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Author Biographies

Monier Abd El-Ghani was born on September 9th, 1955 in Cairo, Egypt. In 1976, he graduated in botany from the Faculty of Science, Cairo University (Egypt); from this institution he also received his MSc and PhD (taxonomy and flora) in 1981 and 1985, respectively. His MSc and PhD studies explored the vegetation structure and the biodiversity of alien plant species in the agroecosystems of the oases of the Western Desert of Egypt and the Faiyum region of the Nile land. His research interest in biodiversity in the arid regions of Egypt and Saudi Arabia resulted in the publication of 6 books and 72 articles in peer-reviewed (55) and national and local (13) journals. For two successive years (1997 and 1998), he obtained a research fellowship granted by the Alexander von Humboldt Foundation in Germany. In 2000, he was awarded the Encouragement State Prize in biological sciences from the Egyptian Academy of Scientific Research and Technology and, in 2003, the Cairo University Encouragement Prize in biological sciences (applied and theoretical). In April 2015, he was awarded his DSc from the Faculty of Science, Cairo University, in the field of plant taxonomy and flora, making him the first to get that degree in this field. In June 2015, he was awarded the State Prize for Excellence in Basic Sciences and, in 2015, the prestigious Georg Forster Research Prize from the Alexander von Humboldt Foundation in Germany.

Francisco Martín Huerta-Martínez is a biologist from the University of Guadalajara in Mexico. He obtained his MSc (botany) at Colegio de Postgraduados in Mexico State in 1995 and his PhD (botany) at the same institution in 2003. He is a professor at the University of Guadalajara in the Biological and Environmental Division with 27 years of experience in the Applied Ecology Department, where he teaches and does research about ecology.

His research interests are plant ecology, plant biodiversity and conservation, biotic interactions, ethnobotany, and forest ecology. He has published several national and international research papers and supervised four PhD theses, two MSc theses, and five undergraduate (biology) theses. From 2004 to 2010 he was a member of the National System of Researchers in Mexico. Currently, he is a member of the Ecological Society of America (ESA) and has participated in several of its annual meetings.

Hongyan Liu is a professor of vegetation ecology and Quaternary ecology at Peking University, China. He received his BS in physical geography and MS in environmental geoscience from Peking University and his PhD degree in botany from Hannover University, Germany. He has investigated the Inner Asian vegetation for over 20 years. His current research focuses on climate- and human-driven vegetation dynamics in the arid regions of Asia at different time scales and combines modern vegetation survey, tree-ring analysis, pollen analysis, and modelling. So far he has published about 80 papers in international journals. He is also the associate dean of research at the College of Urban and Environmental Sciences of Peking University.

Rahmatullah Qureshi obtained his MSc (Botany) in 1996 from the Shah Abdul Latif University, Khairpur (Mir's), Sindh, Pakistan. He joined as Research Associate in Shah Abdul Latif University, Khairpur (Mir's), Sindh, Pakistan, on September 25th, 1998 and got his PhD degree from the same university in 2005 in Taxonomy & Ethnobotany. He qualified Federal Public Service Commission for the post of Seed Certification Officer and joined the department on January 4th, 2002. He started his teaching career by joining the Department of Botany, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan, as Assistant Professor in 2007. Based on his research and teaching achievements, he has been promoted first to Associate Professor (BPS-19) in 2010 and then to TTS in the Department of Botany. His research interests include ethnobotany, plant biodiversity and conservation, phytosociology, biological activities of medicinal plants, and weed ecology. He has published over 155 research papers in prestigious peer-reviewed journals, two international books, and two invited international book chapters. So far, Dr. Qureshi has supervised 43 M.Phil. and 8 PhD theses (4 HEC awardees) and completed 12 research projects; 9 research theses (3 PhDs and 6 MPhil theses) are currently under his supervision. He won five research productivity awards from the Pakistan Council for Science and Technology (PCST) based on his publications, impact factor, number citations, etc. He has presented 45 abstracts at various national and international symposia, conferences, and workshops. Since 2011, he is a elected member of the executive council of the Pakistan Botanical Society as vice president (Punjab).

Chapter 1
Arid Deserts of the World: Origin, Distribution, and Features

Abstract It is not easy to define the word 'desert'. Botanicall, deserts could be defined as areas with little rainfall, and sparse vegetation made up of special plants having particular characteristics that enable them to avoid, resist, or tolerate harsh environments. Four major categories of derts are known: (1) subtropical deserts, (2) cool coastal deserts, (3) cold winter deserts, and (4) polar desert. Most arid deserts are found near the equator because of the plentiful daylight the location offers.The types of vegetation coincide with the pattern of the water resources othe habitat. As their diversity in landforms, soils, fauna, flora, water balances, and human activities, no particular definition of arid environments can be derived. However, the one binding element to all arid regions is aridity.

1.1 Historical

> As quoted from El-Baz (1988): "The word *desert* originated as an ancient Egyptian hieroglyph pronounced *tesert* (Budge 1966), which means a place that was forsaken, or left behind. From this came the Latin verb *deserere*, to abandon. From the latter came *desertum*, a waste place, or wilderness, as *desertus* meaning abandoned or relinquished. This in itself implies that the desert had been a better place. In it, there was life – in some placed teeming life. There was much vegetation, grasses and trees, many animals and human beings. Then something happened, and the place became a wasteland; it was *deserted*".

1.2 Definitions and Features

It is not easy to define what is meant by the word "desert" for its difficulty and conflict. There are almost as many definitions of deserts and classification systems as there are deserts in the world. Most classifications rely on some combination of the number of days of rainfall, the total amount of annual rainfall, temperature, humidity, or other factors. The world's deserts occupy almost one-quarter of the Earth's land surface, which is approximately 75 million km^2. Meigs (1953) divided desert regions on Earth into three categories according to the amount of precipitation they received. In this now widely accepted system, extremely arid lands have at least 12 consecutive months without rainfall, arid lands have less than 250 mm of annual

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rainfall, and semiarid lands have a mean annual precipitation of between 250 and 500 mm. Arid and extremely arid lands are deserts, and semiarid grasslands generally are referred to as steppes.

Deserts are found across our planet along two fringes parallel to the equator at 25–35° latitude in both the Northern and Southern Hemispheres. Botanically, deserts could be defined as areas with sparse vegetation made up of special plants having particular characteristics that enable them to avoid, resist, or tolerate harsh environments. A paucity of trees is another common feature of deserts. Physically, they are large areas with a lot of bare soil and low vegetation cover. Deserts receive little rainfall; however, when rain does fall, the desert experiences a short period of great abundance. Plants and animals have developed very specific adaptations to make use of these infrequent short periods of great abundance. The general landmarks of the arid desert contain sand dunes, oases, and borders (outskirts). Sand dunes are areas of land where the only foot hold is from sand. The sediments are very small and were shaped by wind. Sandstorms occur frequently near sand dunes. An oasis is an area of plentiful vegetation and water surrounded by barren land. Oases usually form near sources of water visible at the surface. The border (outskirts) of arid desert is the perimeter, marking where the desert ends. The desert does not end abruptly; rather, the conditions become somewhat similar to those of semiarid desert and start to become much more hospitable with more vegetation and favourable temperatures. The soils are course, rocky, and shallow and have good drainage. There is less chemical erosion, causing coarse-textured soil. Wind blows most of the sand/soil, thus leaving heavier pieces behind. This causes areas where wind is common to contain only large pieces of sediments.

Usually, the surface streams formed by the little precipitation flow immediately after rainfall—unless the stream has a source of water outside of the desert. Streams that enter a desert usually suffer major water losses before they exit. Some of the water is lost to evaporation. Some is lost to transpiration (taken up by plants and then released to the atmosphere from the plants), and some is lost to infiltration (water entry into the soil of the stream channel).

1.3 Distribution of Deserts

The world's deserts are divided into four categories. Subtropical deserts are the hottest, with parched terrain and rapid evaporation (Batanouny 2001). Although cool coastal deserts are located within the same latitudes as subtropical deserts, the average temperature is much cooler because of frigid offshore ocean currents. Cold winter deserts are marked by stark temperature differences from season to season, ranging from 38 °C (100 °F) in the summer to −12 °C (10 °F) in the winter. Polar regions are also considered to be deserts because nearly all moisture in these areas is locked up in the form of ice.

Most arid deserts are found near the equator because of the plentiful daylight the location offers. The Sahara Desert is an example of an arid desert in Africa. Another example is the Rub' al Khali desert in Saudi Arabia famously known for its sand dunes, a prominent landmark of the arid desert (Table 1.1).

Table 1.1 Types of deserts, together with their location, area and topography, and characteristics (http://www.infoplease.com)

Desert	Location	Area (km^2)	Topography and characteristics
Subtropical deserts			
Sahara	Morocco, Western Sahara, Algeria, Tunisia, Libya, Egypt, Mauritania, Mali, Niger, Chad, Ethiopia, Eritrea, Somalia	9,064,958	70% gravel plains, sand, and dunes. Contrary to popular belief, the desert is only 30% sand. This world's largest nonpolar desert gets its name from the Arabic word *Sahra*, meaning desert
Arabian	Saudi Arabia, Kuwait, Qatar, United Arab Emirates, Oman, Yemen	2,589,988	Gravel plains, rocky highlands; one-fourth is the Rub' al Khali ("Empty Quarter"), the world's largest expanse of unbroken sand
Kalahari	Botswana, South Africa, Namibia	569,797	Sand sheets, longitudinal dunes
Australian desert			
Gibson	Australia (southern portion of the Western Desert)	310,798	Sandhills, gravels, grasses. These three regions of desert are collectively referred to as the Great Western Desert—otherwise known as the "Outback". It contains Ayers Rock, or Uluru, one of the world's largest monoliths
Great Sandy	Australia (northern portion of the Western Desert)	388,498	
Great Victoria	Australia (southernmost portion of the Western Desert)	647,497	
Simpson and Sturt Stony	Australia (eastern half of the continent)	145,039	Simpson's straight, parallel sand dunes are the longest in the world—up to 125 mi. It encompasses the Stewart Stony Desert, named for the Australian explorer
Mojave	United States: Arizona, Colorado, Nevada, Utah, California	139,859	Mountain chains, dry alkaline lake beds, calcium carbonate dunes
Sonoran	United States: Arizona, California; Mexico	310,798	Basins and plains bordered by mountain ridges; home to the saguaro cactus
Chihuahuan	Mexico; Southwestern United States	453,247	Shrub desert; largest in North America
Thar	India, Pakistan	453,247	Rocky sand and sand dunes
Cool coastal deserts			
Namib	Angola, Namibia, South Africa	33,669	Gravel plains
Atacama	Chile	139,859	Salt basins, sand, lava; world's driest desert

(continued)

Table 1.1 (continued)

Desert	Location	Area (km^2)	Topography and characteristics
Cold winter deserts			
Great Basin	United States: Nevada, Oregon, Utah	492,097	Mountain ridges, valleys, 1% sand dunes
Colorado Plateau	United States: Arizona, Colorado, New Mexico, Utah, Wyoming	336,698	Sedimentary rock, mesas, and plateaus—includes the Grand Canyon and is also called the "Painted Desert" because of the spectacular colours in its rocks and canyons
Patagonian	Argentina	673,396	Gravel plains, plateaus, basalt sheets
Kara-Kum	Uzbekistan, Turkmenistan	349,648	90% grey-layered sand—name means "black sand"
Kyzyl-Kum	Uzbekistan, Turkmenistan, Kazakhstan	297,848	Sands, rock—name means "red sand"
Iranian	Iran	258,998	Salt, gravel, rock
Taklamakan	China	271,948	Sand, dunes, gravel
Gobi	China, Mongolia	1,294,994	Stony, sandy soil, steppes (dry grasslands)
Polar			
Arctic	United States, Canada, Greenland, Iceland, Norway, Sweden, Finland, Russia	11,654,946	Snow, glaciers, tundra
Antarctic	Antarctica	14,244,934	Ice, snow, bedrock

1.4 Meaning and Causes of Aridity

Arid environments are extremely diverse in terms of their landforms, soils, fauna, flora, water balances, and human activities. Because of this diversity, no practical definition of arid environments can be derived. However, the one binding element to all arid regions is aridity. Aridity is usually expressed as a function of rainfall and temperature. A useful "representation" of aridity is the following climatic aridity index: p/ETP (where p = precipitation, ETP = potential evapotranspiration), calculated by method of Penman, taking into account atmospheric humidity, solar radiation, and wind (Kassas and Batanouny 1984).

Three arid zones can be delineated by this index: namely, hyperarid, arid, and semiarid. Of the total land area of the world, the hyperarid zone covers 4.2%, the arid zone 14.6%, and the semiarid zone 12.2%. Therefore, almost one-third of the total area of the world is arid land. Also, arid conditions are found in the subhumid zone (aridity index, 0.50–0.75). The term "arid zone" is used here to collectively represent the hyperarid, arid, semiarid, and subhumid zones.

The hyperarid zone (aridity index, 0.03) comprises dryland areas without vegetation, with the exception of a few scattered shrubs. True nomadic pastoralism is frequently practiced. Annual rainfall is low, rarely exceeding 100 mm. The rains are infrequent, irregular, and unpredictable in both space and time, sometimes rainless for several years.

The arid zone (aridity index, 0.03–0.20) is characterized by pastoralism and no farming except with irrigation. For the most part, the native vegetation is sparse, being comprised of annual and perennial grasses and other herbaceous vegetation and shrubs and small trees. There is high rainfall variability, with annual amounts ranging between 100 and 300 mm.

The semiarid zone (aridity index, 0.20–0.50) can support rain-fed agriculture with more or less sustained levels of production. Sedentary livestock production also occurs. Native vegetation is represented by a variety of species, such as grasses and grass-like plants, fortes and half-shrubs, and trees. Annual precipitation varies from 300–600 to 700–800 mm, with summer rains, and from 200–250 to 450–500 mm with winter rains.

Aridity results from the presence of dry, descending air. Therefore, aridity is found mostly in places where anticyclonic conditions are persistent (Evenari et al. 1971), as is the case in the regions lying under the anticyclones of the subtropics. The influence of subtropical anticyclones on rainfall increases with the presence of cool surfaces. Arid conditions also occur in the ward side of major mountain ranges that disrupt the structure of cyclones passing over them, creating “rain shadow” effects. Rainfall is also hindered by the presence of greatly heated land surfaces; as a consequence, large areas of dry climate exist far from the sea.

1.5 Arid Zone Climate and Vegetation

The arid zone is characterized by excessive heat and inadequate, variable precipitation; however, contrasts in climate occur. In general, these climatic variances result from differences in temperature, in the rainy season, and in the degree of aridity. Three major types of climate are distinguished when describing the arid zone: the Mediterranean climate, the tropical climate, and the continental climate (Shmida 1985). In the Mediterranean climate, the rainy season ~~is~~ during autumn and winter. Summers are hot with no rains, while winter temperatures are mild. In the tropical climate, rainfall occurs during the summer. The greater the distance from the equator, the shorter the rainy season (Fig. 1.1).

Winters are long and dry. In the continental climate, the rainfall is distributed evenly throughout the year, although there is a tendency towards greater summer precipitation.

The vegetation cover in arid zones is scarce. Nevertheless, three plant forms can be distinguished: (1) ephemeral annuals, (2) succulent perennials, and (3) non-succulent perennials (Zahran and Willis 1992).

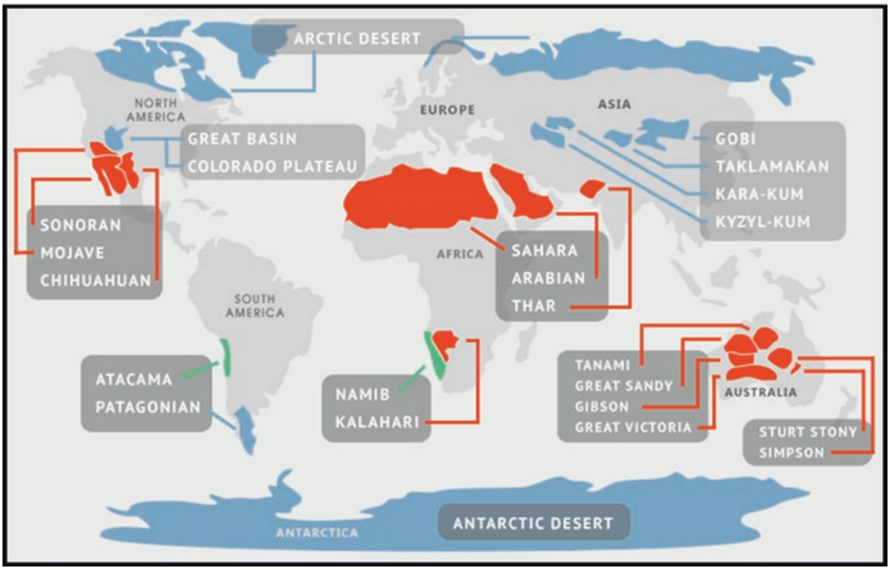

Fig. 1.1 Deserts of the world (http://www.cdn.whatarethe7continents.com)

Ephemeral annuals, which appear after rains, complete their life cycle during a short season (±8 weeks). Their growth is restricted to a short wet period. Ephemerals do not have the xeromorphic features of perennials. In general, ephemerals are small in size, have shallow roots, and their physiological adaptation consistent with their active growth. Ephemerals live through the dry season, which may last a number of years, in the form of seeds. At times, ephemerals can form dense stands and provide some forage.

Succulent perennials are able to accumulate and store water (that may be consumed during periods of drought); this is because of the proliferation and enlargement of the parenchymal tissue of the stems and leaves and their physiological feature of low rates of transpiration. Cacti are typical succulent perennials.

Non-succulent perennials comprise the majority of plants in the arid zone. These are hardy plants, including grasses, woody herbs, shrubs, and trees that withstand the stress of the arid zone environment. Many non-succulent perennials have "hard" seeds that do not readily germinate, under natural desert conditions. The hard seeds have coats, which must be softened by water, scarified mechanically by sand surfaces of the desert, by the activity of microorganisms, etc. before they will germinate.

1.6 Vegetation Types

Walter (1963) wrote: "If the runoff in a region with 25 mm precipitation is 80%, and the area in which the water accumulates constitutes 4% of the total area, that area will receive an amount of water corresponding to a rainfall of approximately

500 mm". This shows how much water the main channels of the wadi can receive. Where there are no wadis, the accumulation of sheet runoff in depressions is of great importance in enriching water revenues.

The types of vegetation coincide with the pattern of the water resources of the habitat. This can be considered to be a communal adaptation to the changing environmental conditions (Batanouny 2001). Three main vegetation types can be distinguished: (1) The *accidental* type (Kassas and Batanouny 1984) is found in those areas where rainfall is not an annually recurring incident, e.g. in the Great Sahara. (2) The *restricted* type (Walter 1963), or mode contractee (Monod 1954), occurs in arid areas where rainfall, though low and variable, is an annually recurring phenomenon. This type is the result of runoff and the accumulation of water at lower elevations. The vegetation is confined to rather restricted areas (wadis, runnels, and depressions with relatively adequate water supply). (3) The *diffuse* type results in vegetation that is more or less evenly distributed (rainfall desert; Zohary 1962). This type occurs in areas with considerable rainfall (>100 mm).

It is not only the water resources of a particular habitat that are controlled by the local topography but also the physical and chemical attributes of the soil (Batanouny 1973), and the soil thickness and its texture are evidently affected by it. A slight depression of a few centimetres in the ground level will lead to the accumulation of a thin veneer of soil carried with the water running into it. Hence, a relatively suitable habitat for plant growth is created despite the harsh conditions of the desert (Batanouny and Hilli 1973).

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Part I
Egypt: The Land of Three Deserts

Chapter 2
The Desert of Egypt

Abstract Egypt is part of Sahara of North Africa in the hyperarid regions, with a hot and almost rainless climate. The Egyptian deserts are among the most arid parts of the world. Therefore, desert vegetation covers vast areas formed mainly of xerophytic shrubs and subshrubs. Egypt includes three deserts: (1) the Eastern, (2) the Western, and (3) Sinai. The Nile land, with its valley and delta, forms the fertile arable lands. Five major habitats can be distinguished: (1) the aquatic habitat, (2) the swampy habitat, (3) the canal bank habitat, (4) the cultivated lands, (5) the northern lakes, (6) the artificial lakes, and (7) the Nile islands. The Mediterranean coastal land of Egypt extends for about 970 km between Sallum on the Egyptian–Libyan border eastwards and Rafah on the Egyptian–Palestinian border. The Red Sea coastal lands include series of high mountains; the highest peak is of Gebel Elba in its southern part.

2.1 Location and Physiographic Features

Egypt is part of Sahara of North Africa and occupies the northeastern corner of Africa and the Sinai Peninsula, covering a total area of over 1 million km^2 (about 1,019,600 km^2) in the hyperarid regions. The Mediterranean Sea bound it to the north, Sudan to the south, Libya to the west, and the Gulf of Aqaba and the Red Sea to the east (Said 1962). It is situated between latitudes 22° and 32° north and lies for the most part in the temperate zone with less than a quarter of its area south of the Tropic of Cancer. Most of landmass is below 500 m above sea level, which limits potential diversity. About 95% of Egypt land is desert; the Western Desert constitutes one of the most extreme arid desert habitats in the world (Fig. 2.1). Generally, the Nile Valley divides Egypt into two geomorphological regions: the eastern dissected plateau and the western flat expanse which form an extension of the Libyan Desert. Although the land to the east of the Nile forms one geomorphological region, it is divided geographically into the Eastern Desert and the Peninsula of Sinai, separated by the Gulf of Suez. Three areas of Egyptian desert may therefore be distinguished: the Eastern Desert, the Western Desert, and the Sinai Peninsula. The whole country forms part of the great desert belt that stretches from the Atlantic across the whole of North Africa through Arabia. It is a cross-road territory with its Mediterranean front connecting it with Europe with which it has had biotic

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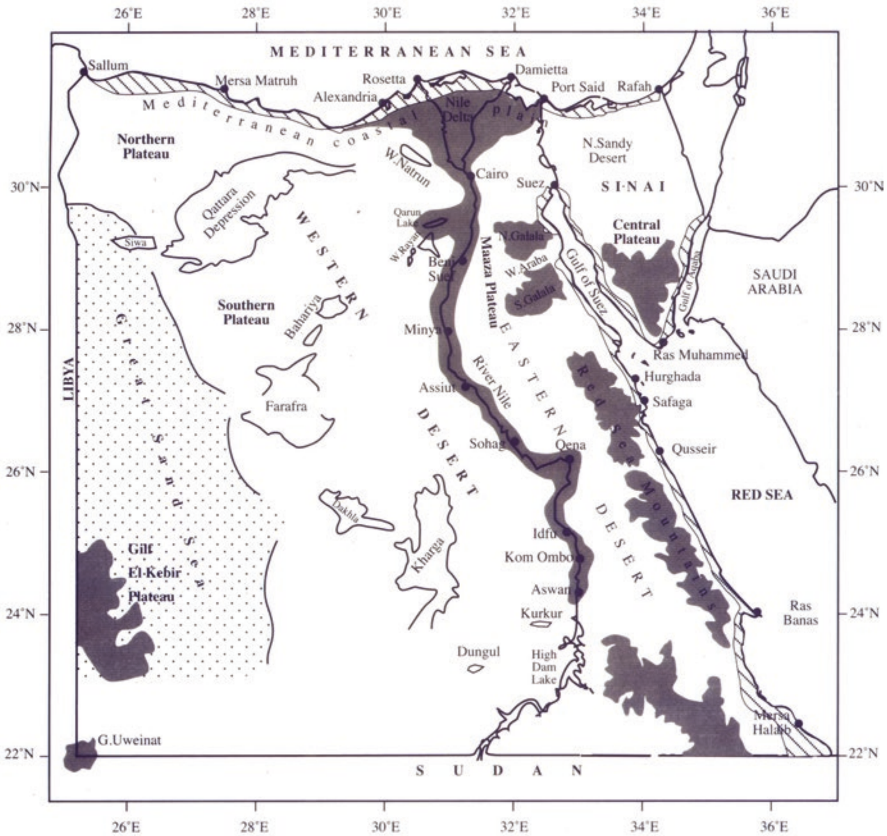

Fig. 2.1 Map of Egypt

exchanges during the glacials and the interglacials, and today we know that routes of migratory birds converge through Egypt. Two highway corridors join Egypt with tropical Africa and beyond: the Nile Valley and the basin of the Red Sea. The Sinai Peninsula is the bridge between Africa and Asia.

Egypt is characterized by a hot and almost rainless climate. The average annual rainfall over the whole country is only about 10 mm. Even along the narrow northern strip of the Mediterranean coastal land where most of the rain occurs, the average annual rainfall is usually less than 200 mm, and the amount decreases very rapidly inland (southwards). The scanty rainfall accounts for the fact that the greater part of the country is barren and desolate desert.

The Egyptian deserts are among the most arid parts of the world. The rainfall does not exceed 10 mm/annum in most parts of the country. The highest rainfall is that along the Mediterranean coast with an average of 150 mm/annum. This amount decreases rapidly as one proceeds southwards till it reaches 30 mm at Cairo. Further to the south, rain decreases reaching 3 mm or even less.

In Egypt, desert vegetation is by far the most important and characteristic type of the natural plant life. It covers vast areas and is formed mainly of xerophytic shrubs and subshrubs. Monod (1954) recognized two types of desert vegetation, namely contracted and diffuse. Both types refer to permanent vegetation which can be accompanied by ephemeral (or annual) plant growth depending on the amount of precipitation in a given year. Kassas (1966, 1971) added a third type as "accidental vegetation" where precipitation is so low and falls so irregularly that no permanent vegetation exists. It occurs mainly as contracted patches in runnels, shallow depressions, hollows, wadis, and on old dunes with coarse sand. Accidental vegetation consists of species which are able to perform an annual life cycle: potential annuals (Haines 1951), or potential perennials (Bornkamm 1987), but can likewise continue growing as long as water persists in the soil. Thomas (1988) identified these plants as those with episodic growth strategies linked to immediate water availability. Recently, Springuel (1997) classified the accidental vegetation in south-eastern Egypt into three groups: (i) runoff-dependent vegetation in the main *wadi* channels, (ii) run-on-dependent vegetation of playa formation, and (iii) rain-dependent vegetation on levelled plains of sand sheets.

2.2 General Features of Phytogeographical Divisions

2.2.1 The Western Desert

The Western Desert covers two-thirds of Egypt (about 681,000 km^2) as it extends from the Mediterranean coast to the Sudanese border for about 1,073 km and from the Libyan border to the Nile Valley for about 600–850 km. Precipitation decreases from 150 mm at the coast to practically zero in the south, and southwest Egypt is known as the driest part of the globe. Well-marked drainage systems (wadis) comparable to those of the Eastern Desert are not found (Zahran and Willis 2009). Another salient feature, resulting from arid conditions, is the uniformity of the surface as compared with other parts of North Africa.

2.2.2 The Eastern Desert

The Eastern Desert of Egypt occupies about 223,000 km^2, i.e. 21% of the total area of Egypt. It is characterized by two main ecological units, the Red Sea costal land and the inland desert with its wadis. According to Zahran and Willis (2009), the latter can be divided into four main geomorphological and ecological regions: (1) Cairo–Suez Desert, (2) Limestone Desert, (3) Sandstone Desert, and (4) Nubian Desert.

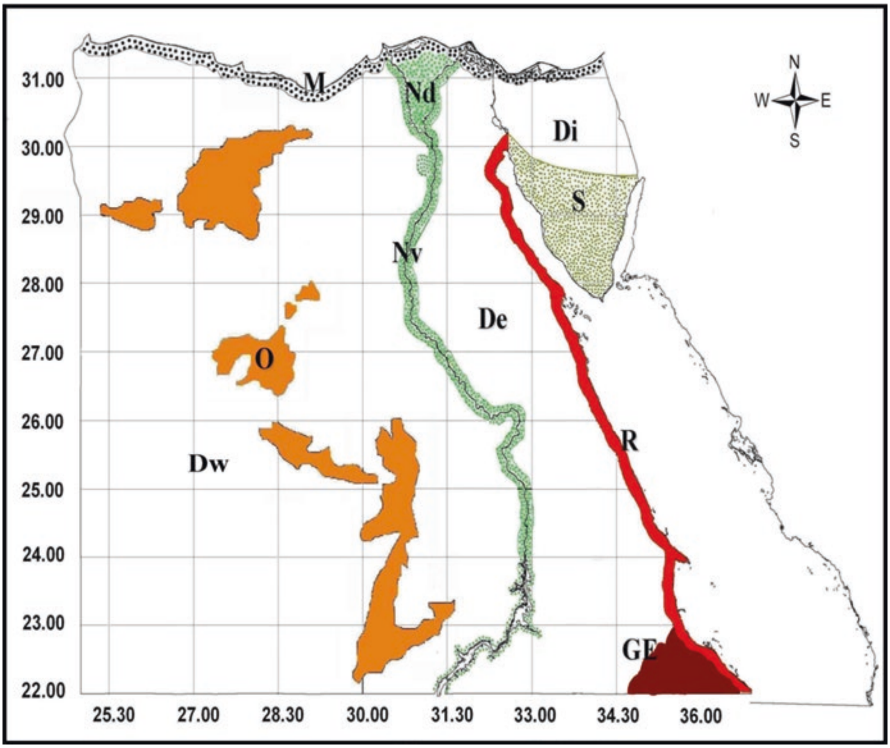

Fig. 2.2 Phytogeographical divisions of Egypt (after Wickens 1977). *M* Mediterranean, *Nd* Nile Delta, *Nv* Nile Valley, *De* Eastern Desert, *Dw* Western Desert, *Di* Isthmic Desert, *S* Sinai Peninsula, *R* Red Sea, *O* Oases, and *GE* Gebel Elba

The inland part of the Eastern Desert of Egypt lies between the Red Sea coastal mountains in the east and the Nile Valley in the west, an area of about 223,000 km^2 (Fig. 2.2). It is a rocky plateau dissected by a number of wadis. Each wadi has a channel with numerous tributaries, and the whole desert is divided piecemeal into the catchment areas of these drainage systems. Most of the wadis drain westwards into the Nile.

The coastal mountain ranges of the Red Sea represent a conspicuous habitat type of special interest for their complex patterns of natural communities interrelating the floras and faunas of Egypt, Sudan, and Ethiopia. One of these ranges is the Gebel Elba Mountains of south-eastern Egypt. This mountain range is considered as a continuation of the granitic formation of the Red Sea highland complex between Egypt and Sudan, situated between 36° and 37° of the eastern longitudes and about 22° of the northern latitude. The flora and fauna of this area comprise hundreds of species of plants and animals; these include a number of endemics and a number of species that represent the northern outpost of the biota of the Ethiopian highlands. The floristic richness of Gebel Elba area is noticeable, compared to the rest of

Egypt, that this is considered as one of the main phytogeographical territories of the country (El Hadidi 2000) as it borders the Saharo–Arabian and Sudanian floristic regions. The flora and vegetation of Gebel Elba group is much richer than that of the other coastal mountain groups (Drar 1936; Hassib 1951), where the Palaearctic and Afrotropical regions meet. It comprises elements of the Sahelian regional transition zone (sensu White and Léonard 1991) and represents the northern limit of this geo-element in Africa. Within its massive, the vegetation on the north and northeast flanks is much richer than that on the south and southwest (Kassas and Zahran 1971). Its ecological features, together with its particular geographic position, seem to have promoted plant diversity, singularity, and endemism in this area and favoured the persistence of extensive woodland landscape dominated with thickets of *A. tortilis* (Forssk.) Hayne subsp. *tortilis*, which is not known elsewhere in the Eastern Desert of Egypt (Zahran and Willis 2009).

In spite of the biogeographical and botanical interests of Gebel Elba mountain range, it has been overlooked in most global biodiversity assessments (Heywood and Watson 1995). Of the 142 woody perennial threatened plant species that are included in the Plant Red Data Book of Egypt (El Hadidi et al. 1992), 56 or 39.4% were known from Gebel Elba district. Therefore, this area was protected in 1986 as Gebel Elba National Park (Prime Ministerial Decrees 450/1986, 1185/1986, and 642/1995), covering 35,600 km^2, aimed to promote the sustainable management of natural resources and maintain its biodiversity. Biodiversity conservation in Egypt is supported by a number of important protected areas network (21 representing 8% of the country's land surface, and further 19 area are recently proposed for protection), based on natural region classification of the land, and having for mandate to preserve a representative sample of ecosystem characteristic of each region.

2.2.3 The Sinai Peninsula

The Sinai Desert covers approximately 6% of the total land area of Egypt and is a desert of the "Saharan type" (McGinnies et al. 1968) linking Asia with Africa. The Sinai Peninsula constitutes a transition between the Egyptian deserts and those of the Middle East. It is an interesting phytogeographic region as it borders the Mediterranean, Irano–Turanian, Saharo–Arabian, and Sudanian regions (Zohary 1973). Besides, the great diversity of climate (mean annual precipitation decreases from about 100 mm in the north, near the Mediterranean, to 5–30 mm in the south; Danin 1978), rock and soil types make the existence of some 900 species and 200–300 associations possible (Danin 1986). The northern part of the peninsula is covered with sand; in the central part, limestone hills and gravel plains predominate. The landscape of the southern region is characterized by a variety of landforms which display varied environmental and vegetational spectra. The major landforms include plains, wadis, oases and springs, salt marshes, and sand dunes. Southern Sinai, however, has an intricate complex of high, very rugged igneous and metamorphic mountains that represent the highest peaks in Egypt, among others, Gebel

Katherina (2,641 m), Gebel Musa (2,285 m), and Gebel Serbal (2,070 m). The western coastal plain, known as El-Qaa, borders the Gulf of Suez. These mountains are highly rich in their flora and fauna (Moustafa et al. 1998) and support mainly Irano–Turanian steppe vegetation dominated by *Seriphidium herba-album* accompanied by *Gymnocarpos decanter*. The vegetation is characterized by sparseness of plant cover of semishrubs, restricted to wadis or growing on slopes of rocky hills and in sand fields, and paucity of trees (Danin 1986).

South Sinai Mountains represent a great harbour of endemism (Moustafa 1990) where the area has wetter climate than most of Sinai and characterized by having large outcrops of smooth-faced rocks which support rare species (Danin 1972, 1978, 1983). The mountainous region of southern Sinai probably contains a greater biodiversity than in the rest of Egypt. A large section of the area was declared a Protectorate in 1996, centred upon the town of St. Catherine (1,600 m a.s.l.) with its world-famous sixth-century Monastery built on the traditional site of the "burning bush" of the Bible, at the foot of Mt. Catherine. From the mountain of St. Catherine, at 2,641 m, the highest point in Egypt and marking the watershed of the peninsula, wadi systems drain eastwards towards the Gulf of Aqaba and westwards towards the Gulf of Suez.

Although southern Sinai is classified as "very arid" (Zahran and Willis 2009), there is in fact a great deal of water draining down the wadis, sometimes as violent and destructive flash floods, but under normal circumstances, most of the water is underground, occasionally surfacing to produce short sections of freely flowing permanent water. Sparse vegetation occurs everywhere, but the wet areas are particularly rich with plants and consequently with insects and other animals.

2.2.4 The Nile Land

In Egypt, the River Nile is the primary source of fresh water. It also provides Egypt with a very fertile and productive land along both the Nile Valley and Delta regions (Fig. 2.1). Of the total course of the River Nile, only the terminal 1,530 km lie within the borders of the country. It consists of a complex system of various units of water bodies (lakes, marshes, streams, canals, drains, etc.) and landforms (plains and valleys). Within these units, a great variety of climate, vegetation structure, and land use and also a number of biogeographical regions exist. The Nile land, with its valley and delta, had attained most of its present and prominent features during the Neonile phase (30,000 years BP) of the Pleistocene period. The Nile Valley flows in elongated S-shaped pattern for a distance of about 900 km long from Aswan to Cairo. The Nile Delta, with an area of about 22,000 km^2, comprises about 63% of Egypt's fertile land. It has strong geological similarities with the desert to the west and the Nile Valley to the south. The total length of the canals and drains is approximately 47,000 km (Van der Bleik et al. 1982).

The Nile system had been subjected to a series of large-scale schemes of river control, using a series of barrages and dams that had been built across the river and its tributaries. These dams and barrages had segmented the natural hydrobiological system with undoubted impact on the biota (Kassas 1971). The construction of dams and barrages in the River Nile had caused great environmental changes, including the destruction of many natural habitats and the formation of artificial ones like cultivated fields on river island and aquaculture plots. Khattab and El-Gharably (1984) reported that among the serious problems is the vast spread of aquatic weeds in the Egyptian water bodies, particularly the net of the canals and drains in the Nile Valley region. The degree of infestation is affected by environmental factors, including water transparency, depth of water, physico-chemical water quality, water current, and air temperature. According to Zahran and Willis (2009), the Nile system of Egypt includes a number of habitats formed and/or greatly influenced by the water of the River Nile. These are (1) the aquatic habitat, (2) the swampy habitat, (3) the canal bank habitat, (4) the cultivated lands, (5) the northern lakes, (6) the artificial lakes, and (7) the Nile islands.

In a country like Egypt, where a warm climate prevails most of the year, the hydrophytes of the River Nile and its irrigation and drainage systems are greatly developed. The establishment of the Aswan High Dam in the most extreme south of Egypt controls to great extent the flow of water in the Nile and its Damietta and Rosetta branches. This control has led to numerous ecological changes in the Nile system, the effect of damming on downstream reaches being marked. Changes due to damming include silt-free water running downstream which results in the extensive use of fertilizers to compensate for the lack of the silt. Side effects also include changes in the chemical and physical characteristics of irrigation water, the presence of water in the canals all the year around, and the level of water in the Nile system particularly in Lower Egypt being noticeably lower and the current being of decreased velocity. The absence of silt in the Nile below the High Dam has made it no longer necessary to dredge the canals. Dredging removes large quantities of seeds and perennating organs of water plants; such factors are causing a noticeable and considerable increase in the growth rate and densities of the fresh water hydrophytes of the Nile system. Also the introduction of a new-water weed (*Myriophyllum spicatum*) to the Delta has appeared and started to spread during the last 20 years. The distribution of *M. spicatum* is restricted to the Nile system in Upper Egypt, but it is not yet present northwards in the Nile Delta.

Usually a 3-year crop rotation is applied in the croplands of the Nile land (including Nile Delta, Nile Valley). The crop succession during this period is (1) temporary Egyptian clover (or fallow fields)—cotton; (2) wheat–maize (or rice in the northern Delta); and (3) permanent Egyptian clover (or broad beans)—maize. So, an area is usually divided into three parts in order to have all the crops in the same year (El-Khshin et al. 1980). Planting time for the winter crops is September–November, February–March for cotton, and April–May for maize and rice. The crop longevity is 5–6 months for all crops, except cotton (7–8 months). Hand pulling and manual hoeing are the most frequent methods of all the crops, except rice.

2.2.5 The Western Mediterranean Coast

The Mediterranean coastal land of Egypt extends for about 970 km between Sallum on the Egyptian–Libyan border eastwards and Rafah on the Egyptian–Palestinian border (Fig. 2.1), with an average width ranging from 15 to 20 km in N–S direction. It lies within the Mediterranean/Sahara regional transition zone, where the vegetation comprises floristic elements for both of the Mediterranean and Saharo–Arabian regions (White 1993). Floristically, it remains one of the less known territories of the country. El Hadidi (2000) distinguished between a Mareotis sector which extends between Sallum eastwards to Alexandria, where Cyrenaican elements are prominent, and a Sinaitic sector extending from Port Said eastwards to Rafah, where East Mediterranean taxa prevail. Ecologically, it represents the narrow less arid belt of Egypt that can be divided into three sections: western, middle, and eastern (Zahran et al. 1990). The western section extends from Sallum eastwards to Abu Qir, near Alexandria, for about 550 km.

2.3 Concluding Remarks

1. Floristically, the Mediterranean coastal land of Egypt represents one of the richest phytogeographical territories of the country. El Hadidi and Hosni (2000) reported that 1,060 species or 51% of the total flora of Egypt are recorded from this territory. Three hundred twenty-one species were confined in their distribution to a specific habitat and only known from this territory, of which more than two-thirds are typical Mediterranean chorotype. Four plant species are known to be endemic to this territory and not recorded elsewhere in the country; these include *Allium mareoticum* Bornm. & Gauba, *Echinops taeckholmianus* Amin, *Fumaria microstachys* Hausskn., and *Helianthemum sphaerocalyx* Gauba & Spach (Boulos 1995).
2. Physiographically, the western section of the Mediterranean coastal land can be distinguished into two main provinces: an eastern province between Alexandria and Ras El-Hikma and a western province between Ras El-Hikma and Sallum (Selim 1969). One of the salient features of the latter province is the dissection of its landscape into an extensive system of shallow wadis (gullies; sensu El Hadidi 2000). They drain from the southern limestone plateau which lies parallel to the west Mediterranean coast and reaches a maximum elevation of about 200 m above sea level at Sallum. The phytosociology and vegetation analyses of these wadis were the subject of El Hadidi and Ayyad (1975), El Hadidi et al. (1986), El-Kady and Sadek (1992), Kamal and El-Kady (1993), and El Garf (2003).
3. Since the 1950s, much attention has been paid to the western section of the Mediterranean coastal land. Till the recent, less attention has been paid to the distant part of the western Mediterranean coast from Sidi Barrani to Sallum on