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Landscape ecology of the western desert of Egypt

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The Western Desert of Egypt (formerly called the Libyan desert) extends over more than 1000 km throughout the whole country, from the Mediterranean to the Sudanese border. The precipitation gradient extends from about 150 mm at the coast to practically zero (Fig. 1). It may be that SW-Egypt is the driest part of the globe. Since agricultural land use and range lands are restricted to a small proportion of the area, most parts are relatively undisturbed by man. The western desert, therefore, is an excellent place to study desert ecosystems under different degrees of aridity.

We had the opportunity to study this area during several expeditions, between March 1982 and October 1986, within the framework of the Special Research Project 'Geo-scientific problems of arid areas' sponsored by the 'Deutsche Forschungsgemeinschaft'. Among a number of geological and hydrological sub-projects one sub-project was set up in order to elaborate on soil and vegetation maps of the Western Desert. The results of the pedological investigations, which are still continuing, are reported by Stahr *et al.*, 1985; Gauer & Stahr, 1984; Blume *et al.*, 1984; Alaily & Blume, 1986; Alaily *et al.*, 1987*a,b*. In the present paper we mainly deal with the role of the vegetation in the ecology of the landscapes investigated. Many investigators have studied the vegetation near the Mediterranean coast (*see* Ayyad & Le Floc'h, 1983; Bornkamm & Kehl, 1985; El Kady, 1987). Others studied the inhabited oases (*see* Kassas, 1971; Abd El-Ghani, 1985; Abu Ziada & El-Sayed, 1980), but only a few records exist about the large parts of inland deserts outside the inhabited oases, including the small spot-like oases in the Toshka depression (*see* Kassas, 1971; Bornkamm, 1986; Alaily *et al.*, 1987*a*; Kehl, 1987).

In the following paper we characterize five desert zones, referring only to precipitation-dependent vegetation, which means that oases are excluded (see Fig. 1). If we disregard the littoral habitats, the northernmost zone of the Western desert shows dwarf shrub vegetation with *Thymelaea hirsuta* as the most important plant. Other species dominating different communities are *Asphodelus microcarpus, Plantago albicans, Hamada scoparia* (in degraded land) and *Lycium europaeum* as a higher shrub (in *wadis*) see Stahr *et al.*, 1985, zones II and III; El-Kady, 1987). The phytogeographic analysis shows predominantly Saharo-arabian species with a rather large proportion of Mediterranean species (Bornkamm & Kehl, 1985). At 100–150 mm precipitation the climatic diagram (zone III.4 according to Walter & Lieth, 1967) shows one 'humid month' (relatively speaking) and fulfills the demands of a semi-desertic climate in the sense of Müller-Hohenstein, 1981 (*see also* Walter & Breckle, 1983; Knapp, 1973). The vegetation is permanent and diffuse, i.e. all habitats (Migahid *et al.*, 1971) are covered by vegetation, but the growth of high shrubs (>2 m) has a contracted pattern: it is restricted to the *wadis*.

The zone is inhabited by both the town population and nomads. The agricultural land use comprises tree cultivation (dates, figs, olives, almonds), dry farming (barley), grazing and cutting or uprooting of ligneous species as fuel. The characters of this zone have been described thoroughly by the Egyptian ecologists, especially near Ras El Hikma (see Ayyad, 1969), Omayed (*see* Ayyad, 1980; Ayyad & Le Floc'h, 1983; and the literature cited here), and Maktila (Migahid *et al.*, 1974, 1975a,b,c; El-Kady, 1987).

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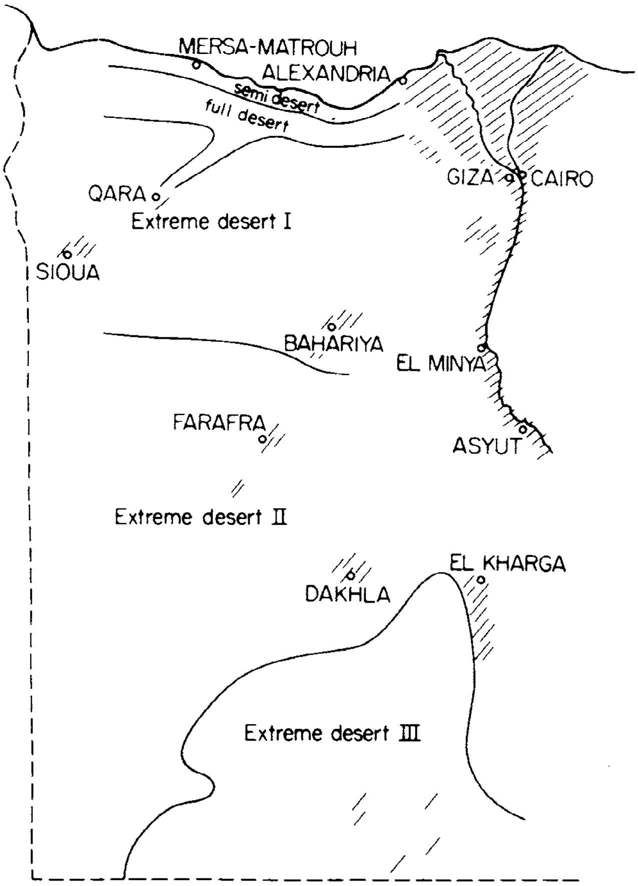

Figure 1. Desert zones in the western desert of Egypt. Dashed areas = oases.

The second zone extends nearly 100 km south of the coast. Here the precipitation goes down to 10–20 mm, and all 12 months are aridic. Along this gradient the vegetation becomes more and more contracted, and many of the annuals, which are indicators of more or less regular rainfall, disappear (Stahr *et al.*, 1985 zones IV and V). Saharo-arabic species totally dominate (Bornkamm & Kehl, 1985). The most important species are *Pituranthus tortuosus, Artemisia inculta, Gymnocarpus decandrum, Carduncellus mareoticus* a.o. (Stahr *et al.*, 1985; Kehl *et al.*, 1984). The vegetation is contracted but permanent, which means that in certain places (like playas) soil water bodies exist throughout the year. The area is grazed by camels at a very low stocking rate, the intensity being dependent on the climatic conditions of the year.

About 90% of the Western Desert receives rainfall less than 10–20%. Here a number of changes occur as compared with the main desert, so we refer to it as an extreme desert. The vegetation is contracted and covers less than 1% of the total area. Since no permanent water bodies are available, the vegetation is temporary, but as there are no rainy seasons, the vegetation is not annual either. This type of vegetation has been called 'accidental vegetation' by Kassas (1952, 1966, 1971): 'This type of vegetation may be called accidental vegetation in distinction from the ephemeral annual vegetation and the perennial or permanent vegetation that are met within deserts with a more regular rainfall' (Kassas, 1952). Important dominating species are *Zygophyllum coccineum, Cornulaca monacantha, Salsola baryosma, Stipagrostis* spp. div., *Fagonia arabica, Francoeuria crispa, Anabasis articulata* a.o. Most species of the accidental vegetation are potential perennials, but they can perform their life cycles in less than one year if necessary. If water stays available for a longer period they continue growing up to the moment where the water is exhausted. In the vegetation spots only a few plants are living, usually 99% are dead. The density of the vegetation very much depends on the size of the catchment area; smooth surfaces favouring lateral water flow; sand cover of the topsoil preventing evaporation; high water capacity in the subsoil.

Under very special runoff conditions, e.g. wadimouths between large rocks, local water bodies may exist over a longer period (Walter & Breckle, 1983). Under such conditions even tree growth (*Acacia raddiana*, *Tamarix* spp.) may occur, but the distance between two trees amounts to several hundred km in certain cases.

In the western Desert the extreme desert still shows a significant differentiation (Fig. 1). The zone between latitude c. 30·5° N (north of the Qattara depression) and c. 28° (height of Bahariya) bears vegetation characters of both the full desert and the hyperaridic desert types. The vegetation cover is lower than 0·1% of the total area, and accidental vegetation is as indicated by the regular occurrence of different Tamarix species and the (very sporadic) growth of *Acacia raddiana*. We call this zone extreme desert I. Agricultural land use is already impossible here. In this zone the Qattara depression is embedded which—at altitudes below sea level—shows a very peculiar vegetation with a number of southern (i.e. Sudanian) species (Bornkamm & Kehl, 1985). Rainfall in the extreme desert I amounts to about 5–10 (20) mm/year.

In the largest part of the Western Desert, only accidental vegetation exists. Within this zone, extreme desert II (Fig. 1), in the sand dune areas, the hilly landscapes, the *hamada* and serir plains, tiny spots of (mostly dead) vegetation occur with extreme distances (10 km and more) between them (Bornkamm & Kehl, 1987). Rainfall in the extreme desert II amounts to about 1–5 mm/year. The runoff and below-surface conditions become more important than the amount of precipitation itself, and the relationship between runoff, infiltration and vegetation is very complex (Evenari, 1985). An exception is the mountains of the Gilf Kebir (elevation between 650 and 1082 m), where in the deep *wadis* and shallow depressions vegetation (containing 15 species, *see* Alaily *et al.*, 1987*a*) is widespread.

In the very center of the E-Sahara with sand plains predominating, accidental vegetation is almost absent (Bornkamm, 1986). The rainfall here is near zero. Nevertheless sporadically and locally animal life exists and food chains occur which are based on the input of organic material of two types: litter blown by wind and deposited at wind protected sites; migrating birds.

Because some ecosystem characters are developed, these incomplete ecosystems void of producers, which depend on allochthonous organic matter, have been called allochthonous ecosystems (Bornkamm, 1987*b*). They characterize the extreme desert III in SW Egypt and the adjacent parts of N Sudan. The scheme in Fig. 2 (bottom part) makes clear that the ecosystem functions are restricted by lack of water (primary production and decomposition) and isolation (predation by large carnivores), as compared with complete ecosystems (Fig. 2, top part). Some of these restrictions can already be found in ecosystems with accidental vegetation (Fig. 2, center).

The results of our investigations are summarized in the following scheme (Table 1). It has to be kept in mind that criteria of three different meanings are used: 'diffuse' or 'contracted' concerns spatial patterns, 'permanent' (together with annual) or 'accidental' concerns temporal patterns, and 'allochthonous' or 'autochthonous' concerns ecosystem functions. Our classification of desert types is not consistent with some others. Recently Shmida (1985) called true deserts areas with <120 mm rainfall (this comprises a great deal of our semi-deserts), and extreme desert areas with rainfall <70 mm (this comprises a great deal of our full deserts). Inevitably terminology has to be adjusted; a general terminology still is needed.

In relation to land use it has already been pointed out that typical agricultural or pastoral activities are restricted to semi-deserts (zone 1), whereas extensive grazing is possible in the full desert in favourable years. This is not possible in the extreme desert, although suitable soils occur (Alaily *et al.*, 1987*b*). Vast areas seem relatively undisturbed to the unexperienced visitor. This does not mean that the extreme desert is free of land-use pressure. Activities like quarrying; mining; car riding by military personnel, adventure tourists, scientists, smugglers; activities radiating from irrigation farms (like garbage spread, hunting); burning of small wild oases are performed in a highly land-consuming manner (*see also* Batanouny, 1983). In absolute terms these influences are not very strong, but the

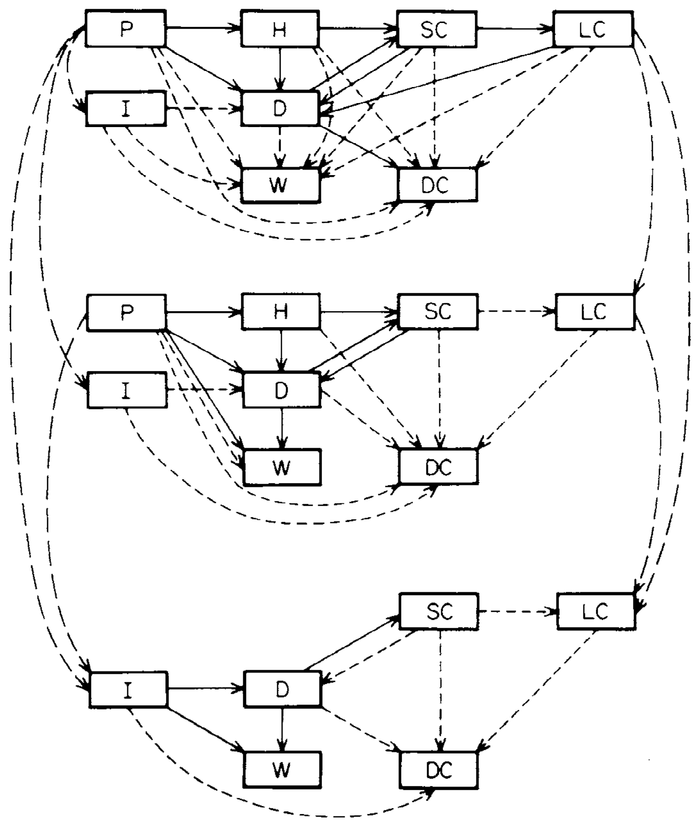

Figure 2. Functional relationships of different ecosystem types. Above: autochthonous ecosystem with permanent vegetation; center: autochthonous ecosystem with accidental vegetation; below: allochthonous ecosystem; solid lines: main processes within ecosystems; dotted lines: subordinate processes within ecosystems; broken lines: processes between ecosystems. Abbreviations: DC, decomposers; DT, detritivores; H, herbivores; I, import; LC, large carnivores; P, producers; SC, small carnivores; W, weathering.

ecosystems of the extreme desert are so vulnerable that these influences exert a considerable impact by destroying vegetation, enhancing input of organic matter, and eliminating larger herbivores and other animals from a great part of their former habitats (Niethammer, 1971). It can be expected with certainty that human impact in the extreme desert will rise with increasing mobility. Extreme desert is regarded as no-man's land and therefore is not respected in its natural value (Alaily *et al.*, 1987*b*). Every effort should be made to protect sufficient amounts of these peculiar ecosystems.

Let us now draw conclusions concerning the topic of our symposium: What is special about desert ecology, and are there unifying characters? Regarding our summary (Table 1) the first impression is great diversity. In semi- and full deserts all typical ecosystem functions like primary production, herbivores, detritivores and mineralization are rather well developed (Fig. 2). In landscapes with accidental vegetation the ecosystems are discontinuous in time. Primary production is followed by grazing, but predation is lowered by spatial isolation, and decomposition is prevented by recurrent dryness. Allochthonous ecosystems are void of producers. Based on litter, they start food chains with detritivores, leading to carnivorous insects, reptiles and birds. Locally high input of organic matter by migrating birds does not result in higher consumption because the consumers are not present.

Another source of variation is the relation of the above-ground and below-ground portions of plants. The shoot: root ratio, of course, depends on the species given and their performance, but generally in humid areas this ratio frequently is >1, whereas in deserts it usually (but not always) goes down to values of 1 and less (Evenari *et al.*, 1975, 1976; Noy-Meir, 1973, 1985). In accidental vegetation it is neither possible, nor useful, to

Table 1. *Distribution pattern of vegetation*

		Groundwater-dependent			Precipitation-dependent			Rainfall in mm/year + occurrence
Desert type	Ecosystem type	Life form	Spatial	Temporal	Life form	Spatial	Temporal	
Semi-desert	Autochthonous	P	Contracted e.g. in *wadis*	Permanent	P	Diffuse + contracted e.g. in *wadis*	Permanent	<250 >50
		A	Contracted e.g. at wadimouth	Seasonal	A	Diffuse + contracted	Seasonal	Seasonal
Full-desert	Autochthonous rarely allochthonous	P	Contracted e.g. in oases	Permanent	P + pP	Contracted e.g. in runnels + playas	Mostly permanent + rarely accidental	<50 >10–20
		A	—	—	A	Contracted e.g. in runnels + playas	Seasonal + accidental	Mostly seasonal but spotty
Extreme desert I	Autochthonous and allochthonous	P	Contracted only in oases	Permanent	pP + P	Contracted e.g. in *wadis* + playas	Accidental + rarely permanent	<10–20 >5 episodical and spotty
		A	—	—	A	Contracted e.g. in *wadis* + playas	Accidental	
Extreme desert II	Autochthonous and frequently allochthonous	P	Contracted only in oases	Permanent	pP	Contracted e.g. in *wadis* + playas	Accidental	<5 >1 episodical and spotty
		A	—	—	A	Contracted e.g. in *wadis* + playas	Accidental	
Extreme desert III	Autochthonous in oases otherwise allochthonous	P	Contracted only in oases	Permanent	—	—	—	≤1 extremely episodical and spotty
		A	—	—	—	—	—	

sustain large root systems as in permanent vegetation. The root growth follows the water front but the main vigor is put into shoot growth combined with early flowering and fruit setting. The shoot: root ratio, therefore, rises again to values >1 (Bornkamm, 1987*a*). Other sources of variation are soil processes, like formation of calcrete, salt or gypsum layers, surface phenomena and so on. The first conclusion of our considerations is that every desert type has its specialities.

Concerning unifying characters we feel that deserts have just one factor in common: the scarcity of water, from which all other common characters are derived. The characters listed and interpreted by Noy-Meir (1985) are, of course, not independent of each other. The lack of water is the cause of low productivity, low biomass, low nutrient flow, harsh wind exposure, harsh microclimatological conditions, and rare 'tree' life. Most of them are not desert-specific but can be found in other vegetation zones, where productivity is reduced by another key factor, such as temperature or extreme nutrient deficiency. Likewise the allochthonous factor is met in other types of ecosystems, in which producers are eliminated by an adverse factor (Bornkamm, 1987*b*). More specific are all the special adaptions to the conditions mentioned above (Evenari, 1985). Our second conclusion, therefore, is that the only common factor in deserts is water shortage. But this one factor is answered by a multitude of biological responses.

References

Abd El-Ghani, M. M. (1985). Comparative study on the vegetation of the Bahariya and Farafra Oasis and the Faiyum region. Diss. Cairo. 464 pp.

Abu Ziada, M. & El-Sayed, A. (1980). Ecological studies on the flora of Kharga and Dakhla Oases of the Western Desert of Egypt. Diss. Mansoura (Egypt). 351 pp.

Alaily, F. & Blume, H. P. (1986). Soil association map. Cartography by Pöhlmann, G. & Rössler-Händschke, M., Berlin (West): Technische Fachhochschule.

Alaily, F., Bornkamm, R., Blume, H.-P., Kehl, H. & Zielinski, H. (1987*a*). Ecological investigations in the Gilf Kebir (SW-Egypt). *Phytocoenologia,* **15**: 1–20.

Alaily, F., Bornkamm, R., Kehl, H. & Renger, M. (1987*b*). Evaluation of land in SW-Egypt. *Berliner Geowissenschaftliche Abhandlungen,* **A75**: 517–544.

Ayyad, M. A. (1969). An edaphic study of habitats as Ras El-Hikma. *Bulletin de l'Institut du Désert d'Egypte,* **19**: 245–259.

Ayyad, M. A. (1980). *Regional environmental Management of Mediterranean Desert Ecosystems of Northern Egypt (REMDENE).—Progress Report No. 1, Vol. I, Producers.* Alexandria: Academy of Scientific Research and Technology. 116 pp.

Ayyad, M. & Le Floc'h, E. (1983). *An ecological assessment of renewable resources for rural agricultural development in the western Mediterranean coastal region.* Montpellier: Centre National de la Recherche Scientifique. 104 pp.

Batanouny, K. H. (1983). Human impact on desert vegetation. In: Holzner, W., Werger, M. J. A. & Ikusima, I. (Eds), *Man's Impact on Vegetation.* pp. 139–149. The Hague, Boston, London: Junk. 370 pp.

Blume, H.-P., Alaily, F., Smettan, U. & Zielinski, J. (1984). Soil types and associations of South-west Egypt. *Berliner Geowissenschaftliche Abhandlungen,* **A50**: 293–302.

Bornkamm, R. (1986). Flora and vegetation of some small oases in S-Egypt. *Phytocoenologia,* **14**: 275-284.

Bornkamm, R. (1987*a*). Growth of accidental vegetation in SW-Egypt. *Catena,* **14**: 267–274.

Bornkamm, R. (1987*b*). Allochthonous ecosystems. *Landscape Ecology,* **1**: 119–123.

Bornkamm, R. & Kehl, H. (1985). Pflanzengeographische Zonen in der Marmarika (Nordwest-Ägypten). *Flora,* **176**: 141–151.

Bornkamm, R. & Kehl, H. (1987). Ecological maps of the Western Desert of Egypt—Vegetation units. Cartography by J. Pöhlmann, Technische Fachhochschule Berlin (West).

El-Kady, H. F. (1987). A study of range ecosystems of the western Mediterranean coastal desert of Egypt. Diss. TU Berlin. 145 pp.

Evenari, M. (1985). Adaptations of plants and animals to the desert environment. In: Evenari, M., Noy-Meir, I. & Goodall, D. W. (Eds), *Hot deserts and arid shrublands. Ecosystems of the world, 12 A*. pp. 79–92. New York, Tokyo: Elsevier, 365 pp.

Evenari, M., Bamberg, S., Schulze, E.-D., Kappen, L., Lange, O. L. & Buschbohm, U. (1975). The biomass production of some higher plants in Near-Eastern and American deserts. In: Cooper, J. P. (Ed.), *Photosynthesis and Productivity in different Environments*. pp. 121–127. Cambridge: Cambridge University Press. 715 pp.

Evenari, M., Schulze, E.-D., Lange, O. L., Kappen, L. & Buschbohm, U. (1976). Plant production and Semi-Arid Areas. *Ecological Studies*, **19**: 439–451.

Gauer, J. & Stahr, K. (1984). Yermosol-Bodenlandschaften in Nordwest-Ägypten. *Mitteilungen der Deutschen Bodenkundlichen Gesellschaft*, **39**: 19–24.

Kassas, M. (1952). Habitat and plant communities in the Egyptian desert—I. Introduction. *Journal of Ecology*, **40**: 342–351.

Kassas, M. (1966). Plant life in deserts. In: Hills, E. S. (Ed.), *Arid Lands*. pp. 145–180. London: Methuen/Paris: Unesco. 461 pp.

Kassas, M. (1971). Die Pflanzenwelt. 2. Teil, Pflanzenleben in der östlichen Sahara. In: Schiffers, H. (Ed.), *Die Sahara und ihre Randgebiete. I. Physiogeographic*. Afrika-Studien Nr. **60**: 477–497. München: Weltforum-Verlag. 674 pp.

Kehl, H. (1987). Zonation and establishment of vegetation in selected uninhabited Egyptian and Sudanese oases. *Catena*, **14**: 275–290.

Kehl, H., Stahr, K. & Gauer, J. (1984). Soil-Vegetation relationship of a small catchment area on the Libyan plateau in NW-Egypt. *Berliner Geowissenschaftliche Abhandlungen*, **A50**: 303–324.

Knapp, R. (1973). *Die Vegetation von Afrika*. Jena: VEB Fischer. 626 pp.

Migahid, A. M., Batanouny, K. H. & Zaki, M. A. F. (1971). Phytosociological and ecological study of a sector in the Mediterranean Coastal Region in Egypt. *Vegetatio*, **23**: 113–134.

Migahid, A. M., El-Sharkawi, H. M., Batanouny, K. H. & Shalaby, A. F. (1974). Phytosociological and ecological studies of Maktila Sector of Sidi-Barani. I. Sociology of the Communities. *Feddes Repertorium*, **84**: 747–760.

Migahid, A. M., Shalaby, A. F., Batanouny, K. H. & El-Sharkawi, H. M. (1975*a*). Phytosociological and ecological studies of Maktila Sector of Sidi-Barani. II. Ecology of the communities. *Feddes Repertorium*, **86**: 83–91.

Migahid, A. M., Batanouny, K. H., El-Sharkawi, H. M. & Shalaby, A. F. (1975*b*). Phytosociological and ecological studies of Maktila Sector of Sidi-Barani. III. A Vegetation Map. *Feddes Repertorium*, **86**: 93–98.

Migahid, A. M., El-Sharkawi, H. M., Batanouny, K. H. & Shalaby, A. F. (1975*c*). Phytosociological and ecological studies of Maktila Sector of Sidi-Barani. IV. Range potentialities of the communities. *Feddes Repertorium*, **86**: 579–587.

Müller-Hohenstein, K. (1981). *Die Landschaftsgürtel der Erde*. Stuttgart: Teubner. 204 pp.

Niethammer, G. (1971). Die Fauna der Sahara. I. In: Schiffers, H. (Ed.), *Die Sahara und ihre Randgebiete. I. Physiogeographie*. Afrika-Studien Nr. **60**: 499–603. München: Weltforum-Verlag. 674 pp.

Noy-Meir, I. (1973). Desert ecosystems: environment and producers. *Annual Review of Ecology and Systematics*, **4**: 25–51.

Noy-Meir, I. (1985). Desert ecosystem structure and function. In: Evenari, M., Noy-Meir, I. & Goodall, D. W. (Eds.), *Hot Deserts and arid Shrublands. Ecosystems of the world, 12 A*. pp. 93–103. New York, Tokyo: Elsevier. 365 pp.

Shmida, A. (1985). Biogeography of the desert flora. In: Evanari, M., Noy-Meir, I. & Goodall, D. W. (Eds), *Hot Deserts and arid Shrublands. Ecosystems of the world, 12 A*. pp. 23–77. New York, Tokyo: Elsevier. 365 pp.

Stahr, K., Bornkamm, R., Gauer, J. & Kehl, H. (1985). Veränderung von Böden und Vegetation am Übergang von Halbwüst zur Vollwüste zwischen Mittelmeer und Quattara Depression Ägypten. *Geoökodynamik*, **6**: 99–120.

Walter, H. & Breckle, S.-W. (1983). *Ökologie der Erde. Band 1. Ökologische Grundlagen in globaler Sicht*. Stuttgart: G. Fischer. 238 pp.

Walter, H. & Lieth, H. (1967). *Klimadiagramm-Weltatlas*. Jena: VEB Fischer.