	LC
114. Xanthium strumarium L.	W	A	LC
115. Zilla spinosa (L.) Prantl.	N	P	LC
116. *Gypsophila Vaccaria* (L.) Sm.	W	A	DD
117. Limonium carnosum (Boiss.) Kuntze.	N	P	DD
118. Withania somnifera (L.) Dunal.	W	A	DD

Plant status: N- native, NW- native weed, W- weeds, C- cultivated plants/ P- Perennial, A- Annual.

B- National Red List of the Native Priority Taxa Kuwait.

Genus species	Growth form	Threat category	Criteria Score
Acacia pachyceras O. Schwartz var. najdensis (Chaudhary) Boulos Syn. Acacia gerrardii.	P	CR	24
Centaurea mesopotamica Bornm. Beih.	P	CR	25
Cynomorium coccineum L.	P/P	EN	23
Allium sphaerocephalon L.	P	VU	21
Anthemis pseudocotula Boiss	P	VU	27
Crassula alata (Viv.) A. Berger	A	VU	25
Cuprella homalocarpa (Fisch. & C.AMey.) Salmerón-Sánchez, Mota & Fuertes	A	VU	23
Echium rauwolfii Delile.	A	VU	23
Eremopyrum distans (K.Koch) Nevski	A	VU	25
Heliotropium kotschyi (Bunge) Gurke.	P	VU	27
Launaea angustifolia (Desf.) Kuntze.Revis.	A	VU	23
Malcolmia pygmaea (Delile) Boiss. Syn. and Hesperis pygmaea Delile	A	VU	23
Scorzonera tortuosissima Boiss.	P	VU	23
Stipagrostis drarii (Täckh.) De Winter	P	VU	24
Stipagrostis obtuse (Delile) Nees	P	VU	23
Traganum nudatum Delile.	A	VU	25
Valerianella dufresnia Bunge Ex Boiss.	A	VU	23
Aegilops bicornis (Forssk.) Jaub. & Spach.	A	NT	26
Aeluropus littoralis L.	P	NT	25
Ducrosia anethifolia (DC.) Boiss.	A	NT	23
Ephedra alata Decne.	P	NT	23
Eremopyrum bonaepartis (Spreng.) Nevski	A	NT	25
Dichanthium annulatum (Forssk).	A	NT	27
Stipagrostis ciliate (Desf.) De Winter	P	NT	25
Typha domingensis Pers.	P	NT	23
Eragrostis minor Host	A	NT	25
Aegilops kotschyi Boiss.	A	LC	23
Horwoodia dicksoniae Turril.	A	LC	22
Aegilops triuncialis L.	A	LC	23
Aizoanthemum hispanicum (L.) Klak	A	LC	23
Alhagi maurorum Medik	P	LC	25

Andrachne telephioides L.	P	LC	23
Arnebia linearifolia DC.	A	LC	23
Arnebia tinctoria Forssk	A	LC	25
Artemisia scoparia Waldst. &. Kit.	A	LC	21
Bromus tectorum L.	A	LC	21
Caroxylon jordanicola (Eig) Akhani & Roalson	P	LC	23
Chrozophora tinctoria L. A. Juss.	A	LC	25
Cuscuta planiflora (Viv.) A. Berger	P/P	LC	21
Diplotaxis acris (Forssk) Boiss.	A	LC	21
Diplotaxis harra (Forssk) Boiss.	A	LC	21
Erodium ciconium (L.) L.Her.	A	LC	21
Erodium cicutarium (L.) L.Her.	A	LC	21
Euphorbia serpens Kunth.	A	LC	23
Farsetia aegyptia Turra.	P	LC	23
Gladiolus italicus Mill.	A	LC	22
Gymnarrhena micrantha Desf.	A	LC	23
Halothamnus iraqensis Botsch	P	LC	23
Helianthemum kahiricum Delile.	P	LC	21
Launaea capitate (Spreng.) Dandy.	A	LC	25
Launaea nudicaulis (L.) Hook.	A	LC	21
Oligomeris linifolia (Vahl ex Hornem.) J.F.Macbr.	A	LC	25
Ononis reclinata L.	A	LC	23
Pallenis hierochuntica (Michon) Greute	A	LC	21
Salicornia europaea L.	A	LC	21
Strigosellla grandiflora Botsch.	A	LC	23
Suaeda vermiculata Forssk. Ex J.F. Gmel. Syn.	P	LC	21
Acacia nilotica (L.) Delile	P	DD	26
Ammochloa palaestina Boiss.	A	DD	27
Atriplex dimorphostegia Kar. & Kir.	A	DD	27
Eremopoa persica (Trin.) Roschev.	A	DD	27
Euphorbia densa Schrenk.	A	DD	25
Hyoscyamus pusillus L.	A	DD	25
Ixiolirion tataricum (Pall.) Schult. & Schult.f.	P	DD	25
Leptaleum filifolium (Willd.) D.C.	A	DD	23
Limonium carnosum (Boiss.) Kuntze.	P	DD	21

Meniocus linifolius (Stephan ex Willd.) DC.	A	DD	25
Notoceras bicorne (Aiton) Amo.	A	DD	25
Ogastemma pusillum (Coss. & Durand Ex Bonnet & Barratte) Brummitt.	A	DD	24
Plantago notata Lag.	A	DD	27
Psylliostachys spicatus (Willd.) Nevski	A	DD	25
Scorzonera papposa DC.	P	DD	23
Seriphidium Herba-alba (Asso) Soják	A	DD	23
Zilla spinosa (L.) Prantl.	P	DD	21

Appendix 6.1.A Schedule Visit Cover the Following Locations.

location	Mohema / site	Dec-longitude	Dec-latitude	elevation
Al-Ritqa area	RC	30.05	47.48333333	54
	RB	30.08333333	47.46666667	65
	RA	30.1	47.46666667	65
Shagaya area	SC	29.15	46.7	270
	SC	29.15	46.68333333	270
	SB	29.16666667	46.66666667	233
	SA	29.18333333	46.65	202
AL-Taawon.	*SA1	29.26666667	46.71666667	184
Al-Shaheed German.	*SA2	29.08333333	46.6	254
Khabari Al Awazim.	KC	29.31666667	47.65	NA
	KB	29.83333333	47.08333333	NA
	KA	29.83333333	47.08333333	NA
	*KA1	29.81666667	47.05	NA
Um-Nigga/ Al-Bohaith	BA1	30.08333333	47.71666667	NA

Appendix 6.1.B. Part of the site visit photos.



Pl c vegetation and annual species in and Al-Abraq area. D- shows the new growth of *Zilla spinose* species in Al Abraq area (Nassep, 2017).

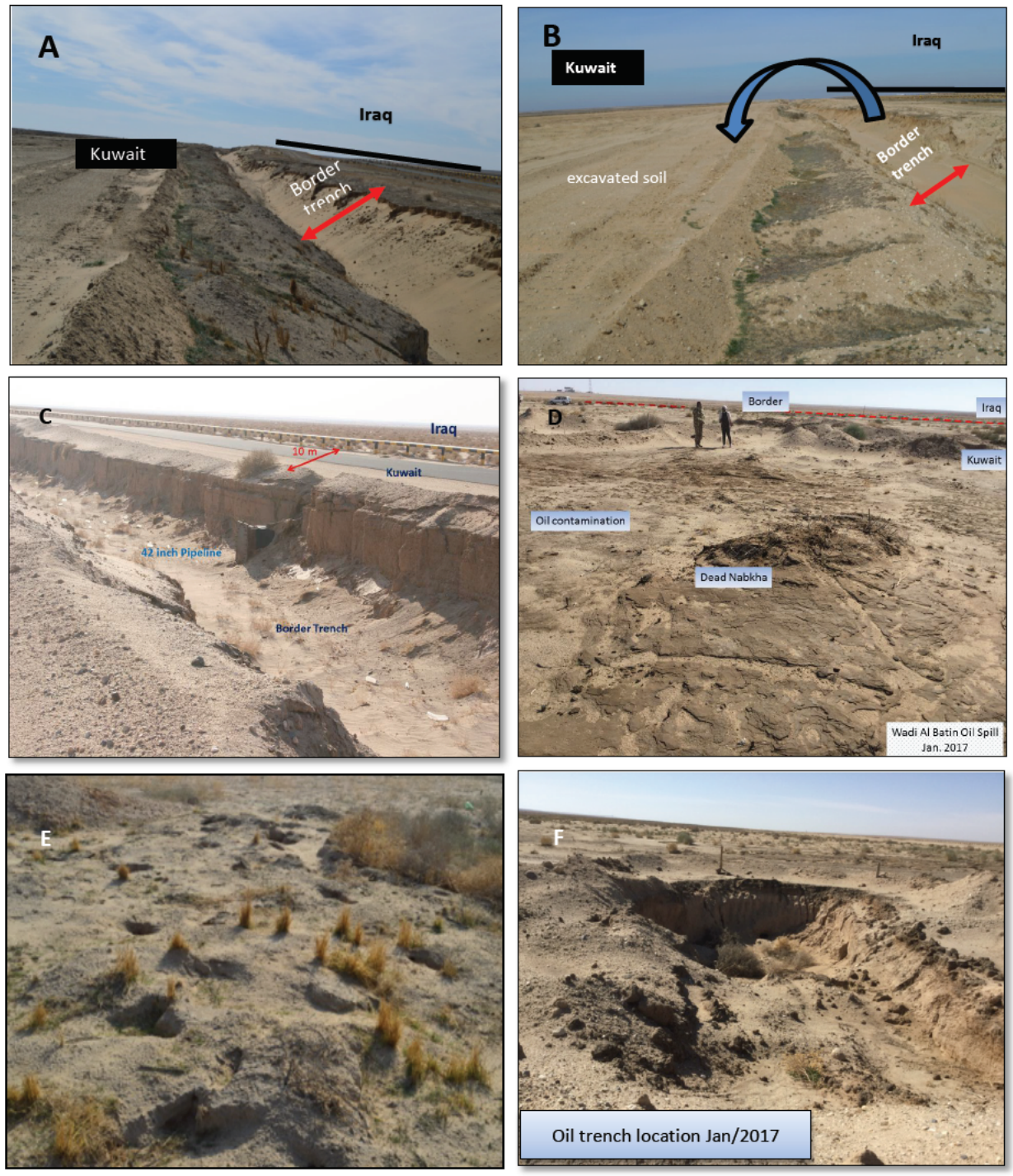


Plate 2: Field photograph shows A- The sediment filling the border trench in Khabari Al-Awazem area. B- The soil from the border trench and covering of vegetation in Khabari Al-Awazem area. C- Field photo showing the border trench and the 42inch pipeline which supplied the oil trenches with crude oil, D- The heavy oil contamination at Wadi Al Batin. E- The destroyed Nabkha in the oil contaminated area. F- One of the oil trench after removing of crude oil (Nassep, Jan. 2017).

Appendix 6.2.1. Reporting Progress at Protected Area Sites: Data Sheet 1.

Name, affiliation and contact details for person responsible for completing the METT (email etc.)				
Date assessment carried out				Mouza Nassep
Name of the protected area				Demilitarised Zone Natural Reserve in Kuwait
WDPA site code (these codes can be found on www.unep-wcmc.org/wdpa/)				555547333
Designation	• National	IUCN Category (IV)	International (please also complete sheet overleaf)	
Country	State of Kuwait			
Location of protected area	The border strip between the State of Kuwait and the Republic of Iraq, from Al-Salmi in the south-west of Kuwait to Bohaith in the north-east/ KW- JA			
Date of establishment	Protected since April 1991 Designated 2011			
Ownership details	• State	Private	Community	Other
Management authority	Environmental Public Authority and Ministry of Interior			
Size of the protected area	1008.22 Km2			
Number of staffs	Permanent/ Ministry of Interior- General Department of Border Guard		Temporary/ suggested according to project needed.	
Annual budget	Recurrent (not discussed)		Project or other supplementary funds	
What are the main values for which the area is designated	-The site associated with the Wadi Al Batin area. -Buffering zone for the adjacent protected areas, the reserves of Wadi Al-Batin, Al-Huwaimliyah protected area, Al- Jdailiah, and Umm Niqqa natural reserve. -Wadi Al Batin area consider being the main responsible for the transfer of many types of igneous rocks fragments and sediment to Iraq and Kuwait (Dibdiba Formation).			
List the two primary protected area management objectives				
management objectives 1	maintaining the necessary ecological operations			
management objectives 2	maintaining the ecosystems and biological and genetic diversity and rational use of the ecosystem.			
No. of people involved in completing assessment	Mouza Nassep, Prof. Raafat Misak, Ministry of Interior staff.			
Including	○ PA manger	○ **PA staff**	○ Other PA agency staff	○ NGO
	○ Local community	○ Donors	○ **External expert**	○ other

Appendix 6.2.2: Protected Areas Threats: Data Sheet 2

Ranked as of **high** significance for those which are seriously degrading values; **medium** are those threats having some negative impact and those characterised as **low** are threats which are present but not seriously impacting values or **N/A** where the threat is not present or not applicable in the protected area.

1. Residential and commercial development within a protected area: Threats from human settlements or other non-agricultural land uses with a substantial footprint					**1**	**2**	**3**
High	Medium	Low	N/A				
		*		1.1 Housing and settlement	Low	Low	Low
			*	1.2 Commercial and industrial areas	N/A	N/A	N/A
			*	1.3 Tourism and recreation infrastructure	N/A	N/A	N/A
2. Agriculture and aquaculture within a protected area: Threats from farming and grazing as a result of agricultural expansion and intensification, including silviculture, maricultural and aquaculture							
			*	2.1 Annual and perennial non-timber crop cultivation	N/A	N/A	N/A
			*	2.1a Drug cultivation	N/A	N/A	N/A
			*	2.2 Wood and pulp plantations	N/A	N/A	N/A
	*			2.3 Livestock farming and grazing	Medium	Medium	Low
			*	2.4 Marine and freshwater aquaculture	N/A	N/A	NA
3. Energy production and mining within a protected area: Threats from production of non-biological resources							
		*		3.1 Oil and gas drilling	Low	Low	Low
			*	3.2 Mining and quarrying	N/A	N/A	N/A
			*	3.3 Energy generation, including from hydropower dams	N/A	N/A	N/A
4. Transportation and service corridors within a protected area: Threats from long narrow transport corridors and the vehicles that use them including associated wildlife mortality							
			*	4.1 Roads and railroads (include road-killed animals)	N/A	N/A	N/A
		*		4.2 Utility and service lines (e.g. electricity cables, telephone lines,)	Low	N/A	Low
			*	4.3 Shipping lanes and canals	N/A	N/A	N/A
			*	4.4 Flight paths	N/A	N/A	N/A
5. Biological resource use and harm within a protected area: Threats from consumptive use of "wild" biological resources including both deliberate and unintentional harvesting effects; also, persecution or control of specific species (note this includes hunting and killing of animals)							
High	Medium	Low	N/A				
			*	5.1 Hunting, killing and collecting terrestrial animals (including killing of animals as a result of human/wildlife conflict)	N/A	N/A	N/A
			*	5.2 Gathering terrestrial plants or plant products (non-timber)	N/A	N/A	N/A
			*	5.3 Logging and wood harvesting	N/A	N/A	N/A

			*	5.4 Fishing, killing and harvesting aquatic resources	N/A	N/A	N/A
6. Human intrusions and disturbance within a protected area: Threats from human activities that alter, destroy or disturb habitats and species associated with non- consumptive uses of biological resources							
			*	6.1 Recreational activities and tourism	N/A	N/A	N/A
		*		6.2 War, civil unrest and military exercises	N/A	Low	LOW
*				6.3 Research, education and other work-related activities in protected areas	High	HIGH	High
		*		6.4 Activities of protected area managers (e.g. construction or vehicle use, artificial watering points and dams)	Low	Low	Low
			*	6.5 Deliberate vandalism, destructive activities or threats to protected area staff and visitors	N/A	N/A	N/A
7. Natural system modifications: Threats from other actions that convert or degrade habitat or change the way the ecosystem functions							
			*	7.1 Fire and fire suppression (including arson)	N/A	N/A	N/A
		*		7.2 Dams, hydrological modification and water management/use	Low	Low	Low
		*		7.3a Increased fragmentation within protected area	Medium	Low	Low
		*		7.3b Isolation from other natural habitat (e.g. deforestation, dams without effective aquatic wildlife passages)	N/A	N/A	Low
			*	7.3c Other 'edge effects' on park values	N/A	N/A	N/A
			*	7.3d Loss of keystone species (e.g. top predators, pollinators etc)	N/A	N/A	N/A
8. Invasive and other problematic species and genes: Threats from terrestrial and aquatic non-native and native plants, animals, pathogens/microbes or genetic materials that have or are predicted to have harmful effects on biodiversity following introduction, spread and/or increase							
High	Medium	Low	N/A				
			*	8.1 Invasive non-native/alien plants (weeds)	N/A	N/A	N/A
			*	8.1a Invasive non-native/alien animals	N/A	N/A	N/A
			*	8.1b Pathogens (non-native or native but creating new/increased problems)	N/A	N/A	N/A
		*		8.2 Introduced genetic material (e.g. genetically modified organisms)	Low	N/A	N/A
9. Pollution entering or generated within protected area: Threats from introduction of exotic and/or excess materials or energy from point and non-point sources.							
			*	9.1 Household sewage and urban waste water	N/A	N/A	N/A
		*		9.1a Sewage and waste water from protected area facilities (e.g. toilets, hotels etc)	Low	Low	Low
			*	9.2 Industrial, mining and military effluents and discharges (e.g. poor water quality discharge from dams, e.g. unnatural temperatures, de-oxygenated, other pollution)	N/A	N/A	N/A
			*	9.3 Agricultural and forestry effluents (e.g. excess fertilizers or pesticides)	N/A	N/A	N/A
			*	9.4 Garbage and solid waste	N/A	N/A	N/A

			*	9.5 Air-borne pollutants	N/A	N/A	N/A
			*	9.6 Excess energy (e.g. heat pollution, lights etc)	N/A	N/A	N/A
10. Geological events: Geological events may be part of natural disturbance regimes in many ecosystems. But they can be a threat if a species or habitat is damaged and has lost its resilience and is vulnerable to disturbance. Management capacity to respond to some of these changes may be limited.							
			*	10.1 Volcanoes	N/A	N/A	N/A
			*	10.2 Earthquakes/Tsunamis	N/A	N/A	N/A
			*	10.3 Avalanches/ Landslides	N/A	N/A	N/A
			*	10.4 Erosion and siltation/ deposition (e.g. shoreline or riverbed changes)	N/A	N/A	N/A
11. Climate change and severe weather: Threats from long-term climatic changes which may be linked to global warming and other severe climatic/weather events outside of the natural range of variation							
			*	11.1 Habitat shifting and alteration	N/A	N/A	N/A
		*		11.2 Droughts	Low	Low	Low
		*		11.3 Temperature extremes	Low	Low	Medium
	*			11.4 Storms and flooding	Medium	Medium	Medium
12. Specific cultural and social threats							
High	Medium	Low	N/A				
		*		12.1 Loss of cultural links, traditional knowledge and/or management practices	N/A	N/A	Low
			*	12.2 Natural deterioration of important cultural site values	N/A	N/A	N/A
			*	12.3 Destruction of cultural heritage buildings, gardens, sites etc	N/A	N/A	N/A

1- **Dr. Amr Abdelzi / Biodiversity of Terrestrial Ecosystem -KISR**

2- **Dr. Rafat Fahmi/ Biodiversity of Terrestrial Ecosystem-KISR**

3- **researcher/Mohammad Ali Oreshi/ Arid land Agriculture & Greenery Department-KISR.**

Appendix 6.2.3 -A. Details of the Discussion with Managers and Staff - Group Meeting Details

1- The relationship between managers and staff with the surrounding managers e.g adjacent protected areas.
2- The extent of knowledge managers and staff have about overgrazing, oil exploration activities, and other related environmental problems.
3- Discussion related to the way the laws are imposed on those who have an entry permit.
4- The extent to which workers are aware of their powers to authorise non-environmental work such as trench digging, oil exploration work and overgrazing.
5- If the manager and employee have knowledge related to the regulations to control land use and activities.
5- Discussion about knowledge and understanding of the value of the protected site.
6- The opinion related to the environmental cresses such as desertification and land encroachment.
7- Discussion about the opinion of the relationship between dust and respiratory related diseases.
8- The extent of the workers' knowledge on the relationship between protecting the area and obtaining beneficial vegetation cover.
9- The staff and mangers opinion on the involvement of the environmental sectors in the management and the possibilities of joint cooperation.
10- Enforcement policy and knowledge of rights and duties.
11- Staff knowledge of the regular work plan.
12- The extent of knowledge that the managers and staff have related to the vegetation cover, water table and ecological value of Wadi Al-Batin area, Al-Ritgaa, Khabari Al-Awazem, and Um-Negaa area.
13- To what extent staff and managers recognise the planning to use the land and water effectively.
14- Type of management applied and benefits gained.
15- If the managers or staff received an evaluation of the area or detailed requirements for improvement of the ecological performance of the site.

16- Staff knowledge of control access in each Mohema A-B-and C.
17- Staff knowledge of supervision of the area according to the environmental prospective.
18- If the managers or staff received an evaluation of the area or detailed requirements for improvement of the ecological performance of the site.
19- Discuss the main tasks of the employees, and the possibility to improve according to the environmental concepts.
20- Type of training and if they have knowledge on ecological and environmental training.
21- Environmental or ecological problems that they might face, which is far from their field of work.
22- Any planned educational programme linked to the objectives and needs.
23- Type of problems that workers face.
24- Staff knowledge of resource and equipment in the protected area.
25- Type and number of staffs managing the site and the categories (civilian or not).
26- Discuss with staff and managers if they think that the number of staffs are enough or not.
27- Staff involvement in research and surveys related to the protection objectives.
28- Staff knowledge of resources and equipment needed to improve management in the protected area.
29- The staff and mangers opinion on the improvement of the protected site.
30- Possibilities of improving existing operations to comply with sound environmental concepts such as trenching and heavy equipment use.
31- Staff implementation and active resource management being undertaken
32- Employment requirement
33- Type of training they use to have, and any idea about future needs.
34- Extent of changes noticed in the protected area as compared to when it was first designated.

35- If managers have knowledge related to budget use, financial requirements, and consumers expenditures (not applicable, managers are not involved in financial decisions).
36- If managers have knowledge related to budget for security, management and equipment (not applicable, managers are not involved in financial decisions).
37- Discuss with employees' types of training they used to have according to the planned objectives.
38- Discuss employees' knowledge related to the regulations to control land use and activities according to the site protection objectives.
39- The perceived relationship with neighbours; co-operation with the staff in the adjacent land.
40- Kind of involvement in local communities' input to managerial decisions, if applicable.
41- Implementation of equipment and having the sufficient equipment to meet management needs.
42- Maintenance of equipment and adequate maintenance.
43- Staff opinions on management activities that do not comply with protection objectives.
44- Staff and managers opinion on changes that have been noticed in the protected area as compared to when it was first designate.

Appendix 6.2.3-B: Protected Area Management Evaluation Assessment score in 16 survey in the applied locations.

Question	Al-Ritqa area (1)	GD	Al-Ritqa area (2)	GD	Shagaya area (1)	GD	Shagaya area (2)	GD	Al-Abraq & AL-Taawon	GD	Al-Shaheed German	GD	Khabary Al Awazem	GD	Al Bohaith	GD	Average Total
1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
2	1	2	1	2	2	2	3	3	1	1	3	3	1	1	3	3	2
3	1	1	2	2	1	1	1	2	1	1	1	1	1	1	2	2	1.31
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	2	2	3	3	3	3	2	2	3	3	1	1	2	2	2.12
6	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	1	1	1	1	1	0	0	2	2	0	0	1	1	2	2	1
9	2	3	2	3	2	2	2	2	2	2	2	2	1	1	2	2	2
10	2	3	2	2	3	3	3	3	1	1	2	2	1	1	2	2	2.06
11	0	0	1	0	1	2	1	1	3	2	1	1	0	0	2	2	1.06
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	0	0	2	2	0	0	1	1	2	2	1
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	1	1	1	1	0	1	0	1	2	2	0	1	1	1	1	1	0.94
16	1	1	1	1	0	1	0	1	1	1	0	0	2	2	2	2	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	2	2	2	2	3	3	2	2	1	1	3	3	1	1	2	2	2

Appendix 6.2.3C: Protected Area Management Evaluation Assessment Form.

Issue	Criteria	Score	Comment/Explanation	Next steps
1. Legal status does the protected area have legal status (or in the case of private reserves is covered by a covenant or similar)? *Context*	The protected area is not gazetted/covenanted	0		
	There is agreement that the protected area should be gazetted/covenanted but the process has not yet begun	1		
	The protected area is in the process of being gazetted/covenanted but the process is still incomplete (includes sites designated under international conventions, such as Ramsar, or local/traditional law such as community conserved areas, which do not yet have national legal status or covenant)	2		
	The protected area has been formally gazetted/covenanted	**3**		
2. Protected area regulations Are appropriate regulations in place to control land use and activities (e.g. hunting)? *Planning*	There are no regulations for controlling land use and activities in the protected area	0	- Oil exploration - Grazing in one part of the DMZ. - Heavy machine passage to Iraq (Khabary Al-Awazem site).	Improvement of the implementation of protection legislation and ecological measures – empower the environmental sectors to ensure success in the new laws applied.
	Some regulations for controlling land use and activities in the protected area exist but these are major weaknesses	1		
	Regulations for controlling land use and activities in the protected area exist but there are some weaknesses or gaps	**2**		
	Regulations for controlling inappropriate land use and activities in the protected area exist and provide an excellent basis for management	3		

3. Law enforcement Can staff (i.e. those with responsibility for managing the site) enforce protected area rules well enough? *Input*	The staff have no effective capacity/resources to enforce protected area legislation and regulations	0	Ministry of Interior guards distributed at each point in order to patrol for security purposes. Staff lack skills and institutional support.	Empower the environmental sectors and increase the number of employees, taking into consideration the need for upskilling within specific environmental specialisms of staff in different sectors according to the management plan developed.
	There are major deficiencies in staff capacity/resources to enforce protected area legislation and regulations (e.g. lack of skills, no patrol budget, lack of institutional support)	**1**		
	The staff have acceptable capacity/resources to enforce protected area legislation and regulations but some deficiencies remain	2		
	The staff have excellent capacity/resources to enforce protected area legislation and regulations	3		
4. Protected area objectives Is management undertaken according to agreed objectives? *Planning*	No firm objectives have been agreed for the protected area	0	The site is managed by a non-environmental society which makes it unlikely for them to achieve the goals and objectives of protection.	Develop of annual management plan to achieve objectives: - Review of management effectiveness (METT) - Ecological and biodiversity monitoring programmes. - Vegetation condition assessments - Technical advice and support (GIS mapping, implementation
	The protected area has agreed objectives, but is not managed according to these objectives	**1**		
	The protected area has agreed objectives, but is only partially managed according to these objectives	2		
	The protected area has agreed objectives and is managed to meet these objectives	3		

				of soil erosion management planning, etc.) - Implementation of ecological restoration measures
5. Protected area design Is the protected area the right size and shape to protect species, habitats, ecological processes and water catchments of key conservation concern? *Planning*	Inadequacies in protected area design mean achieving the major objectives of the protected area is very difficult	0	According to the context design, and geographical location discussed in PAME elements, the protected site is valued ecologically and can help in the achievement of objectives of protection. Threats and processes applied develop undesired hydrological changes.	Threat assessment need to be applied to overcome the consequences of border trench applied by ministry of interior.
	Inadequacies in protected area design mean that achievement of major objectives is difficult but some mitigating actions are being taken (e.g. agreements with adjacent land owners for wildlife corridors or introduction of appropriate catchment management)	1		
	Protected area design is not significantly constraining achievement of objectives, but could be improved (e.g. with respect to larger scale ecological processes)	**2**		
	Protected area design helps achievement of objectives; it is appropriate for species and habitat conservation; and maintains ecological processes such as surface and groundwater flow at a catchment scale, natural disturbance patterns etc	3		
6. Protected area boundary demarcation	The boundary of the protected area is not known by the management authority or local residents/neighbouring land users	0	According to the context design mentioned in PAME elements	
	The boundary of the protected area is known by the management authority but is not known by local residents/neighbouring land users	1		

Is the boundary known and demarcated? *Process*	The boundary of the protected area is known by both the management authority and local residents/neighbouring land users but is not appropriately demarcated	2		
	The boundary of the protected area is known by the management authority and local residents/neighbouring land users and is appropriately demarcated	**3**		
7. Management plan Is there a management plan and is it being implemented? *Planning*	There is no management plan for the protected area	**0**		Preparation of environmental management plan based on: - Conservation of natural resources and biodiversity restoration - Financial plan - Designation of skilled employees and a well-developed training plan. - Securing conservation commitments for legal recognition.
	A management plan is being prepared or has been prepared but is not being implemented	1		
	A management plan exists but it is only being partially implemented because of funding constraints or other problems	2		
	A management plan exists and is being implemented	3		
8. Regular work plan Is there a regular work plan and is it being implemented? *Planning/Outputs*	No regular work plan exists	0	Activities plan according to accidental threats.	- Threat conservation assessment needs to be applied.
	A regular work plan exists but few of the activities are implemented	**1**		
	A regular work plan exists and many activities are implemented	2		
	A regular work plan exists and all activities are implemented	3		

9. Resource inventory Do you have enough information to manage the area? *Input*	There is little or no information available on the critical habitats, species and cultural values of the protected area	0	Information of species according to Kuwait University herbarium and museum (2018). Threats observed from field surveys and according to KISR reports. Information related to threat assessment of oil trenches and oil contamination related to institutional report developed by KISR	Research related to the vegetation cover and taxonomical level. In addition to a frequent monitoring plan. The need to provide environmental monitoring devices, such as: Electrochemical devices for field-based and *in-situ* environmental monitoring which allows for auto sampling rather than the traditional way of bringing the sample to the laboratory. Dust monitoring devices for desertification control. Scientific research on soil and border trench and physical solution applied to determine a developed plan.
	Information on the critical habitats, species, ecological processes and cultural values of the protected area is not sufficient to support planning and decision making	1		
	Information on the critical habitats, species, ecological processes and cultural values of the protected area is sufficient for most key areas of planning and decision making	**2**		
	Information on the critical habitats, species, ecological processes and cultural values of the protected area is sufficient to support all areas of planning and decision making	3		
10. Protection systems Are systems in place to control access/resource use in the protected area? *Process/Outcome*	Protection systems (patrols, permits etc) do not exist or are not effective in controlling access/resource use	0	The access can be from other non-environmental sectors such as oil exploration or other society which makes it unlikely for them to achieve the goals and objectives of protection	
	Protection systems are only partially effective in controlling access/resource use	1		
	Protection systems are moderately effective in controlling access/resource use	**2**		
	Protection systems are largely or wholly effective in controlling access/ resource use	3		
11. Research	There is no survey or research work taking place in the protected area	0		Research needed:

Is there a programme of management-orientated survey and research work? *Process*	There is a small amount of survey and research work but it is not directed towards the needs of protected area management	**1**	Activities plan according to accidental threats. Research plan is unknown.	- Technical advice and support (GIS mapping, implementation of soil erosion management planning, etc.) - Biodiversity identification project. - Threat assessment according to the threats data sheet mentioned.
	There is considerable survey and research work but it is not directed towards the needs of protected area management	2		
	There is a comprehensive, integrated programme of survey and research work, which is relevant to management needs	3		
12. Resource management: Is active resource management being undertaken? *Process*	Active resource management is not being undertaken	0	Resources and equipment applied especially according to the threat assessment of oil trench and oil contamination.	Resources and equipment need to be developed according to the threats data sheet mentioned and a proposed annual management plan should be developed.
	Very few of the requirements for active management of critical habitats, species, ecological processes and cultural values are being implemented	**1**		
	Many of the requirements for active management of critical habitats, species, ecological processes and, cultural values are being implemented but some key issues are not being addressed	2		
	Requirements for active management of critical habitats, species, ecological processes and, cultural values are being substantially or fully implemented	3		
13. Staff numbers: Are there enough people employed to	There are no staff	**0**	Staff only for patrolling (Ministry of interior).	Upskilling of staff for the attraction of specific environmental specialisms in
	Staff numbers are inadequate for critical management activities	1		

manage the protected area? *Inputs*	Staff numbers are below optimum level for critical management activities	2	No people employed to manage the protected site.	different sectors according to the management plan developed.
	Staff numbers are adequate for the management needs of the protected area	3		
14. Staff training Are staff adequately trained to fulfil management objectives? *Inputs/Process*	Staff lack the skills needed for protected area management	**0**	Staff only for Patrolling (Ministry of interior).	Development of training courses according to the annual management plan and primary objectives need to be achieved.
	Staff training and skills are low relative to the needs of the protected area	1		
	Staff training and skills are adequate, but could be further improved to fully achieve the objectives of management	2		
	Staff training and skills are aligned with the management needs of the protected area	3		
15. Current budget Is the current budget sufficient? *Inputs*	There is no budget for management of the protected area	0	Currently unknown: Budget implemented for accident projects needed (oil contamination projects).	
	The available budget is inadequate for basic management needs and presents a serious constraint to the capacity to manage	**1**		
	The available budget is acceptable but could be further improved to fully achieve effective management	2		
	The available budget is sufficient and meets the full management needs of the protected area	3		
16. Security of budget Is the budget secure?	There is no secure budget for the protected area and management is wholly reliant on outside or highly variable funding	0	Not discussed with staff. unknown	
	There is very little secure budget and the protected area could not function adequately without outside funding	**1**		

Inputs	There is a reasonably secure core budget for regular operation of the protected area but many innovations and initiatives are reliant on outside funding	2		
	There is a secure budget for the protected area and its management needs	3		
17. Management of budget: Is the budget managed to meet critical management needs? *Process*	Budget management is very poor and significantly undermines effectiveness (e.g. late release of budget in financial year)	0	Budget for emergency situation is provided from higher commities	
	Budget management is poor and constrains effectiveness	**1**		
	Budget management is adequate but could be improved	2		
	Budget management is excellent and meets management needs	3		
18. Equipment Is equipment sufficient for management needs? *Input*	There are little or no equipment and facilities for management needs	**0**	Not applied, unknown	Need to develop a list according to management plan implementation.
	There are some equipment and facilities but these are inadequate for most management needs	1		
	There are equipment and facilities, but still some gaps that constrain management	2		
	There are adequate equipment and facilities	3		
19. Maintenance of equipment: Is equipment adequately maintained?	There is little or no maintenance of equipment and facilities	**0**	Not applied.	Not applied
	There is some *ad hoc* maintenance of equipment and facilities	1		
	There is basic maintenance of equipment and facilities	2		

Process	Equipment and facilities are well maintained	3		
20. Education and awareness Is there a planned education programme linked to the objectives and needs? *Process*	There is no education and awareness programme	**0**	Not applied	According to the objectives the protected area design and context the is not involved in ecotourism, or social networking.
	There is a limited and *ad hoc* education and awareness programme	1		
	There is an education and awareness programme but it only partly meets needs and could be improved	2		
	There is an appropriate and fully implemented education and awareness programme	3		
21. Planning for land and water use Does land and water use planning recognise the protected area and aid the achievement of objectives? *Planning*	Adjacent land and water use planning does not consider the needs of the protected area and activities/policies are detrimental to the survival of the area	**0**	Not applied	Need to be developed according to the proposed annual management plan and managers should consider sustainable use – develop the mapping research using GIS technology.
	Adjacent land and water use planning does not considers the long term needs of the protected area, but activities are not detrimental the area	1		
	Adjacent land and water use planning partially considers the long term needs of the protected area	2		
	Adjacent land and water use planning fully considers the long term needs of the protected area	3		
22. State and commercial neighbours; Is there co-operation with	There is no contact between managers and neighbouring official or corporate land and water users	**0**	Not applied	Not applied
	There is contact between managers and neighbouring official or corporate land and water users but little or no cooperation	1		

adjacent land and water users? *Process*	There is contact between managers and neighbouring official or corporate land and water users, but only some co-operation	2		
	There is regular contact between managers and neighbouring official or corporate land and water users, and substantial co-operation on management	3		
23. Indigenous people Do indigenous and traditional people resident or regularly using the protected area have input to management decisions? *Process*	Indigenous and traditional peoples have no input into decisions relating to the management of the protected area	**0**	Not applied	According to the objectives the protected area design and context the is not involved in ecotourism, or social networking
	Indigenous and traditional peoples have some input into discussions relating to management but no direct role in management	1		
	Indigenous and traditional peoples directly contribute to some relevant decisions relating to management but their involvement could be improved	2		
	Indigenous and traditional peoples directly participate in all relevant decisions relating to management, e.g. co-management	3		
24. Local communities Do local communities' resident or near the protected area have input to	Local communities have no input into decisions relating to the management of the protected area	**0**	Not applied	According to the objectives the protected area design and context the is not involved in ecotourism, or social networking.
	Local communities have some input into discussions relating to management but no direct role in management	1		
	Local communities directly contribute to some relevant decisions relating to management but their involvement could be improved	2		

management decisions *Process*	Local communities directly participate in all relevant decisions relating to management, e.g. co-management	3		
25. Economic benefit: Is the protected area providing economic benefits to local communities, e.g. income, employment, payment for environmental services? *Outcomes*	The protected area does not deliver any economic benefits to local communities	**0**	Not applied	According to the objectives the protected area design and context the is not involved in ecotourism, or social networking.
	Potential economic benefits are recognised and plans to realise these are being developed	1		
	There is some flow of economic benefits to local communities	2		
	There is a major flow of economic benefits to local communities from activities associated with the protected area	3		
26. Monitoring and evaluation Are management activities monitored against performance? *Planning/Process*	There is no monitoring and evaluation in the protected area	**0**	Not applied	The application needs to be annually re-evaluated after the application of the management plan.
	There is some *ad hoc* monitoring and evaluation, but no overall strategy and/or no regular collection of results	1		
	There is an agreed and implemented monitoring and evaluation system but results do not feed back into management	2		
	A good monitoring and evaluation system exist, is well implemented and used in adaptive management	3		
27. Visitor facilities	There are no visitor facilities and services despite an identified need	**0**	Not applied	According to the objectives the protected area design and context the is not involved in
	Visitor facilities and services are inappropriate for current levels of visitation	1		

Are visitor facilities adequate? *Outputs*	Visitor facilities and services are adequate for current levels of visitation but could be improved	2		ecotourism, or social networking
	Visitor facilities and services are excellent for current levels of visitation	3		
28. Commercial tourism operators Do commercial tour operators contribute to protected area management? *Process*	There is little or no contact between managers and tourism operators using the protected area	**0**	Not applied	According to the objectives the protected area design and context the is not involved in ecotourism, or social networking.
	There is contact between managers and tourism operators but this is largely confined to administrative or regulatory matters	1		
	There is limited co-operation between managers and tourism operators to enhance visitor experiences and maintain protected area values	2		
	There is good co-operation between managers and tourism operators to enhance visitor experiences, and maintain protected area values	3		
29. Fees If fees (i.e. entry fees or fines) are applied, do they help protected area management? *Inputs/Process*	Although fees are theoretically applied, they are not collected	**0**	Not applied	The management depend on the governmental sectors in economic issues.
	Fees are collected, but make no contribution to the protected area or its environs	1		
	Fees are collected, and make some contribution to the protected area and its environs	2		
	Fees are collected and make a substantial contribution to the protected area and its environs	3		
	Many important biodiversity, ecological or cultural values are being severely degraded	0	The decision was made to ban the practice of human	The application needs to be annually re-evaluated after a

30. Condition of values What is the condition of the important values of the protected area as compared to when it was first designated? *Outcomes*	Some biodiversity, ecological or cultural values are being severely degraded	1	herding, through the construction of an outer porous fence to control entry. grazing and camping was also banned in the area. Managers provided access roads for vehicle movement inside the area. Underground water wells were constructed; however, these are not widely used in the protected site. The management co-operated with some environmental societies (EPA-KU, KISR, and PAAF) for monitoring and research purposes in the contaminated area and also to investigate the vegetation cover.	management plan is developed. - The site needs a special investigation to observe the vegetation cover in detail and a creation of a vegetation database for monitoring and identification of biodiversity in the area. - The investigation should contain the following: sampling studies of site, improvement of vegetation cover, restoration of biodiversity and soil stabilisation, preventing soil erosion and facilitating plant recruitment and survivor. - A study should be developed to discuss the relation between adjacent protected sites and buffering areas. - Monitoring the product and service delivery and achievement of a planned work program.
	Some biodiversity, ecological and cultural values are being partially degraded but the most important values have not been significantly impacted	2		
	Biodiversity, ecological and cultural values are predominantly intact	3		

				- Threat prevention assessment and develop solutions for planning outputs.
Total score			25	