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The Occurrence of an Arid Botanical Oasis, in a Sandy Mediterranean Area

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Abstract

Dryland areas are usually regarded as highly sensitive to climatic conditions. A positive relationship between average rainfall and environmental factors (water availability, species diversity, etc.) is often assumed for areas with an average rainfall of 100-500 mm. However, the global climatic models, based on purely climatic variables, fail to address some important issues. Climate change is not limited to climatic factors. It is often accompanied by a pronounced variability in surface properties. Needless to say, the spatial variability of the surface properties may have variable effects on water resources, and environmental variables. In other words, a climate change in dry-land areas would be expected to have differential hydrological effects in a sandy area, a rocky area, or in a loess covered area. The present study deals with a sandy area where average annual rainfall is 450 mm, with extreme years of 200-750 mm, a classic Mediterranean climate. However, a striking difference exists in the spatial vegetation cover between the top of the dunes and the adjoining depressions. The vegetation cover is very sparse over the ridges, but very dense in the depressions. In view of the Mediterranean climate one would have expected a classic Mediterranean composition of the vegetation in the depressions. However, all the vegetation cover in the depressions is of arid origin. The manuscript deals with the great variety of factors that allow the development of an arid botanical oasis, in a sandy Mediterranean area.

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Introduction

The southern coastal area of Israel (Figure 1) is characterized by a Mediterranean climate. Average annual rainfall is 450 mm, with extreme years of 200 and 750 mm. The rainy season is limited to the winter season (September to May). Geologically the area is composed of sandy ridges, separated by large flat sandy depressions. The predominant vegetation is composed of desert shrubs. However, a striking difference in the vegetation cover exists between the sand ridges and the adjoining sandy depressions. The vegetation cover is very sparse over the sand ridges, but very dense in the depressions (Figure 2). The explanation proposed for the sparse vegetation over the sand ridges is that the sandy grains do not absorb water, are poor in nutrients, and allow a fast and deep-water percolation, that prevents the establishment of a dense vegetal cover [1,2]. This explanation is not valid for the depressions, where the very dense vegetation cover is indicative of a high-water availability. Such conditions offer a priory, favorable conditions for the establishment of Mediterranean species. However, all the vegetation species in the depressions are of arid origin species (Artemisia monosperma; Cutandi memphitica; Scrophularfia hypercifolia). The aim of the present study is to explain this contradiction. The hypothesis advanced for the pattern described above is that a combination of various factors, above surface and below the surface, is responsible for the dense development of arid plant species in a sandy Mediterranean area. The various factors include the limited rain amounts at most rainstorms, rainwater interception by the dense canopy vegetation, extensive water-repellent surfaces that limit infiltration depth, water absorption by a litter layer, and finally the geological background: a thin sand layer above a clay rich layer (a paleosoil) that prevents deep water infiltration by the sealing process.

Methodology

Effects of surface factors

Field observations drew our attention to the extensive areas of standing waters in the depressions, following any rain event (Figure 3). An additional observation was the importance of rainwater interception by the dense vegetation. Following these observations, the study of the various factors affecting the local moisture regime in the study area focused on the following variables:

Rainfall regime, and rain interception.

The analysis of the rainfall regime was based on a tipping bucket connected to a data logger located above the canopy of a well-developed tree. Several rain-collectors were placed below the canopy of the same tree, at an elevation of 20 cm above the ground. In addition, special attention was given to the temporal distribution of individual rain-showers, and distribution of rain intensities, expected to seriously affect rainfall interception by the dense canopy.

Hydrophobicity

Hydrophobic soils have been identified in arid, as well as in humid environments [7-9]. Hydrophobic, or water-repellent soils, are unable to absorb water. Water infiltration into such soils is reduced, affecting germination, plant growth and productivity. Under such conditions the negative effects of water availability for plants, could be more significant in dry-land than in humid areas, creating thus a drier ecosystem than that allowed by the natural rainfall conditions. Water repellency was measured by the "Water Drop Penetration Time" [10-12]. Water repellent surfaces have been observed in the study area before the start of the present study. Water repellency was measured below

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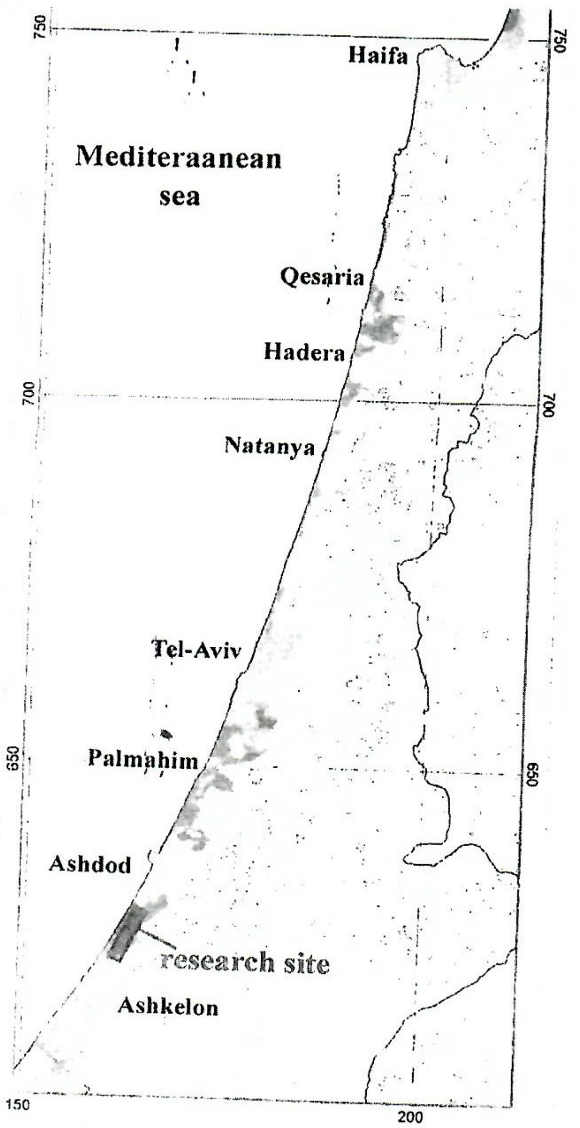

Figure 1: Location map.

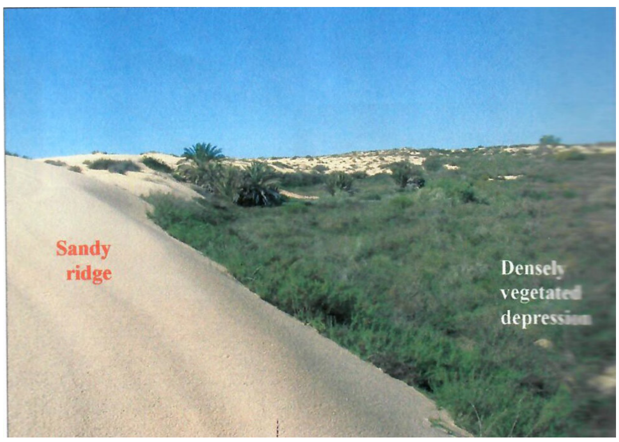

Figure 2: View of the dense vegetation cover in the depression.

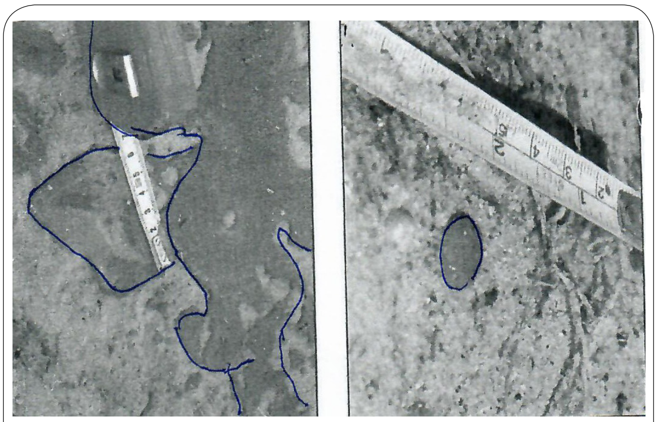

Figure 3: Water repellent patches in the depression.

the canopy of the dense shrubs (where hydrophobicity is expected to be very high), and on a nearby bare surface, at three levels: top of the organic surface layer, at the center of the organic layer, and at the base of the organic layer. Measurements started before the rainy season, under dry surface conditions, and during the rainy season after each rainstorm, and once a week between rain-spells.

Litter layer

The hydrophobic layer is underlain by a litter layer, 5-10 cm thick. This layer is not hydrophobic, but it is expected to absorb rainwater, further limiting infiltration depth. Samples of the litter layer were taken after each rain event in order to determine the water amount absorbed by this layer.

Soil moisture regime

The soil moisture regime was monitored with moisture sensors, 20 cm long (Dialectric Aquameters, EC H_2O produced by Decagon Devices, USA). A pretest of the sensors, conducted in the laboratory, using soil samples brought from the field, showed satisfactory and reliable results. The sensors were inserted at the interface between the litter layer, and the sandy layer; at the interface between the sandy layer and the fine-grained layer below, and 50 cm within the fine-grained layer.

Geological background

In order to study the possible effects of the local geological background on the depth of water penetration, a trench 1.5 m deep was dug in a depression (Figure 4) In addition, the trench offered the possibility to look at the pattern of the roots of the trees. This pattern is expected to provide a good idea on the long-term moisture regime, and the factors affecting it.

Laboratory analysis

Finally, soil samples were taken from the trench, down to a depth of 150 cm. The laboratory studies focused on the particle size composition of the sediments.

Results

Rainfall regime

Most of the rain occurred in three months (November 2005-January 2006), with several rain events above 100 mm. However, rain intensities were quite low. About 70 % were below 6 mm/hr^{-1};

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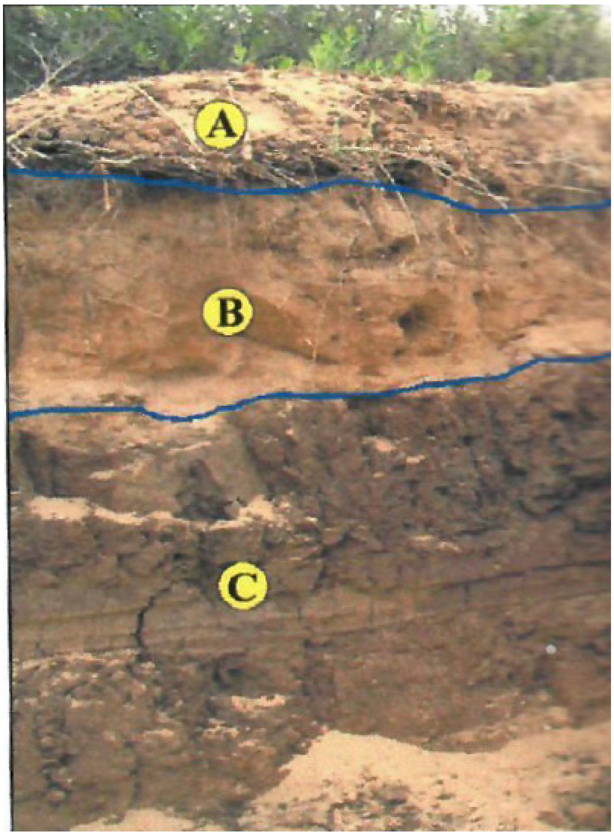

Figure 4: View of the trench in the depression.

and 20 % below 12 mm/hr^{-1}. An additional important character is the highly intermittent pattern of rain showers.

Rain interception by the canopy of the vegetation

Table 1 presents the rain amounts collected by the canopy of the vegetation in 2005-2006. Rain interception by the canopy varied in the wide range of 2.9-33.1 mm. As expected, rain interception increases with increasing rain amount (Table 1).

Date	Rain above canopy (mm)	Rain below canopy (mm)	Interception by canopy (mm)	Percentage loss
1/10/2025	31	20.9	10.1	32.6
13//2005	14.5	11.6	2.9	19.8
28/11/2005	115.3	88.4	26.9	23.3
18/12/2005	54.5	43.7	10.8	19.9
28/12/2005	57.5	40.7	16.8	29.2
17/1/ 2006	120.5	87.4	33,1	27.5
4/2/2006	77.0	57.0	20.0	26.0
26/2/2006	15.6	10.9	4.7	30.1
18/4/2006	49.7	37.0	12.7	25.6
Total amount	535.6	389.5	146.1	26

Table 1: Rain interception by the canopy in 2005-2006.

Table 2 presents the temporal variability of water repellency in 2005-2006. A high value of 1 was already recorded in the first rain event (1/10/2005). This value was recorded in all following rain events. The thickness of the water-repellent layer varied in the range of 5-30 cm. An important observation is that standing water was observed at all visits to the area, during the rainy season. Medium water repellency values were also recorded at the top of the sandy layer.

Temporal variability of water-repellency in 2005-2006

Water repellency persists during the whole winter reason (Table 2). The high value of 1 is characteristic of the upper 10 cm. This value persists until the end of the rainy season. Below 10 cm values vary in the range of 1-4.

Sampling Date	Cumulative rain amount (mm)	Depth (cm)	Degree
1/10/2005	31	1-30	1
28/11/ 2005	160.8	1-30	1-4
28/12/2005	272	1-30	1-4
17/1/2006	393	1-30	1-4
4/2/2006	486	1-30	1-3
18/4/2006	535	1-30	1-2

Table 2: Temporal variability of water-repellency.

Geological background

Figure 4 shows the local stratigraphy. Three units are clearly observed. An upper bright sandy layer, 30-40 cm thick, underlain by a thin darker sandy unit, ~20 cm thick. These two units are underlain by a thick reddish unit, 1.5 m thick. with well-developed calcic nodules. This unit represents a paleo-soil, with a high percentage of silt and clay (up to 60-70 %.). An interesting observation refers to the flat area, east of the sandy environment, where the paleo-soil outcrops at the surface (Figure 5).


Figure 5: Extensive water body, away from the sandy area.

Moisture regime

Figure 6 presents the temporal variability of the moisture regime in the depression, and at the top of the dune. The general trend in the depression is very low moisture values down to 60 cm, and a sharp increase at the transition to the clay rich paleo-soil, down to 140 cm. It is interesting noting that the soil moisture content in the paleo-soil

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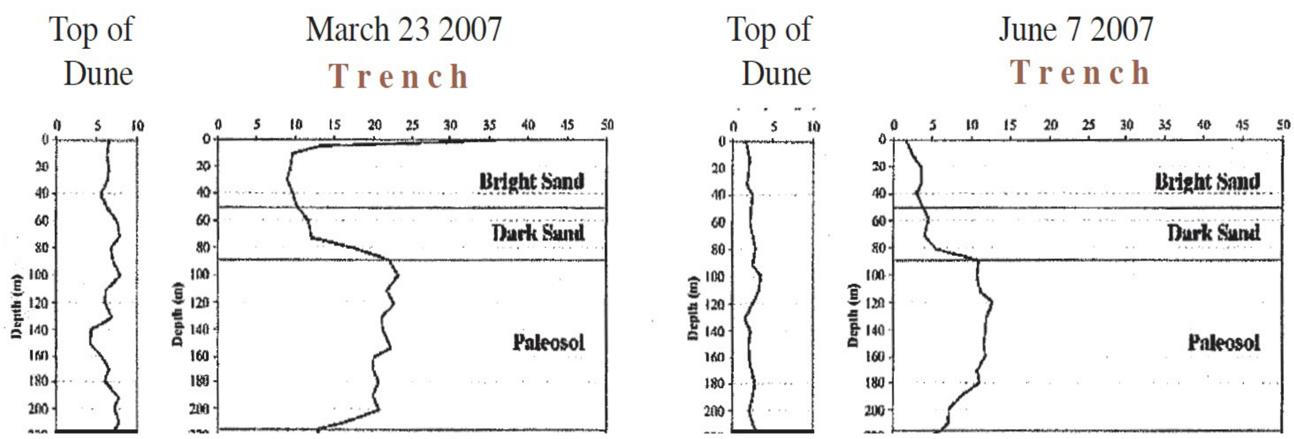

Figure 6: Temporal variability of the water regime in the depression, and at the top of the dune.


Figure 7: Roots pattern in the depression.

remains quite constant and does not increase with depth. The moisture profile at the top of the dune remains quite low, and uniform during the rainy season, down to a depth of 140 cm. An interesting observation refers to the flat area east of the sandy environment, where the paleo-soil outcrops at the surface. This area is covered with water during the whole winter season (Figure 5). The important point is that this area is devoid of any vegetation, hardly few annuals at the margins of the wetted area. An interesting observation refers to the roots system. Within the sandy units the roots are vertical. However, on reaching the paleo-soil the roots pattern changes abruptly to horizontal (Figure 7). The significance of such a pattern is that upon reaching the pale-soil the roots avoid penetrating the paleo-soil, despite the fact that the paleo-soil is richer in water and nutrients, than the overlying sandy units.

Discussion

The explanation proposed for the vegetation pattern described is that the water regime is controlled by the specific properties of the top of the paleo-soil. The top of the paleo-soil is rich in clay particles, up to 70%. In addition, the predominant clay in the study area is the muscovite [13,14] known for its laminar structure, and very high-water absorption capacity, leading to a clay dispersion process, and development of an impermeable layer that limits infiltration depth. Such conditions are not favorable for the establishment of Mediterranean species, but are favorable for desert species.

Conclusion

Climatologists use aridity indices to express the relationships between climatic variables (average annual rainfall, evaporation and radiation) and the environment. These variables imply that the acuteness of aridity depends upon prevailing atmospheric conditions, and that aridity is inversely correlated to annual precipitation. This approach is certainly correct for annual crops, but it does not fit the complex relationships between climate and environment in some dry-land areas. In these areas surface properties, such as extent and composition of biological topsoil crusts [15], and the occurrence and composition of geological formations, rich in clay particles, especially muscovite, that lead to a process of clay dispersion, and limited water infiltration. Such a combination leads to the development of desert species (an oasis) in an area where average annual rainfall is ~500 mm. Data presented clearly show that average annual rainfall is not a good indicator of water resources in dry-land areas. Needless to say, a better understanding of the various factors that determine aridity, provides a better basis for defining the degree of aridity, and provides better tools for the management of dry-land areas. and a superior approach for combatting desertification.

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