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Ancient desert agriculture in the Negev and climate-zone boundary changes during average, wet and drought years

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ABSTRACT

Thousands of ancient terraces in the valleys of the Negev desert show that agriculture was conducted here in the past, based on the utilization of runoff and floodwater from local rainfall. A comprehensive collation and mapping is presented of the geographic distribution of such farming remains in the northern, central and southern Negev. The time range of these remains is also evaluated in detail with the inclusion of new data from the Neolithic to the present. Farming was and is conducted on a seasonal or annual timescale. However, proxy palaeoclimatic indicators in the southern Levant do not have such resolution. How do the ancient agricultural remains relate to climate? How do we define climate in order to make comparisons through time? How dry is dry? The conventional Köppen and Thornthwaite climatic classifications are cumbersome in both spatial and time-series analysis. This article presents for the first time the spatial positions of the climate zones in southern Israel based on the innovative P/PET climatic classification approach (P = annual precipitation; PET = annual potential evapotranspiration). Instrumental data from 13 meteorological stations were used for the required calculations and mapping. The decade 1990–2000 was selected, because of extreme climatic variations in this period, including the cold and wettest year ever recorded, 1991–92, as well as the warm and severe drought year 1998–99. Main conclusions are as follows: 1. The majority of remains of ancient runoff/floodwater farming are located south of Beer Sheva in the arid zone. 2. Only a few sites are situated in the hyper-arid zone in the southern Negev. 3. The southern and eastern borders of the ancient agricultural region in the central Negev coincide with the average decadal climatic boundary between the arid and hyper-arid zone (P/PET = 0.05). 4. The extremely wet year 1991–92 did not cause a significant displacement southward in the position of the arid and hyper-arid zones. Most runoff-farming areas remained within the arid zone. However, north of Beer Sheva the climatic zones shifted dramatically, as the humid zone, usually not extant in the southern Levant, and the sub-humid zone, moved into southern Israel. 5. The severe drought year 1998–99, on the other hand, caused a dramatic displacement northward of all climate zones. The boundary between the arid zone and hyper-arid zone (P/PET = 0.05) moved north of Beer Sheva and west of Arad. Most runoff/floodwater farming areas were situated in the hyper-arid zone. 6. An area with terraced valleys beyond the Negev in the southern foothills near Hebron experienced an arid climate in 1998/99, instead of average semi-arid conditions. This underlines the rational of runoff capture for drought mitigation in the semi-arid zone. 7. The investigation sets a modern standard of defined climate zones in the Negev and their shifts in wet and drought years as a basis for comparison with past climatic changes in relation to ancient agricultural remains.

1. Introduction

1.1. Focus and objectives

This article focusses on the Negev desert (Fig. 1) and its impressive remains of ancient agricultural terrace systems in valleys, which enabled runoff/floodwater irrigation. A comprehensive collation of areas and sites is presented in a geographic framework, including the less arid northern Negev, the arid central Negev highlands, and the hyper-arid southern Negev. The time range of these ancient agricultural sites is also reviewed, going from the Neolithic to the present.

Climate is usually *the* most crucial environmental factor in rainfed agricultural production. Drought may cause severe crop failure, particularly in semi-arid and sub-humid lands. However,

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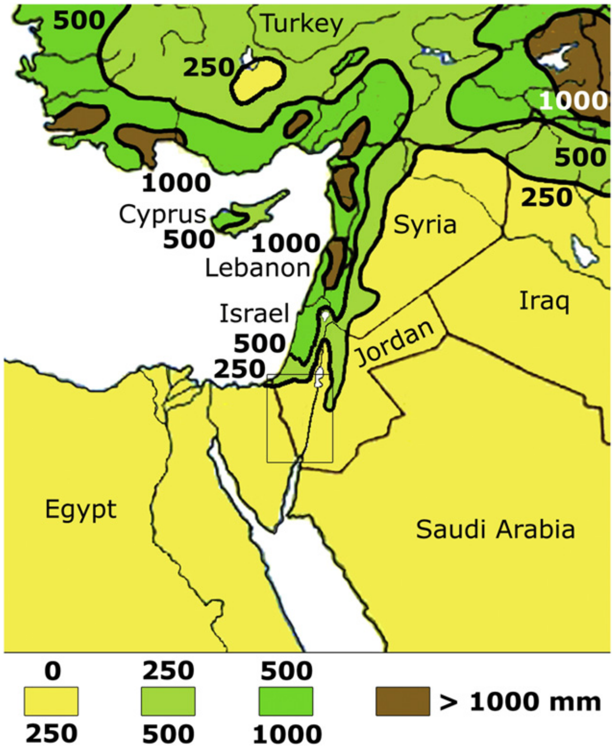

Fig. 1. The Near East with the location of the Negev region in southern Israel, indicated by a rectangle. Average annual precipitation in the region in modern times is shown by the isohyets of 250, 500 and 1000 mm. The desert/steppe zone with 0–250 mm is too dry for agriculture without irrigation. The areas with 250–500 mm are suited for dry farming of cereal crops, dry beans, olives and almonds. The 500–1000 mm zone enables the production of a variety of agricultural crops. The areas receiving more than 1000 mm of precipitation are situated more to the north along the prevalent trajectories of rain-bringing depression systems, while orographic factors also play a significant role. Source: partly based on a map in the Perry-Castañeda Library, University of Texas at Austin.

the actual impact of drought on human society is very much dependent on other factors too, such as societal vulnerability, economic system, food trade, grain reserves and contingency planning (Bruins and Bu, 2006; Rosen, 2007). Studies about ancient agriculture and past climatic changes require a reliable chronology to establish time relationships. Moreover, detailed palaeoclimatic and agricultural data are necessary to investigate causal relationships. Did climate change reach a critical threshold that caused agricultural and economic system collapse (Parry, 1981)?

Agriculture has an annual or seasonal time scale. Fruit trees require attention all year round. The main food crops, such as cereals and legumes, have a seasonal cycle from sowing to harvesting, i.e. less than one year. However, proxy palaeoclimatic indicators often have a lower time resolution – averages of tens of years or more. The ability to conduct past climatic impact studies at the farming system level may be limited by the lack of palaeoclimatic detail.

How can we define the aridity of a specific area or a site location in a precise manner, in order to investigate present and past climatic variations in a quantitative approach? How dry is dry? The traditional climatic classification systems of Köppen (Peel et al., 2007) and Thornthwaite (1948) use dissimilar letter codes and terms. The Negev is classified differently in the above systems (Goldreich, 2003). Both climatic classifications are cumbersome for annual time-series analysis.

This article presents an entirely new climatic classification of the Negev, based on the numerical P/PET aridity index (P = annual precipitation; PET = annual potential evapotranspiration), according to Kafle and Bruins (2009). The period 1990–2000 has been selected, because of the large annual climatic variability within this decade. The year 1991–92 was the wettest year since meteorological recordings began in the mid-19th century in Jerusalem. One of the most severe drought years occurred in 1998–99. Three new maps of the Negev have been made, showing the position of the ancient agricultural remains and the changing climate-zone boundaries in average, wet, and dry years.

These large annual climatic variations reflect the range of conditions ancient farmers had to cope with in the Negev in the past from year to year. It is not the objective of this article to evaluate palaeoclimatic studies. But the average position of the climate zones for the decadal period 1990–2000, as well as the extreme wet and dry years, set a modern standard for comparison with past climatic changes in the Negev in relation to agriculture.

1.2. Climatic details of the Negev and agriculture

The Negev is a subtropical desert (Fig. 1). The coldest month is January and the hottest month July or August. Average temperatures in the northern Negev range from 12 °C in winter to 26 °C in summer. The central Negev highlands have an average temperature range from 8 °C (winter) to 26 °C (summer), while frost may occur in winter. The southern Negev has average temperatures from 12 °C (winter) to 32 °C (summer). The highest temperatures each year may reach 40 °C in the northern Negev and over 45 °C in the southern Negev (Goldreich, 2003).

The long dry summer season lasts from about May to October. Most rains are usually concentrated in the winter months from December to March. Early rains may occur in the autumn (October, November) and late rains in the spring (April, May). The amount of average annual rainfall ranges from 300 mm in the northern Negev to only 25 mm in the southern Negev (Goldreich, 2003).

Cereal food crops like wheat and barley require at least 250–300 mm to obtain a reasonable yield. Fruit trees, including grape vines, olives and pomegranates need more than 400 mm of precipitation. Therefore, most of the Negev is too dry for agriculture based only on rainfall (Fig. 1).

1.3. Desert agriculture based on runoff/floodwater irrigation

Yet the Negev desert contains thousands of remnants of ancient agricultural systems, characterized by terraced fields in valleys. Was the climate wetter in the past? This is the obvious question, already raised in the 19th century by orientalists and explorers (Palmer, 1871). Though the debate about climate changes in relation to the ancient agricultural remains in the Negev highlands still continues (Issar and Zohar, 2007; Rosen, 2007; Bruins, 1994; Rubin, 1989), our knowledge of farming based on runoff/floodwater has increased considerably. The most significant research contribution was made by Evenari, Shanan and Tadmor, who decided to restore ancient farm systems and investigate how these function in the present climate. Their long-term agronomic and hydrological research (Evenari et al., 1961, 1982; Shanan, 1975, 2000; Shanan and Schick, 1980) began in 1958 and continued for about 25 years until the 1980s. The authors proved that wheat, barley, grapevines, olives and other crops can be grown in areas that receive only 85 mm of average annual rainfall, due to the capture of runoff water from hillslopes and floodwater from dry stream channels (wadi in Arabic, nahal in Hebrew) (Evenari et al., 1982).

Three basic landscape elements are required to enable such farming in the desert: (1) a runoff contributing area in which geomorphic surface conditions are suitable for runoff generation, i.e. the infiltration rate is usually lower than rainfall intensity; (2)