Chapter 1
Afro-Asian Mediterranean Coastal Lands

1.1 Introduction

The Mediterranean gave birth to the whole world: all the world is her debt (Semple, 1932). Modern civilization traces back to seeds of culture-matured in the circle of the Mediterranean lands and transplanted thence to other countries whence they have been disseminated over the world. The Mediterranean Sea with its bordering lands has been a melting-pot for the peoples and civilization, which have rushed into it from continental hinterlands. It has been a catchment basin, and also a disturbutionary's center for its composite cultural achievements. This double role in history is an outgrowth of its geographical location and its relation to the neighboring continents.

Because of its geography and history, the Mediterranean Basin is an unique original region: the sea itself (Mediterranean means "in the midst of the land"), the complex and tortuose of landscape that surrounds it. Its unique climate, have all influenced the extraordinary development of the prehistoric civilization along its shores. Such development has deeply marked an irreversible-fragile environment with limited resources. Branigan and Jarrett (1975) stated that a significant role in the evolution of a succession of civilization have been played by the Mediterranean Sea and its surrounding lands. To Mesopotamia, Babylon, Syria, Palestine and Egypt, the Mediterranean was the Great Sea, their knowledge being confined to the Levant. To the ancient Greeks it became *Mare Interim*, "the interior sea" and later the Italians named it *Mare nostrum* (our sea). The name "Mediterranean" generally used at the beginning of the Christian era. It describes this almost landlocked sea and gives some prominence to the terra, the land that surrounds it. We may quote what is written by Semple (1932): Mediterranean civilization has given the world standards. These are embodied in classical culture and Christianity, and still represent ideals of achievement and conduct. The new faith born of a narrow tribal beliefs from the hill country of Judea and Galilee, emerged as a principle of universal brother-hood from the gradual calming of local religious incidents to an active intercourse between all parts of the Mediterranean Basin under the *Pax Romana*.

The Mediterranean Basin with its fantastic variety of landscapes, people, plants and animals, is one of the most complex regions on Earth in terms of geological,

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history, geographic, morphology and natural history. It is characterized by various habitats: high mountains, seashores, coastal wetlands, desert wadis, coastal dunes, small islets, dry scrublands, moist fir forests, grasslands etc. Diversity of living organisms between these habitats is obvious (Blondel and Aronson, 1999).

The Mediterranean climate is characterized by prolonged and intense summer drought of at least 2 or 3 and up to 11 months. Rains occur during the winter season. According to the respective length of the dry and rainy season and the total amount of rainfall, the Mediterranean climate can be differentiated, into six types: hyper-arid, arid, semi-arid, sub-humid, humid and hyper-humid. Mean annual rainfall can vary from 20–25 mm in the Mediterranean desert (arid) to 2,000–2,500 mm on mountain slopes or maritime areas exposed to rain-bearing winds. The temperature varies widely with latitudes, altitudes and continentally: the mean annual can drop below 10°C and rise above 25°C; the mean daily January minimum can vary from –10 to 15°C; and the mean daily maximum of July/August from 25 to 45°C (Le Houerou, 1992). That the arid lands of the Mediterranean Basin in North African Sahara to the west Asian desert spans a set of climatic systems with a rainless core and winter rainfall (Kassas, 1998).

The Mediterranean Basin in general has had a long history of human occupation: sites of old rain-fed agriculture settlements has been recognized in the East Mediterranean Basin (Fertile Crescent): irrigation farming prevailed in Mesopotamia and Egypt throughout recorded history; nomadic tribes with their flocks of camels, sheep and goats have remained features of human life in this region since millennia. The imacts of human occupations are evident everywhere. Accordingly, the Mediterranean Basin was and is still the focus of attraction of various scientists in the different fields of specializations (ecology, environmental sciences, biodiversity, climatology, geology, land use, agriculture, economy, history, sociology etc.). Endless number of publications has been produced, about the Mediterranean Sea and the land around it.

1.2 Geological History

The geological history of the Mediterranean Sea and its Basin has been described by Hus (1971) and Cohen (1980). They noted that the giant ancestor the Mediterranean Sea was the Tethys Ocean. Some 200 millions years before present, from the beginning of the Mesozoic era which formed a vast wedge-shaped unbroken seaway subdividing the super-continent Pangaea into the Laurasian proto-continent to the north and the Gondwanian proto-continent in the south. The physical geography of the future Mediterranean area changed continuously during this epoch as a result of several periods of continental convergence and collisions of tectonic plates, while seafloor spreading repeatedly rearranged the relative position of the continental plates and oceans in the ancient Tethys. Between the middle Jurassic and the Upper Cretaceous (165–180 million years BP), an eastward motion of Africa relative to Europe, which was then still joined to North America permitted the formation of the Atlantic Ocean. Later, the movement of Africa westwards began the separation from North Africa in the Lower Tertiary. Again, Africa moved eastward relative to Europe from the Upper Eocene (40 million years BP) enlarging the Atlantic. This led to the closing of the gap between Europe and Africa and the elimination of much of the original Tethys. At the same time, a northward movement of Africa initiated the creation of the mountain ranges that encircle the basin. All these complicated movement, of continental drift contributed to the intricate puzzle-like geography of the Mediterranean area. These movements generated the rotation of micro-continents or “micro-tectonic” plates that separated from the main continental blocks. During the Eocene, after more than 100 million years of transcontinental and reshuffling, the Tethys seafloor began to buckle between the colliding tectonic blocks. The Greco-Italian micro-continent, which was joined to the African plate during the Lower Cretaceous (120 million years BP) moved with it and collided with the Eurasian plate in the lower Eocene. In the Upper Oligocene (28 million years BP) the south-eastward motion of Africa relative to Europe caused the rotation of the Iberian plats which included all the large islands of the western Mediterranean and several crystalline blocks subsequently connected either to Africa or to Europe. In the Upper Oligocene (25 million years BP) the African plate, including Arabia, first made contact with south-west Asia, thus, dividing the Tethys Sea into two parts: the southern part, ancestor of the modern Mediterranean Sea, whilst further north and east, which was a shallow, brackish sea that geologist call the Paratethys.

The northward drift of Africa continued during the Miocene together with a general westerly movement up to the present. About 6 million BP present Africa collided with south-western Europe. The newly joined blocks then drifted along together from that point raising the Pyrenees to great heights and, for the first time in history closing the Mediterranean Sea at its western end. Thus, came into being the Maere *Medi-Terraneum* or “sea among the lands”, some times also called the “inland sea”.

1.3 Geomorphologic Features

The Mediterranean Sea lies between latitudes 30 and 45°N and longitudes 10 and 40°E covering a basin between southern Europe and northern Africa, opens to the Atlantic Ocean by the very narrow Strait of Gibraltar and entirely blocked at its eastern end by part of south-west Asia (Fig. 1.1). More than 3,600 km from Gibraltar to Lebanon with an areas of 1,146,000 2,978,000 km^2, it is all that is left of the great ancient ocean Tethys (Branigan and Jarrett, 1975). Blondel and Aronson (1999) stated that the Mediterranean Sea, the largest land sea in the world, extends over 2,969,000 km^2. With its satellites, the Black and the Azov Seas, it is a miniatures ocean. The sea is 740 km wide between Marseilles and Algeria, and 400 km wide between southern Greece and Tripolitania (Libya). Its coastline is 40,000 km in length and several “interior seas” are delimited by the shorelines of the larger archipelagos and northern peninsulas: the Balearic Sea between the Balearic Island

Fig. 1.1. Map of the Mediterranean basin

and continental Spain, the Tyrrhenian Sea between Corsica-Sardinia and the Italian Peninsula, the Adriatic and Lonian Seas between Italy and the Aegean Peninsula and the Aegean Sea between Greece and the Anatolian Peninsula.

The Mediterranean Sea is a great gulf of the Atlantic Ocean cutting back into the landmass of the Eastern Hemisphere. It carries the waters of the ocean 3,726,000 of km inland to the foot of the Lebanon Mountains and yet further through the Black Sea to the rugged coast of Caucasus. “It gives Asia an Atlantic seaboard, and hence rendered it possible for Asiatic navigators from Phoenicia to make the first recorded discovery of Britain. This is the maere *internium*, enclosed by three contrasted continents which it helps to divide, but whose difference in climate, flora, fauna and peoples and civilizations it helps to reconcile” (Semple, 1932).

The Mediterranean consists of a deep gash in the crust of the earth. This prolonged deep gash opens up a natural communication between the Atlantic and the Indian oceans. Also, by splitting the massive block of Europe and Asia, it acts like a link, as a hyphen, between East and West. We have here a geographical phenomenon for exceeding any local framework, and without exaggeration it is of worldwide consequence and proportions (Siegfried, 1948).

The Mediterranean Sea has an Asiatic, European and African coastlines and each continent possesses distinctive features of ecosphere, relief, hinterland connections and differentiated types of the prevailing Mediterranean climate. Europe has a long coastline of about 13,000 km measured from the Strait of Gibraltar to the mouth of Don River (Tanais), the ancient boundary of eastern Europe. The coastline of Africa measures only 5,000 km and is sharply divided into a long stretch of mountain coast to the west, and a longer stretch of plateau coast to the east, each is rather uniform until they combine in the Tunisian Peninsula and each is backed by the same desert hinterland. This part of Africa suffers from serious heat and drought, except where the coastal mountains receive a more or less ample rainfall in the winter. On the eastern edge of the African part lies Egypt, a striking contrast to the rest. The Asiatic Coastline runs from the Don River to the Isthmus of Suez, measures 6,000 km and therefore exceeds that of Africa. It forms a natural gateway between the Orient and Occident (Semple, 1932). A striking geomorphologic features of the Mediterranean Basin is the steepness of the coast, which almost everywhere sinks abruptly to the seafloor at 2,500–4,000 m. The average depth of the Mediterranean Sea is 1,400 m but deeper troughs occur in some places, for example at the southern tip of the Peloponnese (5,100 m) and southeast of Sicily (4,100 m). The average water salinity is 3.7–3.9%, varying little except in some southern regions, and to a lesser degree at the southern end of the Adriatic Sea.

The Mediterranean Basin is characterized by a wide topographic diversity which result in large part from the numerous mountain chains with heights ranging between 1,540 m (Mt Chambi in Tunisia) to 2,330 m (Mt Hodna-Muket in Algeria), and 3,090 m (in Lebanon). Higher peaks occur in Italy (3,260 m), Morocco (4,165 m) and Iran (5,600 m). Mountain chains are found throughout the length of the Mediterranean Basin along its European border and in the African side from the Atlantic to the Gulf of Gabes in Tunisia. East of these there are no encircling range neither in Libya nor in Egypt. The African shield as far as the Sinai Peninsula drops from the tableland by a series of faulted terraces to the coast, and this step-little formation is continued northwards in the floor of the sea. The eastern margin of the Mediterranean Basin is also lacking in mountain folds of any size. The Arabian Plateau, which in the Levant lands underlies sedimentary rocks of considerable thickness in some places, lies outside the region most affected by the mountain-building process, and although there are some folding of the sediments only is Lebanon was this sufficiently intense to produce high mountains; even there is only one peak that rises to more than 3,000 m (Querns es Suda, 3,057 m, Branigan and Jarrett, 1975).

The Mediterranean Basin is divided into two: western and eastern. The western basin stretches from the Strait of Gibraltar to the Sicilian Channel. At its western end, the Strait of Gibraltar, which is only 14.8 km across the narrow point, has a floor that rises to within 366 m of the sea surface and preventing the deeper waters of the Mediterranean flowing outwards to the Atlantic. The deepest point of the Western basins 4,265 m midway between the Islands of Capris and Sardinia. Most of the Eastern basin is occupied by the Ionian Basin, which stretches from the Sicilian Channel almost to the Levantine coast and its deepest point is 5,121 m in Agen Sea.

1.4 Climate: Main Features

The Mediterranean climate is found in five main regions of the world (California, Chile, South Africa. Australia and the Mediterranean Basin) covering about 2% of the total land area of the world. It is primarily coastal and is described as a maritime climate. The Mediterranean Basin is the largest region of land with the

Mediterranean climate (60%) followed by Australia (22%). California (10%), Chile (5%) and the Western Cape (South Africa, 3%). All these regions, located on the western or southwestern coasts of continents, and share the general Mediterranean climate features (Newbigen, 1924; Kendrew, 1961; Von Chi-Bonnardel, 1973; Le Houerou, 1992; Dallman, 1998). The Mediterranean Basin is the only climate region that includes parts of three continents (Europe, Africa and Asia), giving it a very rich flora particularly where continents meet.

The Mediterranean type of climate is most extensive along the edges of the Mediterranean Sea; its dry phase is most extensive on the south and south-east sides of the Sea towards the North African and Asian deserts. This climate border the North African coast everywhere except in the most humid parts of Tunisia, Algeria and Morocco and continues southwards into the Sahara until the rainfalls becomes too meagre and irregular in occurrence to support it. At the east end of the Mediterranean Sea, the dry climates with winter rain come down to the coast in Sinai, southern Israel and south-eastern Turkey, and extend inland throughout the Middle East including the plateau of Turkey (Erinc, 1949, 1950) as well as the northern half of Arabia (Meigs, 1962). The Mediterranean climate is classified by Emberger (1955) as a non-tropical with regular annual rainfall with summer as the dry season.

The Mediterranean climate, including the Mediterranean basin has been divided into four main zones (Meigs, 1962; UNESCO/FAQ, 1963), by the degree of drought of a given dry month, defined as the number of days in the month in which can be deemed dry from a biological point of view (denoted "x" below):

1. xerothermomediterranean, i.e. warm and dry when $150 < x < 200$;
2. thermomediterranean subdivided in turn into accentuated with a long dry season where $125 < x < 150$ and "attenuated" with a shorter dry season, where $100 < x < 125$;
3. mesomediterranean again subdivided into "accentuated" with a long dry season where $75 < x < 100$ and "attenuated" with a shorter dry season, when $40 < x < 75$;
4. sub-mediterranean, a transitional type when $0 < x < 40$. This type of climate is not regarded as Mediterranean climate proper (not eumediterranean).

An alternative classification, Le Houerou (1992), uses precipitation and evapotranspiration to define eight zones: hyper-arid, arid lower, air-upper, semiarid, sub-humid, humid, hyper-humid and wet. Each is characterized by its own vegetation types as follow: desert, desert bush, thorn woodland, very dry forest, dry forest, moist forest, wet forest and rain forest.

Yet a third classification based on the average duration of summer drought is given below. The Mediterranean Sea extends over 3,600 km from west to east and in that distance the total annual rainfall near sea level decreases from 891 mm at Gibraltar to 389 mm at Athens and to 84 mm at Port Said. The decrease in annual rainfall eastward is due mainly but not entirely to increasing distance from the Atlantic. Patterns of rainfall distribution, like those of temperature variations, are also affected by relief. Where mountain range lies across moisture bearing winds, such as in Morocco, their windward slopes may have rainfall totals greater than many wet areas of northern Europe, but they often also act as rainfall barriers and cast extensive rain shadows. In these enclosed and elevated regions, winter temperature are lower than the Mediterranean averages. Summers are also apt to be very hot away from the moderating influence of the sea.

According to Branigan and Jarrett (1975), because of the position and form of the Mediterranean Sea, the lands around it are one of the most clearly defined climatic units in the world. In summer, following the northward march of the sun, the Mediterranean region lies in the belt of north-east trade winds and of high pressure and it is therefore dry. In winter, with the retreat of the sun south of the equator, the region falls under the general influences of the westerlies and is therefore wet because of the depressions associated with them. In general the Mediterranean region has a temperate and changeable climate for the winter half of the year and a more uniform climate of the hot desert type during the summer. Long periods of sunshine and cloudless skies are experienced at all seasons.

The general climactic features of the Mediterranean Basin may be summarized as follow:

1. Rain falls in the winters half of the year with an annual average, of less than 100 mm to more than 2,000 mm. The total amount of rainfall is highly variable from year to year, with much coming in storms lasting only as few days.
2. Summer is the period of drought which may be partial or complete, and at least 2 up to 11 months are dry.
3. The annual average of temperature is small, because typically the winters are mild and summers are hot.
4. Mean annual rainfall varies from 20 to 25 mm in the Mediterranean arid lands (deserts) to 2,000–5,000 mm in the mountain slopes or locally in mountainous areas exposed to rain-bearing winds.
5. Temperature varies latitudinally, altitudinally and continentally: the annual mean can drop below 10°C or rise above 25°C, the mean daily minimum of January may vary from –10 to + 15°C and the mean daily maximum of July/August varies from 25 to 45°C.
6. Winter cold stress, an important biological attribute can be non-existent, light mild, intense or prolonged depending upon latitude elevation and continentally. Emberger (1930) stated "cold stress becomes a potent discriminating factor of vegetation distribution pattern, crop selection and land use".
7. Mediterranean climate areas, experience decreasing rainfall as the latitude approaches 30° towards the equator. Correspondingly, there is a gradual changes in vegetation towards xerophytes adapted to semi-arid and arid deserts. In contrast as latitude approaches 40–45° towards the poles, rainfall steadily increase and becomes distributed more evenly throughout the year.
8. Elevation is important in relation to temperature and rainfall. In the mountains, temperature decreases by roughly 5°C/1,000 m. Rainfall is typically greater with increased elevation. Vegetation, correspondingly changes with elevation. Orientation of mountain slopes has also a profound effects on vegetation.

9. The Mediterranean climate and adjacent areas can be described on the basis of the average duration of summer drought into six sub-climatic zones: (Koppen, 1931; Thornthwait, 1948; Emberger, 1955; Bagnouls and Gaussen, 1957; Meigs, 1962; Di Castri, 1991):
   1. Hyper-arid (11–12 dry months).
   2. Arid (9–10 dry months),
   3. Semi-arid (7–8 dry months),
   4. Sub-humid (5–6 dry months),
   5. Humid (3–4 dry months),
   6. Hyper-humid (1–2 dry months).

These categories correspond reasonably well with the variation in vegetation and particularly suitable for the diverse Mediterranean Basin itself, because its seasons of peak rainfall varies substantially from one region to another.

1.5 Mediterranean Basin Countries

The Mediterranean Basin countries (21) are; Albania, France, Greece, Italy, Portugal, Spain, Yugoslavia[1] (in Europe), Morocco, Algeria. Tunisia, Libya and Egypt (in North Africa), and Cyprus, Iran, Iraq, Egypt (Sinai), Palestine-Israel, Jordan, Lebanon, Syria, Saudi Arabia and Turkey (in Asia). The surface areas of the territories of these countries under the influence of the Mediterranean climate (shown in Table 1.1) reveal the following (Le Houerou, 1992) (Fig. 1.1):

1. The total surface areas of these 21 countries under the influence of the Mediterranean climate is 7,357,000 km^2 distributed in Europe (9%, 690,000 km^2), Africa (46%, 3,347,000 km^2) and Asia (45%, 3,320,000 km^2).
2. 100% of the surface areas of the territories of eight countries (Morocco, Tunisia, Cyprus, Iraq, Israel, Jordan, Lebanon, and Syria), 80% of Iran, 64% of Spain, 62% of each of Greece and Portugal and 50% of each of Libya, Egypt and Saudi Arabia territories are under the influence of the Mediterranean climate.
3. 40, 30, 18, 16 and 10% of the territories of Italy, Turkey, Albania, France and Yugoslavia,[1] respectively, are influenced by the Mediterranean climate.

The geographical distribution of the six bioclimatic zones of the Mediterranean climate within the territories of the 21 countries of the Mediterranean Basin (Table 1.2) shows that (Le Houerou, 1992):

1. Territories of all North African countries (Morocco, Algeria, Tunisia, Libya and Egypt), most of the Middle East countries (Iran, Iraq, Syria, Jordan, Palestine,

[1]Yugoslavia is no longer a country since February 2003 and officially is divided into three independent countries: Serbia, Montengro and Kosovo.

Table 1.1 Surface areas of the territories of 21 Mediterranean basin countries of the European, African and Asian continents under the effect of the Mediterranean climate (after Le Houerou, 1992)

Countries	*S* (10^3 km^2)	*P* (%)	Countries	*S* (10^3 km^2)	*P* (%)
A- Europe			*C- Asia*		
1- Albania	5	18	1- Cyprus	9	100
2- France	87	16	2- Iran	1,300	80
3- Greece	81	62	3- Iraq	434	100
4- Italy	118	40	4- Israel–Palestine	20	100
5- Portugal	57	62	5- Jordan	97	100
6- Spain	317	64	6- Lebanon	10	100
7- Yugoslavia (former)	25	10	7- Syria	144	100
			8- Saudi Arabia	1,075	50
			9- Turkey	231	30
Total Europe	690	9	*Total Asia*	3,320	45
B- Africa		100	*Grand total*	7,356	100
1- Morocco	320	50			
2- Algeria	191	100			
3- Tunisia	156	50			
4- Libya	880	50			
5- Egypt	500	46			
Total Africa	3,347	46			

S = Surface area, *P* (%) = percentage from the total surface area of the country.

Israel and Turkey) are under the influence of the hyper-arid and arid bioclimatic zones together with small parts of Spain and Italy.

2. All North African (except Egypt), Asian and European countries, have territories influenced by the semi-arid bioclimatic zone.
3. Mediterranean Basin countries with territories in the humid bioclirnatic zone include Morocco. Algeria and Tunisia (in North Africa), all Asian and European countries.
4. The hyper-humid bioclimatic zone prevails in the Mediterranean territories of all seven European and six of the Middle East (Turkey, Lebanon. Jordan, Iran, Iraq and Cyprus) countries in addition to Morocco, Algeria and Libya of North Africa.

Apart from these six bioclimatic zones, the Mediterranean Basin also has a mountainous bioclimatic zone which prevails in the territories of countries with high mountains (all European, Asian (except Syria), and three North African countries (Morocco, Algeria and Tunisia), Le Houerou, 1992).

Such very diverse bioclimatic zones bear a large number of botanical, and consequently zoological types, including: desert and sub-desert steppes, evergreen and deciduous mountainous shrublands and forests. Land-use also varies widely depending on climatic, edaphic, historical and socio-economic conditions (Le Houerou, 1981, 1992).

Table 1.2 Geographical location of the hyper-arid (HA), arid (A), semi-arid (SA), sub-humid (SH), humid (H), and hyper-humid (HH) bioclimatic zones of the Mediterranean basin in territories of European, North African and Middle East (Asian) countries (Le Houerou, 1992)

	Bioclimatic zones					
Countries	HA	A	SA	SH	H	HH
A- Europe						
1- Portugal	–	–	+	+	+	+
2- Spain	–	+	+	+	+	+
3- France	–	–	+	+	+	+
4- Italy	–	+	+	+	+	+
5- Yugoslavia (former)	–	–	+	+	+	+
6- Greece	–	–	+	+	+	+
B- Asia						
1- Turkey	–	+	+	+	+	+
2- Syria	+	+	+	+	+	–
3- Lebanon	–	–	+	+	+	+
4- Israel–Palestine	+	+	+	+	+	–
5- Jordan	+	+	+	+	+	+
6- Iran	+	+	+	+	+	+
7- Iraq	+	+	+	+	+	+
8- Cyprus	–	–	+	+	+	+
C- North Africa						
1- Egypt	+	+	–	–	–	–
2- Libya	+	+	+	+	–	+
3- Tunisia	+	+	+	+	+	–
4- Algeria	+	+	+	+	+	+
5- Morocco	+	+	+	+	+	+

1.6 Biodiversity of the Mediterranean Basin: General Features

Located at the cross roads between Europe, Asia and Africa, the Mediterranean Basin has served as a melting pot and meeting ground for species of varying origins. Many elements in the course of history have colonized the basin (Blondel and Aronson, 1999).

The physical environment and climate of the Mediterranean Basin have changed radically since the Mesozoic with the result that biological composition of its different regions and migration routes of invading species have changed repeatedly. Opportunities for invasion and secondary speciation have been continually renewed. As a result, one can find species originating from such different biogeographical realms as Siberia, South Africa and even some relics of the Antarctic continent for several components of the soil fauna.

The Mediterranean Basin, thus, might be considered as a huge "tension zone" (Raven, 1964) lying amid the temperate, arid and tropical biogeographical regions which surround it, a zone where intricate interpenetration and speciation has been particularly favoured and fostered as compared to the more homogeneous regions to the north and south. As a consequence of its kaleidoscopic topographical, climatic and edaphic complexity. The Mediterranean Basin is exceptionally rich in regional or local plant and animal endemics at the levels of genera, species and subspecies (Medial and Verlaque, 1997).

The Mediterranean Basin was recognized by Myers (1990) as one of the 18 world "hot-spots" where exceptional concentrations of biodiversity occur, over and above general trend that species richness increases with decreasing latitudes, such that one finds more species of plants and animals in the Mediterranean than further north. Blondel and Aronson (1999) after Hammond (1995), Quezel (1985), Cheylan and Poitenvin (1998), Cheylan (1991), Covas and Blondel (1998) and Higgins and Riley (1988) tabulated the status of biodiversity of the Mediterranean basin as follow (Table 1.3).

Table 1.3 Total number of species, number of endemic species and proportion of world number of the species of the vascular plants, reptiles, amphibians, mammals, birds, insects and butterflies of the Mediterranean Basin

Group	Number of species	Endemism	Proportion of world number of species (%)
Vascular plants	25,000	50	7.8
Reptiles	165	68.5	2.5
Amphibians	63	58.7	1.5
Mammals	197	25	4.2
Birds	366	17	3.8
Insects	150,000	–	1.9
Butterflies	321	46	–

The flora of the Mediterranean basin is one of the richest in the Old World. It includes more than 25,000 species of flowering plants (Quezel, 1985), reaching about 30,000 species and subspecies (Greuter, 1991), as well as some 160 or more species of ferns. This is about 10% of all known plant species on Earth, a figure estimated at between 238,000 and 260,000, although the land area of the Mediterranean Basin represents only 1.5% of the land surface of the Earth.

Gomez-Campo (1985) stated that the main reason for the Mediterranean's richness is plant species in not so much the variety of species in any given area as the remarkable number of endemics, many of which are restricted to a single or a few localities in sandy areas, islands, geological "islands" of unusual soil or rock type or isolated mountain ranges. The Mediterranean Basin, as pointed out by Medial and Verlaque (1997) is nearly as rich in endemics as the whole of tropical Africa, even though the latter is about 4 times larger and harbours about the same number of vascular plant species. Thus, the Mediterranean Basin is an important reservoir of plant diversity.

One of the features of the Mediterranean Basin flora is that annual species, and particularly the ruderals, are especially well represented, because this life-history strategy is adapted to perturbation, including the stress of 6 or more months of absolute summer drought particularly in hyper-arid and arid areas. A further interesting feature of the flora is that the distribution of endemic species varies greatly according to regions.

The types of natural vegetation found in the Mediterranean lands are not only controlled by the different bioclimatic types but also by local variations in temperature and rainfall. Branigan and Jarrett (1975) stated that there are nine vegetation types: broad-leaved evergreen forest, stunted and degenerate woodland, deciduous forest, aquatic grasses and reeds, coniferous forest, grasslands, including steppe, dry-steppe and semi-desert, desert and alpine vegetation.

Broad-leaved evergreen forest (high maquis, Dallman, 1998) can be regarded as the type most characteristic of Mediterranean vegetation. The dominant trees are evergreen oaks of various kinds, the most numerous being holm oak (*Quercus ilex*), rock oak (*Q. suber*) and kermes oak (*Q. coccifera*). Other species include: *Arbutus unedo, Erica arborea, Myrtus communis* and *Genista hispanica*.

Stunted and degenerate woodland (low maquis) is represented by three species of the genus *Cistus* (*C. salviifolius, C. crispus, C. ladanifer*). Commonly associated with *Cistus* spp. is the genus *Cytinus* whose parasitic plants grow on the roots of *Cistus* and are found under the shrub. Deciduious forest is represented by two species of *Quercus* (*Q. aegilops* and *Q. cerris*).

Aquatic grasses and reeds are mainly represented by *Phragmites australis*, *Typha domingensis* and species of *Cyperus, Juncus, Panicum, Echinochloa* etc.

Coniferous forests are dominated by *Abies pectinata*, *A. marocana*, *Pinus pinaster*, *P. sylvesiris*, *P. pyrenaica*, *P. brutia*, *P. halepensis*, *P. pinea*, *Cupressus semprevirens*, *Cedrus libani*, *Juniperus communis*, *J. thurifera* and *J. drupacea*.

Steppe vegetation evolves in climatic conditions characterized by wide seasonal variation in temperature and low rainfall. Trees are absent and the landscape is one of various species of grasses and bulbous plants. Following the rains of winter the steppe is a scene of luxuriant growth; but this lasts only for a couple of months and begins to wither with the approach of hot, rainless summer. In autumn only hardy bushes and thorny plants show sign of life, and in general the steppes looks barren ad scorched. The main vegetative cover of the dry steppes and semi-desert is formed of *Stipa tenacissima* and *Lygeum spartum*.

Desert vegetation occur in the most arid areas in Morocco, Algeria, Tunisia, Libya and Egypt (North Africa) as well as in the Middle East (Israel, Palestine, Jordan, Syria, Iraq. Iran. Saudi Arabia, Turkey and Cyprus). Plants of these deserts show a further degree of adaptation to heat and drought, few parts of the desert are entirely devoid of vegetative life, and there are more species of plants than one might expect (details of the plant life of these arid deserts are described in the following pages).

The alpine flora, on the other hand, has adapted itself to extreme cold and may be found on islands of rock even above the snow-line of the high mountains. The dominant and most common species of the alpine vegetation are: *Erigeron alpinus, Azolla procumbens, Salix retusa, Juniperus nana, Corchus vernus, Colchicum alpinum, Erica carnea* and *Leontopodium alpinum*.

In invertebrates, as in plants, the Mediterranean Basin is very rich in terms of species diversity; 75% of the total European insect fauna are found in the Basin (Baletto and Casale, 1991). However, this is a limited fraction (2%) of the world's estimated 8 million insect species (Hammond, 1995), a figure that could be overestimated. Levels of endemism are high for most groups of insects. In some isolated mountains and larger islands endemics can account for 15–20% of the insect fauna. A figure that rises to 90% in some caves.

Baletto and Casale (1991) tentatively estimated the number of insect species in the basin or 150,000 only 70% of which have been described and named. Dafni and O'Toole (1994) estimated that there are 3,000–4,000 species of bee, which makes the Basin a prominent center of diversity for this group. As many as 1,500–2,000 species of bees occur in Israel (arid land) alone (O'Toole and Raw, 1991).

Reptiles are at home in the dry, warm Mediterranean Basin and are much more abundant and diverse than amphibians. Reflecting the contrasted ecology and physiology of the two groups, the diversity of reptile species increases from north to south (and from west to east) in parallel with aridity gradients. For example, there are 20 species of reptiles in Italy (with no endemics) whereas in North Africa and the Near East the number of the reptile species are 59 and 84, respectively, out of these there are 26 endemic species in each. In contrast, amphibian species richness increases from south to north (and from east to west). Since the north-south and east-west aridity gradients favour reptiles in the southern and eastern parts of the Basin, whereas the more humid climate in the northern and western parts favour amphibians, regions that are rich in reptiles and tend to be poor in amphibians and vice-versa. The total number of amphibian species in Italy is 17 (6 are endemics) whereas in North Africa and Near East there are 12 and 15 species of amphibians with two endemics in each (Cheylan and Poitenvin, 1998).

Covas and Blondel (1998) reported that judging from the great number of bird-watchers who visit the Mediterranean each spring and summer, the diversity of their quarry must be very high. There may be as many as 366 bird species, there compared to only 500 for the whole Europe.

Three groups of avi-fauna are clearly dominant in the Mediterranean Basin. The largest includes 144 northern species characteristic of the forests, freshwater marshes, and rivers all over western Eurasia. The second consists of 94 steppe species most of which presumably evolved in the margins of the current Mediterranean area, notably in the "eremic" Saharo-Arabian region extending from Mauritania eastwards across North Africa, the Red Sea and the Arabian Peninsula and on to the semi-deserts of southern Asia. The third group encompasses species more or less linked to shrubland habitats, the so-called matorrals. Good examples are the partridge (*Alectoris* spp.) and the many species of warbliers (*Sylvia* spp. and *Hippolais* spp.). Given the extent and diversity of shrubland formations in the Mediterranean Basin, the number of bird species of this group is surprisingly small (42 species, or 11.5% of the regional bird fauna).

A low level of endemism is a characteristic feature of the avi-fauna of the Mediterranean Basin. Only 64 species (17% of the total) are endemics. This appear to have evolved, within the geographic limits of the Basin (Covas and Blondel, 1998).

The terrestrial mammal faunas of the Mediterranean Basin (approximately 197 species, 25% of which are endemics) are distributed within the four quadrants of the Basin as follows (Cheylan, 1991):

The richest are 106 species that occur in the eastern part, including 23 of Asian species that do not occur elsewhere in the Basin, 84 species in the North Africa part, 80 species in Aegean part, and 72–77 species in the western (European) part.

The mammal faunas are sensitive to physical barriers, which means that the mammals of southern Europe, the Middle East and especially the North African are quite distinct. Although only 14 km wide, the Strait of Gibraltar has effectively isolated Europe from Africa for non-volant mammals since its opening after the Messinian Crisis[2] (Blondel and Aronson, 1999). As a consequence, mammal faunas on the northern side of the sea are basically Euro-Siberian in origin with Wild Boar (*Sus scrofa*), deer (*Cervus, Capreolus*) and the Brown Bear (*Ursus arcios*) as typical elements.

A large number of the North African mammal fauna are Afro-tropical or Saharo-Sahelian. Small shrews and rodents (*Crociduru, Mellivora, Mastomys*, and *Acomys*) colonized western North Africa, mainly Morocco from the south. Example of species of tropical origin that colonized the Near East through the Nile Valley are the genet (*Genetta genetta*), a mongoose (*Herpestes ichneumon*), the bubal antelope (*Alcephalus busephalus*), spiny mice (Acomys), large fruit-eating bat (*Rousettus aegyptiacus*) and the ghost bat (*Taphopzous nu-diventris*). Occasional vagrants to North Africa of species from the Saharo-Arabian region include the Hunting Dog (*Lycaon pictus*), the cheetah (*Aciynonyx jubdatus*) and several species of gazelles (*Addax nasomaculatus, Gazella dama* and *Oryx damah*).

The mammals, of the Mediterranean Basin include few local or regional endemics. Notable amongst these is the amazing Etruscan shrew (*Suncus etruscus*) which grows to be no more than 3.6–5.2 cm long and 1.6–2.4 g in weight (Jurgens et al., 1996). It is typically Mediterranean species lives only within the thermo- and meso-Mediterranean life zones and is widespread wherever it finds suitable habitats warm enough to allow for survival during winter. Endemic rodents include several gerbils and no fewer than eight species of voles (*Pitymus* spp.).

1.7 Habitats and Vegetation of the Mediterranean Basin Arid Lands

1.7.1 Habitats

Landscapes and landforms of the arid land (hot deserts) are, on the whole, almost identical despite differing in other aspects. Kassas (1955), Hills (1966), Adams et al.

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[2]The Messinian Salinity Crises referred to as the Messinian Event as a period when the Med. Sea evaporated partly or completely during the Messinian period of the Miocene epoch 5.96 million years ago.

(1978) and Evenari (1985) classify the habitats of hot deserts, including those of the Mediterranean Basin into fourteen types, namely: (1) Desert mountains, (2) Desert plains, (3) Alluvial fans, (4) Alluvial blankets, (5) Pediment, (6) lnselberg, (7) Drywash, (8) Dry lakes (playas), (9) Sabkha, (10) Salina, (11) Desert flats, (12) Desert pavement, (13) Badlands and (14) Sand dunes.

The following is an outline of the general characteristics of these habitats (Adams et al., 1978).

1. *Desert Mountains*. Desert mountains are usually barren and angular and exhibit primary stages in erosion and weathering. Their surfaces are washed away by rain running off the slopes in gullies or rivulets, or stripped bars by sand particles carried in the wind. The nature of the bed rocks influences their ruggedness; and bare outcrops are common. Smooth rounded surfaces, are exceptional produced by the heating-cooling process of insolation splitting shallow leaves of rock away, leaving a smooth surface. Soil is rare on desert mountains, and where it exists, it is very shallow, accumulating in pockets between rocks in fissures, and providing the only suitable medium for plant life in these mountains. Wind action is also responsible for the poor soil cover, carrying away loose particles not protected by hollows.
2. *Desert plains*. The desert mountains usually rise abruptly from the plains, of which there are three principal types (see also Section 1.8.1.5):

   (a) Hammada: The hammada/is a stone – covered plain. Wind abrasion exceeds insolation, and soil is virtually absent, because any which does accumulate is immediately blown away. The surface is thus virtually devoid of vegetation, and when any is seen, it is usually in fissures protected from the wind. The bedrock type will influence the plant colonization potential.
   (b) Reg: The surface of a reg is also flat, but is covered with rock detritus or gravel. While the wind can remove the finer particles lying between rock fragments, it cannot reach the soil protected by the larger pieces, and these areas plants can grow. The surface soils are thicker than those of the hammada plain, but unless there is adequate rainfall, plants are usually small, or only temporary inhabitants.
   (c) Erg: The erg is not as flat as either the hammada or the reg for it is the classical "sand sea", identified by its undulating surface of crests and troughs. The sand forming the surface of an erg originates in mountains, regs or hammadas, often a considerable distance away, or from neighbouring desert zones. The undulations are wind-formed and mobile as a rule. Vegetation is sparse. especially on the more mobile surfaces, but where the surface is relatively stable, plants can be found, particularly in the troughs and hollows between the crests.

3. *Alluvial fans*. Alluvial fans are formed when the streams running off the mountains in deep gorges meet the plains below. The streams carry rock detritus and alluvium, which is quickly deposited into fan-shaped structures spreading out from the foot of the mountains. A gradation of rock particle sizes is found in the fan, with the largest boulders deposited near the mountain face, and the

alluvium spread further out. The water running down the gorges flows under the boulders, so that the finer alluvium is carried along underground. Alluvial fans store large volumes of water underground, and dense vegetation can be supported. In the individual water channels, the vegetation can be even thicker. The size of the plants is regulated by the depth of the sediments and their water storage potential.

4. *Alluvial blanket*. As the number of gorges down the mountain sides increases, the number of alluvial fans multiplies. Eventually the fans unite to form a continuous layer or blanket. Being on a larger scale than alluvial fans, the alluvial blankets, which are alternatively known as "bajada", have a greater vegetation potential.
5. *Pediment*. The mountain faces, as they are weathered and eroded, gradually retreat and the surface left behind at their feet (the pediment) is a gentlyinclined bare rock, hammada-like surface. Pockets of soil are the only suitable spots for plant colonization. The pediment surface extends from the mountain face until it disappears under the alluvial blanket or fan.
6. *Inselberg*. The bases of rock rising up from a pediment or protruding above the alluvial fan, are known as inselbergs. They are also encountered on desert plains.
7. *Drywash*. The drywash goes under various other names: in the United States it is known as "arroyo" in Africa and Arabia as "wadi", in Chile as "quebrada", in China as "chap" and in South Africa as "laagte". The drywash is a water drainage channel on the surface of an alluvial fan. It can vary in width from 3 to 30 m, and according to its age it can develop a braided or detailed branching drainage system. The soils associated with a drywash are of good quality and can support large plants. Erosion by water flow is common, and the vegetation tends to be denser on the banks than in the actual beds as a result. Dry river bed is another name of drywash (Evenari, 1985) which carries water only during floods, which can be torrential but are short-lived and occur at irregular intervals.
8. *Dry lake or Playa*. In the desert plains there are occasional depressions, where rainwater can accumulate when it runs off pediment slopes. A lake bed can form in the lowest part of a desert basin, and water can persist there for several weeks (though rarely for longer) after rain. The surface of the playa is usually flat, and can support little or no vegetation. There are two distinct types of desert dry lakes:

   (a) Clay Pan or Clay Flat: This is formed in the desert valleys. When such a pan dries out, the clay surface usually cracks and eventually pulverizes. The water table tends to be well below the surface, but very deep-rooting plant species can become established, provided that they are not inhabited by poor soil or water quality.
   (b) Salt Pan, Salt Flat or Salt Playa: Although the water table is usually within 3–4 m of the surfaces in such areas, plants cannot grow because of the high

salt content of the deposits. Salt crystals are found on the surface and these are among the most hostile surfaces of the desert.

9. *Sabkha*. Sabkhas are found in desert areas which lie close to the sea, and are depressions which are not fed by either streams or run-off water. The surface of the sabkha is within –2 m of a very salty water-table, and in the dry season it is covered by a salt crust which overlies a saline bog. A sabkha usually has sand dunes on its edges. It can become flooded by the sea during high tides, or flooded by rainwater after a storm. The salt crust can be broken up during periods of desiccating winds, and the crystalized salt can be blown away to contaminate the soil in neighbouring areas. While no plants can be found growing in a sabkha, a limited range of plants can grow on the periphery, if they are able to tolerate the high level of salinity.
10. *Salina*. When a dry salt lake or playa remains moist or contains water throughout the year, it is known as a "salina". Vegetation will grow on the perimeter, but the range of species depends on the quality of the water and the soil.
11. *Desert flat*. The desert flat is found in broad valleys where the surface slopes gently between a dry lake and the alluvial deposits. The slope of a flat is 1° instead of the 7° usual for alluvial fans. The surface deposits are finer than those of alluvial fans, and are therefore very suitable for plant establishment.
12. *Desert Pavement*. A desert pavement is a type of surface which develops on desert flats, alluvial fans and alluvial blankets. It is formed when the wind blows away the sand, silt and clay deposits. The surface is almost level, and consists of rounded pebbles between 15 and 75 mm long. When the pebbles are rolled together by wind and rain, and become tightly interlocked, the surface is known as "pebble armour" or "serir". Vegetation can become established on this surface, but is sparser than that found on alluvial fan soils. Deep-rooting species are particularly well-adapted to the desert pavement surface.
13. *Badlands*. Badland scenery is usually associated with hilly or mountainous land, which has been deeply scored by gullies created in the aftermath of the occasional heavy storms. The normal rainfall is too scant to support plants, whose roots would otherwise bind the surface and stabilize the slopes. Badlands are most common in highland areas composed of soft bedrock types. Where there are harder rocks which are better able to resist erosion, these remain as tall pillars or platforms, rising above the surrounding landscape.
14. *Sand dunes*. There are four major sand dune types:

    (a) Barchan: The barchan dune is crescent-shaped, with the tails of the dune pointing downwind. It is constantly on the move, and progresses across the desert either on its own or as part of a swarm, where numbers of dunes become linked and move together.
    (b) Siefs or Longitudinal Dunes: These dunes usually run in parallel lines up to ten kilometres in length. They appear to have originated as barchans which have become temporarily anchored by a plant or group of plants. These hold down the tail of the dune enabling the free end to move on its own. The dune then coalesces with other barchans and thus forms the longitudinal

dune. Another theory is that, conversely, the barchan is formed out of a sief when the speed of the winds flowing over the sief drops and friction on the sand causes turbulence which breaks up the continuous surface into smaller crescent dunes.

(c) Transverse Dunes: Whereas the longitudinal dune is formed parallel to the wind, the transverse dune develops across its path. These dunes are either an amalgamation of barchans, or they are formed when there is more sand than can be used by a swarm of barchans.

(d) Whaleback Dunes: Very large siefs. on which both barchans and smaller siefs can develop are called whaleback dunes. They are either an agglomeration of a number of siefs, or can be considered as erosional dunes, because of the rocky surface exposed between them. Water is stored within all the large dunes as they tend to move quite slowly, and plants can be seen growing on them, with the roots reaching down to the sub-surface storage areas. Nevertheless, vegetation is sparse, and consists either of deep-rooting species, or those plants whose roots can survive in the moving surface, taking their moisture from dew.

Dunes can be classified according to size, environment, growth stage, origins, shape and wind direction. There are simple compound or complex dunes, depending on the prevailing conditions. When complex or compound dunes coalesce together into larger units still, they form a "dune field".

Not all these habitat types can be found in every dry desert. Each desert habitat has a distinct type of plant communities associated with it. The nature of the habitat determine the precise manner in which plants, and animals are able to exploit their potential.

1.7.2 Vegetation Forms

Based on the life-forms and habits of the plants forming them, Adams et al. (1978) classified the vegetation types of the Afro-Asian Mediterranean coastal deserts under the following two groups:

Group A: Ephemeral, succulent perennial and woody perennial vegetation forms or,

Group B: Accidental, ephemeral, suffrutescent perennial (undershrubs) and frutescent perennial (shrubs) vegetation forms.

These are described below:

Group A

a. Ephemeral vegetation form

Fifty to sixty percent of all desert plants are ephemerals. They have extremely short life cycles and are herbaceous, i.e. non-woody in character. Their growth is rapid:

the time from germination to death is telescoped into 6–8 weeks. Their activity has to coincide with the moist season: they deal with the dry season and drought quite simply by by-passing them altogether. Therefore, they have no need to develop xerophytic or drought-resistance properties. Their roots are shallow, they are small plants, they grow very fast and flower quickly. The seeds can remain dormant in the soil until the next important rains, and even if there is no rain for several successive years, the seeds are not damaged. 10 mm of rain may not sufficient to promote germination: some seedlings might appear after 1–5 mm of rain; germination is only completed after 25 mm of rain. However, even a cloud-burst producing 75 mm of rain may not automatically ensure germination, and from this evidence we may conclude that the seed contains some agent which inhibits germination unless the circurrtances are all favourable. Germination may also be related to the number of sunny days following rainfall, the two classes of ephemerals (winter and summer) have different temperature requirements and optima. For winter ephemerals, the optimum ranges between 15.5 and 18°C, while the optimum for summer ephemerals ranges between 26 and 32°C (Adams et al., 1978).

Ephemerals are the first colonizers of most kinds of desert terrain as their seeds may be spread by animals, insects and wind. When the plants die and decay, they are attacked by soil organisms and soil fertility is thereby gradually improved, enabling the establishment of other plant types. In good years the plants produce a larger number of seeds than are produced in poorer, drier years.

b. Succulent perennial vegetation form

The phenomenon of succulence occurs when the parenchyma or outer cells of the plant stem or leaf enlarge or proliferate. The evolution of this characteristic means that the volume of the plant's stem or leaves is increased, which enables the plant to store an increased volume of water within its structure. The deposition of a water-proofing layer of wax or similar substance on the external surface of the plant reduces the risk of loss of water from leaves or stern, and this, in combination with the cell proliferation, enables the plant to reduce its overall water requirement. Succulent perennials are either spiny, like the cacti, or non-spiny but with swollen leaves. The cacti of the American continent, the succulent euphorbias of the African dry zones and certain other succulents have a further quality which fits them to life in their dry environments: they are able to close their stomata during the heat of the day to avoid excessive loss of water through transpiration and open them during the coolness of the night instead.

c. Woody perennial vegetation form

Although ephemeral plants make up 50–60% of the total number of plants in the desert, "woody perennial" is the dominant plant type. The group is composed of a number of morphologically different forms of plants ranging from grasses and woody herbs, through shrubs to trees. They are all very hardy, for they have to cope with the major characteristics of the desert environment: drought, heat and wind.

They can be evergreen or deciduous; deciduous species can be either drought-deciduous in hot deserts and cold-deciduous in the case of the cooler deserts. They grow most actively after rain and become dormant either during periods of drought, or during the cold season. Many of the woody perennials are spiny or harsh textured (Adams et al., 1978).

The seeds of woody desert perennials have a particular germination characteristic in many cases. Many perennials produce seed which will only germinate if the seed coat is damaged in some way. This damage can occur in a number of natural ways; for instance by the action of stones and boulders pushed along wadi beds after sufficiently large volumes of water have accumulated, these stones having a grinding effect on the coats of such seeds as may be amongst them and cracking the coats open. Other seeds rely on the effects of the digestive juices in animal intestines to soften their coats, prior to germination. Once the seeds of woody perennials in the desert have germinated, they produce only a few leaves before they appear to stop growing. This is because activity shifts to the root structure, which grows deeper and deeper down into the soil, to penetrate the moister layers below. Once the roots are well-established, the plant starts to produce more leaves and expand above its surface growth (Adams et al., 1978).

Group B

It is possible also to separate the vegetation of dry lands into four major orders: accidental form, ephemeral form, suffrutescent (sub-shrub) perennial form and frutescent (shrub) perennial form. Each of these orders has a number of classes, and the predominant orders are the ephemeral form and the suffrutescent perennial form. Each contains a sequence of classes, developing from the more primitive to the more sophisticated depending on soil quality (Adams et al., 1978).

a. Accidental form

Only ephemeral plants are included in this order (though not all ephemerals are of the accidental type). Growing only when rain occurs, the formation cannot be considered permanent in any way. It is determined by extremely erratic rainfall, as is found, for example, in the Western Desert of Egypt where only 10 mm of rain can he expected every 10 years.

b. Ephemeral form

There are three categories in this group: succulent-ephemeral, ephemeral grassland, and herbaceous ephemerals. When any of these are found, rainfall is known to occur annually. The plants are ephemeral in the main, but perennials can be found occasionally. There is therefore some moisture, but because the soils are not water-retentive, it does not last throughout the year. As aridity decreases and rainfall regularity improves, the ephemerals become displaced by perennials.

(i) *Succulent-ephemerals*

The growing season for succulent ephemerals is longer than the 6–8 weeks typical of the non-succulent ephemerals, for they have the ability to store some moisture in their tissues. They can tolerate the severe conditions prevalent in soils that develop on erosion pavements, such as pediments, regs and hammadas.

The typical plants can be further sub-divided into three types: winter ephemerals summer ephemerals, and salt-marsh ephemerals.

1. *Winter ephemerals* growing after winter rains such as in those deserts influenced by the Mediterranean climatic types. The species involved include: *Aizoon canariensis, Aizoon hispanicum, Mesembryanthemum crystallinum, M. forsskaolii, M. nodifiorum, and Zygophyllum simplex.*
2. *Summer ephemerals* growing after summer rains such as in areas influenced by the Indian Monsoon or tropical climate systems. Typical species include: *Salsola inermis*, *S. kali* and *S. volkensii*.
3. *Salt-marsh ephemerals* include: *Halopeplis amplexicaulis* and *Salicornia herbacea*.

(ii) *Ephemeral grasslands*

This form can develop into grassland over large stretches of ground, and in particular on shallow sand drifts. The predominants include species of: *Aristida, Bromus, Cenchrus, Eragrostis, Poa, Schismus, Stipa* and *Tragus*.

(iii) *Herbaceous ephemerals*

These herbaceous ephemeral plants are only found on soft deposits in good locations, where a water supply is preserved even if for only a short while, and include: *Bassia muricate, Caylusea hexagyna, Schouwia thebaica, Tribulus terrestris* etc.

c. Suffrutescent perennial (sub-shrub) forms

This is the most wid-spread form occurring where there is a permanent flora of perennial species, and it includes a perennial grassland form. There are three layers: a suffrutescent layer 300–1,200 mm high, a grassland layer of the same height and a ground layer. The suffrutescent flora usually predominates, and the ground layer of dwarf and prostrate perennials is sometimes augmented by some ephemerals.

(i) *Succulent sub-shrubs*

These plants have evolved sufficiently to have an internal moisture reserve system. Where salt-marsh communities are found, the dominants include species of: *Arthrocnemum, Salicornia, Suaeda, Anabasis, Hammada,* and *Zygophyllum.*

(ii) *Perennial grassland*

Soils which are capable of storing some water are the habitats of these plants. They are particularly valuable for sand-sheet and sand-dune stabilization, and the different soil types encourage different plant associations. This type is dominated by, for example, *Hyparrhenia hirta, Lasiurus hirsutus, Panicum turgidum, Pennisetum dichotomum* and *Poa sinaica*.

(iii) *Woody perennials*

This order is a transitional order falling between the succulent and the grassland forms. Plant cover is always thin, in particular in the more arid locations and many of the species which grow on rocks-the chasmophytes and rhizophagolithophytes – are included here.

d. Frutescent perennial (shrub) forms

This form is typical of all the vast desert scrublands. There are three layers: frutescent (1,200–3,000 mm) suffrutescent (below 1,200 mm) and ground.

(i) ***Succulent perennials***

The cacti of the American deserts, and the succulent Euphorbias of tropical Africa and Arabia are part of this category. The saxaul, *Hammada persicum*, is also included.

(ii) ***Scrublands***

Scrubland can only be found in good locations where there is adequate soil and rainfall, and where there are mountains around to supply runoff water. Scrubland indicates the highest level of water reserves available in the desert, and is particularly relevant to semi-arid areas. The dominant plants include species of: *Acacia, Pistacia, Prosopis, Retama, Tamarix* and *Ziziphus.*

1.8 Environment and Plant Life of the Afro-Asian Mediterranean Coastal Lands

Climatic aridity, as stated before, affects wide areas of the Mediterranean Basin particularly in the Mediterranean territories of the North African and SW Asian countries. The European Mediterranean section, however, is mainly located in the humid and hyper-humid Mediterranean bioclimatic provinces with only very small parts of the Spanish and Italian territories only under the influence of arid climate. The following pages will describe the environment and plant life of the arid zone lands of the North African and South West Asian regions of the Mediterranean Basin.

1.8.1 North African Mediterranean Coastal Lands

1.8.1.1 Landforms

The region of North Africa extends along the southern Mediterranean. According to the World Atlas of Desertification (UNEP, 1992), Africa north of the Sahara includes Morocco, Algeria, Tunisia, Libya and Egypt, plus Western Sahara and Cape Verde. This is an area of 545.3 million hectares; 98.3% of which are drylands vulnerable to desertification and the hazards of drought. Hyper-arid territories represent 70.6% of the total area (Kassas, 1996).

Aridity and geographical location of the North African region have a prominent effect on its biological element that rival these of the tropics in importance.

The region is the home of the wild relatives of many food crops, medicinal plants and feed for animals. However, the biological diversity is continuously deteriorating in view of the human population explosion, modernization and innumerable human activities using improper technologies. Batanouny (1996) stated "One should consider the loss of say 10 species from the flora or fauna of the desert ecosystem is relatively, drastic and considerable as compared to the biomes with greater species richness". From an ecological point of view, the North African countries represent a transition from the Mediterranean climate to the Saharan one. This has a remarkable impact on the bio-diversity and its distribution along the climatic gradient from north to south.

Morocco, the most westerly of the Arab states of North Africa, extending from the Peninsula of Ceuta in the north to the borders of Spanish Sahara in the south. To the east and southeast it is bounded by Algeria; while to the west and north lie the Atlantic Ocean and the Mediterranean Sea. The total area of Morocco is 714,000 km^2 out of which 77% is under the influence of climatic aridity, 15.4% semi-arid and 7.6% humid and mountainous (Batanouny and Ghabbour, 1996).

The physical geography of the Moroccan territory is complex ranging, for example, from low, flat plains such as the Rharb to the wild and rugged grandeur of the Rif and the high Atlas.

Two major series of mountain ranges – a northern and southern – partially enclose a triangular plateau which has its base along the coast between Rabat and Essaouria and which is sometimes known as the Moroccan Meseta. To the south and south-east of the Meseta the most prominent feature is the high Atlas range, which extends north-southwards from the coast near Agadir. The ranges are cut off sharply at the coast, giving rise to very dramatic cliffs and headlands. The highest point in Morocco rises to 4,165 m (Branigan and Jarrett, 1975).

Algeria extends for a distance of about 1,000 km along the Mediterranean coast between Morocco and Tunisia. It has total estimated area of about 2,224,000 km^2, the largest of the territories of north-west Africa. The greatest part of Algeria (1,897,000 km^2) lies in the Sahara Desert and a substantial part actually lies to the south of the Tropic of Cancer.

Tunisia is by far the smallest of the North African countries with a total area of 164,000 km^2. About half of this area is desert, or at least semi-desert which occurs largely in the rain shadow of the Atlas. While the annual rainfall at, for example Casablanca is about 406 mm, at Gabes, which lies in approximately the same latitude, the corresponding figure is just over 167 mm.

Libya is almost entirely a Saharan country, and only along the coastal strip does a variation of the Mediterranean type of climate occur. Libya (total area = 2,105,000 km^2) is characterized by a remarkably smooth coastline with two most prominent features being the Gulf of Sirte which thrusts southwards almost to latitude 30°N and the E1-Maij Peninsula which sweeps northwards to the east of the gulf around Al-Gabal Al-Akhdar. The greater part of the main plateau of Libya carries deserts of the varying types (hammadas, reg, erg etc.).

Egypt occupies the northeastern corner of the North Africa region. It is roughly quadrangular, extending about 1,073 km from north to south and about 1,229 km from east to west. Thus the total area of Egypt is little more than 1,000,000 km^2 (1,019,600 km^2) occupying nearly 3% of the total area of Africa (Ball, 1939; Said, 1962; Zahran and Willis, 1992). Out of this area, the Sinai Peninsula, the Asian part of Egypt, occupies about 61,000 km^2 in the northeast.

Egypt is bordered on the north by the Mediterranean Sea, on the south by the republic of Sudan, on the west by Libya and on the east by the Red Sea and the Gulf of Aqaba. It extends over about 10° latitudes being bounded by latitude 22 and 32°N, i.e. lies mostly within the temperate zone, less than a quarter being south of the Tropic of Cancer. The whole country forms part of the great desert belt that stretches from the Atlantic across the whole of North Africa through Arabia. The Mediterranean coast of Egypt extends for 970 km from Sallum eastward to Rafah in three sections: the western coast (550 km), the middle (deltaic) coast (180 km) and the eastern (Sinai) coast (240 km) (Zahran and Willis, 1992).

1.8.1.2 Climate

The North African Arid Zone by and large has a Mediterranean climate characterized by winter rains and long dry summers. Monod (1937) divided it into two zones: arid and desert. The Arid Zone is defined here as having steppe vegetation distributed in a continuous and diffused pattern whereas the Desert Zone has large tracts of barren land with shallow soils, its perennial vegetation being confined to the run-off networks and laid out in clustered "contracted" pattern. The limit between the two zones is approximately the 100 mm isohyet. The upper limit of the steppe vegetation is approximately the 400 mm isohyet. Thus, as a first approximation one has the very simple definitions: Desert Zone < 100 mm <Arid Zone < 400 mm. The areas of these zones in the five countries of the North Africa are shown in Table 1.4.

The following is a description of the different climatic particulars of the North African region.

(i) Rainfall

The average annual precipition varies from almost zero in the most aird part of the Sahara to 400 mm at the northern edge of the Arid Zone. Examples of the monthly and annual averages in Desert and Arid Zones are given in Table 1.5. It is clear

Table 1.4 Areas of arid and desert zones in North African countries (after Le Houerou, 1985)

	Non-arid		Arid		Desert		Arid+desert		
Country	Area	%	Area	%	Area	%	Area	%	Total area
Morocco	197	31.7	120	19.3	303	49	423	68.3	620
Algeria	181	7.6	200	8.4	2,000	84	2,200	92.4	2,381
Tunisia	37	23.9	55	35.4	63	40.7	118	76.1	155
Libya	5	0.2	90	5.1	1,665	94.7	1,755	99.8	1,760
Egypt	0	0.0	30	3.0	970	97.0	1,000	100	1,000

Table 1.5 Average monthly and annual rainfall (mm) in the desert and arid zones of the North African countries (after Dubief, 1963)

Country	Zone	J	F	M	A	M	J	J	A	S	O	N	D	Year
Morocco														
– Boudnib	DZ	5.4	4.2	11.1	8.2	4.2	4.7	0.9	6.9	10.6	17.2	12.7	13.8	99.9
– Tarfaya		6.8	4.4	3.0	0.5	0.1	0.0	0.0	0.2	5.3	1.1	12.9	8.9	43.0
– Marrakech	AZ	24	30	17	33	15	7	2	3	10	20	34	27	242
– Agadir		37	28	29	20	4	1	0	0	6	21	40	43	226
Algeria														
– Bechar	DZ	7.0	7.2	12.7	7.5	2.3	2.9	0.4	3.6	6.6	13.8	11.6	9.6	85.25
– In Salaf		2.9	0.8	2.1	1.1	0.3	0.1	0.0	0.7	0.1	1.3	2.3	33.9	15.6
– Aflo	AZ	31	33	38	32	28	20	9	11	24	45	30	33	342
– Ain Sefra		10	10	14	9	15	28	8	7	15	29	29	18	192
Tunisia														
– Tozeur	DZ	10.0	8.3	13	10	5.0	3.0	0.2	2.0	7.0	9.0	12	10	89
– Fort Sait		6.7	3	4.1	1.3	2.7	1.0	0.0	0.0	1.5	2.4	4.1	4.0	30.8
– Sousse	AZ	43	34	30	22	18	6	1	5	50	43	37	38	327
– Gabes		22	17	21	10	9	1	0	2	14	30	34	15	175
Libya														
– Bani Walid	DZ	6.7	3.7	8.3	6.0	5.6	0.3	0.0	0.0	7.0	8.5	7.0	14.4	71.0
– Sabha		2.0	2.0	0.8	0.6	0.2	0.0	0.0	0.0	0.0	0.7	0.2	0.0	8.0
– Triopoli	AZ	61	34	26	15	5	1	0	0	15	37	43	76	313
– Sirt		42	28	13	3	2	1	0	0	7	16	26	34	172
Egypt														
– Port Said	DZ	18	12	9	5	3	1	0	0	0	3	11	16	78
– Cairo		5	4	4	2	2	0	0	0	0	2	2	4	25
– Alexandria	AZ	48	24	11	3	2	0	0	0	1	6	33	56	184
– Sallum		38	4	5	0	7	0	0	0	1	4	29	27	132

DZ = desert zone, AZ = arid zone.

that in the Arid Zone there are two gradients of variation in the amount of average rainfall: a latitudinal gradient and altitudinal gradient. The latitudinal gradient is positive northwards whereas the altitudinal gradient is usually of the order of 10–12% per 100 m difference of altitude. The latitudinal gradient varies from 0.25 to 1.0 mm/km since rains increase from 100 mm in the south at the edge of the desert zone to 400 mm at the northern limit of the Arid Zone. Altitudinally, rainfall doubles for an increase of 800–1,000 m in elevation. In the Desert Zone there are three gradients: latitudinally, longitudinally and altitudinally. The latitudinal gradient is similar to that of the Arid Zone rains decrease from north to south with an absolute minimum on the Tropic of Cancer (23° 27′N), close to zero. The gradient is of the order of 0.15–0.33 mm per kilometre, or 16–36 mm per degree of latitude between the 10- and 50-mm isohytes; it is steepest in the Gulf of Sirte and most gradual in southeastern Algeria. The longitudinal gradient is less obvious, but there is, by and large, an increase in aridity from west to east, from the Atlantic Ocean to the Red Sea; the eastern Sahara (Libyan Desert) between 15 and 32°E is virtually rainless.

The altitudinal gradient in the Saharan mountains is slightly less than in the Arid Zone.

In the *Arid Zone*, rains occur from September or October until April or May. However, there are four different regimes according to: (1) whether or not there are significant summer rains, and (2) if summer rains are negligible, whether the maximum occurs in autumn, winter or spring.

The first regime with summer rains occurs at higher elevations above 1,000–1,500 m in the highlands of Algeria and Tunisia. Summer rain may amount to 10–20% of the total amount (Aflou and Laghouat in Algeria: Kasserine and Sbeitla in Tunisia).

The three other regimes have a sharp summer minimum, close to zero, but a maximum in the autumn, usually in the lowlands; in spring in the highlands; and in winter in the eastern part of the region (Libya-Egypt) where 50% or more of the annual total falls in December and January.

There are thus: (a) an eastern regime with winter maximum; (b) a highland regime with spring maximum and (c) a mountain regime with summer rains.

In the *Desert Zone* it is something of an exaggeration to speak of seasonality of rainfall; however, one can distinguish several trends. A typical Mediterranean regime exists in the north with no summer rains. To the south of the 25th parallel there is a clear tropical trend with summer rains amounting to 25–50% of the annual total.

As in all arid zones in the world, interannual variability is inversely related to the annual average. At the upper limit of the Arid Zone (the isohyet of 400 mm) the maximum rainfall observed in any particular year is 4–5 times the minimum, and the coefficient of variability is of the order of 40%. At the border of the desert the maximum reaches 10–12 times the minimum and the coefficient of variability is of the order of 60–80%. Monthly variations are still higher and any particular month in any particular year may be abnormally rainy or absolutely dry, and there is no correlation between consecutive months. Thus, rainfall is totally unpredictable, unlike the dry tropics, where rains usually occur in a single well-determined short season. In the desert, variability is generally over 60%. However, in the southern Sahara, under a tropical regime, variability is usually much lower. Besides temporal variability of rainfall, there is also in arid lands a very great spatial variability, because rain-storms are highly local in their incidence. This has been observed by many authors (e.g. Kassas and Imam, 1954, 1959 in Egypt, and Evenari et al., 1971, 1982 in Israel).

(ii) Temperature

The mean annual temperature varies between 17 and 20°C along the coast, from 18 to 22°C in the Arid Zone and from 20 to 25°C in the Sahara. From an ecological point of view the most important data are the mean minimum of the coldest month, $\overline{m}$, and the mean maximum of the hottest month, $\overline{M}$. Since these data best characterize the normal thermal environment for plant and animal life. These temperatures are quite variable according to latitude, altitude and continentality. The mean minimum temperature of the coldest month (January) varies from 10°C on the seashore of southern Morocco and northern Libya to –2°C in the arid highlands of Morocco and Algeria. Vegetation is particularly sensitive to $\overline{m}$ since this parameter is closely linked to frost and to the length of the winter rest period of plants. From the systematic study of plant communities and crop performance the following thermal thresholds have been selected (Le Houerou, 1970, 1975) that are now often used in the climatic classification of the region:

- $\overline{m} > 9$°C: no frost at ground level, very warm winters; no rest period for vegetation.
- $9 > \overline{m} > 7$: no frost under shelter, warm winters, no rest period for vegetation.
- $7 > \overline{m} > 5$: 5–10 days of light frost under shelter, mild winters, virtually no rest period for vegetation.
- $5 > \overline{m} > 3$: 10–20 days of light frost, temperature winters, rest period of 1–2 weeks for vegetation.
- $3 > \overline{m} > 1$: 20–30 days of forst, cool winters, rest period of 2–4 weeks for vegetation.
- $1 > \overline{m} > -2$: 30–60 days of serious frost, cold winters, rest period of 1–3 months for vegetation.
- $-2 > \overline{m} > -5$: 60–120 days of hard frost, very cold winters, rest period of 3–5 months for vegetation.

The value of $\overline{m}$ decreases with elevation at a rate of about 0.5°C per 100 m of difference of level.

Very warm winters occur in the southern and western Sahara: this explains why many tropical species (both plants and animals) are found in southern Morocco. Cool and cold winters occur only in the highlands of Tunisia. Algeria and Morocco-cool above 600 m and cold above 1,200 m. The larger part of the region lies within the range of mild and temperate winters.

The average maximum of the hottest month, $\overline{M}$, is much less variable: 30°C in a narrow strip along the coast 35–38°C in the hinterland and 40–45°C in the Sahara: nowhere does it reach 46°C. The hottest parts are in southern Algeria (Adrar 45.6°C, Aoulef 44.7°C and Salah 44.7°C) and not in the Libyan–Egyptian desert as one might expect (Dakhla 38.5°C, El Kharga 39.4°C, Al Kufrah 39.1°C). The absolute maximum ranges from 45 to 55°C in the Sahara. The highest shade temperature ever measured anywhere on earth seems to be at AlAziziah (Libya) where on September 3, 1922 it attained 58°C.

(iii) Relative humidity

The diurnal average relative humidity exceeds 70% throughout the year on the coasts. In the interior Arid Zone it is of the order of 60–65% in winter and 35–40% in summer. In the Sahara it reaches 40–55% in winter and drops to 20 or 25% in summer.

(iv) Hot winds

Hot winds, to which special local names have been given – *sirocco*. *ghihli*, *chergui*, *khamsin* etc. – blow with a frequency of from 20–90 days/year, especially in spring and autumn. The temperature of the air ranges from 35 to 45°C and the humidity drops to between 5 and 15% during these dry spells. When they occur in spring these hot winds are very detrimental to crops and native vegetation, which may dry out in a very few days annihilating the hopes for a good crop or lush grazing resulting from a favourable rainy season.

(v) Evaporation and evapotranspiration

Evaporation is of the order of 2,200–2,500 mm/year in the Arid Zone and 2,500–3,000 mm/year in the Desert Zone. Potential evapotranspiration is of the order of 1,400–1,600 mm/year in the Arid Zone and 1,600–2,200 mm/year in the desert.

1.8.1.3 Geomorphology

The Arid Zone of North Africa provides classic examples of arid-land geomorphology. The ranges of hills and mountains of the Atlas Chain, show erosion forms in accordance with their structure and lithology. These ranges are separated by wide synclines in which are developed four huge Quaternary pediments often covered by a thick calcareous crust of Early and Middle Pleistocene age. As endomorphism is the general rule, the lower parts are occupied by Quaternary alluvia which are often saline.

The Sahara presents four main types of land forms:

(1) Rocky or stony hills with steep slopes.
(2) The *regs* (also called *serirs* in the eastern Sahara). which are gravelly-pebbly desert pavements covering subhorizontal plains denuded by aeolian erosion. These regs may have various origins: flat structural surfaces of rather soft rocks; old pediments reshaped by aeolian erosion; coarse alluvial deposits of detritus.

They are therefore classified as "autochthonous" and "allochthonous" (Monod, 1937).

(3) The hammadas are structural surfaces, more or less flat, covered by large flagstones of limestone, sandstone or basalt.

(4) The ergs or sand seas are bodies of dunes of various sizes and shapes from the small crescentic very mobile *barkhans* to the huge fixed *ghourds* 50–200 m high, with the intermediate *elb*, and *silk*. Soft sandstones are often curved in *yardangs* especially in the southeastern Sahara (Mainguet, 1972).

The rocky mountains and hammadas represent 10% of the desert area (0.5 million km^2), the regs cover some 68% (3.3 million km^2), and the ergs occupy 22% (1.1 million km^2).

1.8.1.4 Soils

In the Arid Zone mature soils are exceptional and are found only under little-disturbed vegetation in protected areas (Le Houerou, 1985).

One can first distinguish the soils under open forest or woodland of *Pinus halepensis* or *Juniperus phoenicea*. On soft or hard limestones, these are usually shallow, of the rendzina type, with 3–5% (exceptionally 5–10%) of organic matter in the top layers. On marls and shales, soils are of the brown calcareous type, with a deep layer of accumulation of calcium carbonate: exceptionally they may be vertisols. Red or brown mediterranean soils are to be found on karstic limestone plateaux, for instance in eastern Libya.

Under steppe vegetation the mature soil is of the isohumic type with 2–3% of organic matter; the organic matter content decreases progressively with depth. There is often a layer of accumulation of calcium carbonate below 50 cm from the surface. There are huge areas of Pleistocene calcareous crusts on the pediment. These give way to shallow soils.

Depressions are filled with alluvia of various nature (sandy, silty, loamy and clayey). Many depressions have saline or alkaline soils, with a shallow saline water table and are covered with halophytic vegetation, mainly of Chenopodiaceae.

From a chemical viewpoint, the soils are usually alkaline with pH from 7.5 to 9.0. Calcium carbonate content is high. Sulphates are common, especially gypsum, and sodium chloride is almost always present. Phosphorus and potassium are, in general, adequate for plant growth but nitrogen is usually deficient. Trace-element deficiencies have been reported very rarely. From an ecological and agronomic point of view the main soil factor to be considered in the Arid Zone is the moisture regime which is closely related to ecosystem structure and productivity. In this respect the most significant soil characteristics are: (a) topographic or geomorphic position (run-off or run-on): (b) texture [permeability of the upper layer (water intake), infiltration rate, field capacity etc.]: (c) depth (storage capacity); and (d) toxicity.

The good productive soils are those which are able to store water during the short rainy periods, and to release it afterwards to the vegetation or crops during the long dry spells – that is soils which owing to their hydrodynamic characteristics are able to reduce the effects of drought.

1.8.1.5 Plant Life

The flora and vegetation of the Arid and Desert Zones of North Africa has been studied in depth since seventeenth century, e.g.: Zanoni (1675), Spottswood (1696), Shaw (1738), Poiret (1789), Vahl (1790–1794), Desfontaines (1798–1800), Broussonet (1795–1801), and Schousboe (1801a, b). The four volumes of Flora Atlantic by Desfontaines were published between 1798 and 1800 and included not less than 1,500 species. The bibliography now amounts to several thousand publications which include Oliver (1938), Tadros (1949), Hassib (1951), Kassas (1952), Täckholm (1956, 1974), Quezel (1965), Sauvage (1954), Monod (1958), Keay (1959), Le Houerou (1959, 1975, 1985, 1992), Meigs (1966), Ayyad (1973), Batanouny (1973), Ayyad and El-Ghareeb (1982, 1984), Zahran (1982a), Zahran et al. (1985), Zahran and Willis (1992), Dallman (1998) and Blondel and Aronson (1999). The location of the region at the contact between three continents and three floras: Eurosiberian, Mediterranean and Sudano-Decania (Palaetropical) makes its flora much richer and varied than one might expect. From the point of view both of flora and vegetation we may distinguish four different zones: a Mediterranean Arid Zone, a Mediterranean Desert Zone in northern Sahara and the higher mountains of the central Sahara, a Sahara-Sindian Desert Zone in the central Sahara and a Sudano-Deccanian Tropical Desert Zone in the southern and south-western Sahara (Le Houerou, 1992).

I. Phanerogams

Approximately 3,000 species of the flowering plants have been recorded in the different habitats of the North African Mediterranean region with about 50% in the Arid Zone and 50% in the Desert Zone. However, as the Desert Zone is 10 times larger than Arid Zone, it means that the former is substantially poorer in species than the latter. For example, in Egypt (Boulos, 1995), there are 1,095 species in the Arid Zone with surface area of only 10,000 km^2 whereas the Desert Zone with surface area of 990,000 km^2 comprises 990 species. The origin of the flora of the region is mostly Mediterranean to the north, Tropical to the south and Sahara-Sindian in the central Sahara.

Ozenda (1958) estimated that in the central Sahara the percentages of the various elements to be: 28% (Mediterranean), 47% (Sahara-Sindian), 17% (Tropical) and 8% (Pluriregional). In the southwestern Sahara these proportions are (Monod, 1958): 4, 14, 62 and 20%, respectively.

From the systematic point of view, the flora of the Arid Zone habitats of the North African Mediterranean region include some 600 genera. The number of species per genus average about 2.5% in the Arid Zone and 1.7% in the Desert Zone (Le Houerou, 1959). Some 100 families are represented, the main ones being the Asteraceae, Brassicaceae, Fabaceae, and Poaceae which together account for 40% of the flora. Other important families are: Apiaceae, Boraginaceae, Caryophyllaceac, Chenopodiaceae, Cistaceae, Euphorbiaceae, Geraniaceae, Lamiaceae, Polygonaceae. Rubiaceae, and Scrophylariaceae which together cover a further 40%.

The main genera, listed in decreasing order of number of species, are *Astragalus, Helianthemum, Silene, Linaria, Euphorhia, Centaurea, Ononis, Erodium, Galium, Medicago, Plantago, Bromus, Aristida, Stipagrostis, Rumex, Trifolium, Convolvulus, Atriplex, Cyperus, Salsola, Fagonia, Tamarix, Launaea* and *Reseda.*

Endemism is high: about 300 species (that is, 10% of the flora) of which half are found in the western part of the region (Mauritania, Morocco and Algeria), and half in the eastern part (Tunisia, Libya and Egypt). There are some forty endemic genera, mostly found in the Sahara north of the twentieth parallel. They include: *Ammodaucus, Ammosperma, Argania, Battandiera, Chlamidophora, Cladanthus, Eremophyton, Foleyola, Fredolia, Gaillonia, Koniga, Lifago, Lonchophora, Mecomishus, Megastoma, Monodiella, Muricaria, Nucularia, Oudneya, Pegolettia, Perralderia, Pscuderucaria, Randonia, Rhetinolepis, Rupicapons, Saccocalyx, Spitzelia, Stephanochilus, Tourneuxia, Traganopsis,* and *Warionia* (Le Houerou, 1985).

The southern Sahara is characterized by tropical families such as: Apocynaceae, Asclepiadaceae, Caesalpiniaceae, Capparidaceae, Celastraceae, Menispermaceae, Mimosaceae, Moraceae, Nyctaginaceae, and Zygophyllaceae whereas typical Holarctic families almost disappear: Apiaceae, Brassicaceae, Caryophyllaceae, Chenopodiaceae and Rosaceae.

Tropical genera well represented include: *Abutilon, Acacia, Althaea, Balanites, Boerhavia, Boscia, Cadaba, Calotropis, Cassia, Chloris, Commicarpus, Corchorus, Enneapogon, Fagonia, Ficus, Glossonema, Grewia, Hibiscus, Hyparrhenia, Hyphaene, Indigofera, Lasiurus, Leptadenia, Maerua, Melhania, Oropetium, Pentzia, Rhynchosia, Salvadora, Schoenefeldia,* and *Tephrosia*.

II. Cryptogams

The cryptogamic flora is not very well known, approximate number is shown in Table 1.6.

The total number of cryptogamic species known is thus 1,311 – that is, 22% of the number of phanerogams, which is much less than in temperate climates where cryptogam species are more numerous than phanerogams.

III. Main vegetation zones

In relation to the main bioclimatic sub-zones prevailing in the North African Mediterranean region, Le Houerou (1992) described eight vegetation zones, namely: the upper arid subzone, middle arid subzone and lower arid subzone (Arid Zone), upper desert subzone, middle desert subzone, lower desert subzone (Desert Zone) in addition to the two zones in the True Desert Zone and the Saharan mountains. The following is a short description of each of these vegetation zones:

Table 1.6 Number of species of the six cryptogamic groups (from Le Houerou, 1992)

Group	Species number
1. Algae	
a. Cyanophyceae	45
b. Xanthophyceae	300
c. Chlorophyceae	73
2. Fungi	60 (of which 30 are free-living)
3. Lichens	90
4. Mosses	702
5. Liverworts	20
6. Vascular cryptogams	
a. Ferns	20 (oasis and mountains)
b. Horsetail	1

A. The arid zone

This zone corresponds with the arid Mediterranean climate, having average annual rainfall ranging from 100 to 400 mm: it is divided into upper, middle and lower arid sub-zones.

a. *Upper arid subzone*

The primeval vegetation is forest along the coast in the warm and mild winter (varieties of the climate, $m > 5°C$) dominated by *Tetraclinis articulata* or *Juniperus Phoenicea*, with tree and shrub species: *Ceratonia siliqua. Chamaerops humilis, Olea europaea, Periploca laevigata, Pistacia lentiscus, Rhus pentaphyllum*, and *Withania frutescens*. In western Morocco *Argania sideroxylon* is codominant with *Tetraclinis* (Safi and Essaouira areas). In eastern Libya *Tetraclinis* is absent and the dominant species is *Juniperus phoenicea* with some remnants of *Arbutus pavarii, Ceratonia siliqua, Cistus* sp. *Cupressus sempervirens, Pistacia lentiscus, Olea europaea* etc. In the hinterland of the cool and cold winter varieties of the climate ($m < 5°C$) the primeval forest is dominated by *Pinus halepensis* with a number of companion species, such as: *Artemisia atlantica, Calycotome villosa, Capparis spinosa, Coridothymus capitatus, Cistus libanotis, Juniperus oxycedrus, Phillyrea media, Pistacia atlantica, Retama sphaerocarpa, Rhus tripartitum, Stipa tenacissima,* and *Thymus hirtus*.

Only about 70,000 ha of this zone can be classified as forest; 2 million hectares are covered by evergreen open bushland or shrubland of the garigue type. This garigue vegetation is mostly located on the shallow soils of the hills of the Arid Zone. On the pediments and plains it has almost everywhere, been cleared for grazing and/or cropping. This generalized deforestation has resulted in an extension of steppe vegetation over huge areas (Quezel, 1985; Le Houerou, 1959, 1969a). This change is supported by evidence from prehistorical, historical and present-day data drived from palynology, geographic descriptions from antiquity through the nineteenth century, and modern surveys using remote-sensing techniques, via, sets of aerial photographs taken several years or decades apart. The resulting steppe vegetation is kept more or less stable by heavy and permanent pressure from livestock. The main steppic vegetation types resulting from deforestation are the followings:

(i) *Alfa grass (*Stipa tenacissima*) steppe* is usually located on shallow soils (hills and pediments with a superficial thick calcareous crust) and results from deforestation by woodcutting and burning, without cultivation. *Stipa tenacissima* is a forest species which can only regenerate in the shade (Le Houerou, 1969a). In the steppe it survives only by rhizomatous expansion of its tussocks. The species cannot withstand cultivation for more than 2–3 years. Alfa grass steppes occupied some 12 million ha at the end of the nineteenth century, but has now reduced by about 50% owing to over-exploitation (alfa grass is exported for high-quality paper), repeated burning for grazing, and clearing for cultivation. In Tunisia, for example, the area of alfa grass steppe has reduced by an average of 10,000 ha/year since the beginning of this century. The mechanism of this degradation of vegetation and soil was described in detail by Le Houerou (1969a, b) as part of the general process of steppization. The main companion species of alfa grass in the upper arid bioclimatic zone are: *Artemisia campestris (*sandy soils*), A. herba alba (*silty soils*), Astragalus incanus* subsp. *nummularoides, Atractylis humilis subp. caespitosa, A. serratuloides (*shallow soils*), Avena bromoides, Centaurea tenuifolia, Dactylis hispanica, Fumaria ericoides, F. thymifolia, Helianthemum cinereum* subsp. *rubellum, H hirtum, H virgatum* subsp. *ciliatum, Hippocrepis scabra, Phagnalon rupestre, Pituranthos scoparius, Stipa parviflora,* and *Thymus hirtus*.

Degradation of the alfa grass steppe in turn leads to various chamaephytic steppes. The most widespread of these is the type dominated by *Artemisia herba-alba*.

(ii) Artemisia herba-alba *steppes* cover huge areas of silty soils. and are among the best Arid Zone pastures in the region. This type of steppe is found from Spain throughout the whole of North Africa to the Near and Middle East (Syria, Israel–Palestine, Jordan, Iraq, Iran. Afghanistan). Soils are always silty, with often a hard pan of calcium carbonate between the surface and a depth of 100 cm. The usual companion species are: *Ajuga pseudoiva, Anabasis oropediorum, Asteriscus pygmaeus, Astragalus armatus (*gypseous soils*), Atractylis humilis* (highly calcareous soils), *A. serratuloides* (shallow soils), *Carrichtera annua, Eruca vesicaria, Eryngium dichotomum, E. ilicifolium, Lygeum spartum* (gypseous soils)*, Noaea mucronata* (shallow soils)*, Matthiola fruticosa, Plantago ovata, Poa bulbosa, Salsola vermiculata* var. *villosa* (gypseous and slightly saline soils)*, Stipa capensis, and S. parviflora* (shallow soils).

When the *Artemisia herba-alba* steppe is cleared for cultivation and then abandoned it gives way to a post-cultivation steppe characterized by the dominance of *Artemisia campestris* and *Cynodon dactylon* which, after a period of 5–10 years, returns to the *Artemisia herba-alba* steppe.

(iii) *Sandy Steppes* of *Artemisia capestris* are derived also from evergreen bushland or shrubland, but on sandy soils. The co-dominant species are: *Alkanna* *tinctoria, Anacyclus cyrtolepidioides, Argyrolobium uniflourm, Astragalus caprinus, Carduncellus pinnatus, Centaurea dimporpha, Cutandia divericata, Dianthus crinitus, Echinops spinosus, Echiochilon fruticosum, Eragrostis papposa, Eragrostis trichophora, Hedysarum spinosissimum, Helianthemum sessiliflorum, Launaea resedifolia, Lotus creticus, L. pusillus, Minuartia geniculata, Plantago albicans, P. colorata,* and *Stipa lagascae*.

b. *Middle arid subzone*

The primaeval vegetation is still an evergreen open forest or bushland of *Juniperus phoenicea* with some of the dominant species of the Upper Arid Subzone, such as *Cistus libanotis, Olea europaea, Rhamnus lycioides*, and *Rosmarinus officinalis*. However, the floristic composition is different, with an increased number of Arid Zone species such as: *Coridothymus capitatus, Celsia ballii, Centaurea tenuifolia, Fagonia cretica, Genista microcephala, Launaea acanthoclada, L. arborescens, Pituranthos scoparius, Reseda duriaeana,* and *Scrophularia arguta*.

This evergreen shrubland still occupies over 1.5 million ha on the hills of the Middle Arid Subzone, but has been eliminated over most of the zone and replaced by steppe communities physiognomically similar to those of Upper Arid Subzone owing to the dominance of the same species: *Artemisia campestris A. herba-alba, Lygeum spartum,* and *Stipa tenacissima*. However, the floristic composition is again different with the addition of pre-Saharan species such as: *Acacia tortilis* subsp. *raddiana, A. gummifera (Morocco), Cleome arabica, Gymnocarpos decander, Hammada schmittiana, H. scoparia, Lygos raetam, Rhanterium suaveolens, Stipagrostis obtusa, S. plumosa*, and *Zygophyllum album* any of which can be co-dominant.

c. *Lower arid subzone*

Some remnants of the evergreen shrublands are still found in remote places, including: *Argania sideroxylon, Cistus libanotis, Juniperus phoenicea, Pistacia atlantica, Rhus tripartitum*, and *Rosmarinus officinalis*. This tends to show that the Lower Arid Subzone may well have been wooded land several centuries ago. Some of those remnants (*Juniperus phoenicea*) have actually been found below the 100-mm isohyet in particular niches (cliffs), especially in southern Jordan and in the Sinai (Long, 1957; Danin, 1972).

The Lower Arid Subzone is almost entirely covered with a chamaephytic steppe vegetation where the main species are: *Acacia gummifera, A. raddiana, Anabasis aphylla, A. articulata, Anarrhinum brevifolium, Astragalus armatus* subsp. *tragacanthoides, Atractylis serratuloides, Calycotome intermedia, Chenolea arabica, Cleome arabica, Diplotaxis harra, Echiochilon fruticosum, Erodium arborescens, Fagonia glutinosa, F. kahirina, Farsetia aegyptiaca, Forsskaolea tenacissima, Fredolia aretioides, Gymnocarpos decander, Hammada scoparia, H. schmittiana, Helianthemum ellipticum, Herniaria fontanestii, Linaria aegyptiaca, Lycium arabicum, Lygos raetam, Marrubium deserti, Nitraria retusa, Noaea mucronanta, Ononis natrix* subsp. *falcata, Pergularia tomentosa, Reaumuria* *vermiculata, Rhanterium suaveolens, Salsola sieberi, S. tetrandra, S. vermiculata* var, *brevifolia, Suaeda mollis, Thymelaea hirsuta, T. microphylla, Traganum nudatum,* and *Zygophyllum album.*

One important ecological and vegetational fact is that this bioclimatic zone contains the southernmost extensions of the alfa steppe.

B. The desert zone

The Desert Zone corresponds geographically to the northern Sahara between the isohyets of 25–100 mm.

a. ***Upper desert subzone (50–100 mm isohyte)***

In contrast to the Arid Zone, here, vegetation on shallow soils is disposed in a contracted pattern along the drainage system with large barren interfluves on the pediments, whereas on deep soils and especially on sandy material the vegetation pattern remains diffuse and of the steppe type.

The dominant perennial species are chamaephytes (small shrubs) except on sand dunes where perennial grasses play an important role.

The main chamaephytic species are: *Agathopora alopecuroides, Anabasis articulata, A. setifera, Anthyllis henoniana, Anvillae radiata, Astragalus pseudotrigonus, Atriplex mollis, Bubonium graveolens, Calligonum comosum, Cornulaca monacantha, Euphorbia guyoniana, Fagonia microphylla, Fredolia aretioides, Globularia arabica, Gymnocarpos decander, Hammada schmittiana, H. scoparia, Helianthemum confertum, H. kahiricum, Limoniastrum feei, L. guyonianum, Lygos raetam, Moltkia ciliata, Pituranthos battandieri, Pulicaria crispa, Salsola tetragona, S. vermiculata* var. *microphylla, S. cyclophylla, Tamarix boveana, T. pauciovulata, Traganum nudatum, Warionia saharae, Withania adpressa,* and *Zilla spinosa*.

On sand dunes characteristic and dominant species are: *Calligonum comosum, Cyperus conglomeratus, Ephedra alata subsp. alenda, Euphorbia guyoniana, Genista saharae, Panicum turgidum, Pennisetum dichotomum, P. elatum, Stipagrostis acutiflora, S. plumosa, S. pungens,* and *S. scoparia*.

b. ***The middle desert subzone***

The middle desert subzone vegetation is distributed in a contracted pattern – that is along runnels and wadis and in depressions. There is, however, diffuse vegetation in the sand dunes and on the cliffs. The regs and hammadas are barren, without perennial vegetation. A small number of tropical species (10%) mix here with the dominant Mediterranean flora. Characteristic species are: *Acacia raddiana, Achillea fragrantissima, Antirrhinum ramosissimum, Artemisia judaica, Asteriscus graveolens. Atriplex leucoclada, Balanites aegyptiaca, Caylusea hexagyna, Fagonia arabica, F. bruguieri, Hyoscyamus muticus, Iphiona mucronata, Lasiurus hirsutus, Launaea spinosa, Leptadenia pyratechnica, Maerua crassifolia, Matthiola livida, Morettia canescens, Moringa peregrina, Ochradenus baccatus, Pituranthos chloranthus subsp. intermdius. Pulicaria crispa, Randonia africana, Reaumuria hirtella, Reseda villosa, Trichodesma africanum, Zilla spinosa. Ziziphus saharae,* and *Zygophyllum coccineum.*

c. *The lower desert subzone*

The lower desert subzone vegetation is restricted to main wadis and depressions benefitting from run-off or having shallow water tables. Vegetation is a mixture of Mediterranean and tropical species in approximately equal proportions.

Among the main Mediterranean species are: *Alhagi graecorum, Anabasis articulata, Astragalus vogelii, Brocchia cinerea, Caylusea hexagyna, Cornulaca monacantha, Foleyola billottii, Hammada schmittiana, Lavandula coronopifolia, L. stricta, Morettia canescens, Moricandia foleyi, Nucularia perrini, Plantago ciliata, Polycarpaea fragilis, Randonia africana, Reseda kahirina, R. villosa, Salsola haryosma, S. vermiculata, Salvia pseudojaminiana, Shouwia thebaica, Tamarix aphylla, T. brachystylis, T. leucocaris, T. nilotica,* and *Trigonella anguina.*

The main tropical species are: *Acacia asak, A. ehrenbergiana, A. raddiana. A. seyal, Aerva persica, Aristida mutabilis, Aristida sahelica, Balanites aegptiaca. Calotropis procera. Capparis decidua, Cassia aschrek. C. italica, Cenchrus biflorus, Chrozophora bracchiana, Cleome droserifolia, Crotalaria aegjptiaca, C. saharae, Desmostachya bipinnata. Hyphaene thebaica, Indigofera argentea, Lasiurus hirsutus, Leptadenia pyrotechnica, Maerua crassifolia, Panicum turgidum, Pergularia tomentosa, Psoralea plicata, Salvadora persica, Solenostemma arghel, Tephrosia leptoscachya,* and *Ziziphus mauritiana.*

C. The true desert (less than 10 mm isohyte)

The true desert is virtually rainless. Perennial vegetation is linked to water tables often due to fossil aquifers (as in the Libyan-Egyptian desert), or to exogenous water-courses.

Occasional showers on limited areas may produce an ephemeral burst of short-lived annuals such as: *Brocchia cinerea, Monsonia nivea, Plantago ciliata, Stipagrostis plumosa*, and *Trigonella anguina*.

Perennial vegetation on water tables is dominated by: *Acacia albida, A. nilotica, Alhagi graecorum, Cornulaca monacantha, Desmostachya bipinnata, Hyphaene thebaica, Imperata cylindrica, Phragmites australis, Phoenix dactylifera, Saccharum ravennae, Salvadora persica, Traganum nudatum* and *Zygophyllum album.*

D. The Saharan mountains

The higher elevations of the Saharan mountains above 1,800–2,000 m have a vegetation similar to the Middle Arid Subzone, with strong Mediterranean affinities. Characteristic species of this arid montane vegetation are: *Agrostis tibestica, Argyrolobium uniflorum, Artemisia campestris, A. herba-alba, A. tilhoana, Asplenium quezeli, Atriplex halmius, Avena tibestica, Ballota hirsuta, Campanula bordesiana, Crambe kralickii, Cupressus dureziana, Dichrocephala tibestica, Ephedra tilhoana, Erigeron trilobus, Festuca tibestica, Ficus gnaphalocarpa, F. ingens, F. salicifolia, Globularia alypum* var, *vescetirensis, Helianthemum lippii, Helichrysum monodianum, Hyparrhenia hirta, Lavandula antinea, Luzula tibestica, Marrubium deserti, Micromeria biflora, Myrtus nivellei, Olea laperrini,* *Oryzopsis coerulescens, Pentzia monodiana, Periploca laevigata, Phagnalon tibesticum, Pistacia atlantica, Pituranthos scoparius* var*, fallax, Rhus tripartitum, Salvia chudaei, Senecio hoggariensis, Silene mirei, Stipa parviflora, Teucrium polium,* and *Varthemia sericea.*

IV. Main vegetation types

The arid zone habitats of the North African Mediterranean region are distinguished by 7 vegetation types (Le Houerou, 1992), namely: Forest, Matorral (garrigue), erme, steppe, pseudo-steppes, desert savanna and sand-dune open woodland.

a. *Forest*

Even within the Arid Zone, forests (defined as vegetation having trees over 5 m high and over 100 single stems per hectare) occur. They are, however, very rare and located in the upper bioclimatic subzone (300–400 mm of average annual rainfall). They are almost always open forest of *Pinus halepensis* (Aleppo pine), *Tetraclinis articulata*, *Argania sideroxylon* (in southern Morocco only) or *Juniperus phoenicea*. There is always an understorey of shrubs, except in certain types of Argania woodland or parkland. Such forests probably occupy not more than 100,000 ha in the Arid Zone in Morocco, Algeria, Tunisia and Libya (Cyrenaica).

b. *Matorral or Garrigue*

The matorral[3] (American equivalent: chaparral) consists of evergreen tall shrubs or small trees is found on the hills between isohyets of 200 and 400 mm, and covers some 30,000 km^2 in the North African Arid Zone. Most of the plant species of the garigue (garrigue = matorral) are spiny cushion shrubs, e.g. *Euphorbia acanthothamnos* and *Sacropoterium spinosum,* drought-deciduous and dimorphic plants, e.g. *Euphorbia dendriodes, Calycotoma villosa,* aromatic plants of the mint family, e.g. *Rosmarinus officinalis* and *Lavandula stoechas* and bulbs, e.g. *Narcissus tazetta, N. bulbocodium, Pancratium arabicum, P. maritimum, Crocus biflorus* etc. (Dallman, 1998).

c. *Erme*

Erme is a low-growing community of forbs and grasses consisting of unpalatable plants, including Liliaceae (*Asphodelus, Urginea*), thistles (*Carduncellus, Carthamus, Carlina, Centaurea, Onopordon* etc.), and other unpalatable species such as *Cleome arabica, Euphorbia* spp., *Ferula* spp., *Peganum harmala, Thymelaea hirsuta, Thapsia garganica* etc. . . . and an annual grass. *Stipa capensis*, is often dominant. Erme is a post-pastoral vegetation type resulting from overgrazing around villages, wells . . . etc. It is estimated to cover some 20,000 km^2 in the

[3]The spelling of matorral and garrigue could be also mattoral and garigue, respectively (Branigan and Jarrett, 1975; Dallman, 1998; Blondel and Aronson, 1999).

region, mostly in the Arid Zone. When similar heavy grazing pressure is exerted in desert areas, the ground usually remains barren.

d. *Steppe*

Steppe is the typical vegetation type of the Arid Zone of North Africa, and extends into the Desert Zone; it covers some 400,000 km^2 between the isohyets of 100 and 400 mm. It also occurs between the isohyets of 50 and 100 mm in depressions with permeable soils which receive run-on water. Steppe is a short, open treeless vegetation, with various proportions of bare ground, physiognomically dominated by perennial species. Plant cover may be anywhere between 5 and 80%. One generally differentiates three main types of steppes:

(i) *Gramineous steppe* is dominated physiognomically by perennial grasses such as *Stipa tenacissima* (alfa grass), *Lygeum spartum* (esparto grass). *Stipa* spp., *Panicum turgidum, Stipagrostis pungens, Stipagrostis* spp. Alfa grass steppe covers some 60,000 km^2 in Morocco, Algeria, Tunisia and Libya (Tripolitania only). Esparto grass steppes cover about 30,000 km^2 from Morocco to Egypt.

(ii) *Chamaephytic steppe* is characterized by the dominance of low shrubs or half-shrubs 0.2–0.5 m high. This type of steppe covers 250,000–300,000 km^2 in our area.

The main dominant species are: *Anthyllis henoniana* on shallow soils; *Artemisia campestris* and *A. monoica* on sandy soils, *Artemisia herba-alba* on silty or shallow soils, sealed on the surface; *Gymnocarpos decander* on shallow soils; *Hammada scoparia* on silty soils, *Noaea mucronata* on shallow soils; *Rhanterium suaveolens* on loose sandy soils; and *Thymelaea hirsuta* on a variety of soils.

(iii) *Crassulescent steppe* is dominated by fleshy halophilous shrubs mostly belonging to the Chenopodiaceae. It occurs over some 30,000 km^2 in the Arid and Desert Zones.

The main dominant species in approximate order of decreasing halophily are: *Halocnemum strobilaceum, Halopeplis amplexicaulis, Arthrocnemum glaucum (A. macrostachyum), Salicornia fruticosa, Salsola baryosma, S. sieberi, S. tetragona, S. tetrandra, S. vermiculata, Suaeda fruticosa, S. monoica, Atriplex halimus, A. glauca. Traganum nudatum, Zygophyllum album* and *Z. coccineum*.

(iv) *Non-halophilous succulent steppe* is only found in the western part of the region, along he Atlantic Ocean in southern Morocco. Dominant and characteristic species are non-halophilous succulents such as: *Aizoon theurkauffii, Euphorbia balsamifera, E. echinus, E. resinifera, Kalanchoe faustii, Senecio anteuphorbium* and *Zygophyllum waterlottii*.

This type of steppe shows a strong tropical affinity in spite of the fact that the region receives winter rains; winter temperatures are mild (never dropping below 10°C) and atmospheric humidity is high. The flora itself is peculiar to this part of the region and is usually referred to as "Canarian" or "Macaronesian".

e. *Pseudo-steppe*

This has taller-growing types of vegetation than steppes (0.5–3 m high); and could also be called open bushland or open shrubland. Dominant shrubs cover 5–20% of the ground with interspersed smaller shrubs and annuals. The main tall shrubs are: *Acacia gummifera, A. raddiana, Argania sidoroxylon. Balanites aegyptiaca, Calligonum comosum, Capparis decidua. Ephedra alata, Limoniastrum guyonianum, Lygos raetam, Maerua crassifolia, Nitaria retusa, Periploca laevigata, Rhus tripartitum, Tamarix* spp and *Ziziphus lotus*.

This type of vegetation occurs in the best-watered locations: wadi terraces, areas subject to floods, various depressions, sand dunes and cliffs. It is totally different from matorral in botanical composition, structure physiognomy and habitat.

f. *Desert savanna*

This is found in the Sahara along the main wadis, in wadi beds. terraces, spreading areas and in the karstic (limestone) depressions. It consists of a layer of scattered trees interspersed with tall perennial grasses. The most common trees are: *Acacia raddiana, Balanites aegyptiaca, Maerua crassifolia, Pistacia atlantica,* and *Ziziphus spina-christi*. The main grasses are *Cymbopogon schoenanthus, Lasirus hirsutus, Panicum turgidum,* and *Pennisetum dichotomum*. Small shrubs occur such as *Aerva persica, Solenostemma arghel*, and *Zilla spinosa*.

g. *Sand-dune open woodlands*

These are extremely rare and composed of small trees and shrubs 5–8 m high such as *Calligonum azel, Ephedra alata* subsp. *alenda, Genista saharae, Leptadenia pyrotechnica and Lygos raetam*. These are found in remote places in the Grand Erg Oriental and in the Idehan Ubari (Fezzan).

1.8.1.6 Representative Sectors

The preceding pages have presented a general account of the major vegetation forms growing naturally under the prevailing climate of the North African coastal lands. Details on the environment and vegetation types of these Mediterranean coastal areas will be described from three representative sectors: the Jefara and Al-Gabal AlAkhdar sectors in Libya and the Mariut sector of Egypt.

I. Libyan coastal sectors

The Mediterranean coastal land of Libya extends for about 2,400 km from the Tunisian – Libyan border in the west to the Libyan – Egyptian border in the east. It is a remarkably uniform coastal land along which there are natural harbours, some very rocky and steep, others are low and swampy. Coastal sand dunes and salt depressions represent a characteristic features of the Libyian Mediterranean coastal land (Branigan and Jarrett, 1975).

Ecologically, the Libyan Mediterranean coastal belt is categorized into two natural regions: the north-western and the north-eastern. The northwestern region lies in the NW part of Tripolitania and on the whole it is the best favoured and the most prosperous part of the whole country. The core of this region is the Jefara sandy plain bounded on the north by the low marshy coast and to the south by the purple cliffs of Gebel Nefusa. Cultivation is possible along this coastal strip wherever the rainfall is comparatively high. The remainder of Jefara is semi-desert, with Esparto-grass (*Stipa tenacissima*) maintained by semi-nomadic grazing. Cultivation depends partly upon winter rain and partly upon water drawn from wells especially in summer. Olives, citrus fruits, almond, vegetables and barley are produced. The chief crop, however, is the date. In some other areas nearby parts of the Jefara coast where irrigation is possible, wheat and tobacco area also grown.

The north eastern region lies within the north protecting bulge of Cyrenaica, around Al-Gabal Al-Akhdar (the green mountain). On this mountain, forests of cypress (*Cupressus* spp.), ilex (*Ilex* spp.) and Juniper (*Juniperus* spp.) predominate.

Further south, these forests give way to another vegetation type called garigue (widespread in the Mediterranean basin) and then to a wide treeless grassland steppe.

Though the natural flora of the coastal and inland deserts of Libya has been studied by several authors, e.g. Maire (1952–1977), Keith (1965), Boulos (1971, 1972, 1977, 1979a, b), Greuter et al. (1984–1986, 1989), Ali and Jafri (1976), Jafri and El-Gadi (1978), Pratov and El-Gadi (1980), Qiser and El-Gadi (1984), and El-Gadi (1989) etc.; yet few published reports have dealt with its vegetation ecology: Edrawi and El-Naggar (1995), Ebrahim (1999), El-Kady (2000), Al-Sodany et al. (2003), and El-Morsy (2008).

A. Jefara coastal sector

a. *Climate*

The Jefara coastal belt extends for about 400 km along the north western Mediterranean borders of five Libyan coastal governorates, namely Zuwarah (in the west) followed eastwared with Subratha, Azzawarah, Tripoli and Al-Khoms. The average area of the Jefara coastal plain is about 4,032 km^2 (Hassan, 1975). It has a typical Mediterranean semi-arid climate (El-Morsy, 2008). The mean annual rainfall ranges between 238 mm (Zuawarah) to 296 mm (Al-Khoms). The main bulk of the precipitation (> 97%) usually occurs in the September–April period. The mean annual temperature ranges between 19.8 and 19.1°C with monthly means up to 27.6°C (August) and down to (12.1°C) (January). Mean annual relative humidity ranges between 68 and 72.6% with monthly means ranging from 76% (June–August) to 65.2% (December–January).

b. *Habitats and flora*

The Jefara coastal plain is organized, ecologically; into five habitats: sand dunes, rocky ridges, salt marshes, wastelands and field crops. Each of these habitats has its own vegetation type with their characteristic and associate species. The flora comprises about 293 species: 62 (21.1%) monocots and 231

(78.84%) dicots belonging to 154 genera and 46 families (El-Morsy, 2008). The Compositae has the, relatively, highest number of species (56, 19.1%) followed by Gramineae (38, 12.47%), Leguminosae (22, 7.51%), Chenopodiaceae (18, 6.48%), Cruciferae (14, 4.78%), Liliaceae and Caryophyllaceae (13, 4.44% each), Umbelliferae and Plantaginaceae (8, 2.73% each), Cyperaceae, Labiatae and Solanaceae (7, 2.39% each), Boraginaceae (6, 2.05%), Polygonaceae, Papaveraceae, Geraniaceae, Zygophyllaceae and Euphorbiaceae (5, 1.71% each). Each of the remaining 28 families is represented by 1–4 species.

Most taxa (155 species) are annuals; there are 133 perrnnials and only 5 biennials. The life-form spectrum of these floristic elements shows that: 53.6% are therophytes, 18.8% are chamaephytes, 13.3% are cryptophytes, 12.6% are hemicryptophytes and 1.7% are nanophanerophytes. More than 72% (42 species) of these elements belonging to the Mediterranean region, the remaining species (81, 28%) are distributed as follow: 25 species (8.5%) are cosmopolitan, 13 (4.44%) are Saharo-Sindian, 11 (3.74%) are palaeotropical, 8 (2.73%) are pantropical, 6 (2%) are naturalized and cultivated and 5 species (1.7%) are neotropical.

c. *Vegetation types*

The vegetation types of the five habitats are formed of 42 communities: 9 in the sand dunes, 5 in the rocky ridges, 15 in the salt marshes, 5 in the wastelands and 8 in the field crops (El-Morsy, 2008).

The following is a short account of these communities with respect to their characteristic and associate species.

1. *Sand Dune habitat*

Chains of coastal sand dunes extend along the Jefara coastal belt forming more or less a continuous bars. This habitat is characterized by the storing rain of water forming a freshwater layer above one of seawater. Psammophytes (sand-loving plants) constitute the main bulk of the sand dune vegetation. The dominant species, are all perennials: *Anabasis articulata, Artemisia lampestris, Asparagus stipularis, Cyperus capitatus, Euphorbia paralias, Lotus cytisoides, Lygos raetam, Silene succulenta* and *Stipagrostis ciliata*. There are 26 associate species: 15 perennials and 11 annuals: *Aeluropus lagopoides, A. littoralis, Alhagi graecorum, Allium roseum* var. *tournexii, Calycotome villosa* var. *tournexii, Ecballium elaterium, Elytrigia juncea, Iris sisyrinchium, Muscari racemosum, Pancratium maritimum, Polygonum equisetiform, Salsola longifolia, Sporobolus spicatus, Stipagrostis lanata* and *Urginea maritima* (perennials), and *Apium garveolens, Cakile maritima, Cutandia dichotoma, Daucus guttatus*, *Lagurus ovatus, Parapholis incurva, Plantago ovata, Pseuderucaria teretifolia, Reseda pruinosa, Rumex crispus, Schoenefeldia gracilis* (annuals).

2. *Rocky Ridge habitat*

Six perennial species predominate the rockey ridge habitat: *Deverra tortuosa Globularia alypum, Lycium europaeum, Lygeum spartum, Medicago marina* and

Thymus capitatus. The associate species are 58: 47 perennials, 3 biennials and 8 annuals. The common perennial associates include: *Asparagus aphyllus, Cornulaca monacantha, Cynara caringera, Echinops hussonii, E. spinosissimus, Echiochilon fruticosum, Echium sericeum, Glaucium flavum, Helianthemum stipulatum, H. virgatum, Herniaria hemistemon, Kickxia aegyptiaca, Limonium axillare, Ononis natrix, Pancium repens, Phagnalon nitridum, Reaumuria hirtella, Salsola longifolia, Sarcocornia fruticosa, Scilla peruviana, Scorzonera undulate and Ziziphus lotus* etc. the biennial associates are: *Centaurea calcitrapa, Onopordum ambiguum, and O. alexandrinum.* The associate annuals are: *Beta vulgaris, Schenopheldia gracilis, Astragalus hamosus, Centaurea glomerata, Lagurus ovatus, Limonium amplexicaulis, Neurada procumbens, and Scabiosa arenaria*.

3. *Salt Marsh habitat*

The salt marsh habitat occupies the shoreline as well as depressed salt-affected areas within the sand dunes and rocky ridges. Its halophytic vegetation is formed of 15 communities dominanted by: *Arthrocnemum macrostachyum, Atriplex glauca, A. halimus, A. portulacoides, Cressa cretica, Cyperus laevigatus, Halocnemum strobilaceum, Inula crithmoides, Juncus acutus, J. rigidus, Limoniastrum monopetalum, Sporobolus spicatus, Suaeda pruinosa, Tamarix nilotica* and *Zygophyllum album*. The few associate species are mainly halophytes including: *Aeluropus lagopoides, A. littoralis, Imperata cylindrica, Limonium narbonense, Reaumuria hirtella, Salsola longifolia, Silene succulenta,* and *Spergularia marina* (perennials) and *Mesembryanthemum crystallinum,* and *M. nodiflorum* (annuals).

4. *Wastelands*

The wastelands are actually the non-cultivated areas occupying the zone landward to the salt marsh habitat. The number of the floristic elements here is, the highest (> 150 species) among the other habitats of the Jefara coastal area: about 70 species are perennials, 75 annuals, and a few biennials (5 species).

Five perennial xerophytes (drought tolerant and drought resistant species) predominate: *Artemisia monosperma, Cornulaca monacantha, Nicotiana glauca, Peganum harmala and Thymelaea hirsuta*. The perennial associates are mostly xerophytes with few halophytes. The xerophytes include: *Alkanna lehmani, Anabasis articulata, A. setifera, Androcymbium gramineum, Artemisia compestris, A. monosperma, Asparagus aphyllus, A. stipularis, Asphodelus ramosus, Aster squamatus, Bellevalia sessiliflora, Calycotome villosa, Calotropis procera, Centaurea dimorpha, Citrullus colocynthis, Convolvulus prostratus, Conyza stricta, Cynodon dactylon, Cyperus rotundus, Deverra tortusa, Echinops hussonii, E. spinosus, Echiochilon fruticosum, Echium sericeum, Erodium bryoniaefolium, E. glaucophyllum, Glaucium flavum, Haplophyllum tuberculatum, Helichrysum lacteum, Launaea angustifolia, L. nudicaulis, Lycium europaeum, Lygeum spartum. Marrubium vulgare, Matthiola livida, Medicago sativa, Muscari comosum, Paronychia argentea, Phagnalon nitidum, Plantago albicans, Polygonum equisetiforme, Salvia lanigera, Solanum incanum, Sonchus maritimus, Thymus* *capitatus, Verbascum letourneuxii, Verbena tenuisecta* etc. The perennial associate halophytes are: *Atriplex glauca, A. portulacoides, Cressa cretica Imperata cylindrical, Reaumuria hirtella, Salsola longifolia, Suaeda pruinosa Tamarix nilotica and Zygophyllum album*. Five associated biennials have been recorded in this habitat: *Carthamus lanatus, Centaurea calcitrapa, Echium plantagineum, Onopordon ambiguum* and *O. alexandrinum*. The annual associates include: *Amarauthus lividus, A. tricolor, Asphodelus tenuifolius, Bassia indica, Beta vulgaris, Chenopodium ficifolium, C. murale, Conyza aegyptiaca, C. bonariensis, Crepis libyca, Diplotaxis acris, D. harra, Echium sabulicola, Euphorbia peplis, Filago desertorum, Geranium rotundifolium, Hyoscyamus desertorum, Lactuca serriola, Malva parviflora, Matthiola longipetala, Papaver rhoeas, Phalaris minor, Reichardia tingitana, Setaria verticillata, Silene villosa, S. viviani, Sisymbrium irio, Solunum nigrum, Sonchus oleraeceus, Spergularia diandra, Tribulus terrestris, Urospermum picroides, Urtica urens, Vaccaria hispanica, Volutaria lippii, Xanthium spinosum* etc.

5. ***Field crops***

The cultivation of fruit trees (olive, citrus, grapes, date palm etc.), and vegetables is a minor component of the inland zone of the Jefara coastal plain. The natural vegetation growing in this habitat has about 150 species, mostly annuals (106 species) with a few (4) biennials: *Carthamus lanatus, Echium plantagineum, Onopordum ambiguum and O. alexandrinum* and 40 perennials. Among the perennials, 8 species are widespread and abundant, five of these are halophytes growing in the wetter areas: *Arundo donax, Cyperus conglomeratus, C. longus, C. rotundus* and *Phragmites australis*. Other abundant perennials are xerophytes: *Convolvulus arvensis, Echiochilon fruticosum* and *Thymelaea hirsuta*. Except *Cressa Cretica* (halophyte), all of the associated perennials are xerophytes, e.g.: *Alkanna lehmanii, Allium roseum* var. *tourneuxii, Androcymbium gramineum, Asphodelus ramosus, Aster squamatus, Astragalus kahiricus, Bellevalia sessiliflora, Centaurea dimorpha, Conyza stricta, Cynodon dactylon, Echinops hussonii, E. spinosissimus, Erodium bryonifolium, E. crassifolium, Euphorbia retusa, Gundelia tournefortii, Launaea fragilis, L. nudicaulis, Lotus glaber, Ononis natrix, Oxalis corniculatus, O. pes-caprae, Paronychea argentea, Plantago albicans, Polygonum equisetiforme, Salvia deserti, S. lanigera, S. officinalis, Spergularia marina, Verbascum letourneuxii, Ziziphus spina-christi* etc. The asscociated annuals classified under 3 groups.

(a) Annuals active all year (11 species): *Amaranthus lividus, Bassia indica, Chenopodium galucum, C. murale, Lactuca serriola, Malva parviflora, Pseuderucaria teretifolia, Reichardia tingitana, Setaria verticillata, Solanum nigrum and Sonchus aleraceus,*
(b) Summer active annuals (15 species): *Amaranthus graecizans, A. hybridus, A. tricolor, Ammi majus, A. visnaga, Conium maculatum, Dactyloctenium aegyptium, Datura innoxia, Echiochilon colona, Eleusine indica, Emex spinosa, Polypogon monospelienis, Portulaca oleracea, Salsola kali* and *Sesbania sericea* and,

(c) Winter active annuals (about 80 species): e.g. *Adonis dentata, Aegilops kostchyi, Anagallis arvensis Anthemis melampodina, Anthemis retusa, Asphodelus tenuifolius, A. viscidulus, Avena fatua, A. sativa, Brassica tournefortti, Bromus catharticus, B. diandrus, Calendula arvensis, Capsella bursa-pastoris, Carduus argentatus, C. getulus, Centaurium pulchellum, Coronopus didymus, Cotula anthemoides, C. cinerea, Crepis aculeata, Cutandia dichotoma, Eruca longirostris, E. sativa, Euphorbia helioscopia, E. peplis, E. prostrata, Filago contracta, F. desertorum, Fumaria densiflorae, Geranium rotundifolium, Hordeum marianum, Ifloga spicata, Kickxia spura, Koelpinia linearis, Lamium amplexicaulis, Lepidium sativum, Linaria tenuis, Lobularia libyca, Lolium perenne, Matthiola longipetala, Medicago intertexta, M. polymorpha, Melilotus indicus, Ononis serrata, Papaver dubium, P. hybridum, P. rhoeas, Phalaris canariensis, P. minor, Picris altissima, Plantago lagopus, P. ovata, Poa annua, Polycarpon tetraphyllum, Reseda pruinosa Rumex crispus, R. dentatus, R. vesicarius, Scabiosa arenaria, Sencio glaucus subsp. coronopifolius, Setaria virdus, Silene villosa, S. viviani, Stellaria pollida, Trifolium rupsinatum, Vicia articulata, V. monantha, V. sativa, V. villosa* etc.

B. Al-Gabal Al-Akhdar coastal sector

a. *Geomorphology and climate*

Al-Gabal Al-Akhdar (the green mountain) upland is a plateau formed as a result of tectonic elevation of a primary plain of marine accumulation with height up to 878 m. The area of Al-Gabal Al-Akhdar has been studied ecologically by Al-Sodany et al. (2003) in a 30-km N–S transect between El-Hamamah; near sea level (33° 53′N, 21° 39′E) to El-Bydda (600 m 33° 17′N, 21° 40′E). This coastal area is characterized by four geomorphological units: coastal plain, coastal hills, inland plateau and wadis.

1. The coastal plain extends for about one km landwards from the sea. It is composed of marine accumulation and three main habitats: saline sand flats, sand dunes (up to 50 m high) and sand flats.
2. The coastal hills (up to 100 m high) generally confined to marginal parts of the coastal plain.
3. The inland plateau which appears in the form of three terraces: the first up to 400 m high at Ras El-Hilal, the second up to 600 m high at El-Bydda and the third up to 880 m high at Slentah.
4. Wadis, dissecting the plateau, running in N-S and covered with a shallow sandy-loam soil.

   The Meditterannean climate of Al-Gabal Al-Akhdar area is classified under 3 bioclimatic zones according to the elevation of land above sea level. In El-Hamamah just at sea level, the aridity index (Q) is 1.3 i.e. arid climate prevail. This changes to a semi-arid ($Q = 2.0$) climate in El-Wesaetah at 300 m and then to subhumid ($Q = 2.8$) in El-Bydda at 600 latitude.

The annual means of temperature, rainfall, relative humidity and wind velocity in these three bioclimatic zones are: 19.9, 17.4 and 16.4°C, 323.6, 417.5 and 567.1 per year, 73.0, 65 and 68% and 42.7, 65 and 68 km/h (Al-Sodany et al., 2003).

b. ***Plant life***

The flora of Al-Gabal Al-Akhdar coastal area is formed of about 119 species: 43 annuals (36%) and 76 perennials (63.9%), belonging to 105 genera and 44 families. The compositae is represented by the, highest number of species (15) followed by Gramineae (13), Leguminosae (12), Liliaceae and Labiatae (7 each), Euphorbiaceae, and Solanaceae (4 each), Cruciferae, Cistaceae, Chenopodicceae, and Iridaceae (3 each), Cyperaceae, Ranunculacea, Cupressaceae and Anacardiaceae (2 each). The remaining families represented by a single species. Regarding the life-form spectera, therophytes have the highest contribution (36.1%) followed by cryptophytes (19.3%), phanerophytes (17.6%), chamaephytes (13.5%) and hemi-cryptophytes (13.5%). Most of these taxa (105) belong, floristically to the Mediterranean region, and include nine endemic species: *Arbutus pavarii* (Ericaceae), *Cupressus sempervirens* var. *horizontalis* (Cupressaceae), *Arum cyrenaicum* (Araceae), *Cyclamen rholfsianum* (Primulaceae), *Romulea cyrenaica* (Iridaceae) and *Bellis sylvestris* var. *cyrenaica, Crepis libyca*, *Onopordum cyrenaicum* and *Cynara cyrenaica* (Compositae). The monoregional Mediterranean taxa are 55, the biregionals are 19 whereas the pluriregional are 31 species. The monoregional species belonging to other floristic regions: 4 belong to the Saharo-Arabian region (*Brassica deserti, Conyza aegyptiaca, Solanum nigrum and Trisetaria acrochaeta*), and one is a tropical plant (*Oxalis pes-carpae*). There are seven cosmopolitan species: *Conyza bonariensis, Convolvulus arvensis, Cynodon dactylon, Scripus maritimus, Chenopodium ambrosoides, Polypogon mospeliensis* and *Sonchus oleraceus*. The remaining species belong to the Sudanian, Euro-Sibarian and/or Irano-Turanian floras either biregaonally or pluri-regionally (Al-Sodany et al., 2003).

The four geomorphological units of Al-Gabal Al-Akhdar coastal sector comprise 10 habitats as follows (Al-Sodany et al., 2003):

1. Three habitats in the coastal plain: saline sand flat, coastal sand dunes and sand flats,
2. Two habitats in the coastal hills: seaward slope and leeword slope,
3. Two habitats in the plateau: first terrace and second terrace, and
4. Three habitats in the wadi: south-east slope, north-east slope and wadi bed.

Six vegetation groups, named after the dominant species, are recognized in these habitats, these are:

– Group I has two co-dominant species: *Juniperus phoenicea – Sarcopoterium spinosum*, occupying a wide elevation gradient and recognized in all habitats except sand dunes,

– Group II also has two co-dominant species: *Suaeda vermiculata, Crucinella maritima* along the seaward direction of the coastal hills,
– Group III is dominated by *Lygos raetam* in the coastal sand flats,
– Group IV is dominated by *Pancratium maritimum* and *Ammophila arenaria* in the coastal sand dunes.
– Groups V and VI are dominated by *Crucinella maritima* and *Limoniastrum monopetalum*, respectively, in the saline sand flats of the coastal plain.

The highest number of the associates (113 species) occur in group I with 70 perennials, and 43 annuals. Among the perennials are: *Arbutus pavarii, Callycotome villosa, Ceratonia siliqua, Cupressus sempervirens* var *horizontalis, Euphorbia characias, E. dendroides, Lycium europaeum, Myrtus communis, Olea europaea, Phlomis floccosa. Pinus halepensis, Pistacia lentiscus, Quercus coccifera, Lygos reatam, Rhus tripartita, Rosmarinus officinalis, Tamarix africana,* and *Thymelaea hirsuta (*phanerophytes*), Centaurea ragusina Cistus incanus, Conyza bonariensis, Fumana thymifolia, Globularia alypus, Helianthemum salsifolium, H. stipulatum, Helichrysum stoechas, Malva sylvestris, Thymus capitatus* and *Withania somnifera (*chamaephytes*), Ajuga iva, Anchusa undulata, Asteriscus spinosus, Convolvulus arvensis, Marrubium vulgare, Medicago marina, Reichardea picroides, Satureja thymbra, Stachys tournefortii, Thapsia garganica and Tolpis virgata* (hemicryptophytes), *Arum cyrenaicum, Asparagus aphyllus, Asphodelus ramosus, Barleria robertiana, Bellevalia mauritanica, Cynodon dactylon, Dactylis glomerata, Eleocharis palustris, Gagea fibrosa Gladiolus trinervia, Ranunculus asiaticus, Romula cyrenaica, Scirpus maritimus, Smilax aspera* and *Urginea maritima* (cryptophytes). All of the annual associates (40 species) belong to group I and only four of them have also been recorded with other groups: *Euphorbia helioscopa* with groups II and IV, *Ononis pedula* with group II and III, *Medicago ridigula* with group II, *Poa annua*, and *P. bulbosa* with groups II and VI. The other annuals include: *Aegilops kotschi, Ammi majus, Avena barbata, Beta vulgaris, Biscutella didyma, Brassica deserti, Briza maxima, Bromus alopeuros, B. redbens, Carduus argentus, Carthamus lanatus, Chrozophora tinctoria, Conyza aegyptiaca, Crepis libyca, Cynara cyrenaica, Cynosurus coloratus, Euphorbia peplis, Hordeum muriun, Lathyrus aphaca, Lotus tetragonolobus, Onopordum cyrenaicum, Plantago arenaria, P. lagopus, Polypogon monspeliensis, Rumex simpliciflorus, Scorpiurus muricatus, Solanum nigrum, Sonchus oleraceus, Trifolium tomentosum, Trisetaria linearis, Urtica urens* and *Vicia laxiflora*.

II. Egypt's coastal sector (Mariut)

a. *General remarks*

The Mediterranean coastal land of Egypt extends for about 970 km from Sallum in the Libyan-Egyptian border (eastwards) to Rafah in the Palestine border. It is a narrow coastal belt assigned to the dry arid climatic zone of Koppen's (1931) classification system (as quoted by Trewartha, 1954) and the

Mediterranean bioclimatic zone of Emberger (1955). However, the bioclimatic zone of UNESCO/FAO (1963) indicates that it is a subdesertic warm climate.

Geographically, the Mediterranean coastal land of Egypt can be divided into three sectors (Zahran et al., 1985, 1990): western (Mariut), middle (Deltaic) and eastern (Sinai) sectors. The first two sectors belong to the North African Mediterranean coast while Sinai sector belongs to the South West Asian Mediterranean coast.

b. ***Location and climate***

The Mariut coast of Egypt extends along the Mediterranean Sea for about 550 km from Sallum eastwards to Abu Qir (about 30 km east of Alexandira). It is the northern coast of the Western Desert of Egypt that narrows or widens according to the position of its southern boundary – the Western Desert Plateau – with an average width, of about 20 km. Its remarkable feature is the prevalence of ridges formed of oolitic limestone, often 20 m or more high extending parallel to the sea-shore for long distances (Ball, 1939). Commonly one line of ridges skirts the coast closely, while another runs parallel to it a few km inland, and there is sometimes a third ridge between the second and the edge of the Western Desert Plateau.

Rainfall occurs mainly during the October–March period (60% or more); the summer is virtually dry. The highest amount usually falls during either January or December and varies appreciably along the coast from 119.7 mm/year in Sallum and 144.0 mm/year in Mersa Matruh[4] and 192.1 mm/year in Alexandria. The annual mean temperature maxima and annual mean minima are: 25.3, 24.3, 24.9, 13.3, 14.3 and 14.9°C, respectively. Relative humidity is lower in Salum (mean annual = 69%) than in Mersa Matruh (67%) and higher in Alexandria (72%). The reverse in true for evaporation being highest in Sallum (mean annual = 7.2 mm/pich/day) followed by that of Mersa Matruh (6.5 mm pich/day) and Alexandria (3.8 mm pich/day).

Winds along the Mariut coast are generally strong and violent, and dust storms and pillars are not unusual. Dry hot dust-laden winds from the south known as khamasin blow occassionaly for about 50 days during spring and early summer. There can also be strong, winds blow strongly with an average velocity of about 20–23 km/h during winter and early spring. Wind speed decreases in May and June, but July is windy. Shaltout (1983) stated that, the ends of summer records many calm days and the average wind speed drops to 15 km/h. In Burg El-Arab area (about 50 km west of Alexnadria), Ayyad (1973) estimated the mean annual evapotranspiration to be 995 mm.

It is worth to state that the climate of Mariut coast of Egypt and, according to Murray (1951), has not changed since Roman time (2,000 years ago). Zahran and Willis (2008) stated: Sutton (1947) quotes records of annual rainfall made by Thurnburn (1847–1849) and brought up to 1970 as follows: 1847–1849 = 191 mm, 1881–1886 = 209 mm, 1901–1906 = 47 mm, 1921–1926 = 178 mm, 1939–1941 = 161 mm, 1951–1956 = 187 mm and 1960–1970 = 207 mm.

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[4]Mersa Matruh is located at about 350 km west of Alexandria.

c. *Land use*

The Western Mediterranean coastal land of Egypt is called the Mareotis District, being related to Mariut Lake. In the past this lake was a fresh-water one. Kassas (1972a) states "Strabo (66-24BC) records that Lake Marea is filled by many canals from the Nile through which a greater quantity of merchandise is imported". De Cosson (1935) notes that the lake was rather deep fresh water and adds: "There seems to be little doubt that 2,000 years ago it was of greater extent than in modern times. The Canopic Nile Branch and the other canals that fed the lake gradually silted and its water receded. Thus, Lake Mariut was in Graeco-Roman times a fresh-water lake, the water of which was used for irrigating the fields. This source of freshwater gradually diminished and by the end of the twelfth century the lake became saline".

Kassas (1970) infers that, in this coastal region, agriculture and horticulture became established by a resident population of cultivators. The farms depended partly on irrigation from an ancient branch of the Nile (the Canopic) that extended for some distance west of the present site of Mariut, but the location of farms far beyond the reach of this branch indicates that effective methods of dryland farming were used. According to Kassas (1972a), the Mareotis district was an area of prosperous cultivation particularly vineyards, and was densly inhabited. Good wine was produced in such quantities that Mareotis wine was laid down for keeping over long periods. By the tenth century, the district gradually declined and the vineyards were replaced by desert. It is unlikely that there have been major climatic changes during the last 2,000 years that could have caused the deterioration of the area. There is also evidence that the fresh water of Lake Mariut and its arm that extended westward for 79 km was used for irrigating farms and orchards fringing the shores of the lakes and banks of its western arm. These strips of irrigated agriculture must have been limited in extent because of the topography.

Earlier this century some attention was given to the Mareotis region. The extension of a railway westward from Alexandria to Mersa Matruh, and the plantation of vine, olive and date palm at Ikingi (20–25 km west of Alexandria) were "early steps towards regeneration" (De Cosson, 1935). Several attempts have been made to reintroduce a variety of orchard crops in Mareotis: vine (*Vitis vinifera*), fig (*Ficus carica*), date palm (*Phoenix dactylifera*), olives (*Olea europaea*), carbo (*Ceratonia siliqua*), almond (*Prunus amygdalus*) and pistachio (*Pistacia vera*) (Kassas, 1972b).

At present the main land uses of Mareotis are grazing and rain-fed farming (or irrigated by underground and run-off water). The main annual crop is barley (*Hordeum vulgare*). Figs are successful on calcareous coastal dunes and olives, almonds and pistachio in inland alluvial depressions. Irrigated agriculture of pasture, grain crops and fruit trees (mainly vine) is spreading after the extension of irrigation canals from the Nile up to 60 km west of Alexandria (Ayyad, 1983).

d. *Plant cover*

(i) Floristic analysis

The Western Mediterranean coastal belt is by far the richest part of Egypt in it floristic composition owing to its relatively high rainfall. The number of species in this belt makes up about 50% of the total of the Egyptian flora which is estimated to be about 2,000 (Oliver, 1938) about 2,080 species (Täckholm, 1974), 2,094 species by Boulos (1995). However, Boulos (1999, 2000, 2002, 2005, 2009) recorded a total of 2,145 species of which 44 species are cultivated. Most of these species are therophytes that flourish during the rainy season, giving the coastal belt a temporary flush as a grassland desert. During the longer dry period, only the characteristic woody shrubs and perennial herbs are evident; these constitute the scrub vegetation of the area, scattered sparsely in parts and grouped in denser more distinct patches in others (Tadros, 1956).

Hassib (1951) describes the percentage distribution of both annual and perennial species among the life-forms in this coastal belt as follows: neither mega- and meso-phanerophytes nor epiphytes are represented. But there are the micro- and nanophanerophytes (3.2%), stem succulents (0.1%), chamaephytes by (9.2%), hemicryptophytes (11.7%), geophytes (11.9%), hydrophytes and helophytes (4.0%), therophytes (58.7%) and parasites (1.1%). Maquis vegetation that characterizes the other Mediterranean countries is not represented in Egypt. The prevailing life-form of perennials is chamaephytes; nanophanerophytes are less.

Xerophytes make up about 90% of the total number of species in this coastal belt; most are therophytes (67%), followed by geophytes (11%), halophytes and helophytes (11%), chamaephytes (6.6%), micro-and nanophanerophytes (3%), parasites (1.2%) and stem succulents (0.1%). The common xerophytes include: *Achillea santolina, Ammophila arenaria, Anabasis articulata, Euphorbia paralias, Gymnocarpos decander, Hammada scoparia, Helianthemum lippii, Lygos raetam, Ononis vaginalis, Pancratium maritimum, Plantago albicans, Thymelaea hirsuta* and *Thymus capitatus.*

The halophytes include about 45 species. Algae are well developed in the rock coastal areas but apparently absent from the loose soil. The submerged phanerophytes include: *Cymodocea major, Posidonia oceanica* and *Zostera notei.* Terrestrial halophytes include *Arthrocnemum macrostachyum*, *Atriplex* spp., *Juncus acutus, J. rigidus, Limoniastrum monopetalum, Nitraria retusa, Salicornia fruitcosa, Suaeda fruticosa, S. pruinosa, Tamarix nilotica* and *Zygophyllum album*.

The helophytes and fresh-water hydrophytes represent about 4% of the total number of flora of this coastal belt. They include: submerged species (e.g. *Ceratophyllum demersum*, *Potamogeton crispus)*, floating species (e.g. *Eichhornia crassipes*, *Lemna* spp.), reeds (e.g. *Phragmites australis* and *Typha domingensis)*, and sedges (e.g. *Cyperus* spp., *Scripus* spp.).

(ii) Habitats and vegetation types

In spite of the relative simplicity of the relief and the apparent uniformity of the climate, the plant habitats in the region present some diversity. For the causal observer, however, the physiognomy of the vegetation seems monotonous over large tracts of land, owing to the prevailing life-form of the perennial plants, being mostly chamaephytes and to a less extent nanophanerophytes with scattered distribution. The only variation in the physiognomy is the change from the short vernal (spring) aspect of the vegetation to the longer aestival (summer) aspect (Tadros, 1956).

The distribution of plant communities here is controlled by topography, the origin and nature of the parent material and the degree of degradation influenced by human manipulation (Ayyad and El-Ghareeb, 1984). Generally, the vegetation of this coastal belt belongs to the *Thymelaeion hirsutae* alliance with two associations:

1. *Thymelaea hirsuta*, *Noaea mucronata* association with two variants dominated by *Achillea santolina*,
2. *Anabasis articulata, Suaeda pruinosa* association (El-Ghonemy and Tadros, 1970).

The local distribution of communities in different habitats is linked primarily to physiographic variations. According to these variations two main sets of habitats may be distinguished – one on ridges and plateaux and the other in depressions. Ridge and plateau habitats may be further differentiated into two main types. The coastal ridge is composed mainly of snow-white oolitic (calcareous) sand grains overlained by dunes in most places whilst inland are less calcareous ridges and the southern tabeland. The southern tabeland is characterized by the dissection of the landscape into an extensive system of wadis which drain into the Mediterranean Sea and form a distinct type of habitat. Inland siliceous dunes are sporadically distributed on the southern tableland and support a community different from that of calcareous dunes on coastal ridge. Habitats of depressions differ according to the relative proximity of the water-table to the surface and consequently to the level of salinity and extent of waterlogging. Five main types of ecosystems may be recognized (Ayyad and El-Ghareeb, 1984; Zahran and Willis, 1992, 2008; Salama et al., 2005).

1. Sand dunes (coastal calcareous and inland siliceous);
2. Rocky ridges and plateaux with skeletal shallow soils;
3. Saline depressions;
4. Non-saline depressions;
5. Wadis.

1. *Sand dunes*

Along the Western Mediterranean coast lies a chain of intensely white calcareous granular sand dunes. They are formed of loose oval pseudo-oolitic grains, each composed of a series of successive coats of calcium carbonate. These dunes form a fairly continuous ridges with an undulating surface and present a type of habitat notable for its monotony. However, such monotony does not invariably mean that either the soil or the vegetation lacks variety. Owing to proximity to the sea, the dunes are more humid and exposed to the immediate effect of the northerly winds. They are also reached by sea spray (Ahmed and Mounir, 1982). Certain sections of the coast are devoid of dunes.

A short distance from the beach, fresh water is frequently obtained by digging carefully in the sand to a depth 3–4 m. This fresh water is undoubtedly rain water, which, having a lower specific gravity than saline water below, can form a layer above it; there may be a hard pan of limestone rock underlying the sand which prevents percolation of rain water, the sand acting as a reservoir of fresh water.

Plants growing in sand dunes are highly specialized and many have the ability to elongate vertically on burial with sand (Girgis, 1973). They are also subject to partial exposure of their underground organs, often without being seriously affected. The coarse grain and loose texture of the sand result in poor water-retention because of rapid percolation. Many psammophytes develop extensive superficial roots that make use of dew.

The vegetation of these sand dunes has been studied by Oliver (1945), Tadros (1953, 1956), El-Sharkawi (1961), El-Ghonemy (1973), Girgis (1973), Ayyad (1973), Ayyad and El-Bayyoumi (1979), Ayyad and El-Ghareeb (1984) etc. Bordering the sea, a community of *Ammophila arenaria* and *Euphorbia paralias* can be usually distinguished on the mobile young calcareous sand dunes. Associates include *Lotus polyphyllos* and *Sporobolus virginicus*.

The vigorous growth made by *Ammophila* when sand covers it dominates the mobile dunes. It is a pioneer species in invading mobile coastal dunes and is consequently extensively used for stabilizing sand-dunes. On the older, advanced and higher dunes, where the sand may be consolidated in parts. *Crucianella maritima* and *Ononis vaginalis* dominate. Associated species include *Ammophila arenaria, Cakile maritima, Centaurea pumila, Echinops spinosus, Echium sericeum, Elymus farctus, Euphorbia paralias, Hyoseris lucida, Launaea tenuiloba, Lotus polyphyllos, Lygos raetam, Pancratium maritimum, Plantago albicans, Reseda alba, Salvia lanigera,* and *Silene succulenta*. In the more advanced stages of dune stabilization, communities of *Crucianella maritima, Echinops spinosus, Elymus farctus, Euphorbia paralias, Pancratium maritimum* and *Thymelaea hirsuta* become successively more common. When the coastal ridge is fairly exposed a community of *Globularia arabica, Gymnocarpos decander, Helichrysum conglobatum* and *Thymus capitatus* predominate.

The inland siliceous dunes are dominated by communities of *Plantago albicans, P. squarrosa* and *Urginea maritima*.

2. *Rocky ridges*

Two (or sometimes three) ridges run south of the sand dune zone extending parallel to the Western Mediterranean coast of Egypt and are separated from the sea by the sand dunes. These ridges are composed of oolitic sand and shell debris, often 20 m or more high with smooth rounded summits. The outer ridge closely skirts the coast while the second one runs parallel with it at a distance of a few km inland. The third ridge, when present, is between the second one and the edge of the Western Desert.

The vegetation of these rocky ridges is an association of *Thymelaea hirsuta* and *Gymnocarpos decander* (Tadros, 1956). However, local variation in the nature of the position and degree of slope lead to parallel variations in the distribution of the vegetation. The characteristic species of this community include *Aegilops kotschyi, Arisarum vulgare, Bupleurum nodiflorum, Carduus getulus, Chenolea arabica, Erodium cicutarium, Limonium tubiflorum, Lotus corniculatus, L. ceticus, Lygeum spartum, Malva aegyptia, Medicago minima, Moricandia suffruticosa, Orlaya maritima, Plantago notata, Reaumuria hirtella, Reichardia orientalis, Scorzonera alexandrina, Stipa capensis, S. parviflora* and *Teucrium polium*.

Rocky sites with low moisture availability are dominated by communities of *Globularia arabica* and *Thymus capitatus* while sites with fairly deep soils and high moisture availability are dominated by communities of *Asphodelus microcarpus, Herniaria hemistemon, Plantago albicans* and *Thymelaea hirsuta*. In sites of intermediate rockiness and moisture availability, *Echinops spinosus, Helianthemum stipulatum, Noaea mucronata, Pituranthos tortuosus* and *Scorzonera alexandrina* are abundant (Ayyad and Ammar, 1974).

These communities extend to the plateau of the south tableland. Two other communities dominated by *Hammada scoparia* and *Anabasis articulata* are found on degraded shallow skeletal soils subjected to active erosion. Associate species of this community include *Asphodelus microcarpus, Atriplex halimus, Carthamus mareoticus, Noaea mucronata, Pituranthos tortuosus, Verbascum letourneuxii* and *Zilla spinosa*. *Salsola tetrandra, Suaeda fruticosa* and *Suaeda pruinosa* are poorly represented. Bushes of *Capparis spinosa* and *Ephedra alata* often grow in vertical rock.

3. *Saline depressions*

The saline depressions (littoral salt marshes) are a common habitat of the Western Mediterranean coastal belt. Tadros (1953) recognized two series of salt marshes. One is formed from depressions directly adjacent to the dune strips. The salinity of this series results from the evaporation of seepage water, where the water-table is exposed or near the surface and where there is poor drainage. The soil is mostly calcareous-sandy due to the encroachment of sand from the neighbouring dunes. In certain places in these salt marshes, low bushes of *Arthrocnemum macrostachyum* and *Halocnemum strobilaceum*, others eventually become buried under moist conditions, forming dense black rotten material from which frequently the smell of hydrogen sulphide can be detected. The second series of salt marshes is formed from the dried bed of Lake Mariut lying between the two ridges. The causes of salinity are essentially as in the first series, but the soil texture is different, having a considerable proportion of silt, regarded as having been derived from the Nile during its previous connection with the lake.

The littoral salt marsh vegetation of the Western Mediterranean coast of Egypt has been described by several authors: e.g. Oliver (1938), Hassib (1951), Tadros (1953, 1956), Migahid et al. (1955), Ayyad and El-Ghareeb (1982, 1984), Ahmed and Mounir (1982) and Zahran and Willis (1992, 2008).

Apart from the communities of the swamp vegetation dominated by *Phragmites australis, Scripus tuberosus* and *Typha domingensis*, the halophytic vegetation is characterized by some 11 communities:

1. *Salicornia fruticosa-Suaeda salsa* community. This usually occupies the zone on the more elevated banks with less submerged saline soil. Associate species are *Phragmites australis* and *Salicornia herbacea*.
2. *Juncus rigidus* community. This occupies lower parts of the marsh with high moisture content where the calcareous and fraction dominates the soil texture. Associated plants include *Halimione portulacoides*, *Inula crithmoides, Juncus acutus, Limonium pruinosum* and *Sporobolus pungens*. In certain patches of this community, there are societies dominated by *Schoenus nigricans*.
3. *Sporobolus pungens* community. This occupies higher parts of the marsh, especially where calcareous sand is plentiful. The associate species are *Juncus rigidus* and *Limonium pruinosum*.
4. *Halocnemum strobilaceum* community. This community occurs over a wide range of fluctuations of salt concentration between the wet and dry seasons where there is a high proportion of fine fractions affecting soil texture. Associate species are *Arthrocnemum macrostachyum, Juncus rigidus* and *Salicornia fruticosa*.
5. *Salicornia fruticosa – Limonium pruniosum* community. This is present in somewhat more elevated and less saline parts than that of the *H. strobilaceum* community. Common associated species include *Inula erithmoides, Juncus rigidus, Parapholis marginata, Plantago crassifolia* and *Sphenopus divaricatus. Halimione portulacoides* and *Phragmites australis* dominate in some patches, the latter species being associated with depressed areas with high water content.
6. *Arthrocnemum macrostachyum-Limoniastrum monopetalum* community. This occurs on even more elevated substrates than the *S. fruticosa-L. pruinosum* community. Characteristic species are *Cressa cretica, Frankenia revoluta*, *Mesembryanthemum nodiflorum* and *Parapholis marginata*.
7. *Zygophyllum album* community. *Z. album* frequently forms an almost pure community on saline patches recently covered by drifted sand in shallow layers. It is also found in communities with other species in similar habitats.
8. *Lygeum spartum* community. This occurs in less saline parts with high organic matter content. Associate species are *Frankenia revoluta, Halimione portulacoides, Limoniastrum monopetalum* and *Limonium pruinosum*.
9. *Salsola tetrandra* community. This community is usually present on the elevated border of the dry saline beds of the marshy valleys. *S. tetrandra* is a very efficient at conserving soil against the wind blowing as well as being a soil builder. The associate species include *Anthemis cotula, Coris monspeliensis,*

Frankenia revoluta, Haplophyllum tuberculatum, Limoniastrum monopetalum, Salicornia fruticosa, Sphenopus divaricatus, Suaeda fruticosa, S. pruinosa and *Traganum nudatum*.

10. *Limoniastrum monopetalum-Lycium europaeum* community. This is another community rich in floristic composition. It may follow in succession the community dominated by *Salsola tetrandra*. Associate species include *Asphodelus microcarpus, Bassia muricata, Carthamus glaucus, Cutandia dichotoma, Echinops spinosus, Ifloga spicata, Lotus villosus, Noaea mucronata, Orlaya maritima, Plantago albicans, Reaumuria hirtella* and *Suaeda pruinosa*.
11. *Atriplex halimus-Picris radicata* community. This is the richest of all communities of the salt-affected land. It occurs on deep sandy loam at the edges and upper parts of valleys where the vegetation covers the soil almost completely. Associate species include *Anthemis microsperma, Chenolea arabica, Chrysanthemum coronarium (Glebionis cornaria), Koeleria phleoides, Lolium rigidum, Lycium europaeum, Medicago minima, Picris radicata, Salvia lanigera, Schismus barbatus* and *Stipa capensis*.

4. *Non-saline depressions*

The non-saline depressions (barley fields) are the most fertile areas of the Western Mediterranean coastal belt of Egypt. These depressions are mainly limited to the plains south of the second ridge in the eastern section of the coast, but are widespread in the valley and plains of the western section.

The soils of these depressions (e.g. the Abu Sir depression), are variable (Ayyad, 1976). In some parts, highly calcareous soils are derived from drifted oolitic grains of the coastal ridge; in other parts alluvial, less calcareous, loamy soils are derived from the Abu Sir ridge.

There depressions provide favourable conditions for cultivation; extensive areas are occupied by barley, figs and olives. Farming operations promote the growth of a considerable number of species, mostly therophytes. Weeds of barley fields are recognized as the *Achilleetum santolinae mareoticum* association, with subassociation of *Chrysanthemetosum coronariae* and *Arisaretosum vulgare*, composed of the following characteristic species: *Achillea santolina, Anagallis arvensis, Calendula aegyptiaca, Carthamus glaucus, Convolvulus althaeoides, Echinops spinosus, Echium sericeum, Eryngium creticum, Hordeum murinum, Koeleria phleoides, Lathyrus cicera, Muscari comosum* and *Vicia cinerea*.

According to Ahmed and Mounir (1982), there are still other species of different communities occasionally present in the barley fields, e.g. *Atriplex halimus, Trifolium tomentosum* and *Suaeda fruticosa.* These species may indicate possible affinities with other associations. The "accidental" species recorded include: *Anchusa hispida, Anthemis cotula, Asteriscus graveolens, Avena sterilis, Beta vulgaris, Bupleurum subovatum, Crucianella maritima, Echiochilon fruticosum, Emex spinosus, Filago spathulata, Francoeuria crispa, Gagea fibrosa, Helianthemum stipulatum, Hippocrepis bicontorta, Hymenocarpus nummularius, Hyoseris lucida, Ifloga spicata, Koniga arabica, Limonium tubiflorum, Lotus creticus, Malva* *parviflora, Moricandia nitens, Ononis vaginalis, Orlaya maritima, Ornithogalum trichophyllum, Papaver hybridum, Reseda alba. Salvia aegyptiaca, Scorzonera alexandrina, Silene villosa, Thesium humile* and *Verbascum letourneuxii*.

The vegetation belongs to the *Plantagineto-Asphodeletum microcarpae* associations. The *Anabasis articulata* community is found on more or less sandy soils with low contents of calcium carbonate, a *Zygophyllum album* community where the soil content of calcium carbonate and salinity are higher. A *Plantago albicans* community occurs where salinity is lower and an *Asphodelus microcarpus-Thymelaea hirsuta* community on fine-textured soils (Ayyad, 1976). The characteristic species include *Alkanna tinctoria, Brachypodium distachyum, Brassica tournefortii, Bupleurum subovatum, Carthamus glaucus, Centaurea glomerata, Linaria haelava, Lolium perenne, Malva parviflora, Medicago littoralis, Onopordum alexandrium, Orobanche ramosa, Papaver rhoeas, Polygonum equisetiforme, Raphanus raphanistrum, Reseda alba, R. decursiva* and *Zygophyllum album*.

5. The wadis

The landscape of the Western Mediterranean coastal land of Egypt is dissected by a drainage system (wadis) originating from a southern limestone plateau lying parallel to the Mediterranean Sea. The plateau reaches a maximum elevation of about 200 m above sea level at Sallum and slopes gently to the coastal plain west of Mersa Matruh (from 10 to 20 m above sea level). These wadis drain northwards into the Mediterranean Sea. An ecological account of one of these wadis (Wadi Habis) is given below.

5.1. *Wadi Habis*

Wadi Habis (31° 24′N, 27° 03′E) is of ecological and historical interest. In this wadi there are archaeological remains of apparently Graeco-Roman age (about 300 B.C.–600 A.D.). The Graeco-Roman occupation of the wadi was restricted to its mouth and its immediate vicinity.

According to El-Hadidi and Ayyad (1975), Wadi Habis is characterized by nine habitats: fallow saline areas, fallow non-saline area, barley fields, olive orchards, wadi bed, lower position of slopes, middle slopes, upper slopes and plateau.

The saline fallow areas are dominated by *Reseda decursiva* and *Asphodlus tenuifolius*. The abundant associates are *Carthamus glaucus* and *Onopordum alexandrinum* while other associates include *Centaurea glomerata, Chrysanthemum coronarium, Echium sericeum, Glaucium corniculatum, Malva parviflora, Papaver rhoeas, Paronychia argentea, Plantago albicans. Salvia lanigera, Senecio desfontainei* and *Trigonella maritima.*

In the non-saline fallow areas, the most abundant species are: *Chrysanthemum coronarium, Picris sprengeriana* and *Trigonella maritima*. Other associates include *Asphodelus tenuifolius, Chenopodium murale* v. *microphyllum, Emex spinosus, Eragrostis pilosa, Erucaria pinnata, Lolium rigidum, Matthiola longipetala, Schismus barbatus, Silene apetala* and *Trifolium tomentosum*.

The barley fields support about 40 species dominated by *Chrysanthemum coronarium, Convolvulus althaeoides, Launaea nudicaulis* and *Plantago albicans*. Other associates include: *Achillea santolina, Adonis dentata, Anagallis arvensis, Arisarum vulgare, Avena sterilis* ssp. *ludoviciana, Beta vulgaris, Brassica tournefortii, Echinops spinosus, Echium setosum, Erodium laciniatum, Lamarckia aurea, Lathyrus aphaca, Linaria haelava, Lotus creticus, Medicago littoralis, Noaea mucronata, Papaver hybridum* and *Senecio desfontainei*.

The olive orchards of the frontal section are characterized by a dense cover of weeds which may be distinguished into two main synusiae. The upper is dominated by grasses such as *Hordeum murinum* subsp. *leporinum, Lolium rigidum* and *Lophochloa cristata* and the lower by *Achillea santolina, Astragalus boeticus* and *Matthiola longipetala* subsp. a*spera*. Other associates include: *Anchusa milleri, Emex spinosus, Euphorbia parvula, Filago desertorum, Fumaria bracteosa, Glaucium corniculatum, Hippocrepis cyclocarpa, Reichardia orientalis, Roemeria hybrida, Schismus barbatus, Scorpiurus muricatus* var. *subvillosus* and *Spergularia diandra*.

The vegetation of the wadi bed is sparse, but the number of speices is high. In this habitat, fine soil material has little chance to settle owing to the high velocity of the water stream during the rainy season. The wadi bed is filled mainly with large boulders, the sparse vegetation being largely restricted to shallow soil accumulation between rock fragments. Common perennials in the wadi bed are *Allium erdelii, Echium sericeum, Euphorbia terracina* and *Salvia lanigera*. Less common ones include: *Allium aschersonianum, A. barthianum, Arisarum vulgare* var. *veslingii, Cynara sibthorpiana, Lygos raetam, Scorzonera alexandrina, Silybum marianum* and *Suaeda pruinosa*. Common annuals include: *Astragalus boeticus, Erodium gruinum* and *E. hirtum*. Less common annuals include: *Aizoon hispanicum, Chenopodium murale* var. *microphyllum, Emex spinosus, Fumaria bracteosa, Mesembryanthemum nodiflorum, Minuartia geniculata* var. *communis, Polycarpon succulentum, Polygonum equisetiforme, Rumex vesicarius, Spergula fallax, Spergularia diandra* and *Trifolium formosum*. More than two-thirds of the taxa recorded in the wadi bed are Mediterranean. The lower gentle slopes support meadow-like vegetation of annual species; the most common are: *Astragalus hamosus, Hippocrepis bicontorta, Medicago littoralis, M. truncatula* and *Spergula fallax*. Perennial associates include: *Allium barthianum, Asphodelus microcarpus, Cynara sibthorpiana, Salsola lonifolia, Salvia lanigera, Scorzonera alexnadrina, Silybum marianum* and *Traganum nudatum*.

On the middle slopes the vegetation is dominated by shrubby species including: *Artemisia inculta, Gymnocarpos decander, Limonium sinuatum* and *L. tubiflorum* and grasses such as *Hyparrhenia hirta* and *Stipa capensis*. Other associates include: *Allium erdelii, Asparagus stipularis* var. *tenuispinus, Avena sterilis* subsp. *ludouiciana, Brassica tournefortii, Bromus rubens, Carduus getulus, Erucaria pinnata, Hammada scoparia* (= *Hyloxylon scoparium*), *Limonium thouini, Lycium europaeum, Mesembryanthemum nodiflorum, Noaea mucronata, Phalaris minor, Picris sprengeriana, Pituranthos tortuosus, Plantago albicans, P. squarrosa, Reichardia orientalis, Salvia verbenaca, Spergula fallax, Spergularia* *diandra, Suaeda pruinosa, Traganum nudatum, Trifolium scabrum, T. stellatum* and *Umbilicus horizontalis*.

The upper slopes are usually steep and almost completely devoid of soil cover. They support a typical cliff vegetation dominated by *Asparagus stipularis, Capparis orientalis, Ephedra aphylla, Lycium europaeum, Periploca angustifolia, Phlomis floccosa* and *Umbilicus horizontalis*. Common perennials include: *Allium barthianum, Asphodelus microcarpus, Echinops spinosus, Gymnocarpos decander, Hammada scoparia, Hyparrhenia hirta, Micromeria nervosa, Noaea mucronata, Scorzonera alexandrina* and *Thymus capitatus*. Common annuals include *Echium setosum, Mesembryanthemum forsskaolii (= Opophyllum forsskaolii*), *Picris sprengerana, Reichardia orientalis* and *Thesium humile* var. *maritima*. Less common are: *Anagallis arvensis, Arisarum vulgare* var. *veslingii, Astragalus asterias, Carthamus glaucus, Convolvulus althaeoides, Cutandia dichotoma, Echium sericeum, Fagonia cretica,Globularia arabica, Helianthemum ciliatum, Hippocrepis cyclocarpa, Leontodon hispidulus* (= *Crepis bulbosa*), *Limonium thouini, Lotus creticus, Malva parviflora, Medicago aschersoniana, Pallenis spinosa, Plantago crypsoides, Pteranthus dichotomus, Ranunculus asiaticus, Salvia lanigera, S. verbenaca* and *Valantia hispida*.

In the plateau of the wadi, the vegetation is dominated by *Gymnocarpos decander, Hammada scoparia* and *Phagnalon rupestre*. In this habitat the fewest associate a species have been recorded, including *Artemisia inculta. Asparagus stipularis* var. *tenuispinus, Atractylis prolifera, Echinops spinosus, Ephedra aphylla, Filago desertorum, Globularia arabica, Helianthemum ciliatum, Lycium europaeum, Micromeria nervosa, Noaea mucronta, Periploca angustifolia, Reichardia orientalis, Reseda decursiva, Rumex vesicarius, Salvia lanigera,* and *Thymus capitatus*.

1.8.1.7 Wetlands

Wetlands are swampy ecotones that function as downstream recipient of water from natural sources, e.g. seas, rivers, wadis etc. as well as human activities, e.g. agricultural, industrial and sewage. The ecological importance of the wetlands stems from their hydrologic attributes being rich in their biological, genetic and chemical resources. Their productivity is high and they comprise valuable habitats for fisheries wildlife and birds (Shaltout and Al-Sodany, 2008).

The coastal wetlands of the North African countries are both Atlantic (in the west) and Mediterranean (in the north). According to Flower (2001), these wetlands consist of ten lakes, three in each of Morocco and Tunisia and four in Egypt. The three lakes of Morocco (Sidi Bou Rhaba, Zerga and Bokka), are located along the Atlantic coast, those of Tunisia (Chitane, Ichkeul and Korba) and Egypt (Mariut, Edku, Burullos and Manzala) are located along the Mediterranean coast.

Studies conducted on the various aspects of these lakes are many and include: Andreossy (1799, *Notes on Lake Manzala*, non-published), Muschler (1912), Montasir (1937), El-Masry (1961), Abu Al-Izz (1971), Al-Kholy (1972), Samaan (1974), Banoub (1979), Khedr (1989, 1999), Zahran and Willis (1992, 2008), Khedr and Zahran (1999), Shaltout and Al-Sodany (2008), Flower (2001), Flowers et al. (2001), Birks and Birks (2001), Birks et al. (2001), Peters et al. (2001), Fathi et al. (2001), Ramadani et al. (2001), Shaltout and Khalil (2005), Khalil and Shaltout (2006), Eid (2008) etc.

Unfortunately the ten lakes of the North African countries were and are still under increasing threats due to human impacts through the uncontrolled water withdrawal, eutrophication, pollution, destruction of biodiversity etc. the CASSARINA[5] project described ecosystem changes in nine of these lakes over the last century and related these to environmental and human stressors in the catchments (Flower, 2001).

As the present chapter of this book is concerned with the North African Mediterranean coastal land, our report will be restricted to six lakes distributed along that coast of Tunisia (Chitani, El-Ichkeul and Korba) and Egypt (Edku, Burullos and Manzala).

A. Tunisian lakes

1. *Lake Chitane*

This is a very small (0.025 km^2), shallow (40–100 cm depth) lake with fresh and soft water (salinity = 0.04–0.12%). It is located on the north of Gebel Chitane at 150 m altitude, 37° 11′N and 9° 10′E overlooking the Mediterranean Sea to the north. The mean annual rainfall over the area of the lake is about 500 mm with maximum and minimum temperatures of 39.5 and 11°C, respectively.

Lake Chitane is protected and was declared nature reserve on 1993. Its ephemeral outflow to the NW has a perimeter fence some 50–100 m from the lake protecting its catchment. Up-slope from the lake, subsistence farming is practised on a small[6] and a small aquifer supplies two small freshwater springs feeding the upper mire bog and eventually the lake. Water flowing through the mire is currently being exploited for crop irrigation. The sandstone aquifer and the peat bog are acid and this confers acidity to the lake (Ramadani et al., 2001).

The plant life of Lake Chitani is quite distinct. It is an important site for the very rare floating hydrophytes; the water lily (*Nymphaea alba*) and the North African species: *Nitella opaca* (Birks et al., 2001). Other characteristic aquatic and terrestrial flora are: *Isoetes velata, Potamogeton natans, Myriophyllum alterniflorum, Juncus acutiflorus, J. heterophyllus, J. bulbosus, J. effuses, Lemna minor, Typha angustifolia, Lotus ornithopodioides and Cotula* spp.

2. *Lake El-Ichkeul*

Lake El-Ichkeul (37° 2′N, 9° 48′E) is a large (89 km^2) shallow (10–80 cm), brackish (salinity = 1.66–3.7%) basin that has experienced major disturbance in recent decades. It is located in a coastal area where the mean annual rainfall is about 578 mm and maximum and minimum air temperatures are about 44 and 11°C,

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[5]CASSARINA = Change and Sustainability: Aquatic Ecosystem Resilience in North Africa.

[6]Mire = Deep mud.

respectively. It is connected to the Mediterranean Sea through the Oued Tinja and Lac de Bizerte (Ramadani et al., 2001).

Although Lake Ichkeul is surrounded by the productive agricultural land (mainly cereals), of the Mateur region, the main changes stem from twentieth century hydrological modifications of the five main inflowing rivers. Following canalization, all but one of these inflows has been barraged since 1984 so that freshwater inputs are now much reduced (Ramadani et al., 2001). In the past, water usually flowed out from the lake during dry periods. Since 1986, Sluice gates on the Tinja River outflow have control over seawater inflow but there are conflicts between fisheries and biodiversity interests. Recently, the salinity of Ichkeul Lake has increased so that hypersalinity persisted in the mid-1990s (Karaiem and Ben Hamza, 2000). This lake was designated a Biosphere Reserve on 1977 and World Heritage Site in 1996. The marshland and the lake used to receive 200,000 over-wintering and migrating birds annually, mainly ducks, coots, grebes cormorants, spoonbills, storks, herons, and waders. The geese have declined in the 1990s mainly because of the loss of marshland.

The plants of Ichkeul Lake are of ecological interest. The exposed lake shores are dominated by *Sarcocornia fruticosa (Arthrocnemum fruticosum), Juncus subulatus, Ammi visnaga and Frankenia laevis*. In the fore-shore depressions, there are communities dominated by *Tolypella glomerata, Callitriche* sp., *Potamogeton pectinatus, Zannichellia palustris, Enteromorpha intestinalis* and *Chaetomorpha linum*. Other flora recorded in the lake are: *Ruppia cirrhosa, Trifoluim stellatum*, *Scirpus miritimus* and *S. littoralis*. However, according to Ramadani et al. (2001), the two species of *Scirpus* were absent during the 1998 monitoring and the *Ruppia cirrhosa* was well established in the centre of the lake. Small residual patches of *Phragmites australis* indicated the potential for *Phragmites* regeneration if salinity is reduced. Until the late 1980s, *Phragmites* formed an extensive marginal fringe around most of the lake shore but by the mid-1990s, this had almost disappeared, the zone being marked in 1997–1998 with dead, occasionally *Balanus* encrusted bases of stems.

3. *Korba lake*

Lake Korba (36° 46′N, 11°E) is an elongated small (0.32 km^2) hypersaline (salinity = 2–7.9%) lagoon with a depth ranging between 15 and 85 cm, in an area receiving about 450 mm annual rainfall and maximum and minimum temperatures of 40 and 11°C, respectively (Ramadani et al., 2001). It occupies a long narrow shallow channel on the east coast of the Cap Bon peninsular. A partially vegetated sand dunes separates it from the Mediterranean, approximately 100 m distant. Water quality is affected at the south part by pollution from the town of Korba and also by sea water penetration. At two points, the sand dune is breached forming temporary connection with the Mediterranean. Seasonally, fresh water inflows to the north end of the lake from the nearby Chiba and Boulidin stream occur but water abstraction for agriculture is intense. Ramadani et al. (2001) stated that in recent years, saltwater has encroached into the freshwater-table in the Korba region. On the lake's west side, soil is irrigated for crops in summer months and is separated from the lake by *Salicornia europaea* salt marsh community. At the center of the lake, the depth varies from 30 to 60 cm and the shallower northern part consists of hard-packed grey clays, probably ancient and of marine origin. A large part of the lake bed is covered by a dense mat of green filamentous algae.

In Korba Lake, the recorded aquatic macrophytes include: *Ruppia cirrhosa, Posidonia oceanica,* and *Chara, lamprothamnium*. All these taxa tolerate sea-water. The littoral salt-marsh is dominated by *Juncus maritimus, Blysmus compressus*, and *Cyperus* spp. together with *Scirpus maritimus* and *Typha angustifolia*. The presence of *Typha* may suggest some fresh-water influence. On the other hand, the presence of Gramineae fruits may originate from *Phragmites australis* or other grasses of salt-marsh or sand dune habitats likely to be growing around the lake. The growth of *Zygophyllum album*, *Mesembryanthemum crystallinum* and *Verbena* sp. may indicate the presence of saline sand soil.

B. Egyptian lakes

In Egypt, the northern coast of the Nile Delta close to the Mediterranean sea is characterized by three shallow lakes: Edku (in the west), Burullos (in the middle) and Manzala (in the east). They are separated from the sea by narrow to very narrow strips of land and are connected with it through narrow outlets (straits). These straits are either remnants of the mouths of old deltaic branches of the Nile or merely gaps in weak sections of the bars known as tidal inlets (Abu Al-Izz, 1971). These deltaic Mediterranean lakes receive the main bulk of the drainage waters from the Nile Delta (Zahran and Willis, 2008). Mean annual rainfall ranges between 196.7, 196.7 and 112.2 for the three lakes respectively (Ramadani et al., 2001).

The Nile deltaic Lakes have been subjected to major disturbances since ancient times caused by several factors, such as continual degradation and deposition, the accumulation of the remains of vegetation, the blowing of sand and the construction of levees. All these factors and others have caused a decrease in their areas starting 1799 (Al-Kholy, 1972; Butzer, 1976). For example, the area of Lake Edku was about 80,000 feddans in 1799 decreased to 17,000 feddans on 1970 and those of Lake Burullos and Lake Manzala were 270,000 and 470,000 feddans on 1799 decreased to 130,000 feddans and 300,000 feddans on 1970 respectively (Feddan = 4,200 m^2). Today, the loss in areas is rather greater.

Ramadani et al. (2001) stated that the hydrological regime of these deltaic lakes results from a balance of freshwater runoff from the agricultural regions in the south and seawater from the north. The undisturbed margins are extensively vegetated, mainly by reedwamps (*Phragmites australis* and *Typha domingensis*). These two reeds are also frequent on the shorelines and islets. Water hyacinth (*Eichhornia crassipes*) is proliferating everywhere. Productive agriculture around the lakes, date palm and sugar cane plantations, cereals and leguminous crops, has been encouraged by the increased supply of fresh Nile water for irrigation in recent decades. The water quality of all lakes is locally affected by sewage and agro-chemicals drainage water mainly from southern agricultural drainage regions. According to Goodman and Meininger (1989), many Palearctic bird species usually migrate via the Deltaic Mediterranean Lakes in internationally significant numbers, and hence changes in their nature are important conservation issues.

1. *Edku lake*

Lake Edku (31° 15′N, 30° 15′E) lies parallel to the Mediterranean Sea at about 36 km east of Alexandria with an area of about 126 km^2 and depth between 50 and 200 cm. It receives drainage water through two main drains, as well as, saline water from the sea to which it is connected by the Boughaz channel (El-Masry, 1961; Ramadani et al., 2001). It is surrounded by a productive agriculture to the south, by ongoing land reclamation activities to the east, and by housing and industry to the west side where much reclamation has occurred since the nineteenth century. The northern border of the lake is a sand ridge that separates the lake from the sea and supports date-palm groves, subsistence agriculture and several villages.

The wetland vegetation comprises submerged, floating, reed swamp, sedge meadow as well as halophytic elements. *Phragmites australis* usually dominates the reed swamp habitat with abundant growth of *Typha domingensis*. The floating type is dominated by *Eichhornia crassipes* associated with *Jussiaea repens, Lemna minor*, *L. gibba, Azolla nilotica, Wolfia hyalina, Alternanthera sessilis* and *Spirodela polyrrhiza*. Submerged vegetation is dominated by *Ceratophyllum demersum* associated with *Najas armata, Potamogeton pectinatus, P. crispus, and Ruppia maritima*. The sedge-meadow vegetation is dominated by *Juncus acutus* associated with *Cyperus articulatus* and *Scirpus litoralis* and some halophytes including: *Inula crithomides, Arthrocnemum macrostachyuns, Atriplex portulacoides, Salicornia fruticosa*, and *Zygophyllum album* (El-Masry, 1961; Birks et al., 2001).

2. *Lake Burullos*

Burullos wetland is located along the Mediterranean coast bordered from the north by the sea and from the south by the agricultural lands of north Delta (Kafr El-Sheikh Governorate). It lies in a central position between the two branches of the River Nile: Rosetta in the west and Damietta in the east (31° 36′N and 31° 07′E to 31° 22′N, 30° 33′E to 31° 22′N, 31° 07′E). It has a total area of about 460 km^2 including the lake and approximately 75 islets with a shoreline of about 65 km. The area of the sand bar is about 165 km^2 (Ramadani et al., 2001; Shaltout and Khalil, 2005).

Lake Burullos is connected with the Mediterranean Sea at its NE side through the El-Burullos outlet (Bougaz El-Burullos) which is about 250 m wide and 5 m deep. The depth of the lake ranges between 40 cm in its middle sector and near the shores and 200 cm near the outlet to the sea.

Lake Burullos has probably suffered less disturbance than Lake Edku but it is subjected to land reclamation, particularly along its southern and eastern edges. The northern border is a low sand ridge that is currently under development with a town and a major road linking Rosetta and Damietta. This lake is a Ramsar Site and plays host to large populations of migratory and resident water-birds. Valuable cover is provided by extensive beds of reed vegetation formed mainly from *Phragmites australis* and *Typha domingensis*. Water hyacinth (*Eichhornia crassipes*) is abundant. On the northern side of the lake there are extensive patches of the submerged weed *Potamogeton pectinatus* which are considered important refuges for fish fry.

Six major types of habitats characterize Burullos wetland: salt marshes, sand formations, lake cuts, drains, the lake proper and it's islets. According to Shaltout and Khalil (2005), the flora of these habitats comprises 197 species: 100 annuals and 97 perennials (including 12 hydrophytes). These species belong to 139 genera and 44 families. The grasses have the highest contribution to the total flora (18.1%) followed by Compositae (13.6%), chenopods (10.1%), legumes (7.0%) and crucifers (6.0%). Twelve species are wide spread and recorded in about 75% of the habitats, including 7 perennials (*Phragmites australis, Arthrocnemum macrostachyum, Halocnemum strobilaceum, Sarcocornia fruticosa, Cynodon dectylon, Suaeda vera* and *Tamarix nilotica*) and five annuals (*Salsola kali, Senecio glaucus subsp. coronopifloius, Mesembryanthemum nodiflorum, Polypogon mospeliensis* and *Spergularia marina*). The following is a brief account of distribution of species between the six major habitats (Shaltout and Khalil, 2005).

1. Salt marshes

In the salt affected lands of Burullos wetlands, a total of 51 species have been recorded, including: 30 perennials and 21 annuals. The most abundant species are: *Arthrocnemum macrostachyum, Halocnemum strobilaceum, Juncus acutus, Phragmites austrarlis, Tamarix nilotica* and *Salsola kali*. Others are rare such as: *Cyperus rotundus, Atriplex canescens, Cyperus alopecuroides, Cynomorium coccineum, Polypogon monspeliensis, Chenopodium murale* and *Sonchus oleraceus*. Species not found elsewhere are: *Alternaria sessilis, Echinops spinosus, Frankenia revoluta, Imperata cylindrica, Ricimus communis, Scirpus holoschoenus, Tamarix aphylla, Carex divisa, Astragalus peregrinus, Amaranthus lividus, Frankenia pulverulenta* and *Rapistrum rugosum*.

2. Sand formations

A total of 45 species have been recorded in this habitat: 18 annuals and 27 perennails. Species not recorded from elsewhere are: *Cistanche phelypaea, Convolvulus lanatus, Orobanche cernua, Panicum turgidum, Silene succulenta, Bromus catharticus, Cakile maritime* and *Fagonia arabica*. The common species are: *Arthrocnemum macrostachyum, Halocnemum stroblilaceum, Zygophyllum album* and *Salsola kali*, whereas the following are rare: *Cynodon dactylon, Cressa cretica, Cynanchum acutum, Alhagi graecorum* and *Sphenopus divaricatus*.

3. Lake cuts

A total of 29 species have been recorded in this area: 12 annuals and 17 perennials. Only *Rumex pictus* is unique to this habitat of the lake ecosystem. The common species are: *Arthrocnemum macrostachyum, Halocnemum strobilaceum,* *Sarcocornia fruticosa, Suaeda vera, Zygophyllum album, Juncus rigidus, Launaea nudicaulis, Salsola kali* and *Spergularia marina*. Some species are rare, such as: *Tamarix nilotica, Cynodon dactylon, Suaeda pruinosa, Juncus rigidus, Alhagi graecorum, Chenopodium album, Trigonella stellata, Reichardia tingitana* and *Amaranthus viridis*.

4. Drains

4.1. *Terraces of the drains*

A total of 87 species have been recorded in this habitat: 50 annuals and 37 perennials. Species not found elsewhere are: *Polypogon viridis, Salix tetrasperma, Silybum marianum, Brassica rapa, Coronopus didymus, Coronopus squamatus, Juncus bufonius, Raphanus raphanistrum* and *Trifolium alexandrinum*. The common species are: *Arthrocnemum macrostachyum, Suaeda vera, Salsola kali* and *Senecio glaucus* subsp. *coronopifolius*. The rare species are: *Cyperus rotundus, Typha domingensis, Phyla nodiflora, Saccharum spontaneum, Atriplex portulacoides, Ifloga spicata, Cyperus difformis* and *Emex spinosa*.

4.2. *Slopes of the drains*

A total of 69 species have been recorded in the habitat: 45 annuals and 24 perennials. Species not found elsewhere are: *Plantago major, Amaranthus hybridus, Coriandrum satium, Gnaphalium luteo-album, Lathyrus marmoratus, Phalaris paradoxa, Sisymbrium irio, Sonchus macrocarpus* and *Trifolium resupinatum*. The common species are: *Phramgites australis, Arthrocnemum macrostachyum, Sarcocornia fruticosa, Suaeda vera, Salsola kali, Senecio glaucus* subsp. *coronopifolius* and *Sonchus oleraceus*. The rare species are: *Paspalidium geminatum, Atriplex halimus, Ipomoea carnea, Ranunculus sceleratus, Cichorium endivia* subsp. *pumilum, Hordeum marinum, Medicago polymorpha* and *Anagallis arvensis*.

4.3. *Water-edges of the drains*

A total of 59 species have been recorded: 19 annuals and 40 perennials including 6 hydrophytes. Species not found elsewhere are: *Clerodendrum acerbianum, Sida alba, Medicago itnertexa* var. *ciliaris, Rorippa palustris, Setaria verticillata* and *Setaria viridis*. The common species are: *Phragmites australis, Sarcocornia fruticosa* and *Azolla filiculoides*. Species recorded as rare are: *Halocnemum strobilaceum, Inula crithoides, Cynanchum actum, Suaeda maritima, Centaurea calcitrapa, Sphaeranthus suaveolens, Tamari tetragyna* and *Ammi visnaga*.

4.4. *Open-water of the drains*

A total of 14 speies were recorded in this habitat. The common speices are: *Phragmites australis, Eichhornia crassipes, Ceratophyllum demersum, Azolla filiculoides and Echinochloa stagnina. The rare species are: Arthrocnemum* *macrostachyum, Sarcocornia fruticosa, Lemna perpusilla, Potamogeton crispus* and *Salsola kali*.

5. Lake proper

5.1. *Lake shores*

A total of 65 species have been recorded in this habitat: 22 annuals and 43 perennials including 5 hydrophytes. Species unique are: *Orobanche ramosa* var. *schweinfurthii, Persicaria senegalensis, Vigna luteola, Chyrsanthemum coronarium* and *Poa annua*. The common species are: *Phragmites australis, Arthrocnemum macrostachyum, Sarcocornia fruticosa, Tamarix nilotica, Juncus acutus, Spergularia marina* and *Polypogon monspeliensis*. The species recorded as rare are: *Zygophyllum album, Cyperus rotundus, Persicaria salicifolia, Phyla nodiflora, Cyperus articulatus, Conyza bonariensis, Melilotus indicus, Potamogeton pectinatus, Eichhornia crassipes, Lemna perpusilla, Ludwigia stolonifera* and *Wolffia hyalina*.

5.2. *Open-water of the lake*

Sixteen perennial species have been recorded in this habitat including 10 hydorphytes. Species only recorded in this habitat are: *Ceratophyllum submersum, Najas marina* var. *armata* and *Najas minor*. The common species are: *Phragmites australis, Typha domingensis, Potamogeton pectinatus, Eichhornia crassipes* and *Ceratophyllum demersum*. The rare species are: *Cyperus alopercuroides, Echinochloa stagnina, Lemna perpusila, Ludwigia stolonifera, Wolffia hyaline* and *Potamogeton crispus*.

6. Lake islets

A total of 89 species were recorded in this type of habitat: 45 annuals and 44 perennials including 5 hydrophytes (see Khedr and Lovett-Doust, 2000). Species only recorded from this habitat are: *Allium roseum, Asparagus stipularis, Cyperus laevigatus, Lycium schweinfurthii, Pancratium maritimum, Phoenix dactylifera, Urginea undulata, Adonis dentata, Astragalus boeticus, Brassica tournefortii, Calendula aegyptiaca, Cutandia dichtoma, Echinochloa colona, Erodium laciniatum, Euphorbia peplis, Filago desertorum, Launaea capitata, Lobularia arabica, Paronychia arabica, Parapholis incurva, Portulaca oleracea, Ranunculus marginatus, Silene villosa, Spergula fallax, Sinapis arvensis* subsp. *allionii* and *Sporpolus pungens*. The common species are: *Phragmites australis, Arthrocnemum macrostachyum, Sarcocornia fruticosa, Inula crithmoides* and *Juncus acutus*. The rare species are: *Suaeda pruinosa, Cressa cretica, Aster squamatus, Saccharum spontaneum, Cyperus articulatus, Limoniastrum monopetalum, Tamarix tetragyna, Mesembryanthemum crystallinum, Anagallis arvensis, Potamogeton pectinatus, Eichhornia crassipes, Ceratophyllum demersum* and *Lemna perpusilla*.

3. *Lake Manzala*

Lake Manzala (31° to 31° 30′N and 31° 50′ to 32° 15′E) is the largest of the northern deltaic lakes of Egypt. With an area of about 1,400 km^2 (Khedr, 1989). It lies in the northern quadrant of the delta between the Mediterranean Sea to the north, the Suez Canal, Port Said and Ismailia Provinces to the east, the Damietta Branch of the River Nile and the provinces of Sharkiya and Dakahliya to the west. Rough waves do not occur in Lake Manzala, because it is too deep (0.7–1.5 m). The lake is joined to the Mediterranean Sea by the Straits Ashtum El-Gamil and other openings; the northern section of the lake is, therefore saline. The southern border of the lake has many inlets through which water drains from the surrounding provinces (Port Said, Ismailia, Damietta, Sharkiya and Dakahliya). Sewage water from Cairo also reaches Lake Manzala through the Bahr El-Baqar drain. Fresh water reaches the lake from the downstream part of the Damietta branch of the River Nile. Thus, Manzala Lake receives three types of water: freshwater, sea water and drainage water. Abu Al-Izz (1971) stated "The flow of drainage water rate into the lake diminishes the salinity to between 0.8 and 1.0%" compared to the Mediterranean Sea at 3.3–3.9%. Zahran and Willis (1992) noted that the water of Manzala Lake was used for drinking during times of flood. Since the establishment of the Aswan High Dam in 1965 no more floods occur and, thus, the salinity of the lake's water is increasing. Now the huge amounts of drainage and searage waters reaching the lake every day have considerable effects on its chemical, physical and biological characteristics.

Due to the establishment of Port Said/Damietta coast road associated with landfill and drainage activity, much of the north west area of Lake Manzala is now wholly or partly reclaimed or converted into fish farming lagoons. The southwestern region is probably the least disturbed where dense stands of reed-swamp vegetation *(Phragmites australis* and *Typha domingensis*) occur. These stands are cut and harvested for different uses. Water hyacinth colonizes large area of the lake. The reed-beds support a rich bird life community as well as the fisheries (Ramadani et al., 2001).

The vegetation of Lake Manzala has been reported long ago by Montasir (1937) who recognized three vegetation types: hydrophytic, halophytic and helophytic. The dominant helophytes were *Cryperus* spp., *Juncus* spp., *Phragmites australis* and *Typha domingensis* and the dominant hydrophytes were *Ceratophyllum demersum, Eichhornia crassipes, Lemna* spp. and *Potamogeton crispus*. Khedr (1989) reported that, apart from the dominant reeds, the waters are characterized by five dominant hydrophytes: *Eichhornia crassipes, Ludwigia stolonifera, Najas marina* subsp. *armata, Potamogeton pectinatus* and *Ruppia maritima*. Other species include: *Alteranthera sessilis, Ceratophyllum demersum, Cyperus articulatus, Echinochloa stagnina, Epilobium hirsutum, Juncus subulatus, Leersia hexandra, Lemna gibba, L. minor, Leptochloa fusca, Nymphaea caerulea, Panicum repens, Paspalidium geminatum, Paspalum distichum, Persicaria salicifolia, P. senegalensis, Pistia stratiotes, Scripus litoralis* and *S. maritimus*. Recently, Khedr (1999) recognized eleven aquatic communities in Lake Manzala dominated by: *Ceratophyllum demersum, Najas marina* subsp. *armata, Potamogeton crispus* and *Ruppia maritima* (submerged), *Eichhornia crassipes, Ludwigia stolonifera* and the fern *Azolla filiculoides* (floating) and *Echinochloa stagnina, Phragmites australis, Scirpus maritimus* and *Typha domingensis* (emergent). The associate species, in addition to those recorded by Khedr (1989), include *Nymphaea lotus* and *Spirodela polyrhiza* (floating) and *Marsilea aegyptiaca, Rorippa palustris* and *Veronica anagallis-aquatica* (emergent).

From a TWINSPAN *two-way classification* of the 100 stands, Khedr (1999) suggested splitting its communities into 8 groups which seem ecologically meaningful. In terms of their indicator species, these groups are:

Group A. Indicated by *Ludwigia stolonifera* and *Azolla filiculoides* characteristic of stagnant freshwater in the western and southern parts of the lake.

Group B. Indicated by *Eichhornia crassipes, Echinochloa stagnina* and *Azolla filiculoides*, and characteristic of the polluted parts of the lake at the mouth of the drains in the south-western shores.

Group C. With *Potamogeton pectinatus* as indicator species, more abundant than floating emergent species in all parts of the lake.

Group D. With *Najas marina* subsp. *armata* and *Ceratophyllum demersum* as indicator species, both of which are dominant in the western and middle parts of the lake. They form very dense monospecific stands that hinder navigation.

Group E. Indicated by *Typha domingensis* which is variably distributed in the lake with relatively low abundance in the northern section close to the sea because, unlike *Phragmites australis*, it is not very salt-tolerant.

Group F. With *Scirpus maritimus* as indicator species in the swamps and around the islands of the lake, particularly in the shallow parts.

Group G. Indicated by *Phragmites australis*, the most frequent species in the lake; occurring in all parts, even those which are saline and polluted.

Group H. Indicated by *Ruppia maritima* which is dominant in the shallow parts and lagoons in the northern section of the lake near the Mediterranean Sea where salinity is relatively high.

1.8.2 South-West Asian Mediterranean Coastal Lands

1.8.2.1 General Remarks

The south-west Asian Mediterranean coastal lands extend along the northern Mediterranean coast of the Sinai Peninsula in Egypt and the coasts of the countries of the Levant Lands,[7] i.e. Palestine, Israel, Lebanon and Syria. Except Lebanon all of these countries have territories in the arid zone of the Mediterranean Basin where the annual amount of rainfall rarely exceeds 350 mm and vegetation is sparse

[7]Levant Lands are the lands of the East or Orient where sun is seen to rise (Branigan and Jarrett, 1975).

and devoid of arboreal dominants. However, according to the map of the world distribution of arid regions (UNESCO/FAO, 1963), only the northern parts of Israel and Syria are marked as semi-arid. It is area of striking contrasts in its topography and climate. Its highest mountain peak, in Edom (Transjordan) rises up to 1,700 m above sea level; its lowest depression, the Dead Sea region, falls to 396 m below sea level. Its northern districts enjoy a typical Mediterranean climate while its southern parts are desolate desert (Zohary, 1962). Since vegetation is the major component determining the nature of ecosystems, the area under consideration may be subdivided from the vegetation point of view into deserts and steppes, the demarcation line running between the 70- and 100-mm isohyets. Admittedly, the term steppe is not a good one, since the distinction between deserts and steppes is difficult, and terms like semi-desert, semi-steppe, steppe-desert and shrub-steppe are confusing and ill-defined (Zohary, 1973). However, the 70–100 mm isohyets seem to be the lower threshold for rain-fed vegetation, whereas below it vegetation is restricted to runnels and turns out to be "run-on" vegetation (*a mode contracté*).

The biodiversity (flora and fauna) of the SW Asian Mediterranean coastal lands has always been a most attractive subject to explorers and scientists since the sixteenth century. Among the earliest collectors and explorers the name of Rauwolf (1583) is noteworthy. He journed through Palestine, Syria and Mesopotamia in the years 1573–1575. The results of this botanical findings were published by Gronovius in the latter's Flora Orientalis (1755). Strand (1756) was the first to compile a *Flora Palestine* with the guidance of Carl von. Linné (Linnaeus). These were followed by the valuable book *Iter Palaestinuns* by Hasselquist published in the years 1749–1752, and the Flora *Aegyptiaco-Arabica* by Forsskääl published in 1775.

During the first half of the nineteenth century the flora and fauna of the Levant countries and the Sinai became the focus of attention of many eager explorers, botanists and collectors. Among these we may mention: Delile (1809–1812), Fresenius (1834), Aucher-Eloy (1843), Kotschy (1861), Boissier (1867–1888), Tristram (1884), and Hart (1891). During the last decades of the nineteenth century, a series of ecological investigations in Syria, Palestine and Sinai were carried by Post (1896), Bornmuller (1898, 1912), Post and Autran (1899), and Post and Dinsmore (1932–1933). These were followed by Eig (1938, 1948), Eig and Zohary (1939), Zohary (1932, 1941, 1962), Hassib (1951), Bodenheimer (1957), El-Hadidi (1969), Waisel (1971), Täckholm (1974), Danin (1983), Orshan (1985), Ayyad and Ghabour (1986), Zahran and Willis (1992, 2008) and Boulos (1960, 1995, 1997, 2009).

1.8.2.2 Climate

The climate of the SW Mediterranean Coastal deserts is of the Mediterranean type. A major factor determining it is the western jet stream blowing over the Mediterranean from November to March. During the rest of the year, however, there is an easterly flow pattern in the upper atmosphere (Kendrew, 1961; Meigs, 1962; Fisher, 1978; Orshan, 1985). In winter a zone of small low-pressure depressions is formed which cause a succession of distributed cyclonic condition. In summer and very early autumn cyclonic depressions rarely affect the Middle East. A general account on the precipitation and temperature is given below.

(i) *Precipitation*

The fact that rainfall in the SW Mediterranean coastal desert occurs under conditions of instability means that much of it may be heavy but of short duration and extremely capricious, both in periods of onset and distribution. In its more arid parts it may be patchy, with the size of patches sometimes not exceeding a few square kilometers. Average of rainfall are also misleading in many cases, since variation from the mean may exceed 100%. The coefficient of variation of annual rainfall in Israel increases with decreasing amounts of rainfall, reaching a figure as high as 73% in Eliat (Sharon, 1972).

Although the exact distribution of rainfall varies from year to year, the general trend is as follows. Rainfall occurs first in early autumn when the dry summer air masses are displaced by damper and more unstable currents from the west. Light showers may occur during September and October, with heavier and more prolonged falls at the end of October and November. The latter are generally followed by relatively fine periods. The real rainy season begins at the end of December and January or February are generally the months with maximum rainfall. By the middle of May rain has practically ceased, and no rain normally fall until September or October (Table 1.7).

Apart from rainfall, dew is also an important form of precipitation. The number of average annual dew nights measured in the Negev highlands for the years 1963–1966 amounted to 195 and the amount of dew to 33 mm, which is more than a third of the total amount of rainfall (Evenari et al., 1971, 1982). Although dew is generally ineffective in changing the soil moisture content, since it evaporates rather quickly, it has an important effect on lower plants and certain animals (Lange et al., 1970; Shachak et al., 1976).

(ii) *Temperature*

Summer temperatures of the SW Asian Mediterranean deserts are generally high (Table 1.7). The warmest months are July and August with monthly average temperatures around 30°C. July is generally the hottest month inland, August in localities closer to the coast.

Winter temperatures are moderate; the coldest month is January with average winter temperatures reaching as high as 15°C, where they rarely reach the freezing point. Temperatures lower than freezing and occasional snow may occur, but they are generally of a short duration.

Of all criteria for climatic and biotic classifications of the SW Asian Mediterranean coastal desert, annual rainfall seems to be the best. The 350 mm isohyet corresponds roughly to the borderline between the arid and non-arid territories, whereas the 100 mm isohyet corresponds to the borderline between arid/desert and semi-arid/steppe territories.

Table 1.7 Seasonal monthly range (means) and average annual rainfall and temperature of SW Asian countries having arid land territories in the Mediterranean basin (after Orshan, 1985)

	Rainfall (mm)					Temperature (°C)				
	Seasons					Seasons				
Countries	Wn	Sp	Sm	Au	Average annual	Wn	Sp	Sm	Au	Average annual
1. Aleppo (Syria)	64–88	14–34	0.0	Tr-44	373	3–9	10–21	26–32	11–25	18
2. Beersheba (Israel)	39–44	3–32	0.0	0.3–27	204	12–14	14–23	25–26	18–25	20
3. El-Arish (Sinai, Egypt)	16–18	1–16	0.0	0.0–14	95	11–13	19–28	23–26	17–24	19

Wn = Winter, Sp = Spring, Sm = Summer, Au = Autumn, Tr = Traces.

1.8.2.3 Floristic Regions and Vegetation Types

The south-west Asian Mediterranean coastal land is a meeting place of four-plant geographical (floristic) regions: Mediterranean, Irano-Turanian, Saharo-Arabian (all belonging to the Holarctic Region) and Sudanian (Palaeotropic Region). Various territories of these coastal lands are dominated by elements of one of the latter three regions with elements of the other more or less represented in them. It is therefore not easy to delimit the exact borders of each territory, and more or less gradual transition areas between them are quite common (Eig, 1932; Zohary, 1973).

The Mediterranean region, which lies outside the desert proper has, however, a marked influence on it, since its elements are well represented in the flora of its various territories. The Irano-Turanian region is, generally, characterized by its continentality and a relative low amount of rainfall. It is characterized by two stressful seasons limiting plant growth – a cold winter when low temperatures are the limiting factor for plant growth and development, and a hot dry summer when water is the limiting factor. However, in our area with its Mediterranean-type climate, the winter stress period is practically missing. The 100-, 150- and 350-mm isohyets run more or less parallel to the boundaries between the Irano-Turanian, Mediterranean and Saharo-Arabian territories, respectively. The vegetation characterizing the Irano-Turanian territory is a dwarf-shrub steppe.

The Saharo-Arabian region is characterized by its higher temperatures both in winter and summer, and its lower annual rainfall. Under the most extreme conditions the amount of rainfall approaches, and in certain years even reaches, zero. The vegetation dominating the Saharo-Arabian territories is generally restricted (except in sandy areas) to runnels and water-courses, where it is dominated by dwarf-shrubs with annuals as a background. Savanna-like vegetation type characterizes this climatic region (Orshan, 1985).

The Sudanian Region occupies part of Tropical Africa, north of the equatorial rainforest region, as well as the south-eastern corner of Arabia, southern Iran and Baluchistan. The Tropical flora of Palestine contains partly Omni-Sudanian and Eritreo-Arabian elements, and partly bi-and pluri-regional Tropical groups (Zohary, 1962).

Apart from the above mentioned floristic regions, Zohary (1962) considers that the aquatic elements (15 species) of this section of the Mediterranean coastal land come from the Eurosiberian Region.

Ecologically, the arid land territories of the SW Asian Lands of the Mediterranean coast have been classified by Orshan (1985) into five major vegetation types: Steppes (semi-deserts), deserts, Savanoid deserts, sand formations and salinas. The following is a brief account on these vegetation types.

(i) ***Steppes (semi-deserts)***

Due to the destructive effects of man on vegetation in the Levant countires during millennia, it is not easy in many cases to determine the nature of the climax plant communities. This is especially true in semi-desert areas or in the transition zones between the typical Mediterranean areas and those of semi-deserts or steppes.

Remnants of trees which are found here and there in more protected areas suggest that a kind of a steppe-forest with widely scattered trees dominated these areas (Long, 1957). The main species seem to have been *Pistacia atlantica, Amygdalus* spp., *Rhamnus* spp., *Pyrus* spp., and others. Between these trees or shrubs, vegetation is suggested to have been more or less similar to that dominating the area at present, but richer in grasses which had been removed by selective grazing, Boyko (1949) suggested, however, that it had been dominated mainly by perennial grasses.

Remnants of such steppe-forests or groups of trees are found in the upper slopes of the Jordan Valley in Israel and Jordan (Zohary, 1973; Feinburn and Zohary, 1955), in central Sinai and on the higher mountains of southern Sinai where *Pistacia khinjuk* replaces *P. atlantica* on igneous rocks (Zahran and Willis, 1992). They are also found in the central Negev (Danin et al., 1975), in the Jordanian Desert (Zohary, 1940), in the Syrian Desert (Pabot, 1954) and in northwestern Iraq (Guest, 1966).

With increasing aridity the trees are replaced by shrubs – *Ziziphus lotus* in the upper Jordan Valley and the Syrian Desert (Zohary, 1962), and by *Lygos raetam* and *Rhus tripartita* in the upper Jordan Valley. Under higher amounts of rainfall the lower plant layer is dominated by herbaceous perennials or in more arid habitats by dwarf-shrubs or half-shrubs. These plant communities are generally rich in species and of relatively high cover. Among the perennial herbaceous plants *Echinops polyceras, Psoralea bituminosa* and *Carlina* spp., as well as *Hordeum bulbosum*, should be mentioned. The plant communities dominated by these plants occupy generally phosphorus-rich soils and cover the greater part of Golan Heights and the upper Jordan Valley. On such soils this herbaceous marginal vegetation invaded the more humid areas after the destruction of their climax vegetation producing the best grazing areas in the region. It is suggested that the continuous grazing over millennia also prevented the regeneration of *Pistacia atlantica* and other components such as species of *Amygdalus, Pyrus, Crataegus* and others of the supposed climax communities of the area. With increasing aridity the following are the species which dominate the main dwarf-shrub communities:

Sarcopoterium spinosum. Although this is a Mediterranean plant it dominates marginal plant communities together with various co-dominants such as *Thymelaea hirsuta, Ononis natrix, Phlomis brachyodon, Noaea mucronata, Salvia syriaca* and others in the transition zone between typical Mediterranean vegetation and the semi-desert (Feinburn and Zohary, 1955; Danin et al., 1975).

Artemisia herba-alba. This dominates extensive areas in the Negev, the Jordan Valley, the Tih Plateau in central Sinai, the upper elevations of the igneous rock mountains in southern Sinai where it is accompanied by *Pyrethrum santolinoides*, and the Jordanian and Syrian deserts (Pabot, 1954). With increasing aridity in the northern Negev *Artemisia* is accompanied successively by *Thymelaea hirsuta, Noaea mucronata, Salvia Ianigera* and *Gymnocarpos decander* (Danin et al., 1975).

Poa bulbosa is a constant, and in many cases high-cover, companion of the *Artemisia herba-alba* community. It is reported as a dominant plant of extensive areas in the

Syrian Desert after eradication of the shrubs which, apart from being grazed, are used extensively for fuel.

Hammada scoparia. The plant community dominated by this species generally occupies loessial and loess-like plains as well as plateaux and sometimes hill-sides under the most arid steppe conditions in central Sinai, the northern Negev, and the Syrian Desert.

Salsola villosa and *Reaumuria Palaestina*. The plant community dominated by *Salsola villosa* generally occupies soils derived from chalks and marls in the Jordan Valley; so do plant community dominated by *Reaumuria palastina*, which occupies similar soils in the Jordan Valley and the northern Negev in probably more saline habitats (Zohary, 1973; Danin et al., 1975).

Achillea fragrantissima. Small-to medium-sized wadis and runnels in the steppes of the Negev and the Judaean Desert are dominated by the *Achillea fragrantissima* community. The larger wadis in the Negev and northern Sinai are occupied by the *Retama raetam-Thymelaea hirsuta* community. Other communities, dominated by *Achillea fragrantissima* and accompanied by *Zilla spinosa*, occupy the wadis in the higher elevations of southern Sinai on igneous rocks (Orshan, 1985).

Achillea santolina. In the Negev Desert with rainfall amounts of 150–300 mm where dryfarming cultivation is practised, a community dominated by *Achillea santolina* is common in the fields (Zohary, 1973; Danin et al., 1975).

(ii) *Deserts*

With increasing aridity below 80–100 mm of annual rainfall – the vegetation cover decreases until it becomes contracted (Monod, 1958) and restricted to more favourable habitats, e.g. runoff-fed depressions and runnels, rocky habitats and steep northern slopes. Under such conditions the effect of parent rock increases in importance. Accordingly, the differences between the plant communities dominating soils derived from dolomite and limestone, and soils derived from chalks and marls, are greater than under less arid conditions.

The main non-sandy and non-granitic desert areas in the SW Asian Mediterranean Coastal desert are found in Sinai, Israel and also, to a more limited extent, in Syria. The hard rocky hills in the Negev and Sinai, made up mainly of limestone and dolomite, are dominated by *Zygophyllum dumosum*, accompanied in various localities by *Reaumuria* spp., *Gymnocarpos decander* and other species. In the transition areas between deserts and semi-deserts it is also accompanied by *Artemisia herba-alba* (Zohary, 1962).

Plant communities dominated by *Anabasis articulata* occupy the regs of central Sinai, the central Negev, Jordan and Syria. It is accompanied by various species, such as *Gymnocarpos decander, Zilla spinosa, Fagonia* spp. *Anvillea garcini, Asteriscus graveolens* and others (Danin et al., 1975; Zahran and Willis, 1992). *Halogeton alopecuroides* and *Anabasis setifera* dominate in the Negev and Sinai deserts on chalks and sometimes marls which are rather saline, and yield soils more saline than those developed from harder rocks. *Salsola tetrandra* is the leading species of the vegetation dominating the marly chalks in the lower Jordan Valley, the Negev and Sinai (Orshan, 1985).

(iii) *Savanoid deserts*

Sudanian elements penetrate rather deeply northwards in the SW Asian Mediterranean coastal desert through the Rift Valley and the territories adjacent to it. This is probably because of the combination of higher temperatures, especially higher winter minima, on the one hand, and available water throughout the year in the deeper soil layers of the larger wadis on the other. Such a combination of high temperatures and available soil moisture allow trees like *Ziziphus spina-christi, Hyphaene thebaica, Acacia* spp., *Balanites aegyptiaca* and others as well as shrubs like *Calotropis procera, Capparis decidua, Ochradenus baccatus, Lavandula coronopifolia* and others, to penetrate the Rift Valley.

(iv) *Sand formations*

Sand formations are considered to be more suitable for plant growth under arid conditions than non-sandy ones. Their plant cover and productivity are generally markedly higher. By contrast, under amounts of annual rainfall exceeding 350 mm, where rain water leaches the whole profile, the total amount of soil moisture available for land growth is lower in sandy than in non-sandy areas due to the lower water-holding capacity of the sand. Therefore, their total productivity is lower and they are considered to be worse habitats under such climatic conditions (Orshan, 1985).

The sand of the Mediterranean coastal plain, washed out by the Nile River and its tributaries, deposited in the Mediterranean Sea and subsequently carried by the prevailing current, redeposited on the coasts of northern Sinai and Palestine, and blown inland by the prevailing winds, has been leached of some of its mineral components. The following sandy habitats differ from each other in the nature of their vegetation (Kassas, 1955; Zohary, 1973; Orshan, 1985).

(a) *Mobile sand dunes*. The more or less mobile sand dunes are generally devoid of vegetation. However, the more protected bases of these dunes are occupied by the *Stipagrostis scoparia* community, which is poor in species and of low plant cover.

(b) *Sand flats*. The wider depressions between the dunes, as well as more extensive sand fields, are dominated by few plant communities. The most widespread of them in northeastern Sinai and the northern Negev is *Artemisia monosperma, Convolvulus lanatus, Panicum turgidum* and *Pennisetum divisum* as important components. In northwestern Sinai plant communities dominated by *Zygophyllum album* as well as by *Cornulaca monocantha* and *Convolvulus lanatus* prevail.

(v) *Salinas*

Saline habitats are a common feature in the SW Asian Mediterranean deserts. The causes for salt accumulation are: (a) a water table which is high enough to cause an upward movement of salts and their accumulation in the upper salt layers;

(b) poor drainage; and (c) inundation by sea water along the coasts. Generally, the desert salinas are formed by various interactions of these factors which, together with topography, form a diversity of habitats and microhabitats differing from each other with respect to moisture and salt content, and occupied by various communities. These communities are generally poor in species, and throughout the area under discussion are made of more or less the same floristic stock. On the Mediterranean coast of Sinai the plant communities dominated by the following species are arranged in a sequence of belts according to salinity and moisture content (Orshan, 1985; Zahran and Willis, 1992, 2008).

(1) A highly saline and moist belt (a high water table of saline water) with *Halocnemum strobilaceum; and Arthrocnemum macrostachyum*;
(2) A moderately saline and moist belt (a high water table of brackish water) with *Suaeda vermiculata; and Frankenia hirsuta*;
(3) A slightly saline and moist belt (a high water table of brackish to non-saline water) with *Juncus maritimus; and Phoenix dactylifera*;
(4) A deeper water table of brackish to saline water with *Nitraria retusa*;
(5) An outer belt of salinas where soil salinity is low with *Zygophyllum album*.

On the coast of the Dead Sea the following belts were formed with decreasing salinity (Zohary and Orshan, 1949).

(1) *Tamarix tetragyna* and *Arthrocnemum macrostachyum*;
(2) *Suaeda palaestina* on the northern and *S. monoica* and *Tamarix nilotica* on the southern coast;
(3) *Suaeda fruticosa, Seidlitzia rosmarinus, Atriplex halimus* or combinations;
(4) *Nitraria retusa;*
(5) Moist habitats with poor drainage and a high water table of brackish water with *Juncus rigidus, Phragmites australis, Inula crithmoides, Aeluropus litoralis* and others.

Such salinas are sometimes fringed by plant communities dominated by what are probably saline ecotypes of *Prosopis farcta, Alhagi graecorum,* and *Desmostachya bipinnata*.

The aquatic vegetation comprises 15 species (hydrophytes) classified under: submerged species, e.g. *Ceratophyllum demersum, Myriophyllum spicatum,* and *Potamogeton schweinfurthii*, floating species, e.g. *Lemna gibba,* and *L. minor* and emergent species, e.g. *Cyperus longus, Phragmites australis,* and *Typha domingensis*.

1.8.2.4 Representative Coastal Areas

The following pages include an account on the vegetation ecology of two coastal areas in the arid land territories of the SW Asian Mediterranean Coast. The first area occurs in the Asian Mediterranean coast of Egypt: the Sinai Mediterranean coast, and the second one represents the Palestine-Israel Mediterranean coastal land.

Sinai Mediterranean Coastal Area

a. *The physical environment*

The Sinai Peninsula, the Asian extension of Egypt, is a triangular plateau in the NE part of the country with its base, extending along the Mediterranean Sea for about 240 km from Port Said eastward to Rafah on the border with Palestine. The apex of Sinai Peninsula, in the south, is called Ras Muhammed where the eastern coast of the Gulf of Suez meets the western coast of the Gulf of Aqaba.

The Peninsula (61,000 km^2 in area) can be divided ecologically into three regions: northern, central and southern. Having coastal lands extending along the Mediterranean Sea and those of the Gulfs of Suez and Aqaba of the Red Sea, the Sinai Peninsula will be considered in two chapters of this book. Its northern Mediterranean region is described in this chapter whereas the other regions will be included in Chapter 2.

The northern Mediterranean Coastal region of the Sinai is the eastern section of the Mediterranean coastal land of Egypt. It has an area of about 8,000 km^2 and is bordred by the northern limits of the central region in the south, the Mediterranean Sea in the north, Palestine in the east and the Suez Canal in the west. This coastal belt of the Sinai Peninsula consists of a wide coastal plain sloping gradually northwards. It is characterized by three geomorphological units: coastal sand dunes, Lake Bardawil and Wadi El-Arish. The coastal sand dunes (80–100 m high) is extending for several km landward forming a continuous series parallel to the sea. Abu Al-Izz (1971) stated that these coastal sand dunes absorb and store rain water, and the low lands between them are considered a permanent source of fresh water that can be tapped by digging shallow wells. The best quality and highest volume of water is in the delta of Wadi El-Arish (Hume, 1925). The water supply of the wells varies and its quantity depends upon rainfall. The depth of the wells can be a little as 3 m or as much as 60 m. Lake Bardawil is a shallow lake that extends for about 98 km along the western section of the Sinai northern Mediterranean coastal land. It is elliptical is shape with total area of about 6,900 km^2, and is not continuously covered with water because during summer it becomes separate ponds and small lakes. There is no silt since this lake is far from the old branches of the Nile Delta (Zahran and Willis, 1992). Lake Bardawil is highly saline because of its close connection with the Mediterranean Sea. The low sand bar which divides it from the sea is often covered by sea water.

Wadi El-Arish is important geomorphological unit of the northern Sinai. Its basin is about 20,000 km^2 with a length of about 250 km, narrowing in its upper reaches as it cuts across the El-Tih Plateau (the middle region of the Sinai), where the old pilgrimage road to Mekka used to be. Wadi El-Arish can be divided into 3 sections: upper, central and lower (coastal). The upper section is about 100 km with a gradient of 6:1,000; in the central section the wadi descends from 400 to 150 m in about 100 km, i.e. with a gradient of 2.5:1,000. The coastal section covers the final northern 150 km where the wadi has a gradient of 3:1,000.

Generally, the climate of the Sinai belongs to the dry province, that can be divided into two main climatic zones: arid and hyperarid. The arid zone occurs in the northern Mediterranean coastal region (Ayyad and Ghabour, 1986) with relatively shorter dry period (attenuated) and annual rainfall ranging between 100 and 200 mm, some times up to 304 mm in Rafah. The air temperature is up to 30°C in summer and as low as 9°C in winter. The mean annual maximum and minimum relative humidity are 79 and 56%, respectively.

b. *Vegetation types*

The terrestrial vegetation types of the Sinai Mediterranean Coastal desert is described below under these titles:

(i) Vegetation of the coastal belt, and
(ii) Vegetation of shoreline-landward transects.

(i) *Vegetation of the coastal belt*

The natural vegetation of the coastal belt is very sparse; three main habitats can be recognized: Sabkhas, littoral sand dunes, plain dunes and inland dunes (Zahran and Willis, 1992). Sabkhas are present in the northern section near the sea, and can be distinguished into four basic types according to the distribution of plants: (1) salt-encrusted sabkhas; (2) wet sabkhas; (3) dry sabkhas; and (4) drift-sand-covered sabkhas. Salt-encrusted sabkhas have almost no vegetation owing to their extremely high salinities. Only about 2–5% of the area are wet sabkhas vegetated with a community dominated by *Halocnemum strobilaceum*, and with cover of 70–95% associated with two halophytes; *Arthrocnemum macrostachyum* and *Suaeda vera*. In the dry sabkhas, vegetation cover is about 5–10%; *H. strobilaceum* is also the dominant, associated with *A. macrostachyum, Cressa cretica, Juncus rigidus, Limoniastrum monopetalum, Phargmites australis, Suaeda vera* and *S. vermiculata*. In sabkhas covered with a sheet of drift sand, plant cover varies from <5 to 15%. These areas are vegetated by two communities dominated by *Zygophyllum album* and *Anabasis articulata*, with cover of 5–10% and 10–15% respectively. Other associates are *Cressa cretica*, *Cyperus laevigatus* and *Salsola kali*.

The littoral dunes are mostly in two parallel lines with lows (pans) between. These lows act as drainage basins where halophytes dominate. The vegetation of the littoral dunes is largely of patches of *Ammophila arenaria*. Although the cover may reach 50% within the patches, not more than 5% of the total area of the dunes is plant-covered (Kassas, 1955). Beside the dominant grass, the flora of littoral dunes commonly includes: *Eremobium aegyptiacum, Lotus arabicus, Moltkiopsis ciliata, Polygonum equisetiforme* and *Salsola kali*. Among other associates are *Atriplex leucoclada, Cressa cretica, Cyperus laevigatus* and *Juncus acutus* (as halophytes in the lows). Species occasionally present are *Artemisia monosperma, Astragalus tomentosus, Cyperus capitatus, Echinops spinosus, Elymus farctus, Euphorbia paralias, Pancratium maritimum, Silene succulenta* and *Thymelaea hirsuta*.

"Plain" dunes are sand drifts that are lower and less mobile than the littoral dunes. In these dunes *Artemisia monosperma* is dominant. This community is subject to intense human interference by cutting and grazing. In places far from human settlements, the cover may reach 70% or more. The contrast between the vegetation inside a barbed-wire fence and outside is very striking (Kassas, 1955). The flora of an *A. monosperma* community includes several characteristic species, e.g. *Haplophyllum tuberculatum, Neurada procumbens, Panicum turgidum, Pituranthos tortuosus* (= *Deverra tortusa*) and *Urginea maritima*. The last species is subject to selective cutting for its medicinal value. *Cynodon dactylon* is a common species everywhere. Stabilized mounds covered by *Lycium europaeum* are local. In one locality *Lagonychium farctum* is very abundant, growing on the leeward side of these dunes. Other associates are *Alhagi maurorum, Astragalus spinosus, A. tomentosus, Atractylis prolifera, Bassia muricata, Chrozophora verbascifolia, Citrullus colocynthis, Cleome arabica, Echinops galalensis, Eremobium aegyptiacum, Euphorbia terracina, Heliotropium luteum, Ifloga spicata, Launaea glomerata, Lotus creticus, Mentha* sp., *Stipagrostis plumosa, Tamarix aphylla* and *Ziziphus spina-christi*.

The vegetation of inland sand dunes depends on their history which influences the composition of the plant cover. Dunes formed on sabkhas are dominated by *Zygophyllum album* at one stage of development and may contain, at an advanced stage, some other halophytes, e.g. *Nitraria retusa*. The stabilized inland dunes of this type are, in general, dominated by *Panicum turgidum* with cover up to 60%. Associate species are *Anabasis articulata, Artemisia monosperma, Convolvulus lanatus, Cornulaca monacantha, Echiochilon fruticosum, Eremobium aegyptiacum, Fagonia arabica, Moltkiopsis ciliata, Noaea mucronata, Stipagrostis scoparia* (abundant) and *Thymelaea hirsuta* (abundant).

The second type of inland sand dune of the Mediterranean coastal area of Sinai is formed by the accumulation of sand on desert mountains (Kassas, 1955). At the final stage there are huge sand dunes with rocky centres. In this type *Panicum turgidum* is the dominant on the lower dunes whereas *Artemisia monosperma* dominates on the higher parts. *Anabasis articulata, Convolvulus lanatus, Noaea mucronata* and *Thymelaea hirsuta* are common associate species. Other associates include: *Aerva javanica, Asparagus stipularis, Asthenatherum forsskaolii, Echiochilon fruticosum, Fagonia arabica, Haplophyllum tuberculatum, Pituranthos tortuosus, Stipagrostis plumosa* and *Teucrium polium*.

The third type of inland sand dunes are those formed by the accumulation of sand on desert plains. In these dunes three communities have been recognized: one dominated by *Panicum turgidum*, one by *Stipagrostis scoparia* and a third co-dominated by *P. turgidum* and *S. scoparia. Panicum* is a good fodder plant and is, thus, subject to heavy grazing. *S. scoparia* is less grazed, partly protected by its occurrence on the higher parts of the dunes not in easy reach of animals. The average cover of the *P. turgidum* community is 40% and that of *S. scoparia* 50% (Kassas, 1955). Common plants are *Artemisia monosperma, Convolvulus lanatus, Fagonia arabica, Gymnocarpos decander* and *Thymelaea hirsuta*. The flora of the third community also contains *Citrullus colocynthis, Hyoscyamus muticus, Reaumuria hirtella* and *Salsola volkensii*.

(ii) *Vegetation of Shoreline-landward transect*

The landward successive communities of the Sinai Mediterranean coastal land are described in three representative transects set up at three sites: Rafah coast, Sheikh Zuwayid coast and Wadi El-Arish coast (Zahran and Willis, 1992).

Transect 1. This transect is in the most eastern part of the Sinai Mediterranean coast at Rafah. In the first zone, the sand dunes are vegetated by two communities dominated by *Ammophila arenaria* and *Silene succulenta*. The cover of the *Ammophila* stands is thin (5–10%); associates are *Pancractium arabicum, Silene succulenta* and *Tamarix nilotica*. In stands dominated by *S. succulenta*, the cover is 20–30%. *Acacia saligna* (semi-wild), *Ammophila arenaria, Pancratium arabicum* and *Tamarix nilotica* are the associate species. In the second zone of the transect (1 km landward) are huge sand dunes richly vegetated by the semi-wild shrub *Acacia saligna*. The ground layer is almost covered (about 75%) with the succulent xerophytic halophyte *Mesembryanthemum forsskaolii (= Opophytum forsskaolii)*. Other associates are *Casuarina stricta* (cultivated), *Cyperus capitatus, Nicotiana glauca, Phoenix dactylifera* (semi-wild). *Polygonum bellardii, Silene succulenta* and *Xanthium pungens*.

The third zone of the transect (6 km landward) comprises dunes dominated by *Artemisia monosperma*. This vegetation extends landward for a considerable distance (about 22 km: from 6 to 28 km south of the shore-line). In the northern stands, the cover is high (up to 80%), contributed mainly by the dominant xerophyte (about 50%) and partly by the abundant associate species: *Senecio desfontainei* (about 20–25%) and *Neurada procumbens* (about 5%). Other associates are, *Astragalus alexandrinus, Cyperus capitatus, Onopordum alexandrinum* and *Urginea maritima*, but these have neglibible cover. The cover of the *A. monosperma* community decreases gradually southwards. At km 25 south of the coast, the cover is about 70% contributed by the dominant (40–45%), *Stipagrostis scoparia* (about 20%) and *Neurada procumbens* (about 5%). *Senecio desfontainei*, abundant in the northern stand, is absent further south where *Silene succulenta* is commonly present. At 28 km landward, the cover of *A. monosperma* on the dunes is reduced to only 5%. *Eremobium aegyptiacum* is abundant. Other associates are: *Ononis serrata, Onopordum ambiguum* and *Stripagrostis scoparia*. In this zone *Thymelaea hirsuta* dominates in scattered patches in the low areas between the dunes.

Transect 2. This transect is at the coast of Sheikh Zuwayid (about 20 km west of Rafah) and extended for about 22 km from sea landward. Along the whole stretch of the transect are extensive sand dunes. In the beach zone the dunes are dominated by *Ammophila arenaria*, with cover ranging between 30 and 50%. *Salsola kali* and *Silene succulenta* are only associates. The dominance by *A. arenaria* continues landward for about 3 km. The cover decreases in the landward stands to 20–25% and the number increases to four (*Acacia saligna, Artemisia monosperma, Calligonum comosum* and *Silene succulenta*). Gradually *A. monosperma* increases landwards and becomes dominant, associated with an increase in the number of xerophytes. The cover of the *A. monosperma* community ranges from 25 is 35%, contributed mainly by the dominant. Associated species include: *Cynodon* *dactylon, Haplophyllum tube-rculatum, Lycium shawii, Lygos raetam, Onopordum ambiguum, Panicum turgidum, Tamarix nilotica* and *Thymelaea hirsuta*. In the inland sections of the transect, *Thymelaea hirsuta* is abundant in low areas between the dunes.

Transect 3. This transect is in the downstream section of Wadi El-Arish (about 45 km west of Rafah) extending for about 24 km from the sea landward. In the first zone the semi-wild *Phoenix dactylifera* vegetation has a cover of 10–20%. Common plants are *Echinops spinosus*, *Mesembryanthemum crystallinum, Pseudorlaya pumila* and *Silene longipetala*. The dune formation after about 1 km landward is vegetated with *Ammophila arenaria* (cover <5%). Associates include: *Artemisia monosperma, Cutandia dichotoma, Echinops spinosus, Erodium oxyrhynchum subsp. bryoniifolium, Lygos raetam* and *Moltkiopsis ciliata*. The dunes in the third landward zone of the transect are dominated by *Tamarix nilotica* with cover of up to 40%. Asssociates are *Artemisia monosperma, Cornulaca monacantha, Lobularia libyca, Ononis serrata, Silene succulenta, Stipagrostis ciliata* and *Thymelaea hirsuta*. As in the other two transects in the southern section, the dunes are dominated by *Artemisia monosperma*. The cover of this community thins gradually from about 40% in the northern stands to <20% in the southern ones. The number of associated species is, relatively, high and includes: *Asparagus stipularis, Carthamus tenuis, Cornulaca monacantha, Cyperus capitatus, Echinops spinosus, Heliotropium digynum, Herniaria hemistemon, Hyoscyamus muticus, Ifloga spicata, Lycium shawii, Neurada procumbens, Panicum turgidum* and *Thymelaea hirsuta*. The dominance of *A. monosperma* on the dunes continues southward but the cover is thinner. The areas between the dunes support a community dominated by *Thymelaea hirsuta* with 35–40% cover contributed mainly by the dominant shrub and partly (about 5%) by the common associate *Hammada elegans*. Other associates include *Artemisia monosperma, Cornulaca monacantha, Fagonia arabica, Hyoscyamus muticus, Panicum turgidum, Peganum harmala, Zilla spinosa* and *Zygophyllum album*. In some patches of the wadi bed, *Fagonia arabica* dominates, with thin cover (<5%). *Anabasis articulata, Cleome africana, Farsetia aegyptia* and *Pancratium sickenbergeri* are the associate xerophytes of this community.

Palestine-Israel Mediterranean Coastal Area

a. *The physical environment*

Palestine-Israel is the historical geographical area occurring in the SW corner of the Mediterranean Basin. It borders to the east and south by the steppes and deserts of the Near East, which are partly included within its boundaries. It is an area of striking contrasts in its topography and climate (Zohary, 1962). Its highest mountain peak, the Edom (Transjordan), rises to 1,700; its lower part, in the Dead Sea depression falls to 396 below sea level. The northern district enjoys a typical Mediterranean climate while its southern parts are dry desert.

Topographically, Palestine-Israel area has four belts: the coastal plain, the western mountains, the Jordan Valley with its southern continuation to the Gulf of Aqaba and the Transjordan plateau. These topographic belts show particular geomorphological, climatic and habitat features which have their impacts on their natural vegetation types.

The coastal plain broadens towards the south and attains its maximum (60 km) in the Negeve. In its greater part, this coastal plain is subject to a true Mediterranean climate and harbors a flora and vegetation peculiar to that climate. It is here that the main citrus groves are centered. Even since Biblical times this plain has been transversally subdivided into four districts: the Negev Plain (in the south), and the Philistia, Sharon, and Acre plains (in the north). With a gradual deterioration of climatic conditions from north to south, each of these districts exhibits certain biogeo-graphical features of its own. Edaphically, one can distinguish four well-defined longitudinal zones in the coastal plain: the zone of mobile sand dunes, that of interrupted calcareous-sandstone hills, the belt of sandy clays ("red sands"), and the zone of alluvial-colluvial heavy soils. Impeded in their way to the sea by dune and sandstone ridges, some of the latitudinal watercourses which cross the coastal plain have turned considerable stretches of land into swamps and marshes. These have dried up only recently and are now being utilized for agriculture.

The western mountain region constitutes a belt of considerable width. It extends from the southern foot of Mount Lebanon to the Desert of Sinai and reaches its peak (1,208 m) in the north (Jebel Jarmak in upper Galilee). While the western, gently sloping side of these mountain ranges has a Mediterranean climate and vegetation, the abrupt eastern slopes, which face the Jordan Valley, are mostly desert or semi-desert. Of the latitudinal valleys that interrupt the continuity of the western mountain region, the largest are the Esdraelon Plain in the north and the Plain of Beersheba in the south. The Negev, Judea, Samaria, and Galilee are the four main districts into which that region is commonly divided. The Negev is the largest and most desolate part of Israel, a desert with a rough topography. The other districts, though fairly well distinguishable biogeographically, share many features. The rocky, heavily eroded landscape, with its many ravines and shallow valleys, is common to all three. The so-called Judean Desert occupies the eastern parts of Judea and Samaria.

The Jordan Valley, is the most significant topographic feature. It is part of a rift valley, extending from the Orontes River in Syria to the Gulf of Aqaba and continues further into the Red Sea and the continent of Africa. In Israel it ranges in elevation from –396 m in the Dead Sea region to +200 m in the Dan Valley (Huleh Plain); mountains border it on both sides. Its southern part comprises deserts, salinas and tropical oases, while in its northern part there are swamps and stretches of fertile land situated within a Mediterranean wood climax area.

The Transjordan Plateau is higher in its northern and southern edges than in its central part. To the east this plateau merges gradually into the Syrian Desert. Its steep western escarpments are crossed by a series of latitudinal rivers, which empty into the Jordan Valley and the Dead Sea and divide the comparatively narrow western strip of the plateau into transverse districts known since Biblical times as Edom, Moav, Ammon, Gilead and Golan. Edom, the southernmost district of this plateau, is marked by vast sand deserts that border on the highest mountain ranges, which reach a height of 1,700 m. These afford conditions for the extension of Mediterranean woods as far south as the latitude of Cairo (Zohary, 1962).

The climate of the Plestine-Israel area as a whole is of the Mediterranean type, marked by a mild, rainy winter and a prolonged dry and hot summer. Geographical latitude, altitude, the blocking effect of mountain ranges, and distance from the Mediterranean Sea are among the factors which modify this climate. The effect of latitude manifests itself in the abrupt north-to-south decrease of the annual amount of rainfall, so that within a range of about four latitudinal degrees rainfall drops from about 1,000 to 25 mm/year. Temperatures, on the other hand, increase from north to south; the mean annual temperature rises from just below 16°C in the north to approximately 23°C in the extreme south. In a west-to-east direction, annual rainfall and mean temperatures undergo similar but less regular changes. This is because of the interference of the Israel and Jordan mountain ranges. As a result of their interception of rains, part of the Jordan Valley is a rain-shadow desert. In addition, the mountain ranges limit the tempering influence of the Mediterranean Sea to a narrow strip, leaving the greater part open to a wider range of seasonal and diurnal temperatures (Zohary, 1962).

Palestin-Israel climatic zones, according to the amount of annual rainfall are: a sub-humid zone with 1,000–400 mm, a semi-arid zone with 400–200 mm and an arid zone with only 200–25 mm.

Although plant life is not eliminated anywhere in the country by extremes of temperature, plant distribution is greatly influenced by thermal conditions. For instance, a series of tropical plants, that thrive in the southern part of the Jordan Valley, do not advance northward to where winters are colder. Among them are *Maerua crassifolia, Moringa peregrina, Acacia raddiana, Balanites aegyptiaca, Salvadora persica, Abutilon pannosum, Calotropis procera* and *Sebestena gharaf.* Very puzzling is the fact that most of these plants are limited to very low altitudes (300–400 m below sea level), whereas in the central Sahara they reach a considerable height on the mountains (Maire, 1933, 1940). *Balanites aegyptiaca* has been recorded at 13,000 m, *Salvadora persica* at 1,500 m, *Calotropis procera* at 1,800 m, and *Maerua crassifolia* at 1,900 m. Other examples of the part played by minimum temperatures on plant distribution include: *Quercus ithaburensis*, not found above 500 m; *Ziziphus lotus*, which occurs only up to a height of 250 m; and a whole series of species characteristic of the coastal plain, which do not occur in the mountain belt because of the lower temperatures during the winter. Other typical Mediterranean plants (*Laurus nobilis, Spartium junceum, Pistacia lentiscus* etc.) are altogether lacking in the Mediterranean territory of Transjordan, probably also because of the minimum winter temperatures.

The gradient of decreasing rainfall in the region is much steeper in its northern than in its southern half, yet in the south the decrease is much more decisive on plant life than in the north. In the south, even the smallest deviation from the average makes itself felt in density and development of vegetation, while in the north differences amounting to as much as 200 mm/year are hardly reflected in the general appearance of the vegetation. This is self-evident from the fact that depending on soil properties the 100–50 mm isohyetes constitute the lower rain limit of plant life.

The Palestine-Israel area, with the great deserts of Asia and North Africa on its borders, offers the plant geographer an ample opportunity to follow distribution features in the flora and vegetation along rainfall gradients. Hundreds of Mediterranean species are arrested in their southward move by diminishing rainfall. Some of them reach the southern boundary of the Mediterranean territory, while others are detained long before it. The same is true for many plant communities: for example, the *Quercus calliprinos-Pistacia palaestina* maquis association reaches its terminus at the 400–350 mm isohyet the widespread typical Mediterranean dwarf shrub association, *Poterium spinosum*, is detained at the 350–300 mm isohyet; the *Artemista herba-alba* at the 200–150 mm isohyet; and *Zygophyllum dumosum* at the 100–75 mm line. Obviously, local topography and nature of soil causes these boundaries to move slightly on either side of the isohyets.

Among the isohyets outstanding in their biogeographical importance are the 400–350 mm isohyet, the lower limit of Mediterranean forest and, of stable dry farming, and the 100–500 mm isohyet, which constitutes the climatic threshold of plant life in these deserts. Beyond this limit, however, plant life does not cease entirely but becomes wholly dependent on topography. Wadis and depressions, which collect water draining off from the surrounding area, support a fairly well-developed vegetation. Even depressions hardly perceptible to the naked eye form favorable sites for vegetation. This is also why deserts with rough topography are less bare than those dominated by smooth unbroken plains. Equal importance must be ascribed to physical soil properties in deserts. Moisture-absorbing surface layers, such as sand and fine gravel are much more favorable to vegetation than exposed, heavy-textured soils.

Another important feature of rainfall affecting plant life is the instability of its total annual amounts. These fluctuations may be so considerable that 1 year's rain may be no more than a fraction of another year's total. This is especially true for the arid and subarid parts of Palestine-Israel area, as seen from the following figures recorded for the Negev (Ashbel, 1945); Gaza (33 years of measurements) – minimum 238.1 mm, maximum 810 mm; Beersheba (28 years) – minimum 129.8 mm, maximum 336.1 mm; Auja (Nitzana) (13 years) – minimum 10.4 mm, maximum 284.5 mm. In these arid areas a falling short of the average by as little as 20–40 mm may cripple vegetation and be fatal also to the dry farming scattered in lowlands and depressions. The instability of the annual rainfall in the arid zones makes the desert "blossom" in 1 year, restricts the annual vegetation to wadis and depressions in others, and almost annihilates plant life in years of extreme drought. Moreover, where a number of dry years follow each other consecutively, certain desert dwarf shrubs desiccate and die off. Thus, the floristic composition of a plant community may alter drastically from year to year.

The rainy season lasts from October to May, but about 75% of the total amount of rain falls between December and February. The amounts of rain in particular months varies greatly from year to year. For instance, the January total for Ramle was 300 mm in 1 year and 3.2 mm in another; equivalent reading for Jerusalem are 367 and 3.0 mm, the northern shore of the Dead Sea had a January total of 58 mm in 1 year and 4.0 mm in another. Such fluctuations favor the development of certain plants in particular years. The results is the so-called “flower year”, a very striking phenomenon in which certain annual species dominate the landscape at irregular intervals of a few to many years. Annual fluctuations in the rainfall totals of particular months may also bring about prolonged periods of drought within the rainy season. This can be harmful to vegetation and is also apt to alter the species composition of plant communities from 1 year to another.

There is a gradual decrease in the annual, monthly, and diurnal averages of relative humidity from north to south and from west to east throughout the whole area, excluding the coastal plain. This plain also has a high rate of humidity in the south, which presumably accounts for the high growth rate of many tropical and subtropical plants and certainly also contributes to the comparative fertility of the coastal Negev. The average relative humidity of a summer midday amounts to 65% in Natanya (Sharon Plain) and to 75% in the coastal Negev, while in Jerusalem it is only 35 and 40% in the Dead Sea Valley (Ashbel, 1951).

Dew plays an important role in plant life. According to Ashbel (1951), there are over 200 dew nights in the coastal plains and much fewer in the interior parts. Duvdevani (1953) stated that the amount of the yearly dew precipitation varied from 4.7 mm/year in Jericho (Lower Jordan Valley) to 29 mm/year on Mount Carmel.

b. *Plant life*

- *Floristic analysis*

The flora of Palestine-Israel Mediterranean Coastal lands comprises about 2,250 species belonging to 718 genera out of these (1,506 species, 66.9%) are uni-regional elements with bi- and pluri-regional elements (743 species, 32.6%) making up most of the rest. The uni-regional elements are distributed between the five floristic (phytogeographical) groups, as follows: 863 species are Mediterranean elements, 299 Saharo-Sindian, 309 Irano-Turanean, 15 Euro-Siberian and 20 Sudanian. The taxa of the bi-and pluri-regional groups are classified under five subgroups: subtropical (415 species), subtropical-boreal (112 species) subtropical – tropical (69 species), boreal – tropical (85 species) and tropical, 53 species (Zohary, 1962).

A. The uniregional groups

It is worth that, taxa belonging to the Mediterranean, the Irano-Turanian and Saharo-Sindian regions are confined to particular territories of Palestine-Israel area. The other elements are scattered throughout the area or occupy special habitats within those territories.

The following is a short account on these groups.

1. *The Mediterranean element.* Among the Mediterranean element of Palestine-Israel flora, the following six groups have been distinguished by Eig

(1931–1932): sub-Mediterranean, omni-Mediterranean, east Mediterranean, west Mediterranean, north Mediterranean, and south Mediterranean.

(i) *The sub-Mediterranean group*. About 160 Mediterranean species also penetrate into some countries adjacent to the Mediterranean region. Particularly interesting are the Mediterranean littoral species which recur in the Atlantic sector of the Eurosiberian region, e.g. *Glaucium flavum, Cakile maritima, Euphorbia peplis, E. paralias, Eryngium maritimum, Crithmum maritimum, Statice limonium, Centaurium maritimum, Inula crithmoides, Diotis maritima, Juncus subulatus,* and *Pancratium maritimum*. Other examples include: *Thesium humile, Adonis autumnalis, Raphanus raphanistrum, Fumaria capreolata,* and *Ridolphia segetum*. Noteworthy among the sub-Mediterranean species, recurring in some Irano-Turanian countries, are segetals and components of primary vegetation preserved in Mediterranean enclaves of the Irano-Turanian region, eg., *Pinus brutia, Juniperus oxycedrus, Psoralea bituminosa, Putoria calabrica, Stipa aristella,* and *Oryzopsis coerulescens*.

(ii) *The omni-Mediterranean*. This group, which also comprises about 160 species, is widespread over the Mediterranean region. Many of them are leading plants in local plant communities, e.g. *Pinus halepensis, Juniperus phoenicea, Calycotome villosa, Ceratonia siliqua, Pistacia lentiscus, Rhamnus alaternus, Cistus villosus, Lavandula stoechas, Thymus capitatus,* and *Viburnum tinus*. Many species of this group are confined to the coastal plain. Examples of these are *Matthiola tricuspidata, Ononis variegata, Orlaya maritima, Statice sinuata, S. virgata, Alkanna tinctoria, Ajuga iva, Crucianella maritima, Scleropoa maritima, Avena longiglumis, Sporobolus arenarius, Cyperus mucronatus, Leopoldia maritima*, and *Narcissus serotinus*. There are no deciduous trees among the Omni-Mediterranean group.

(iii) *The east Mediterranean (including the sub-east Mediterranean)*. This group is the most prevalent element in the flora of Palestine and Israel and includes the majority of the endemic species. It comprises 485 species, many of them are important components of the vegetation, for example the lead species of the maquis: *Quercus callíprons, Q. boissieri, Q. ithaburensis, Platanus orientalis, Prunus ursina, Cercis siliquastrum, Pistacia palaestina, Rhamnus palaestina, Acer syriacum, Arbutus andrachne*, and *Styrax officinalis*, as well as the dominant species of the garigue and batha formations: *Poterium spinosum, Euphorbia thamnoides, Hippomarathrum boissieri, Anchusa strigosa, Alkanna strigosa, Salvia triloba, Phlomis viscosa. Thymbra spicata, Teucrium creticum, Majorana syriaca* etc. Within this group also are the dominant species of the litho- and chasmophytic communities: *Arenaria graceolens, Dianthus pendulus, Micromeria serpyllifolia, Ballota rugosa. Hyoscyamus aureus, Michauxia campanuloides, Varthemia iphionoides, Centaurea speciosa,* and others. In addition, many local weeds belong to this group, e.g. *Silene crassipes, Medicago*

galilaea, Euphorbia cybirensis, Eryngium creticum, Tordylium aegyptiacum, Exoacantha heterophylla, Cachrys goniocarpa, Astoma seselifolium, Convolvulus hirsutus, Heliotropium villosum, H. bovei, Molucella laevis, Carthamus tenuis, Centaurea verutum, and *Cynara syriaca*.
A characteristic feature of this group is the high number of geophytes (over 12%), among them *Lilium candidum, Hyacinthus orientalis*, eight species of *Iris*, four of *Colchicum*, and four of *Crocus* are worthy of mention.

(iv) *The west Mediterranean*. This group comprises only 14 species and plays almost no part in the vegetation cover of the country (Eig, 1931–1932). One may consider some of them, such as *Ophioglossum lusitanicum* and *Euphorbia dendroides*, as being relics of a more humid period, during which local climatic conditions were more favorable for mesic species than they are today.

(v) *The north Mediterranean group* comprising 30 species, and *(vi) the South Mediterranean group*, with 14 species, are vegetaionally unimportant.

2. *The Saharo-Sindian element*. In the Palestin-Israel area, the Saharo-Sindian element comprises only 299 species, i.e. 13% of the total flora. Eig (1931–1932) has distinguished four groups among this element: the Omni-Saharo-Sindian, and the West, East, and Middle-Saharo-Sindian. He refers the bulk of the Palestine Saharo-Sindian element to the latter one. Although the tripartition of the Saharo-Sindian region is still to be re-examined with regard to its lines of demarcation, it is obvious that there are three distinct floristic centers within this region.
According to Eig (1931–1932), Maire (1933, 1940), the Saharo-Sindian flora is less autonomous in its Origin than are those of the neighboring regions, and many of its species and genera are derived from the Mediterranean, Sudanian, and partly also from the Irano-Turranian stock. Examples of Mediterranean derivatives are species of the genera: *Paronychia, Silene, Matthiola, Medicago, Lotus, Ononis, Erodium, Daucus, Origanum, Thymus, Anthemis, and Picris*. The genera *Capparis, Cleome, Caralluma, Gomphocarpus, Trichodesma, Iphiona, Varthemia,* and *Tetrapogon*, are examples of genera of Sudanian or otherwise tropical origin. The Irano-Turanian derivatives are represented by species of the genera *Calligonum, Suaeda, Salsola, Haloxylon (Hammada), Anabasis, Astragalus, Tamarix, Heliotropium, Onopordum, Echinops,* and *Carthamus*. The South African flora is suggested by the occurrence of the genera *Aizoon, Mesembryanthemum, Notoceras, Caylusea, Neurada, Citrullus, Ifloga* and *Aristida*. However, there are a fair number of genera autochthonous in the Saharo-Sindian region, e.g. *Gymnarrhena, Pteranthus, Gymnocarpos, Sclerocephalus, Anastatica, Zilla,* and *Savignya*.
The most important species in the Saharo-Sindian flora of Palestine-Israel area are: *Calligonum comosum, Anabasis articulata, Suaeda asphaltica, S. vermiculata, Salsola tetrandra, S. rosmarinus, Haloxylon persicum, H. salicornicum, Chenolea arabica, Traganum nudatum, Halogeton alopecuroides, Gymnocarpos fruticosum, Zilla spinosa, Retama raetam (= Lygos raetam), Fagonia mollis, Zygophyllum dumosum, Nitraria retusa, Convolvulus lanatus,*

Danthonia forsskaolii, Aristida scoparia, and many others. The low percentage of geophytes, amounting to about 4% among the Saharo-Sindian flora, is remarkable.

3. *The Irano-Turanian element*. The Irano-Turanian element, including the sub-Irano-Turanian group, comprises 309 species, i.e. more than 13% of the total flora of the area. When the 406 bi-or triregional species are added to that number, the affinity of the local flora to that of the Irano-Turanian region becomes strikingly apparent. In contrast to Mediterranean and Saharo-Sindian species, the Irano-Turanian taxa are rather restricted and there are scarcely any instances of Omni-Irano-Turanian expansion. The bulk of this element in the Palestine-Israel area belongs to the Mesopotamian, the Irano-Anatolian, and the Mauritanian Steppes groups.

(i) *The Mauritanian steppe subregion*. This occupies a belt of considerable width in North Africa, notably in its western part. The flora of this subregion is also marked by a series of generic and specific endemics. In Palestine the Mauritanian steppes element is represented by about 30 species, many of them dominants in the local vegetation. Examples are *Ephedra alte, Noea mucronata, Haloxylon articulatum, Salsola vermiculata, Pistacia atlantica, Rhus tripartita, Zizyphus lotus, Salvia lanigera, Marrubium alysson, Linaria aegyptiaca, Artemisia herba-alba,* and *Achillea santolina*. There is also a striking resemblance between the vegetation of the local Irano-Turanian territory and that of certain parts of the Mauritanian Steppes.

(ii) *The Mesopotamian subregion.* This comprises the Irano-Turanian territory of the Syrian Desert, the whole Jezireh (upper Meso-potamia), and parts of the plains in southern Anatolia and south-western Iran. This subregion has a considerable number of endemics and some particular plant communities by which it is fairly well distinguished from the above-mentioned subrgion. In comparison with the Irano-Anatolian and even the Turanian subregions, it is poor in species.

There are 100 or more species which represent the Mesopotamian element and the majority of the Irano-Turanian endemics in Palestine-Israel area show Mesopotamian affinities. The flora of this subregion includes a remarkable proportion of herbaceous segetals which have also penetrated into the Mediterranean territory. Others of its species associates of various herbaceous steppe communities, but there are scarcely any leading species among them. There are, however, a considerable number of species common to both above subregions, so that their separation into two subregions is still tentative.

(iii) *The Irano-Anatolian Subregion*. This comprises mainly the mountainous area of interior Anatolia, Armenia, and the Iranian Plateau (exclusive certain parts of eastern Iran and western Afghanistan). Parts of southern Transcaucasia may also be included within the Irano-Anatalian subregion.

Its outlines coincide with those defined by Boissier (1867–1888) as "Sous-region de Plateaux".

Characteristics of the subregion are its high mountain ranges alternating with plains and plateaus of varying altitudes and badly drained valleys and basins. It harbors several different elements of the flora of the Irano-Turanian region and is one of its largest centers of speciation in the region. Many endemic species belonging to the genera *Astragalus, Acanthophyllum, Onobrychis, Hedysarum, Acantholimon, Cousinia, Centaurea, Jurinea,* and *Helichrysum* are recorded from here. This subregion is represented in Mount Hermon with species such as: *Atraphaxis spinosa, Pterocephalus pulverulentus, Buffonia virgata, Delphinium antheroideum, Erysimum crassipes. Astragalus bethleemiticus, A. deinacanthus, Euphorbia macroclada, Daphne linearifolia, Scutellaria fruticosa, Thymus syriacus, Phlomis orientalis, Pyrethrum santolinoides (= Tanacetum santolinoides),* and *Cousinia hermonis*. Most of these are confined to the higher altitudes of Transjordan and the Negev.

The remaining subregions of the Irano-Turanian region are also poorly represented. The Turanian subregion (Aralo-Caspian sensu stricto) shows some floristic affinity to Palestine-Israel area but rather to its Saharo-Sindian than to its Irano-Turanian flora. Thus, a series of genera, which have their highest concentration of species in the Turanian sub-region, are characteristic of halic (saline) and sandy habitats in the Saharo-Sindian territory of Palestine-Israel area, e.g. *Calligonum, Haloxylon, Suaeda, Salsola, Anabasis, Nitraria, Zygophyllum, Tamarix*, and others.

4. *The sudanian elements*. This is represented by 20 species. Many of them are trees and shrubs, such as *Maerua crassifolia, Moringa peregrina, Acacia tortilis, Balanites aegyptiaca*, and *Ziziphus spina-christi*. Most of them are conspicuous in the tropical oases of the Jordan Valley. Other species include: *Acacia albida, Loranthus acaciae, Indigofera argentea, Tephrosia apollinea, Acacia laeta*, and *Capparis cartilagina*.

B. The bi- and pluriregional groups

The previously discussed groups are uniregional, i.e. each group is more or less confined to a single plant geographical region. The sum total of uniregional species enumerated so far amounts to 1,506, i.e. 67% of the flora. The remaining 33% of species of the local flora have a wider range of distribution and extend over two or more plant geographical regions. The presence of bi- and pluriregional groups in Palestine-Israel area is not necessarily the result of its particular phytogeographical position. Each plant geographical region harbors, in addition to the uniregional species which constitute its floristic element, a considerable number of bi- and pluriregionals, or interregionals, as they may generally be termed.

There are roughly 200 segetal and ruderal species among the bi- and pluriregional. The Borealo-Tropical group comprises many of them, e.g. *Chenopodium album, C. murale, Urtica urens, Polygonum aviculare, Amaranthus retroflexus,* *Portulaca oleracea, Stellaria media, Capsella bursa-pastoris, Anagallis caerulea, Convolvulus arvensis, Cynodon dactylon*, and others. Many more segetals and ruderals are included in the Borealo-Subtropical group, of which the following may be mentioned: *Sisymbrium officinale, Lepidium latifolium, Geranium dissectum, G. molle, Erodium cicutarium, Euphorbia helioscopia, E. peplus, Malva sylvestris, M. neglecta, Conium maculatum, Galium aparine, Senecio vulgaris, Eragrostis minor, Lolium temulentum,* and *Hordeum murinum*.

Among the bioregional, and especially among the Mediterrano-Irano-Turanian group, are found the largest number of segetals and ruderals. Examples are: *Polygonum equisetiforme, Silene conoidea, S. longipetala. Glaucium corniculatum, Biscutella didyma, Diplotaxis erucoides. Neslia apiculata, Eruca sativa, Rapistrum rugosum, Calepina irregularis, Medicago orbicularis, M. hispida, Trifolium resupinatum, Hymenocarpus circinnatus, Vicia narbonensis, V. peregrina, Lathyrus marmoratus, L. annuus, L. erectus, Erodium malacoides, Malva nicaeensis, M. parviflora, Ammi visnaga, Heliotropium europaeum, Marrubium vulgare, Galium tricorne, Notobasis syriaca, Silybum marianum, Cichorium pumilum, Bromus scoparius, B. macrostachys,* and *Gladiolus segetum*.

Among the halophytic interregionals are species of *Suaeda, Salsola, Frankenia* and *Salicornia*, as well as of *Cressa cretica, Sonchus maritimus, Sphenopus divaricatus*, and *Aeluropus littoralis* (Zohary, 1962).

The 160 endemic species represent about 7.1% of the total number of the flora of Palestine-Israel area (Zohary, 1962) which is rather high when compared with that of Egypt (about 2.9%, Boulos, 1995) but very low when compared with that of the Balkan Peninsula (about 26%). According to Zohary (1962), there is no proportionality between the size of plant families and the number of endemic species: for example the total number of species in Leguminosae, Gramineae, Cruciferae, Caryophylleceae, Chenopodiaceae, Iridaceae are: 268, 198, 124, 97, 60, and 23 respectively, whereas the endemics of these families are: 21, 10, 9, 5, 4 and 8 species, respectively. Among the species giving rise to endemic varieties are: *Quercus calliprinos, Q. ithaburensis, Polygonum equisetiform, Erucaria myagroides, E. boreana, Matthiola longipetala, Lygos raetam, Tamarix gallica, Aegilops peregrina* etc. According to Zohary (1962), some endemics of the Palestine-Israel area show clear taxonomic relations to sister species occurring in or outside the area, e.g. *Reheum palaestinum, Dianthus judaicus, Psoralea flaccida, Pimpinella petraea, Eremostachys transjordanica, Campanula hierosolymitana, C. aaronsohnii, Calendula pachysperma, Cousinia moabitica, Scorzonera judaica, Poa hackelii* and *P. eigii*. There are also endemics that can be considered coastal vicariads (representatives) of corresponding taxa of the interior, e.g. *Polygonum palaestinum, Paronychia palaestina, Scrophularia telavivensis, Galium pasianthum, Senecio joppensis, Echinops philistaeus* and *Allium telavirensis*.

The larger three centers of endemics in Palestine-Israel area are: Coastal plain (20 species), Jordan Valley (25) and the high lands of Edom and the Negev (40). The remaining endemics (75 species) are distributed throughout other parts of Palestine-Israel area. The endemics that occur as obligatory weeds include: *Alkanna* *galilea, Galium chaetopodum, Salvia eigii, Stachys zohariane,* and *Lachnophyllum hierosolymitanum.*

- ***Vegetation types***

The Palestine-Israel Mediterranean area comprises variety of vegetation types ranging from dense forests to thin patches of desert. These are classified under five types (Zohary, 1962):

a. Psammophytic;
b. Halophytic;
c. Steppe and Desert;
d. Wood and shrub;
e. Aquatic.

The following is an ecological account on the first four types, the aquatic vegetation will be included in the chapter of wetlands.

a. *Psammophytic vegetation*

Psammophytic vegetation of the Palestine-Israel Mediterranean coastal area inhabits the light soil belt of the coastal plain which comprises: sand dunes, sandy loess, calcareous sandstone soils (locally known as kurkar) and the sandy-clay soil. All of these habitats are poor in nutrients and have – low moisture-retaining capacity.

(i) *Sand dune vegetation.* According to Eig (1931–1932), Zohary (1962, 1973), the sand dunes of the Palestine-Israel area can be categorized into: northern and southern coastal dunes. For the northern dunes, there is a difference between the vegetation of the low and high shores. On the sand dunes of the low shores, the vegetation is arranged in more or less parallel belts, e.g. sand dunes of the Acre Plain where the narrow, plantless tidal zone is lined further inland by shallow, most sand strip predominated by *Ipomoea littoralis and Salsola kali*. The associates are *Cakile maritima, Euphorbia peplis* and a few other species able to withstand sea spray. The first low front dunes are occupied by a community dominated by *Sporobolus arenarius and Lotus creticus* with common associates: *Agropyron junceum, Pancratium maritimum*, *Euphorbia paralias* and *Oenothera drammaondii*. All are highly resistant to sea spray and most have roots that reach the saline water level. Further landward there is a sandy broad belt occupied by an *Ammophila arenaria-Cyperus conglomerates* community associated with: *Silene succulenta, Medicago marina, Scripus holoschoenus, Tamarix gallica, Oenothera drummondii, Lotus creticus* and *Sporobolus arenarius*. *A. arenaria* is a psammophytic grass resistant to sea water spray and is an excellent sand binder with an extensive branching root system. It is capable of sending new sprouts (shoots) after being buried by sand. Landward, there is an almost plantless strip of mobile sands, varying in depth. Further east there is a broad belt of partially stabilized sand dunes occupied by a community co-dominated by *Artemisia monosperma* and *Cyperus mucronatus* (*C. capitatus*, Boulos, 1995). It is a community rich in species composition, e.g. *Polygonum palaestinum, Tamarix gallica, Lygos raetam* var. *sarcocarpa, Convolvulus secundus, Medicago marina, Echium angustifolium, Orlaya maritima, Oenothera drummondii, Senecio joppensis, Plantago sarcophylla, Rumex occultans, Trisetum lineare,* and *Cutandia memphitica*.

The zonetion pattern of the high and steep shore has a somewhat different arrangement. The tidal zone is practically bare whereas the steep slope facing the sea is occupied by a community dominated by *Sporobolus spicatus,* and *Lotus creticus* associated with: *Diotis maritima, Crithmum maritimum, Inula crithmoides* and *Statice virgata*. The higher sand dunes are occupied mainly by a community dominated by *Artemisia monosperma* and *Cyperus capitatus*.

The belt of the southern coastal sand dunes, however, is, relatively, wider and higher and the dunes in full movement. Here, the vegetation is limited mainly to the sheltered depression between the mobile sand dunes, it is represented by only one community dominated by *Artemisia monosperma – Aristida scoparia* (= *Stipagrostis scoparia*, Boulos, 1995). The associates comprise some desert psammophytes lacking in the northern dunes, e.g. *Panicum turgidum, Pennisetum dichotomum* and *Convolvulus lanatus*.

(ii) *The Sandy loess plains* are the most fertile areas in the Negev, almost the whole area has been under farming cultivation since early times. However, the natural vegetation is represented by only one community dominated by *Artemisia monosperma* and *Lolium gaudini*. The wild grass (*Lolium*) gives the landscape a prairie-appearance. The associate species include: *Leopoldia eburnea, Linaria asclonica, Aegilops bicornis, Ononis serrata, Astragalus annularis, Hippocrepis bicontorta, Colchicum ritchii, Dipcadi erythreum,* and *Trisetum glumaceum (= Trisetaria glumacea).*

(iii) *The Kurkar hills* are the consolidated old dunes occur at some distance from the present shore-line as discontinuous longitudinal ridges of calcareous sandstones. This is inhabited chiefly by coastal dwarf shrub communities dominated by, e.g. *Poterium spinosum – Thymelaea hirsuta, Thymus capitatus – Hyparrhenia hirta, and Ceratonia siliqua – Pistacia lentiscus*.

(iv) *The sandy clay* belt is limited to the Sharon Plain and it is occupied by the prairie – like vegetation dominated by *Desmostachya bipinnata – Centaurea procurrens*. The associate species are many and include: *Aegilops longissima, A. sharonensis Tulpa sharonensis, Nigella arvensis ssp. tuberculata, Reseda orientalis, Anchusa aggregata, Brassica tournefortii, Daucus littoralis, Trifolium dichroanthum, Lupinus palaestinus, Medicago littoralis, M. obscura, Leopoldia maritima, Erodium telavivense, Allium curtum, Silene nodosa, S. gallica, Crucianella herbacea, Lotus villosus, Cutandia philistaea, Trigonella cylindricea, Anthemis leucanthemifolia, and Ifloga spicata*.

b. *Halophytic vegetation*

The halophytic (salt marsh) vegetation in centered mainly in the Saharo-Sindian territory, i.e. areas surrounding the Dead Sea and in the Arava valley, a smaller part occurs in the vicinity of the Mediterranean coast. The salt marshes (salinas) occur in the coastal plain as well as in the interior desert. The first type has been formed through flooding of brackish or saline springs and water courses particularly those of the Acre Plain fed by the saline water of the Kishon and Na'aman rivers. The inland salinas are most abundant in the Dead Sea area and in the Arava Valley. These are called high water table salinas.

Three communities are recognized in the coastal plain salinas dominated by: *Salicornia herbacea, Tamarix meyeri* and *Arthrocnemum macrostachyum – Sphenopus divaricatus*. The halophytic vegetation of the inland salinas is organized into 10 communities named after the dominant or co-dominant species as follow: *Phragmites australis, Juncus rigidus, Arthrocnemum macrostachyum, Tamarix tetragyna, Tamarix gallica, Suaeda monoica, Suaeda forsskaolii, Nitraria retusa, Suaeda palaestina* and *Salsola tetrandra*. The following are short notes on these 13 communities (Zohary, 1962).

Salicornia herbaceae (= *S. europaea*, Boulos, 1995) is an annual herb, sometimes rather stiff at base. Its community occupies the swampy spots. It is associated with *Suaeda fruticosa, Cressa cretica, Pholiurus filiformis* and *Hordeum marinum*.

The community of *Tamarix mayeri* inhabits the banks of the Kishon and Na'aman rivers as well as the borders of the pools and puddles in their vicinity. The associates are mainly halophytic species including: *Arthrocnemum macrostachyum, Obione portulacoides* (= *Atriplex portulacoides*, Boulos, 1995), *Juncus rigidus*, and *Salicornia* spp.

The *Arthrocnemum macrostachyum – Sphenopus divaricatus* community is the most common in the area. It occupies relatively highly saline parts associated with: *Statice limonium, Plantgo crassifolia, Aeluropus repens, Juncus rigidus* and *Phragmites australis*.

The two communities dominated by *Phragmites australis* and *Juncus rigidus* are confined to banks of streams, runnels, springs and ponds containing muddy or brackish water throughout the whole or part of the year. Both are formed of almost pure stands arranged in parallel belts the seaward belt is that of *P. australis*. The *Juncus* community can be associated with rare individuals of *Statice limonium, Inula crithmoides, Aeluropus littoralis, Suaeda baccata* (= *S. aegyptiaca*, Boulos, 1995) and *S. fruticosa*.

The community of *Arthrocnemum macrostachyum – Tamarix tetragyna* occupies badly drained depressions and parts of the wadis inundated during winter. The soil usually remains wet and there is no wide fluctuation in soil moisture content (14–23.5%). The associated species are all halophytes including: *Atriplex halimus, Suaeda forsskaolii, S. palaestina, Mesembryanthemum nodiflorum, Phalaris minor, Cistanche lutea, Frankenia pulverulenta, Statice spicata* and *Beta vulgavis.*

The Tamarix gallica, *Suaeda monoica* community forms almost pure stands of woods in the outlet regions of the wadis as well as in the well-drained but permanently flooded depressions. Rare associate species may present, e.g. *Suaeda forsskaolii, S. palaestina, S. vermiculata* and *Atriplex halimus*.

The community dominated by *Suaeda forsskaolii* occupies broad belts along the bank of the Jordan River at the back of *Populus euphratica* and *Tamarix jordanis* woods and on the elevated foreshore of the Dead Sea. The associated species include: *Suaeda baccta, Rumex dentatus, Aeluropus littoralis, Phalaris minor, Sisymbrium irio, Lolium rigidum* and *Bromus scoparius*.

The Nitraria retusa community covers wide areas in the Arava Valley and is also common in the shores of the Dead Sea. The soil of this community has low moisture content. The stands is usually pure with only occasional individuals of *Prosopis farcta, Alhagi graecorum* and *Statice pruinosa* (= *Limonium pruinosum* subsp. *pruinosum*, Boulos, 1995).

The *Suaeda palaestina* community abounds in the Dead Sea region particularly in the plains between Jericho and its northern shore. The soil of this community is usually muddy in winter, dusty and structureless in summer. The common associates of this community are: *Spergularia diandra, Mesembryanthemum nodiflorum, Sphenopus divaricatus, Salsola tetrandra, Atriplex halimus, Prosopis farcta, Alhagi graecorum, Limonium pruinosum, Statica spicata, and Bassia eriophora*.

The community dominated by *Salsola tetrandra* is rich with associated species particularly annuals, e.g. *Stipa tortilis, Plantago ovata, Aizoon hispanicum, Mesembryanthemum nodiflorum*, *Reichardia tingitana, Crepis arabica, and Chlamydophora tridentata* etc.

Apart from these saline communities, there are a series of smaller ones in the Arava Valley region where *Desmostachya bipinnata* predominates associated with *Tamarix* spp. and *Nitraria retusa*.

c. *Steppe and desert vegetation*

Steppes are areas lacking arboreal vegetation for the shortage of rainfall, i.e. a timberless landscape with an open but more or less continuous vegetation of xerophilous shrubs, undershrubs and herbs. Though under arid climate, the annual amount of rainfall on the steppes allows sporadic dry farming. Deserts can be divided into “rain-deserts”, “run-off desert” and “absolute deserts”. The rain-deserts are areas with patchy – very sparse – vegetation maintained by rainfall whereas the runoff deserts are areas in which the amount of precipitation is insufficient to support any kind of vegetation except in depression, and low-lying places where ground winter or runoff moisture accumulates. Absolute deserts, have no sign of vegetation and the limited rainfall prohibits farming except in oases or flooded lowlands.

In the Palestine-Israel Mediterranean area, the steppe and desert vegetation is applied to the vegetation of both the Irano-Turanian and Saharo-Sindian territories. The Irano-Turaniean territory is affected by annual rainfall of 200–350 mm and its habitats are generally non-saline gray calcareous steppe soil, loess soil and rocky hills. This vegetation consists of thorny and broom like brush woods and dwarf shrub communities (Eig, 1948). These widespread communities are dominated by: *Pistacia atlantica, Ziziphus lotus, Lygos raetam, Phlomis brachystylis,* *Artemisia herba-alba, Haloxylon articulatum* and *Anabasis haussknechtii* (= *A. syriaca,* Boulos, 1995).

The *Pistacia atlantica* community occurs in the eastern slope of the Galilee Mountains, on the eastern slopes of the Saamarian and Judea Mountains, as well as in the Edom. The dominant species is the only tree of this community, it has been referred to an "eila" in the Bible. It is a handsome deciduous tree which may attain a considerable age with height up to 20 m (Zohary, 1962).

The Ziziphus louts community is distributed on hillsides facing the central Jordan Valley between Wadi Far'a and Beit Shean. This community is rich in its floristic composition, and among its associated species are: *Ballota undulata, Salvia graveolens, Echinops blancheanus, Carlina corymbosa, Asphodelus ramosus, Ferula communis, Alkanna strigosa, Astragalus macrocarpus, Gypsophila rokejeka, Anchusa strigosa, Salvia horminum, Scabiosa prolifera, Ajuga chia (A. chamaepitys,* Boulos, *1995), Majorana syriaca, Onosma fruticosa, Pterocephalus involucratus, Elymus geniculatus* etc.

The community dominated by *Lygos raetam* var. *raetam* inhabit wide areas of the rocky mountain side facing the lower and central Jordan Valley. The most common associates are: *Rhus tripartita, Podonosma syriaca, Centaurea eryngioides, Gymnocarpos fruticosum* (*G. decander*, Boulos, 1995), *Varthemia iphionoides, Carlina corymbosa, Gypsophila rokejeka* and *Carthamus nitidus*.

The Phlomis brachystylis community occurs in the Judean desert, particularly the rocky habitats. Its associates are: *Poa eigii, Larex pachystylis, Noea mucronata, Salsola vermiculata* ssp. *villosa*, *Artemisia herba-alba, Lactuca orientalis, and Varthemia iphionoides*.

The community dominated by *Artemisia herba-alba* inhabits the gray calcareous soils of rocky hillsides in the central Negev (south of Avdat at an altitude 800 m). Its associate species are: *Reaumuria palaestina, Gymnocarpos decander, Helianthemus vesicarium, Convolvulus oleifolius, Morecandia nitens, Noea mucronata, Astragalus sanctus, Echinops spinosus, Poa sinaica, Phagnalon rupestre, Erodium hirtum, Scorzonera judaica, Stipa szowitsiana, Tulipa amblyophylla* etc.

The Haloxylon articulatum (= *H. scoparium*, Boulos, 1995) community is largely confined to the heavy fluviatile loess soil of wadi terraces and lowlands slightly saline soils. *H. scoparium* is associated with *Stipa tortilis, Malva aegyptia, Trigonella arabica, Avena wiestii* (= *A. barbata* ssp. *wiestii*, Boulos, 1995), *Astragalus callichrous, Plantago ovata, Enarthrocarpus strangulatus, Ifloga spicata, and Aizoon hispanicum*.

Anabasis syriaca community occurs on loess or loess like soil of the Negev with a few associates, such as: *Poa sinaica, Carex pachystylis, Scrophularia deserti, Colchichum ritchii, and Leopoldia longipes*.

Nine main communities are recognized in the Saharo-Sindian territory dominated by: *Zygophyllum dumosum, Chenolea arabica* (= *Bassia arabica*, Boulos, 1995), *Salsola tetrandra, S. villosa, Anabasis articulata – Lygos raetam, Anabasis articulata – Zilla spinosa, Anabasis articulata, Haloxylon persicum* and *H. salicornicum*.

The Zygophyllum dumosum community inhabits two habitats. One of them is confined to the northern and central Negeve, to hammada hills covered with flint stones, where the subsoil consists of a fine gypseaous matter intermingled with gravel. In this habitat, the associated species include: *Gymnocarpos decander, Reaumuria palaestina, Noea mucronata, Astragalus spinosus, A. tribuloides Traganum nudatum, Atractylis serratuloide*s, *Halogeton alopecuroides, Salsola tetrandra, S. inermis, Helianthemum kahiricum, Diplotaxis harra, Herniaria hemistemon, Scorzonera judaica, Aegilops kotschyi, Erodium laciniatum, E. hirtum, Rumex roseus, Plantago ovata, Gymnarrhena micrantha, Asteriscus pygmaeus,* and *Stipa tortilis*.

In the second habitat, *Z. dumosum* community is confined to fissures and interspaces of a rocky substratum in which saline soil accumulates. This habitat occurs in the eastern portion of the central Negeve where *Farsetia aegyptia, Asparagus stipularis* and *Limonium pruinosum* are the most common associates. *Chenolea arabica* (*Bassia arabica*) predominates in parts of the soft gypseous soil, whereas *Suaeda asphaltica* is a leading species in the gypsiferous rocky substratum of the Judean desert and Transjordan. On marls and other soft limestone substrata of the Judean Desert and Dead Sea regions the leading plants are *Salsola villosa* and *S. tetrandra*.

The community dominated by *Anabasis articulata* and *Lygos raetam* occupies areas in the sandy plain of Tureiba (Meishor Yemin) of the central Negev. The associate species include: *Thymelaea hirsuta, Artemisia monosperma, Verbascum fruticosum, Atractylis flava, Helicophyllum crassipes, Ornithogalum trichophyllum, Asphodelus microcarpus, Aristida obtusa, A. ciliata, Pancratium sickendbergii, Matthiola livida, Lotus villosus, Schimpera arabica,* and *Adonis dentata*.

The community dominated by *Anabasis articulata* and *Zilla spinosa* is very common in southern Transjordan in the vast stretches of sand fields derived from Nubian sandstone. The associates are: *Noea mucronata, Gymnocarpos decander, Lygos raetam, Helianthemum arabicum,* and *Carex pachystylis*.

There is another community dominated by *Anabasis articulata* confined to wadis, runnels and depressions cut across the sterile hammadas of the southern Negev and Edom. The soil is less saline supporting a richer flora and denser vegetation. The associate species are: *Zilla spinosa, Gymnocarpos decander, Anvillea gracini, Crotalaria aegyptiaca, Salvia aegyptiaca, Fagonia grandiflora, F. kahirina, Farsetia aegyptia, Pulicaria undulata* (= *P. incise*, Boulos, 1995) *Diplotaxis harra, Reichardia tingitana, Notoceras bicorne* and *Erodium hirtum*.

There are two communities dominated by *Haloxylon persicum* and *H. salicornicum* inhabiting the sand dune and sand plain habitats of the interior desert. *H. persicum* is at the southern limit of its range and is associated with: *Calligonum comosum, Lygos raetam, Zilla spinosa, Salsola foetida, Farsetia aegyptia, Pennisetum ciliare* and *Eromobium linear. The H. salicornicum* community, is confined to sandy soils or sandy hammadas derived from Nubian sandstone and igneous rocks. It never occurs in coastal sand dunes but in more thermophilous sites of the interior desert. The associate species of this community include: *Panicum turgidum, Crotalaria aegyptiaca, Aristida obtusa, Monsonia nivea, Fagonia bruguieri, Salvia aegyptiaca,* *Citrullus colocynthis, Aerva tomentosa* (= *A. javanica* var. *bovei*, Boulos, 1995) *Robbairea prostrata, Salsola foetida,* and *Schismus barbatus*.

Apart from the above mentioned vegetation types, the steppe and desert vegetation of this region comprise about 60 species belonging to various tropical floras, most importantly the Sudanian element represented by two communities. The first is dominated by *Ziziphus spina – christi* and *Balanites aegyptiaca* in Ghov es Safi and Nimrin with rich associates, e.g. *Acacia tortilis* subsp. *tortilis, A. tortilis* subsp. *raddiana, Salvadora persica, Moringa peregrina, Grewia villosa, Abutilon muticum (= A. pannosum), Lavandula coronopifolia, Cassia obovata, Solanum incanum, Calotropis procera, Boerhavia plumbaginacea, Pennisetum ciliare, Suaeda forsskaolii,* and *Atriplex halimus*. The second community is dominated by *Acacia tortilis* subsp. *raddiana*, widespread in the Arava Valley and the surrounding tributaries. The common associates are: *Acacia tortilis,* subsp. *Tortilis, A. negevensis, Anabasis articulata, Haloxylon salicornicum, Gymnocarpos decander, Zilla spinosa, Ochradenus baccatus, Cleome droserifolia, Cassia obovata, Capparis cartilaginea, C. spinosa* var. *negvensis, Lycium arabicum* (= *L. shawii*, Boulos, 1995), *Daemia cordata, Anvillea garcini, Heliotropuim arabainense, Lavandula coronopifolia, Aerva tomentosa, Hyphaene thebaica,* and *Acacia laeta*.

d. *Wood and shrub vegetation*

This vegetation type is identified also as "class of *Quercetea calliprini*". It comprises Mediterranean forests, maquis,[8] garigues[9] and bathas[10] subjected to a Mediterranean climate with a minimum annual rainfall limit of 350 mm. The vegetation of rocky and stony grounds also belongs to this group (Zohary, 1962).

1. The Maquis

The local maquis and forests can be grouped under four types: pine forests, deciduous tabor oak forests, everygrean oak maquis and forests and carob-lentisk maquis.

(i) Pine forests is the southernmost pine forest of the Mediterranean region characterized by three communities. The first is dominated by *Pinus halepensis* and *Hypericum serpyllifolium*, the second is dominated by *Pinus halepensis* and *Juniperus oxycedrus*; the third by *Pinus halepensis-Cupressus sempervirens*.
   Among the associated species are: *Quercus calliprinos, Q. ithaburensis, Pistacia palaestina, P. lentiscus, Arbutus andrachne, Smilax aspera, Rubia olivieri, Genista sphacelata, Calycotome villosa, Cistus villosus, Cytisopsis*

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[8]Maquis = Mediterranean woodland dominated by sclerophyllous evergreen low trees and shrubs up to 4 m high.

[9]Garigue = French term for sclerophyllous scrub that consists generally of chamaephytes and nano-phanerophytes 1 m or 50 cm high.

[10]Batha = Dwarf shrub formation.

*dorycnifolia, Teucrium divaricatum, Fumana thymifolia, Ceratonia silique, Phlomis visc*osa*, Saturega thymbra, Salvia triloba, Poteruim spinosum, Thymus capitatus, Ononis natrix, Echinops viscosus, Ballota undulata and Carlina involucrata*.

(ii) The Tabor Oak belongs to a large group of broad-leaved deciduous forests, fairly common in some east Mediterranean countries notably Turkey, Iraq and Iran in addition to Israel. Three plant communities are recognized, the first dominated by *Desmostachya bipinata*, the second by *Quercus ithaburensis* and *Styrax officinalis* and the third by *Quercus ithaburensis* and *Pistacia atlantica*. The grass community of *D. bipinnata* inhabits the Sharon Plain; but was destroyed by expanding agriculture. The *Q. ithaburensis – Styrax officinalis* community is the most widespread particularly on the South Western slopes of the Lower Galilee, and its remnants are also met with in the Ephraun Hills of Samaria. The most common associates are: *Pistacia palaestina, Crataegus azarolus, Cercis siliquastrum,* and *Phillyrea media.* The other less common associated are: *Quercus ithaburensis, Q. calliprinos, Clematis cirrhosa, Calycotome villosa, Rhamnus palaestina, Smilax aspera, Rubia olivieri, Bryonia multiflora, Asparagus aphyllus, Thymus communis, Ruscus aculatus, Anemone coronaria, Mandragora officinarum, Cyclamen persicum, Arum palaestinum,* and *Thrincia tuberosa*.

The third community of the Tabor Oak forests is dominated by *Q. ithaburensis* and *Pistacia atlantica*, it usually inhabits the western slopes of Gilead and Bashan, and remnants of it occur on the Huleh Plain. The associated species include: *Crataegus azarolus, Amygdalus communis, Rhamnus palaestina, Styrax officinalis, Calycotome villosa, Ruta graveolens, Carlina corymbosa, Convolvulus dorycnium, Echinops viscosus,* and *Ferula communis*.

(iii) The Evergreen Oak Forest and Maquis is the most typical widely spread forest and maquis vegetation of Sout-West Asian part of the Mediterranean basin, occurring in Palestine, Israel, Syria, Lebanon, Turkey and the Balkans. It is subdivided into two communities dominated by *Quercus calliprinos – Pistacia palaestina* and *Q. calliprinos-Juniperus phoenicea*.

The Q. calliprinos – P. palaestina community occurs in various habitats such as northern Galilee under conditions of heavier rainfall and northern exposure. The associates are: *Q. boissieri, Acer syriacum, Pyrus syriaca, Prunus ursina* and *Sorbus triblobata*. This community is also common throughout the western mountain belt from the foot of the Lebanon up to the Judean mountains, in the south. The common associates are: *Cistus salvifolius, C. villosus, Thymbra spicata, Calycotome villosa, Thymus capitatus,* and *Poterium spinosum*.

Q. calliprinos – J. phoenicea community occurs in the South-Western part of Transjordan at 1,000–1,700 m altitude. This forest occupies a strip of about 80 km in length and with its southern limit near Patra. The common associates are: *Crataegus azarolus, Pistacia paleastina, P. atlantica, Rhamnus palaestina* and *Daphne linearifolia*.

(iv) The Carob-Lentisk Maquis forest is widespread in the western foothills of the mountain belt as well as in the eastern slopes of Galilee and Samaria. This vegetation type also occupies consolidated dunes and the Kurkar hills in the Sharon plain north of Natanya. Three communities are recognized in this vegetation type dominated by: *Ceratonia sliqua-Pistacia lentiscus typicum, C. siliqua – P. lentiscus arenarium* and *C. siliqua – P. lentiscus orientale*.

The C. siliqua – P. lentiscus typicum community predominates in the western – foothills along the mountain belt of Israel particularly in the Matsuba – Eilom area of Galilee, on Mount Carmel, in the Hartuv – Beit Guvrin area and further south to the latitutde of Hebron. The associated species in this community are mostly Mediterranean chamaephytes such as *Cistus villosus, C. salvifolius, Calycotome villosa, Salvia triloba, Ruta graveolens, Poterium spinosum, Thymbra spicata,* and *Phlomis viscosa*. The lianas (climbers) of this community include: *Asparagus aphyllus, Rubia olivieri*, *Clematis cirrhosa,* and *Smilax aspera*, and the associated perennial grasses include: *Hyparrhenia hirta, Andropogon distachyus, Phalaris bulbosa* and *Dactylis glomerata*. *Olea europaea* var. *deaster* shrubs occur in the northern section of this community but absent from the southern section.

The Ceratonia siliqua – Pistia lentiscus arenarium community inhabits the consolidated sand dunes notably in the northern part of the Sharon Plain, fragments of this community occurs also in the surroundings of Nahariya. The associated species are: *Lycium europaeum, Ephedra alte, Ballota philistaea, Lygos reatam* var. *sarcocarpa, Artemisia monosperma, Asparagus stipularis, Prasium majus, Ruta graveolens, Cistus villosus, Clematis cirrhosa, Rhamnus palaestina,* and *R. alaternus*.

The Ceratonia siliqua – Pistacia lentiscus orientalis community occupies the eastern escarpments of the lower Galilee and Samaria which are exposed to Irano-Turanian influence. This explains the presence of some species belonging to semi-steppeand Irano-Turania communities, e.g. *Ballota undulata, Ononis natrix, Ziziphus lotus, Pistacia atlantica, Amygdalus communis* and *Phlomis brachyodon*. The other associates comprises species of the other two communities of carob-lentisk maquis forest.

2. The Garigue and Batha Vegetation

This type of vegetation comprises six communities dominated by *Salvia triloba, Cistus villosus, Poterium spinosum, P. spinosum – Thymelaea hirsuta, Thymus capitatus – Hyparrhenia hirta, Salvia dominica* and *Ballota undulata*.

The garigue community dominated by *Salvia triloba* occurs in the western slope of Mount Carmel. The associated species include: *Calycotome villosa, Rhamnus palaestina, Poterium spinosum, Pistacia lentiscus, Teucrium divarictum, Fumana thymifolia, Rubia olivieri, Asparagus aphyllus, Smilax aspera, Ranunculus asiaticus, Anemone coronaria,* and *Arisarum vulgare*.

The second community representing the garigue vegetation is dominated by *Cistus villosus* and occurs near Kiryath Anavim west of Jerusalem. The list of the associates includes: *Cistus salvifolius, Phlomis viscosa, Poterium spinosum, Teucrium polium, T. divaricatum, Stachys cretica, Phagnalon rupestre, Scorzonera* *papposa, Lactuca cretica, Helichrysum sanguinum, Majorana syriaca, Serrata cerinthifolia, Bellis silvestris, Thrincia tuberosa, Salvia judaica, Oryzopsis holciformis*, *Smilax aspera* and *Rubia olivieri*.

The community dominated by *Poterium spinosum* is the commonest of the batha vegetation communities. It occurs on the northern slopes of the Judean Mountains near Jerusalem associated with many species, such as: *Cistus villosus, Fumana thymifolia, F. arabica, Calyctome villosa, Teucrium polium, T. divaricatum, Hyparrhenia hirta, Andropogon distachyus, Dactylis glomerata, Teucrium polium, T. divaricatum, Osyris alba, Micromeria nervosa, Eryngium creticum, Salvia judaica, Rubia olivieri, Orchis anatolicus, Ophrys fusca, Ranunculus asiaticus, Thrincia tuberosa, Bellis silvestris, Mediago orbicularis, Onobrychis squarrosa, Trifolium campestre, T. stellatum, T. purpureum, Lotus peregrinus, Lathyrus aphaca, Aegilops peregrina,* and *Bromus scoparius*. On the light soils of the coastal plain, *Poterium spinosum – Thymelaea hirsuta* predominates. The associate species are mostly psammophytes, e.g. *Hyperrhenia hirta* etc.

The Kurkir hill in the central Sharon Plain is characterized by the batha community co-domoinated by *Thymus capitatus* and *Hyparrhenia hirta*. The associated species include: *Teucrium polium, Fumana thymifolia*, *F. arabica, Asphodelus microcarpus (= A. ramosus), Thymelaea hirsuta, Helianthemum ellipticum, Alkanna tinctoria, Leopoldia maritima, Tulipa sharonensis, Plantago albicans, P. cretica, Astragalus callichrous, Medicago littralis, Anthemis leucanthemifolia, Erodium telavivense,* and *Lotus villosus*.

The fourth community of the batha vegetation dominated by *Salvia dominica* and *Ballota undulata*, inhabits the chalk rocks and the white-grayish soil of a hill near the Shoval area. It belongs to the semi-steppe batha vegetation. The following species were recorded by Zohary (1962) as associates: *Astragalus feinbruniae, Eremostachys laciniata, Noea mucronata, Phlomis brachyodon, Cachrys goniocarpa, Heliotropium rotundifolium, Lycium europaeum, Asphodelus microcarpus, Hyparrhenia hirta, Anchusa strigosa, Alkanna strigosa,* and *Gypsophila rokejeka*.

Apart from the associated species already mentioned, the communities of the garigue and batha formation, mostly chamaephytes and nano-phanerohytes, include many annuals, and geophytes belonging to the following genera: *Anemone, Ranunculus, Colchicum, Tulipa, Allium, Bellevalia, Scilla, Crocus, Iris, Orchis,* and *Ophrys*.

3. Vegetation of the Rocky and Stony Grounds

The Mediterranean wood and shrub vegetation of Palestine-Israel area comprise a type confined to stony habitat such as rocks, rock crevices, stone fences, walls, cave intrances and rubble heaps (Zohary, 1962). Each of these habitats has its distinctive set of plant life-forms, mainly lithophytes having roots able to penetrate deeply into solid hard rock, which crack as the roots thicken. The characteristic species of these stony habitats are: *Varthemia iphionoides, Stachys palaestina, Podonosma syriaca, Ballota rugosa, Pennisetum asperifolium, Michauxia campanuloides, Centaurea speciosa* and *Dianthus pendulus*. All are chamaephytes able to germinate in minute pits in the rock surface and then to send their roots into the unbroken limestone rock. Old stone walls have small pockets of soil between the layers of stones or in the crevices, and these allow a community dominated by *Umbilicus intermedius* and *Allium subhirsutum* to grow associated with: *Erophila minima, Crepis hierosolymitana, Veronica cymbalaria, Cyclamen persicum, Parietaria judaica* and *Taraxacum cyprium* in addition to several species of mosses and liverworts of these genera: *Targionia, Lunularia, Barbula, Tortula, Grimmia, Encalyptra,* and *Camptothecium*. The old walls in towns and cities are characterized by definit communities, the main species of which are: *Parietaria judaica, Hyoscyamus aureus Antirrhinum siculum,* and *Capparis spinosa* var. *aegyptiaca*. *Adiantum capillus – veneris* often also inhabits these moist walls and cave entrances. The habitat of rubble heaps on field margins is characterized by a community dominated by *Cynocramb prostrata*. Associate species include: *Galium articulatum, Cicer pinnatifidum, Veronica cynbalaria, Vicia sericocarpa, V. angustifolia, Crepis bulbosa,* and *Pisum fulvum*.

1.8.2.5 Wetlands

The wetlands of the SW Asian Mediterranean coastal land are represented by two lakes, namely: Lake Bardawil on the Sinai coast of Egypt and Lake Huleh on the Palestine-Israel coast, including their associated coastal swamps. An ecological account of these wetlands is given below.

A. *Lake Bardawil (Sinai coast)*

Lake Bardawil, on the Mediterranean shore of Sinai, is considered a hypersaline lagoon bordering the sea. The narrow semi-circular barrier-beach that forms the northern boundary of the lake separates it from the sea. Artificially maintained inlets connect the lake with the sea. The lake has no fresh-water supply and no major source of enrichment other than the Mediterranean. The influx of water from the sea is very important to its ecology since this inflow and outflow maintain the salt concentration in the water at tolerable levels. The annual rainfall in the area of the lake is about 82 mm and the annual evaporation about 1,600 mm. This excess of evaporation over precipitation has a marked effect on the salinity of the lake when the inlets are closed and circulation cut off. The salinity of the lake is normally about 45–55 parts/1,000. The water temperature generally varies from 12°C in January to 30.5°C in June (Anonymous, 1982). The vegetation of the shore-line in the wet salt marshes of Lake Bardawil is dominated by *Halocnemum strobilaceum* and *Arthroconemum glaucum (=A. macrostachyum)* and an elevated saline belt by *Zygophyllum album* which forms a pure stand. Within the benthic region of the lake, dense growth of *Ruppia maritima* occurs.

The Mediterranean coastal strip adjacent to Lake Bardawil is about 10 km wide and about 50 km long. This strip of land is poor in species. Depressed areas near the lake are subject to periodic inundation by salt water from the lake; the water evaporates to leave a saline residue. Only halophytes grow in these depressions, the vegetation being dominated by *Halocnemum strobilaceum* and *Arthrocnemum glaucum*. On the elevated parts of the area *Zygophyllum album* forms a more or less pure community and often occupies the whole area, except for a few microhabitats, up to the sand dune zone. The littoral strip also contains several localities with slightly elevated terraces, some 3–5 m above water level, dominated by *Nitraria retusa* with *Lycium europaeum* as a common associate. The elevated slopes of the dunes support *Artemisia monosperma, Lygos raetam, Moltkiopsis ciliata* and *Thymelaea hirsuta*. Depressions between the dunes contain a characteristic salt marsh community of *Juncus subulatus* (dominant) and *Cynodon dactylon, Lycium europaeum, Nitraria retusa* and *Phragmites australis* as associates. In the slightly saline depressions are *Artemisia monosperma* and *Lygos raetam*. At the foot of these dunes are semi-wild date palms (*Phoenix dactylifera*).

Recent studies by Khedr and El-Gazzar (2006), El-Bana (2003), Khalil and Shaltout (2006) recognized six main habitats in Lake Bardawil and its surroundings, namely: 1. open water, 2. wet salt marshes, 3. saline sand flats and hummock (nebkas), 4. stabilized sand dunes, 5. interdune depressions and 6. mobile sand dunes. In the open water, only three flowering plants (*Cymodoceae nodosa*, *Ruppia cirrhosa* and *Halodule uninervis)* grow. The first two species are widely distributed in the lake, but *H. uninervis* has not been reported from the Mediterranean before, and seems to have invaded from the Red Sea through the Suez Canal (Täckholm, 1974; Boulos, 1995). The wet salt marshes of Lake Bardawil are characterized by 16 species of halophytes and helophytes. *Halocnemum strobilaceum* is the dominant species and its associates include: *Arthrocnemum macrostachyum, Frankenia pulverulenta, Phragmites australis, Suaeda maritima* and *Tamarix nilotica*.

A total of 34 species have been recorded from the saline flats and hummocks (nebkas), *Zygophyllum album* dominates the saline flats and *Nitraria retusa* the nebkas. The associated species include: *Bassia muricata, Cutandia dichotoma, Lotus halophylus, Mesembryanthemum creystallinum, Salsola tetragona, Spergularia marina* and *Schismus barbatus*.

The stabilized sand dunes are characterized by two groups of islets: eastern and western, with a floristic assemblage of about 78 species. The characteristic species are *Retama raetam* and *Stipagrostis plumosa* in the eastern islets and *Asparagus stipularis*, *Deverra tortusa* and *Echium angustjfolium* in the western islets. Associate species include: *Anabasis articulata, Bupleurum semicompositum, Daucas litoralis, Echiochilon fruticosum, Launaea capitata, Lycium shawii* and *Schismus barbatus*.

The inter-dune depression is a hostil habitat, divided into saline and non-saline facies on the basis of the level of ground water. In non-saline areas, *Artemisia monosperma, Panicum turgidum* and *Thymelaea hirsuta* are the characteristic species, with associates: *Atractylis carduus, Cynodon dactylon, Ifloga spicata, Pancratium maritimum* and *Salvia lanigera*. Halophytes, such as: *Arthrocnemum macrostachyum* and *Halocnemum strobilaceum* predominate in the saline areas.

A total of 49 species have been recorded on the mobile sand dune, *Stipagrostis scoparia* and *Calligonum comosum* are the characteristic species, with associates: *Artemisia monosperma, Cornulaca monacantha, Eremobium aegyptiacum,* *Heliotrpium digynum. Lotus halophilus, Malva parviflora, Pancratium sickenbergeri, and Retama raetam.*

The flora of all habitats of Lake Bardawil contains a total of 136 species (109 genera and 42 families) representing 30% of the recorded species of the Mediterranean coastal plain of Sinai (Gibali, 1988). Gramineae is represented by 12.5% followed by Chenopodiaceae (11%), Compositae (9.6%), Leguminosae (8.1%), Caryophyllacaeae (6.6%), Cruciferae (3.7%) and Cyperaceae (1.5%). Most of the plant diversity of Lake Bardawil are therophytes (44.1%) followed by chamaephytes (25%), geophytes (11.8%), phanerophytes (5.1%), parasites (2.2%) and hydrophytes (0.7%).

Following the IUCN Red Data Book (El-Hadidi and Hosny, 2000), six threatened species are recorded from Lake Bardawil: *Astragalus camelorum, Bellevalia salaheidii, Biarum olivieri, Iris mariae, Lobularia arabica* and *Salsola tetragona*. The first four species are endemic or near endemic (Khalil and Shaltout, 2006).

B. *Lake Huleh (Palestine-Israel area)*

Lake Huleh is formed by a natural dam of basalt on the NE side of Israel; the Jordan River exists from its southern end. It is a lake near sea-level which in ancient times was called the waters of Merom. Its area used to be about 12–14 km^2 (5.3 × 4.4 km), and about 50 cm deep in summer and 3 m deep in winter. In the 1950s, the lake and its surrounding swamps were subjected to an attempt to alter the environment for agricultural needs and began to dry up. Between 1950 and 1958 about 5,000 ha of the lake's swampy shore were drained and then cultivated for grains, fruit trees, vegetable and cotton. However, due to the very limited benefits obtained, it was recognized that successful development can endure only if a compromise between nature and development is reached. As a consequence, a small section of the former lake and swamp region was recently reflooded in an attempt to prevent further soil deterioration and to revive the nearly extinct wetland ecosystem (Anonymous, 2008b).

Apart from fishing activities, Huleh Lake is considered an important bottle neck for the migratory birds along the Syrian-African Rift Valley between Africa, Europe and Asia (Anonymous, 2008b).

The plant life of the wetlands can be grouped under two main categories:

(1) Water plants (hydrophytes).
(2) Canal bank plants.

The water plants (hydrophytes) are those species growing in the water bodies. They are either totally under water (submerged species) or partly under water (floating and emersed species). The canal bank plants (riparian plants) are those inhabiting the wet banks of the river and its tributaries.

According to Zohary (1962), while most of the hydrophytes of Huleh Lake and its surrounding swamps have their origin in northern temperate regions, there are also fair number of topical origin. The tropical elements include: *Marsilea diffusa, Cyperus papyrus, C. latifolia, C. articulatus, C. polystachyus, C. lanceus, C. alopecuroides, Dinebra retroflexa, Paspalidium geminatum, Nymphaea caeruleca, Polygonum accuminatum, P. senegalense* (= *Persicaria senegalensis*, Boulos, 1995) and *Jussiaea repens*.

Zohary (1962) classified the water plants of the Palestine-Israel sector under two plant sociological classes: Potamotea and Phragmitatea. The Potamotea class comprises the hydrophytes of lakes and slow water currents. It includes five plant communities named after the dominant species. The first is dominated by *Potamegeton lucens* and *Myripohyllum spicatum*, both submerged species growing in deeper water; the second is dominated by submerged: *Nuphar luteum* and *Ceratophyllum demersum* occupying shallow and rather stagnant water bodies. The community dominated by *Potamogeton fluitans* (= *P. nodosus*, Boulos, 1995) is found submerged in slow-flowing streams. Communities dominated by the two floating species *Lemna gibba* and *L. minor* are often encountered in shaded ditches. *Nymphaea alba* and *N. caerulea* have become exceedingly rare.

The class phragmitatea comprises emersed (= protruding above the surface of water) hydrophytes forming eight communities. The first community is dominated by *Phragmites communis* var. *isiacus* and *Typha angustata*. It occurs on the low banks of permanent rivers and streams and of periodically flooded swamps. The associate species include: *Cyperus longus, Panicum repens, Scirpus lacustris, S. littoralis, Polygonum nodosum,* and the very rare, *Caldium mariscus*.

The second community is dominated by *Cyperus papyrus* and *Polygonum acuminatum* and occupies large stretches of the flooded peat soils of the Huleh swamps. The associated species here include: *Galium elongatum, Roripa amphibia, Dryopteris thelypteris, Persicaria senegalensis, and Alternanthera sessilis*.

The community dominated by *Persicaria senegalensis* and *Sparganium neglectum* forms considerable belt in the Huleh swamps but also occurs on river banks. Its associate species include: *Cyperus lanceus, Iris pseudo-acorus, Marselea diffusa, Polygonum occuminatum, P. scabrum, Jussiaea repens, Panicum repens, Typha domingensis,* and *Butomus umbellatus*.

The grass *Panicum repens* is fairly common on wet river banks and in flooded low lands. It forms the outer belt of the swampy vegetation of Huleh Lake. Its associates are: *Scirpus maritimus, Alisma plantago-aquatica, Echinochlea crus-galli,* and *Jussiaea repens*.

The community dominated by *Rubus sanctus* and *Lythrum salicaria* is found on the elevated banks of permanent or ephemeral canals as well as on swampy borders. The common associates are: *Cynanchum acutum, Epilobium hirsutum, Saccharum aegyptiacum* (= S. *aegyptiacum subsp. aegyptiacum*, Boulos, 1995), *Convolvulus saepium, Cyperus longus, Dorycnium rectum, Pulicaria dysenterica, Verbena officinalis, Eupatorium cannabinum,* and *Salix acmophylla*.

The *Inula viscosa* community inhabits areas that are usually flooded during winter but drying up in early summer. Frequently encountered associated species include: *Juncus acutus, Pulicaria dysenterica, Teucrium scordioides, Stachys* *viticina, Festuca arundinaceae, Carex* spp., *Lotus tenuifolius, Oenanthe prolifera, Mentha pulegium, Centaurium spicatum,* and *Cynodon dactylon*.

The community dominated by *Crypsis minuartioides* is confined to slight depressions inundated during winter drying out in summer. Its associates are: *Heliotropuim supinum, Glinus lotoides, Pulicaria arabica, Verbena supina,* and *Chrozophora plicata*.

A minor community dominated by *Veronica anagallis – aquatia* occupies permanent rivulets, and the margins of springs. It is associated with: *Nasturtium officinale, Apium graveolens, Mentha incana, Helosciadium nodiflorum*, *Cyperus fuscus,* and *Fimbristylis ferruginea*.

The canal bank (or riparian) species form wood and scrub vegetation on the banks of the Jordan River and the Dead Sea and its tributaries. Two communities are recognized: the *Populus euphratica* and *Tamarix jordanis* communities. The vegetation forms dense and sometimes ever impenetrable woods. *The P. euphratica* community occupies the front part of the bank, whereas the *T. jordanis* community is mostly behind it. The associated species are: *Lycium europaeum, Atriplex halimus, Glycyrrhiza glabra, Asparagus palaestinus,* and *Prosopis farcta*.