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Editors

Arid Dune Ecosystems

The Nizzana Sands in the Negev Desert

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General Introduction – Desert Sand Dunes and Aims of the Book – Special Characteristics of the Nizzana Research Site

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Sand dunes occur in many parts of the world, not only in deserts and other arid regions but also along many coastlines in humid biomes and environments. Sand dune formation requires a large supply of sand, strong winds and limited vegetation cover. This has been the case during glacial times in areas that today are humid regions and exhibit fossil dune systems densely covered with vegetation, only open after human destruction. Active inland sand dunes are commonly widespread in arid and dry regions. Deserts are often misinterpreted as being always of sand dunes. However, about only 25 to 30% of deserts (depending on literature sources) are covered with sand fields (erg). The main deserts of the globe are listed in Table 1, as well as the percentages of sand-covered areas within.

A variety of desert types have been described in the literature. On the basis of surface properties, the following main types have been identified: rocky and block surfaces (hamada); gravely surfaces (serir); stone pavement surfaces (reg); clay surfaces (takyr); and saline surfaces (sebkha, playa or salina). All these types commonly occur along catenas, often rather mixed (Breckle 2002).

From an ecological point of view, sand deserts offer more favourable conditions for plant cover and species diversity than do other desert types. This is due to the specific characteristics of sand, namely low water absorption; rapid infiltration rate and low evaporation losses (because capillary threads are only 10 to 20 cm long). Thus, all sandy areas represent – even in arid deserts – water-storing bodies. This is rather old ecological knowledge (e.g. Walter 1960). The only limitation for plant establishment and plant cover is a high frequency of extreme wind speeds that limit surface stability. In areas where the frequency of extreme wind speeds is low, the sand surface is relatively stable. Under such conditions, the establishment of crusts and a plant cover takes place, leading to an increased surface stability by further reducing wind speed and sand mobility.

The process of surface stabilization is enhanced by the deposition of fine-grained particles and the development of biological topsoil crusts. There is today an increasing awareness of the very important role that should be attributed to biological topsoil biological crusts in the structure and functioning of arid ecosystems (see Belnap and Lange 2001). Biological crusts are composed primarily of cyanobacteria; these are important in nitrogen fixation, nutrient cycling, surface stabilization and germination. Where present, biological topsoil crusts strongly control the soil moisture regime,

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Table 1 Major drylands/deserts of the world (extracted from various sources, average values; zonobiomes, *ZB*, and zono-ecotones, *ZE*, are according to Breckle 2002)

Name	Type of desert	Surface area (10^6 km^2)	Sand desert area (10^3 km^2)	Location	Description (including *percentage of sand desert*)
Sahara (incl. Egyptian Desert E of Nile)	Subtropical, ZBIII	9.25	2,750	Northern Africa	70% gravel, rock plains. Contrary to popular belief, the desert is only less than *30%* sand (several erg-fields)
Arabian Desert	Subtropical, ZBIII	2.59	620	Arabian Peninsula	Gravel plains, rocky highlands; one quarter is the Rub al-Khali ("Empty Quarter"), the world's largest expanse of unbroken sand (*25%*)
Australian deserts (Great Victoria, Great Sandy, Gibson, Simpson Sturt, Stewart)	Subtropical, ZBIII, ZEII-III	1.38	400	Australia	Sand hills, gravel, rocks, grassland, Simpson parallel sand dunes are the longest in the world: up to 200 km (*30%*)
Gobi	Cold winter, ZBVIIa, ZBVII(rIII)	1.33	200	China, Mongolia	Stony, sandy soil (*15%*), steppes (dry grasslands)
Patagonia	Cold winter, ZBVIIa	0.67	0	Argentina	Gravel plains, plateaus, basalt sheets (*0%*)
Kalahari	Subtropical, ZBIII, ZBII	0.57	400	South Africa, Botswana, Namibia	Sand sheets, longitudinal dunes (*70%*)
Great Basin	Cold winter, ZBVIIa	0.49	15	USA	Mountain ridges, valleys, sand dunes (*3%*)
Thar	Subtropical, ZEII-III	0.45	45	India, Pakistan	Rocky sand and sand dunes (*10%*)
Chihuahua	Subtropical, ZBIII, ZBII(rIII)	0.44	9	Mexico	Grassland, cacti savannah (*2%*)

Taklamakan	Cold winter, ZBVII(rIII)	0.36	290	China	Sand dunes (*80%*), up to 300 m high; gravel
Iranian deserts (Registan)	Cold winter, ZBVII, ZBIII	0.35	35	Iran, Afghanistan	Salt, gravel, rock, sand fields (*10%*)
Colorado Plateau	Cold winter, ZBVIIa	0.34	0	USA	Sedimentary rock, mesas and plateaus – the Grand Canyon, "Painted Desert" (*0%*)
Sonora	Subtropical, ZBIII, ZEII-III	0.31	15	USA, Mexico	Cacti savannah, gravel (*5%*)
Kyzyl-Kum	Cold winter, ZBVII(rIII)	0.30	240	Uzbekistan, Turkmenistan, Kazakhstan	Sands, rock – name means "red sand" (*80%*)
Atacama (Altiplano)	Cool coastal, ZBIII	0.18	20	Chile, Peru, Bolivia	Salt basins, sand (*10%*), lava; world's driest desert, mountains
Mojave	Subtropical, ZBVIIa	0.14	15	USA	Mountain chains, dry alkaline lake beds, calcium carbonate dunes (*12%*)
Aralkum (new desert)	ZBVII(rIII)	0.055	10	Kazakstan, Uzbekistan	Desiccated seafloor, sand desert (*20%*)
Sinai (part of Sahara)	ZBIII	0.060	3	Egypt	Mountains, rocks, gravel, sand (*5%*)
Namib	Cool coastal, ZBIII	0.034	15	Angola, Namibia, South Africa	Gravel plains, huge sand dunes (*50%*), up to 300 m high
Negev (part of Sahara)	ZBIII	0.013	1	Israel	Rocks, gravel, sand (*5%*)

as they affect infiltration rate, surface runoff generation, spatial redistribution of water resources and depth of water penetration.

The Nizzana Research Site is one of the long-term research sites operated by the Arid Ecosystem Research Centre (AERC) established in 1987 by the Minerva Foundation (Germany) and the Hebrew University of Jerusalem. The centre provided technical and partial financial support to many of the studies included in this book. The site is located at the proximity of the Israeli–Egyptian border (Fig. 1) where, at present, human activity is quite limited. The Nizzana Sands site offers an excellent example of the structure and functioning of a sandy desert ecosystem and the importance of biological topsoil crusts. Any sandy area has its own characteristics that derive from its particular geographic location, local rainfall and wind regimes, sand grain mineral composition and geomorphic features of the dune system. The special characteristics of the sandy area where the Nizzana site is located are as follows:

- The sand field on the Israeli side represents the eastern margins of the extensive Sinai erg (see Chaps. 1–3).
- It is climatologically arid (11 months relatively arid, Fig. 2) with cool, moist winters and hot, dry summers (Fig. 2). The rainfall gradient along the sandy study sites (Fig. 1: sites N1 to N5) varies sharply from less than 90 mm in the south to about 170 mm in the north, over a distance of only 35 km. Annual rainfall fluctuates greatly from year to year all over the area. In the south (N1), annual rainfall is between 28 and 160 mm. Most rainstorms are small (below 5 mm), with a predominance of low rain intensities. Due to the proximity of the area to the Mediterranean Sea, dewfall is quite frequent (see Chaps. 4, 12).

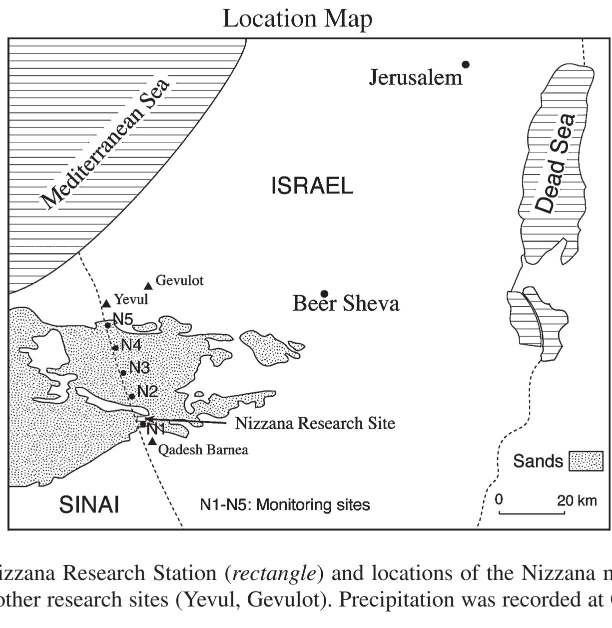

Fig. 1 The Nizzana Research Station (*rectangle*) and locations of the Nizzana monitoring sites (N1–N5) and other research sites (Yevul, Gevulot). Precipitation was recorded at Qadesh Barnea

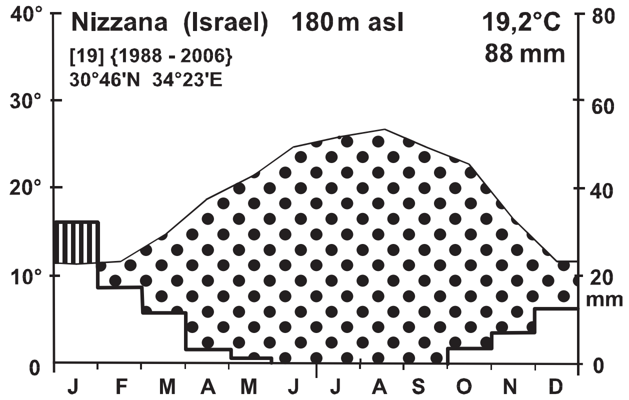

Fig. 2 Ecological climate diagram for the Nizzana Research Station (modified after Walter and Lieth 1967, Breckle 2002), showing temperature and rainfall data for the ca. last 19 years

- The wind regime is characterized by a high frequency of low wind speeds that result in the frequent deposition of fine-grained particles that play an important role in surface stabilization and an extensive development of biological topsoil crusts (see Chaps. 6, 10, 11, 14, 15).
- The extent of stable areas of topsoil crust cover with specific crust properties increases with increasing annual rainfall from south to north.
- Despite the arid climatic conditions prevailing in the area, an extensive vegetation cover is observed that, locally at the base of dune slopes, can reach the high values of 80–100% (see Chaps. 6, 8, 18, 20, 23, 26).
- On a smaller scale, there is a remarkable disturbance gradient between interdunes and dune tops, with high spatial-temporal dynamics of recruitment and mortality, and varying competitive and facilitation processes (Malkinson and Kadmon 2007).
- It is remarkable that the biodiversity (of spermatophytes) in such a dune mosaic system is relatively high (see Chap. 7); however, this depends on the definition of biodiversity. Area-wise, species numbers may be rather low in comparison with tropical regions but the species numbers related to resources such as water availability (resource-related biodiversity) are in the same range as those in the tropics (Breckle 2006).
- The development of such a “fertile” ecosystem is explained by the important role that should be attributed to the biological topsoil crusts that increase surface stabilization, improve nutrient cycling, control the water regime and water resources, and exercise a strong influence on the germination and establishment of higher vegetation (see Chaps. 18, 19, 20, 23, 25, 26).
- The area had been subjected to human activity, mainly grazing by Bedouins, during the period 1967–1982. Human activity ceased after 1982, enabling the investigation of recovery processes of the disturbed topsoil crust and grazed perennial vegetation (see Chaps. 6, 20, 27, 28).

- The marked difference in average annual rainfall from the south to the north (90–170 mm; cf. above) allows studying the possible effects of the foreseen global climatic change over an area (Fig. 1) where the sandy substratum is almost uniform (see Chap. 29).

The detailed studies conducted in the area at different temporal and spatial scales, as well as the interdisciplinary approach adopted in most studies, represent an interesting holistic case study that can more or less directly be applied to other sandy arid areas, while taking into consideration the specific climatic and geomorphic conditions prevailing there.

The book is divided into four main sections. The first section provides an overview of the regional physical characteristics of the area and covers geological, pedological, geomorphological and climatological aspects, as well as desertification processes by land use. The second section focuses on the spatial patterns of the vegetation and topsoil crust covers. The third section covers the numerous studies dealing with ecosystem processes such as sand movement, evaporation and transpiration, runoff generation and water resources, recovery of the vegetation and of the biological crust following disturbance, photosynthesis, dewfall, activity of biological crusts, nitrogen input, demography of annual plants, etc.

The last section presents a synthesis of most of the work presented in the book, and focuses on the important issue of specific surface properties, in particular regarding the sensitivity of the area to climate change as well as the rehabilitation measures available to date for desertified sand dune systems.

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