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The climatic effect of a manmade oasis during winter season in a hyper arid zone: The case of Southern Israel

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ABSTRACT

Most studies conducted on the desert oasis effect have focused on the summer season, while the winter has received less attention. This study aimed to determine existence of the oasis climatic effect in winter season and investigate influence of different vegetation types on its intensity and dynamics. Measurements were conducted during five consecutive years (2004–2009) at the peak of winter in a manmade oasis located in hyper-dry Arava Valley, Israel. Results obtained demonstrate that all types of vegetation had a cooling effect (up to 2 °C) limited to a few mid-day hours. In contrast, from nighttime throughout morning all vegetation types were up to 2 °C warmer than the surrounding desert. This effect was more pronounced with subtropical vegetation in comparison to local desert trees. The effect was most significant in calm, stable weather conditions characterized by low nighttime temperatures, while during unstable weather it was negligible. Influence of tree canopies on incoming and outgoing radiation is a major factor determining the influence of vegetation on local climate conditions in winter season. Since one characteristic of arid climates is extremely low nighttime temperatures during winter, warming created by the oasis has implications for human comfort and energy consumption in the desert environment.

1. Introduction

The climatic definition of the desert 'oasis effect' refers to the phenomenon of a cooling effect caused by vegetation (Givoni, 1991; Kai et al., 1997; Oke, 1987). According to Oke (1987), an isolated moisture source always finds itself cooler than its surroundings in an otherwise arid region, due to evaporation cooling. The desert oasis is the most obvious example of this situation. With regards to factors governing the oasis effect, researchers attribute the phenomenon to different factors: Oke (1987) attributes the phenomenon to evaporation cooling, Givoni (1991) and Kotzen (2003) attribute it mainly to shading while Kai et al. (1997) attribute it mainly to surface energy balance. Potchter et al. (2008) suggest that the oasis effect is influenced by a combination of the above processes, whose relative influence is affected by local climate conditions, vegetation type and cover, as well as anthropogenic changes in the landscape.

The majority of studies on the oasis effect in the desert environment have focused on the phenomenon during the summer, most likely since the desert environment is typified by extreme summer climate conditions. Budyko (1977) and Kai et al. (1997) conducted studies in oases situated in the cold desert environment (BWk according to Köppen classification) and reported a cooling effect in the summer ranging between 2.5 °C and 7 °C. Also in the cold desert environment, Yang et al. (2004) investigated the influence of artificial oases (cultivated lands) on long-term climate changes occurring in the desert region of Xingjiang, China. Their results demonstrate that in the oases, the increase in maximum summer temperatures is smaller and the increase in minimum summer temperatures is greater as compared to the background, hence the summertime diurnal–nocturnal temperature differences are smaller due to the effects of the oases. Studies conducted in Israel have also focused on the oasis effect during the summer season and found inconstant results: A study of the climatic effects of a small floodwater irrigated plot ('liman') of Eucalyptus trees did not reveal temperature differences between the liman and the open desert environment (Schiller and Karschon, 1974). Sebba et al. (1984) investigated two desert kibbutzim (oases) and found a cooling effect of up to 2.2 °C during late afternoon

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hours. Another study of a desert Kibbutz conducted during daytime hours reported mixed results: at certain hours the oasis was slightly cooler while at other hours the oasis was slightly hotter than its desert surroundings (Saaroni et al., 2004). A preliminary investigation conducted by Becker et al. (2003) in the Arava Valley indicated a daytime cooling effect of 1–2 °C and a more pronounced nighttime cooling effect of up to 5 °C. These studies focused on climatic parameters and did not include investigation of vegetation in the research sites and therefore do not provide information regarding the role of the vegetation component in the climatic effects of the oases. Along this line and on a wider scale, Lim et al. (2008) stated that the impact of surface temperature changes forced by different regional vegetation types is not well documented and what is reported addresses urban environments. More recent studies investigated the climatic influence of different vegetation types and cover in the extremely hot and arid zone of Israel during summer. Potchter et al. (2008) found that subtropical irrigated trees can reduce temperatures up to 5 °C during the nighttime and 2 °C during the daytime, while local desert trees create a slight cooling effect during nighttime as opposed to a slight warming effect during daytime hours study. Shashua-Bar et al. (2009) found that in an enclosed courtyard, during daytime, trees reduced temperature up to 2.2 °C and exposed grass had a minor cooling effect, while during the night difference were negligible.

A review of the literature indicates that the winter climatic effect of desert oases is poorly reported. He et al. (2004), investigated the boundary climate of the Tarim Basin oasis in the north margin of the Taklimakan desert in China and found that in the winter, air temperature in the oasis was higher than that of the desert by a maximum of 5.6 °C and the amplitude of differences in air temperature between day and night was smaller in the oasis as compared to the desert. Their study was conducted in the cold desert located at latitude of 41°45′N (BWk according to Köppen classification) and focused on the long term effects of the oasis on climate change trends on macro scale. Luedeling et al. (2009) investigated changes in the number of winter chilling hours in mountain oases in Oman. Their analysis detected a decrease in the number of winter chilling hours by an average of 1.2–9.5 h/year between the years 1983–2008.

In view of the fact that investigation of the climatic effects of oases has not adequately addressed all seasons, the present study aimed to fill part of this gap. It examined the climatic effects of a manmade oasis during the winter season in a hyper arid environment, as part of a comprehensive study of the oasis effect during the different seasons. The aims of the present study were to:

a) Determine the existence of the oasis effect in the winter season and characterize its diurnal behavior.
b) Study the effects of different vegetation in and around the manmade oasis (local desert trees, date palm plantation, and tropical/subtropical garden trees) on the dynamics of the climatic oasis effect in winter season.

Determination of the existence of the desert oasis effect and isolating and quantifying various factors contributing to its development and dynamics during the different seasons has potential implications for development and habitation of the largest geographical area in the world which still is hardly inhabited.

2. Methodology

2.1. Study area

The agricultural settlement En Yahav (area: 80 ha without agricultural areas) was selected as the study site due to its well developed and diverse vegetation, which enabled investigation of the relationship between the oasis effect and plant-related factors. En Yahav is located in the center of the Arava Valley, Southern Israel (Fig. 1a). The Arava is a long and narrow valley, stretching 170 km from the southern tip of the Dead Sea to the northern tip of the Gulf of Aqaba (30–31°N). It's width near En Yahav is 30 km. En Yahav is situated on a plateau 80 m below sea-level. The Arava Valley is part of the mid-latitude global desert zone and its climate is extremely hot and dry (BSh according to Köppen Classification). This is the hottest and driest region in Israel (annual precipitation is 32 mm, during the rainy season which is winter) although the winter is characterized by low temperatures. Average daily temperature in January is 13.8 °C (range 8.3–19.3 °C) and temperatures below 0 °C may occur. Average winter relative humidity is 52% (range 41–65%). These climatic conditions can create cold stress since they are accompanied by strong wind that may reach 40 km/h. Climate data were obtained from the Sapir meteorological station, located 8 km south of En Yahav (height 10 m below sea level) and wind data were measured at En Yahav (Bitan and Rubin, 1994).

The settlement is surrounded on the north and east by large date plantations, from the east to south by plastic-covered greenhouses of seasonal crops, and from the west by open desert. A grove of local desert trees (*Tamarix aphylla)* is located at the eastern edge of the settlement. Vegetation within the settlement is well developed and varied (Fig. 1b and c).

2.2. Classification and characteristics of the vegetation

The layout of the agricultural settlement is broad planted avenues (~20 m wide) separating rows of small sparsely placed houses running on north–south and east–west axes (Fig. 1b). The horticultural vegetation of En Yahav includes lawns, garden trees and bushes of tropical and sub-tropical origin. The dominant trees are: *Tipuana tipu* (Pride of Bolivia Rosewood or Tipu Tree); *Jacaranda acutifolia (*Jacaranda); *Ficus retusa* (Banyan Fig); *Ficus rubiginosa* Vent.; *Ficus bengalensis* (Zeyton or Maskhout Banyan); *Phoenix dactylifera* (date palm). Also found are *Prosopis alba* (Argentine mesquite) and *T. aphylla* which are well adapted to dry conditions.

Many of the trees reach great heights (canopy height >15 m), exhibiting a form of exaggerated etiolation. Trees such *Delonix regia raf* (*Poinciana regia Bojer*) and the Jacaranda (*Jacaranda acutifolia Hump. Et Bonpl*), elsewhere typified by broad bushy canopies, are characterized in En Yahav by elevated vertical growth, vertically elongated trunks and branches (Fig. 2). Since temperatures and light intensities in the region are very high, and water is not a limiting factor due to irrigation, this phenomenon of increased height is apparently caused by the rapid accumulation of dry material, further intensified by competition with surrounding trees for light.

2.3. Methods

Meteorological stations were placed in six different locations in and around the settlement, representing different vegetation cover and landscape: a) open desert environment, b) open grass surrounded by trees, c) irrigated date plantation, d) grove (~4000 m^2) of un-irrigated local desert trees *T. aphylla*, e) densely planted irrigated garden trees (mainly Ficus, Jacaranda and Tipu tree) on a north–south avenue, f) sparsely planted garden trees (same species) on an east-west avenue (Figs. 1a and 2). Fig. 2 shows the landscape, sky view factor and leaf area index (LAI) for each station. Sky view factor (SVF) has been used in other studies as representative of shading levels (Dimoudi and Nikolopoulou, 2003; Hwang et al., 2011).