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Climatic trends in Israel 1970–2002: warmer and increasing aridity inland

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Abstract Climatic trends in Israel during the period 1970–2002 were studied in detail on the basis of three parameters: average annual temperature, annual precipitation and the annual aridity (humidity) index P/PET (P = Precipitation; PET = Potential Evapotranspiration). Significant warming is evident in all 12 evaluated meteorological stations, situated in different parts of Israel. Along the Mediterranean coast, the average annual precipitation and P/PET values remained more or less at the same level. However, more inland, both eastward and southward, precipitation and P/PET trends are declining, indicating increased aridity. Eilat, Beer Sheva and Sedom Pans, situated in the desert, showed the most significant increase in aridity among the 12 meteorological stations we investigated. The relationship between changes in temperature and precipitation showed a negative correlation in all cases except for Eilat, the southernmost and driest part of Israel. The negative correlations for Negba, Kefar Blum, Har Kena'an, Beer Sheva and Sedom Pans are statistically significant. In conclusion, the climate in Israel has become more arid in most regions, except for the coastal plain.

1 Introduction

Since the late-nineteenth century, global surface temperatures have increased by approximately 0.74°C (Trenberth et al. 2007). However, warming has not been

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uniform and some areas have even become somewhat cooler (Easterling et al. 1997). The rate of warming in nine dryland regions (South-West USA, South-West Asia, Central-East Asia, North Africa, African Sahel, Horn of Africa, Southern Africa, Australia and Patagonia) was found to be slightly higher than for the global land areas in general (Hulme 1996). If warming would lead to drier bio-climatic conditions, agricultural production in the semi-arid and dry sub-humid zones in the world would be most vulnerable. A more arid climate is usually accompanied by an increase in the frequency and severity of droughts (Heathcote 1986). Therefore, development of proactive drought contingency planning becomes increasingly more urgent, particularly in view of declining freshwater resources and the low level of global grain reserves (Bruins and Lithwick 1998; Bruins 2000). Many countries situated in drylands, including Israel, have developed agricultural production trends focussed on cash crops, by which most annual food grain requirements have to be imported from the world market. Such a strategy is risky, as global warming, increased aridity and severe future drought in large food grain production regions—USA, Canada, China, India—may cause severe shortages of food grains on the world market (Bruins and Bu 2006).

Israel is situated in the subtropical dryland zone between latitudes 29.5° and 33.5° north of the Equator. The country has a length of *ca* 450 km from north to south and a maximum width of *ca* 110 km in the northern Negev. Israel is placed in a very sensitive climatic position at the transition from the inner desert to a sub-humid Mediterranean climate. The Negev and Judean desert form a small part of the largest desert belt on our planet, which stretches from the Atlantic coast of the Sahara to the Thar Desert in India (Goldreich 2003).

Notwithstanding the small size of the country, the climate in Israel shows remarkable variability and change over minor distances (Goldreich 1994, 2003). The climate changes significantly in the country from north to south and from the coast inwards. Israel encompasses all four dryland zones (Kharel and Bruins 2004), as defined by United Nations Environmental Programme (UNEP 1992, 1997) and the United Nations Convention to Combat Desertification (UNCCD 1994): hyper-arid, arid, semi-arid and dry sub-humid (Le Houérou 1996).

In this article we present a study of climatic trends in Israel for the period 1970–2002, based on a detailed analysis of monthly temperature and annual precipitation data from 39 meteorological stations. Our climatic trend analysis evaluates three different parameters for the above period of *ca* 30 years: annual temperature, annual precipitation and the calculated annual aridity index P/PET (P is precipitation; PET is potential evapotranspiration). A drier or wetter climate in bio-climatic or agricultural terms is not just a matter of only rainfall (input), but also of potential evapotranspiration (output), in which temperature is an important factor. If temperature increases then PET also increases, reducing P/PET if P remains the same, and vice versa.

2 Methodology

The climate in Israel is characterized by a completely dry summer in June, July and August. The rainy season and agricultural year begins in September–October and the rainfall ends in April–May. The regular calendar year commencing on January

1st cuts the rainy season in the middle. Therefore, we have used an annual division beginning on September 1st and ending on August 31st, which is common in Israel concerning studies involving rainfall and climatic data.

Whereas temperature and precipitation are very useful individual parameters to study climatic change, the overall expression and significance of climatic change in bio-climatic terms is better expressed by the aridity or humidity index P/PET. The Penman method (Penman 1948) is generally preferred in terms of accuracy to calculate PET. But the required physical and meteorological parameters needed for its calculation are usually not recorded in most meteorological stations. Therefore, the geographical density of stations allowing for Penman PET calculation will be very low, which is unsuitable for time series analysis and mapping purposes on a national or global scale to calculate potential evapotranspiration. For this fundamental reason the simpler Thornthwaite approach was selected by the World Atlas of Desertification in the most recent classification of arid zones by the United Nations Environmental Program (UNEP 1992, 1997). The UN Convention to Combat Desertification (UNCCD 1994) adopted the same approach.

The drawback of the Thornthwaite method is that it systematically underestimates PET in dry climates and overestimates PET for moist and wet environments. Consequently, an empirical adjustment factor is applied to the data to bring the Thornthwaite values more closely in line with those of the Penman method (Hulme et al. 1992; UNEP 1997). The UNEP map also changed the numerical boundaries between some arid zones, based on the P/PET ratio, to bring the results more closely in line with Penman based results. The P/PET boundary in the UNEP map between the hyper-arid and arid zone is, therefore, increased from 0.03 (in the UNESCO 1979 map) to 0.05 (in the UNEP 1992, 1997 map). Likewise the upper boundary of the sub-humid zone is decreased from 0.75 to 0.65, with a change in terminology to "dry sub-humid".

The various climatic regions, as defined by the P/PET values, are shown in Table 1, based on the classification used by UNEP (1992, 1997) and UNCCD (1994), see also Hulme et al. (1992) and Le Houérou (1996).

The climatic trend of 39 meteorological stations was studied, usually for the period 1970–1971 to 2001–2002, or otherwise for the years with available data. We employed the methodology, advocated by UNEP (1997), by which the Thornthwaite calculation for PET is subsequently adjusted to Penman PET with the help of an empirical factor.

Table 1 The dryland and humid zones, according to the respective values of the P/PET index, as define by UNEP (1992, 1997), UNCCD (1994) and Le Houérou (1996)

	P/PET range
Dryland zones	
Hyper-arid	< 0.05
Arid	0.05 to <0.20
Semi-arid	0.20 to <0.50
Dry sub-humid	0.50 to <0.65
Humid zones	
Wet sub-humid	0.65 to <0.75
Humid	≥ 0.75

The Thornthwaite formulae for the calculations are as follows (Thornthwaite 1948; Thornthwaite and Mather 1955, 1957):

$$\mathrm{PET} = 16C\left(10T_{\mathrm{m}}/I\right)^{\mathrm{a}} \tag{1}$$

$$I = \mathrm{sum}\ \left(T_{\mathrm{m}}/5\right)^{1.51} \tag{2}$$

$$a = \left(67.5 \times 10^{-8} I^3\right) - \left(77.1 \times 10^{-6} I^2\right) + (0.0179\ \mathrm{I}) + (0.492) \tag{3}$$

PET is the potential evapotranspiration in mm, C is the daylight coefficient, T_{m} is the average monthly temperature (°C), a is an exponent derived from the heat index (I).

Following the necessary calculation of monthly values, the annual Thornthwaite PET ($\mathrm{PET}^{\mathrm{T}}$) is obtained. $\mathrm{PET}^{\mathrm{T}}$ is subsequently adjusted with an empirical correction factor to obtain a result that approaches Penman PET ($\mathrm{PET}^{\mathrm{P}}$), using the following formula:

$$\mathrm{PET}^{\mathrm{P}} = 1.3 \times \left(\mathrm{PET}^{\mathrm{T}}\right) - 0.428 \times (\mathrm{P}) + 246 \tag{4}$$

P is the annual precipitation value. Thus the annual aridity index ($\mathrm{P/PET}^{\mathrm{P}}$) of 39 meteorological stations (Fig. 1) in Israel was calculated for each available year, usually from 1970–1971 to 2001–2002.

The most severe drought year and the wettest year were determined for each station, including the change in percentage from the average annual value of precipitation. The long-term climatic trend of the annual temperature, annual precipitation and annual aridity index were studied for each of the 39 meteorological stations with the help of the linear regression line (line of best fit). The statistical significance of the linear regression line is evaluated using the Student's t-test.

In this article we present the results of temperature, rainfall and P/PET trends during the period 1970–2002 of 12 selected meteorological stations (Fig. 2), as presenting the results of all 39 studied stations would require too much space. These stations are selected in specific spatial distribution patterns in order to highlight the regional variations of the climatic trends in different parts of the country.

Four meteorological stations were selected along or near the Mediterranean coast from north to south: Ein HaHoresh, Tel Aviv-Sede Dov, Hazor-Ashdod and Negba (Fig. 2). Another four meteorological stations were selected in the eastern inland part of the country, from north to south: Kefar Blum (northern Jordan valley), Har-Kena'an (upper Galilee), Sede Boqer (central Negev) and Eilat (southern Negev, Red Sea). Finally, four stations were selected along a west-east transect in the northern Negev, where Israel reaches its greatest width: Besor Farm, Beer Sheva, Arad and the Sedom Pans (southern Dead Sea).

3 Results and discussion

3.1 Temperature trends

Figure 3(a) shows the average annual temperature patterns of the four meteorological stations along the Mediterranean coast during the period 1970–2002. These

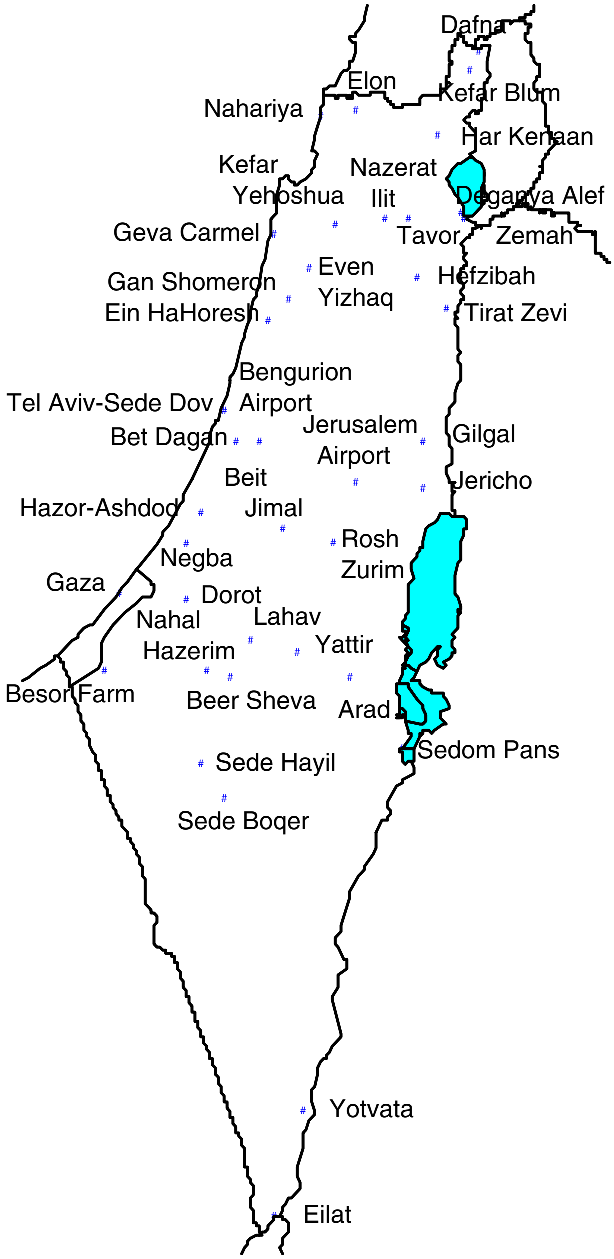


Fig. 1 Map of Israel showing the location of all 39 meteorological stations used in this study

four stations showed similar patterns of temperature changes for the studied period, except for Ein HaHoresh in 1972–1973, 1973–1974 and 1974–1975. Please note that no meteorological data exist during 1970–1971 and 1971–1972 for this station. Ein HaHoresh is located in a more northerly position along the coast, as compared to the other stations. All four stations display a significant increase in temperature, according to our study.

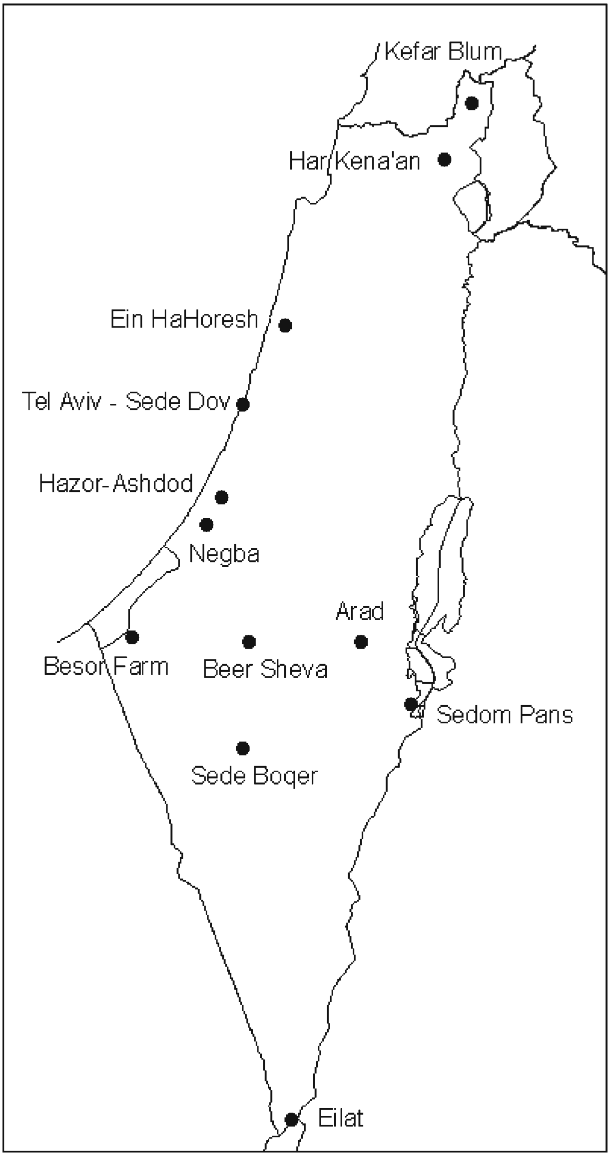


Fig. 2 Map of Israel showing the location of 12 meteorological stations mentioned in this article

Figure 3(b) shows the trend line (linear regression line) of Tel Aviv-Sede Dov, one of the four stations along the Mediterranean coast. It shows the most distinct warming trend of the stations along the coast with 99.5% significant level (Table 2). The rise in average annual temperature of 1°C was recorded for the period 1998–1999, 1999–2000, 2000–2001 and 2001–2002 in Tel Aviv-Sede Dov. Urbanization effects for land surface warming have been noted by many authors in the past (e.g., Jones 1990) for many cities around the globe. The cause of warming for this station may also be related to urbanization effects, although the Tel Aviv-Sede Dov

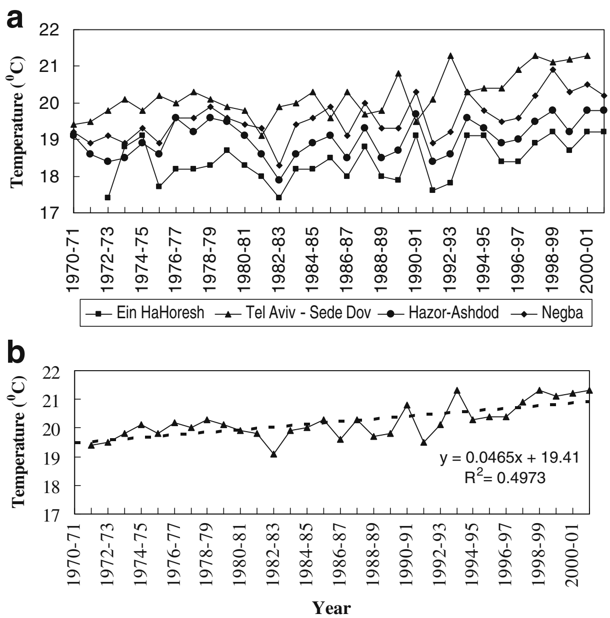


Fig. 3 **a** Yearly variations of the average annual temperature at four meteorological stations along Israel's Mediterranean coast during the period 1970–2002; **b** temperature pattern and trend line of Tel Aviv-Sede Dov for the period 1970–2002

meteorological station is situated at the margin of the Tel Aviv metropolis. However, we have not studied the urbanization effect in this study and left it for future research.

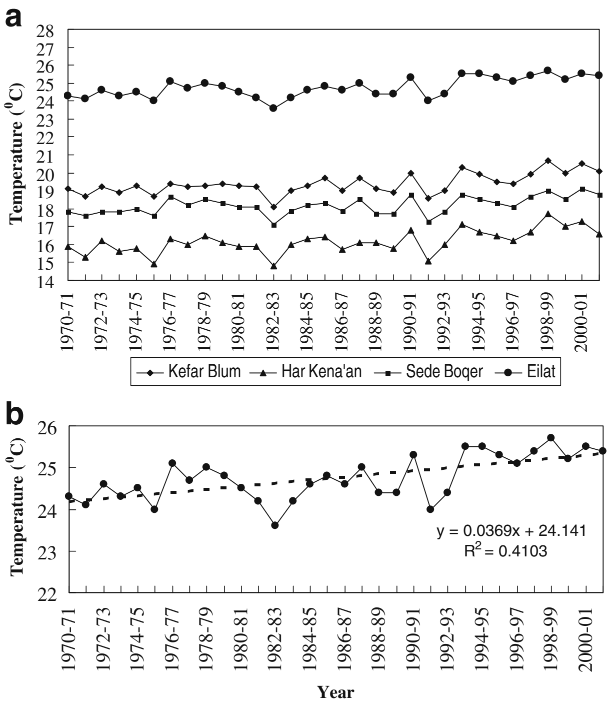
Figures 4 and 5 show the temperature patterns in the inland more eastern part of Israel (from north to south) and in the northern Negev (from west to east), respectively. A significant warming trend is noticeable in these two regions as well. Eilat along the Red Sea, Beer Sheva and the Sedom Pans at the southern part of the Dead Sea show the most distinct trends in temperature increase (Fig. 4b) with 99.95% significance level (Table 2). Eilat and the Sedom Pans are situated in

Table 2 The linear trend values (°C/year) and their statistical significance levels of temperatures for all the 12 meteorological stations situated in the coastal plain along the Mediterranean Sea, the inland more eastern part of Israel and the Northern Negev

Area	Period of measurement	Linear trend value of temperature (°C)/year
Coastal plain		
Ein HaHoresh	1970–2002	0.0284[a]
Tel Aviv	1970–2002	0.0465[b]
Hazor-Ashdod	1970–2002	0.0215[a]
Negba	1970–2002	0.0381[b]
Inland eastward		
Kefar Blum	1970–2002	0.0381[b]
Har Kena'an	1970–2002	0.0423[b]
Sede Boqer	1970–2002	0.0269[b]
Eilat	1970–2002	0.0369[c]
Northern Negev		
Besor farm	1975–2002	0.0341[b]
Beer Sheva	1970–2002	0.0509[c]
Arad	1970–1999	0.0287[a]
Sedom Pans	1970–2002	0.0453[c]

[a]Significant at 97.5%
[b]Significant at 99.5%
[c]Significant at 99.95%

Fig. 4 **a** Yearly variations of the average annual temperature at four meteorological stations in the eastern inland part of Israel during the period 1970–2002; **b** temperature pattern and trend line of Eilat for the period 1970–2002



the hyper-arid region. The temperature trend of Arad showed a highly fluctuating, somewhat different pattern in comparison to the other stations within this group (Fig. 5a).

The linear trend values and their statistical significance levels of average annual temperatures increases of all the studied stations are shown in Table 2.

Concerning annual variations in the yearly average temperatures, all meteorological stations show that 1982–1983 and 1991–1992 were the coolest years and 1998–1999 was the warmest year during the period 1970–2002 as can be seen in Figs. 3a, 4a and 5a. Interestingly, Trenberth et al. (2007) also found that the year 1998 was the warmest year in their study of global land areas. In addition, the estimates prepared by the World Meteorological Organization and the Climatic Research Unit concluded that 1998 was the warmest year in the 20th century. The strongest El Nino-Southern Oscillation in the past century occurred during that year. According to Jones (1994) the dramatic cooling over the land areas of the world between 1991 and 1992 was caused by the dust veil in the wake of the eruption of Mt. Pinatubo. The last 6 years from 1994–1995 to 2001–2002, rank among the warmest years in this study within the period 1970–1971 to 2001–2002 for almost all of the 12 meteorological stations, showing the increasing warming effects in recent years. This is also supported by the findings of Trenberth et al. (2007) in which they showed that the years 1995 to 2006 (1996 being the exception) rank amongst the 12 warmest years on record since 1850.

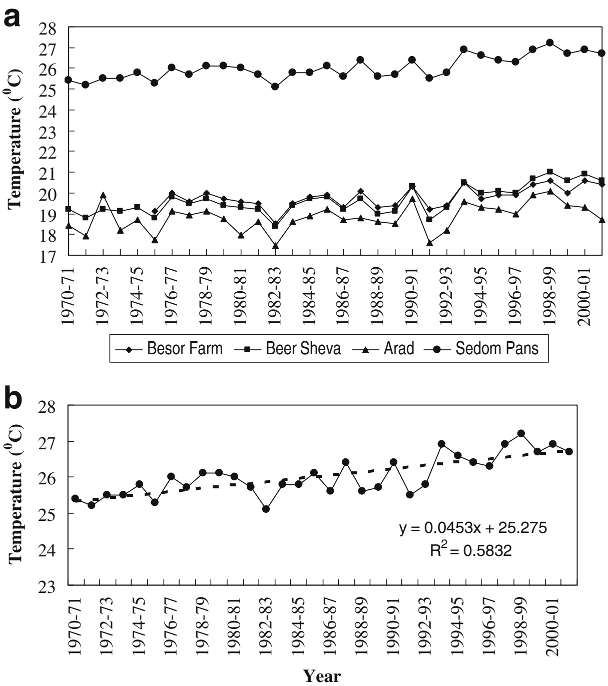


Fig. 5 **a** Yearly variations of the average annual temperature at four meteorological stations along a west-east transect in the northern Negev during the period 1970–2002; **b** temperature pattern and trend line of Sedom Pans for the period 1970–2002

3.2 Precipitation trends

Figures 6, 7 and 8 show the yearly variations of the annual precipitation patterns for all the 12 meteorological stations situated in the coastal plain along the Mediterranean Sea, the inland more eastern part of Israel and the northern Negev for the period 1970–2002. The linear trend values (millimeter/year) and their statistical significance levels of average annual precipitation changes for all the above mentioned three regions are shown in Table 3.

Among the four meteorological stations evaluated in the coastal plain, Negba was the only station showing a negative trend (decreasing rainfall) for the period 1970–2002. All the other three, Ein HaHoresh, Tel Aviv-Sede Dov and Hazor-Ashdod

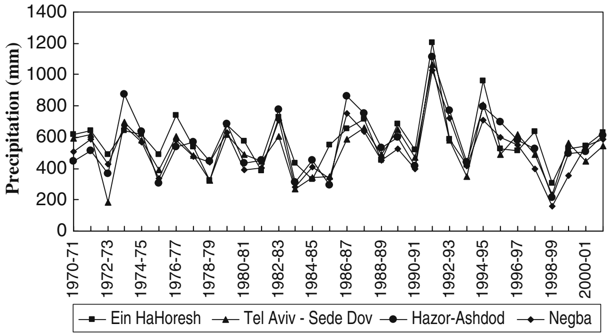


Fig. 6 Yearly variations of the average annual precipitation at four meteorological stations along the Mediterranean Sea during the period 1970–2002

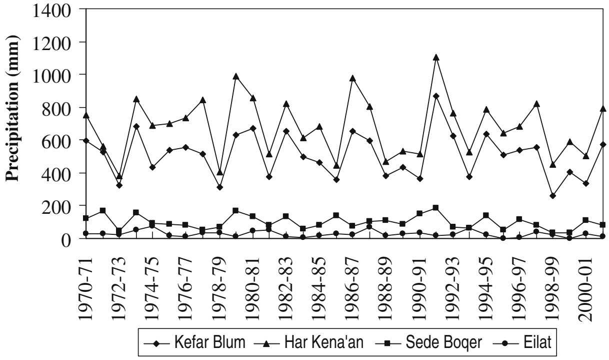


Fig. 7 Yearly variations of the average annual precipitation at four meteorological stations in the Eastern Inland part of Israel during the period 1970–2002

(Fig. 6), show positive trends (increasing rainfall) (Table 3). However, these trends are not significant. Our results support the findings by Alpert et al. (2002), as they also noticed the mixed rainfall trends along the Mediterranean coast of Israel for the period 1951–1995 without significant trends.

In the more inland eastern parts of Israel, all four stations, Kefar Blum, Har Kena'an, Sede Boqer and Eilat, show a negative trend of decreasing rainfall (Table 3). The average annual precipitation declined at Kefar Blum in the upper Jordan valley from *ca* 530 to 480 mm, at Har Kena'an in the upper Galilee from *ca* 695 to 665 mm, and at Eilat in southernmost hyper-arid part of the Negev desert from *ca* 35 to 20 mm.

A similar pattern is observed in three of the four meteorological stations along a west-east transect in the northern Negev desert. The station located most to the west and not far from the Mediterranean Sea, Besor Farm, showed an increase in precipitation (Table 3). The average rainfall at Besor Farm rose from *ca* 190 to 230 mm. However, going eastwards away from the Mediterranean Sea, the other three studied stations in the northern Negev show a decline in precipitation. The average rainfall at Beer Sheva during the period 1970–2002 dropped from *ca* 230 to 180 mm, at Arad from *ca* 140 to 115 mm and at the Sedom Pans south of the Dead Sea from *ca* 58 to 28 mm.

The cause of the variation in the precipitation pattern along the west-east transect may be understood as an effect of the proximity to the sea (Goldreich 1994). The

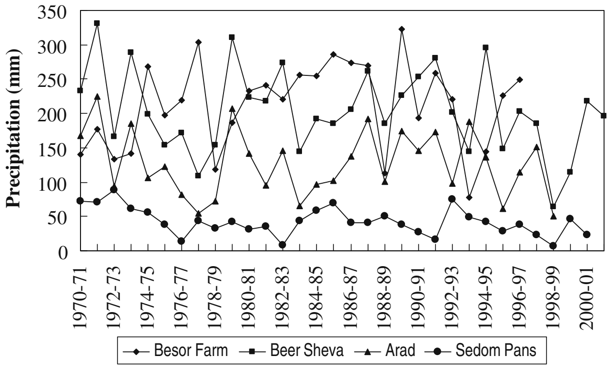


Fig. 8 Yearly variations of the average annual precipitation at four meteorological stations in the Northern Negev of Israel during the period 1970–2002

Table 3 The linear trend values (mm/year) and their significance level of precipitation for all the 12 meteorological stations situated in the coastal plain along the Mediterranean Sea, the inland more eastern part of Israel and the northern Negev

Area	Period of measurement	Linear trend value of precipitation (mm)/year
Coastal plain		
Ein HaHoresh	1970–2002	0.646 (NS)
Tel Aviv	1970–2002	1.2937 (NS)
Hazor-Ashdod	1970–2002	2.0846 (NS)
Negba	1970–2002	−0.032 (NS)
Inland eastward		
Kefar Blum	1970–2002	−1.656 (NS)
Har Kena'an	1970–2002	−0.902 (NS)
Sede Boqer	1970–2002	−0.916 (NS)
Eilat	1970–2002	−0.511 (NS)
Northern Negev		
Besor farm	1975–2002	1.236 (NS)
Beer Sheva	1970–2002	−1.561 (NS)
Arad	1970–1999	−0.704 (NS)
Sedom Pans	1970–2002	−0.961[a]

[a]Significant at 97.5% level
NS not significant

linear trend results for the precipitation of the meteorological stations are statistically not significant except for the Sedom Pans (Table 3). Annual and monthly rainfall analysis showed most significant changes in the south of Israel (Ben-Gai et al. 1998). Our results suggest that precipitation along the Mediterranean coast tends to show a slight increase, while all studied stations inland (eastward and southward) show a slight decrease in rainfall.

On an annual comparative basis, all four stations in the Mediterranean coastal plain had the highest annual rainfall in 1991–1992 and the most severe drought year in 1998–1999. Our analysis showed for 1998–1999 an increase in drought severity going southward along the coastal plain, as shown by the decrease in precipitation from the mean long-term average value: Ein HaHoresh 304 mm (−47.91%), Tel Aviv-Sede Dov 234 mm (−54.99%), Hazor-Ashdod 213 mm (−62.15%) and Negba 157 mm (−69.66%). The rainfall amounts for these stations in the wettest year 1991–1992 were respectively: 1,203, 1,064, 1,112 and 1,025 mm.

In the inland more eastern part of Israel, there are differences amongst the investigated stations concerning the wettest and the driest year. Kefar Blum had the worst drought in 1998–1999 with 260 mm (−48.67%) and the wettest year in 1973–1974 with 682 mm (+34.48%). Har Kena'an had the driest year in 1972–1973 with 385 mm (−43.56%) and the wettest year in 1991–1992 with 1107 mm (+62.44%; Fig. 7). In Sede Boqer the most severe drought year was 1998–1999 with 34 mm (−65.67%) and the wettest year was 1991–1992 with 188 mm (+89.61%). Eilat, the southernmost station in Israel, showed a precipitation pattern that deviated from all other stations investigated. The driest year was 1995–1996 with hardly any rainfall (0.8 mm), while 1974–1975 was the wettest year with 76 mm (Fig. 7).

In the northern Negev the most severe drought year was 1998–1999 for all four meteorological stations (from west to east): the Besor Farm with 78 mm (−63.08%), Beer Sheva with 64 mm (−68.71%), Arad with 51 mm (−60.03%) and the Sedom Pans with only 7 mm (−82.78%). However, the wettest year varied considerably among these stations: 1994–1995 at the Besor Farm with 323 mm (+52.15%), 1971–1972 in Beer Sheva and Arad with 331 mm (+61.85%) and 225 mm (+76.74%), respectively, and 1972–1973 for the Sedom Pans with 89 mm (+109.97%).

3.3 P/PET aridity index trends

The linear trend values (per year) of the aridity index P/PET and their significance level for all the 12 meteorological stations situated in the coastal plain along the Mediterranean Sea, the inland more eastern part of Israel and the northern Negev for the period 1970–2002 are shown in Table 4. The four meteorological stations in the coastal plain studied here in terms of the P/PET aridity index showed a negative trend value for Tel Aviv and Negba and positive for Ein HaHoresh and Hazor-Ashdod for the period 1970–2002. The average annual P/PET value for Ein HaHoresh remains about 0.5, placing it on the boundary between the semi-arid and dry sub-humid zone. Tel Aviv-Sede Dov, more to the south, is situated in the semi-arid zone, having an average annual P/PET value of 0.40. The average P/PET values for Hazor-Ashdod and Negba are 0.47 and 0.41, respectively, both situated in the semi-arid zone.

All four stations in the inland more eastern part of Israel, going from north to south, show a trend to increased aridity, as the P/PET values show a negative trend value (Table 4). The P/PET value for Kefar Blum declined during the period 1970–2002 from *ca* 0.43–0.34, though remaining in the semi-arid zone. The P/PET value for Har Kena'an declined from *ca* 0.72 to 0.63 and the climate in the area changed from wet sub-humid to dry sub-humid (Table 1). Sede Boqer in the central Negev also became more arid, as the P/PET index declined from *ca* 0.08 to 0.06, approaching the boundary with the hyper-arid zone (Table 1). Eilat in the southern Negev became extremely hyper-arid, as the P/PET index decreased from *ca* 0.015 to 0.007.

Concerning the investigated stations in the northern Negev, Besor Farm shows a different trend among the four evaluated stations. Besor Farm showed an increase in humidity, as the P/PET index rose from *ca* 0.14 to 0.16, though remaining in the arid zone. The other three stations in the northern Negev showed an increase in aridity. In Beer Sheva the P/PET index declined significantly from *ca* 0.16 to 0.11 within the arid zone. In Arad the P/PET value decreased from *ca* 0.10 to 0.08, also within the arid zone. At the Sedom Pans the P/PET index declined from *ca* 0.023 to 0.010.

Table 4 The linear trend values (per year) and their statistical significance level of the aridity index for all the 12 meteorological stations situated in the coastal plain along the Mediterranean Sea, the inland more eastern part of Israel and the northern Negev

Area	Period of measurement	Linear trend value of aridity index/year
Coastal plain		
Ein HaHoresh	1970–2002	0.001 (NS)
Tel Aviv	1970–2002	−0.0007 (NS)
Hazor-Ashdod	1970–2002	0.0014 (NS)
Negba	1970–2002	−0.0007 (NS)
Inland eastward		
Kefar Blum	1970–2002	−0.0026 (NS)
Har Kena'an	1970–2002	−0.0028 (NS)
Sede Boqer	1970–2002	−0.0008 (NS)
Eilat	1970–2002	−0.0003[a]
Northern Negev		
Besor farm	1975–2002	0.0006 (NS)
Beer Sheva	1970–2002	−0.0016[b]
Arad	1970–1999	−0.0008 (NS)
Sedom Pans	1970–2002	−0.0004[c]

[a] Significant at 97.5%
[b] Significant at 95%
[c] Significant at 99%
NS not significant

The three meteorological stations, Eilat, Beer Sheva and Sedom Pans showed statistically significant aridity index trends among all the 12 meteorological stations for the period 1970–2002 (Table 4). Thus it is no surprise that the climate in Beer Sheva has become more arid, while the Eilat area near the Red Sea and Sedom Pans south of the Dead Sea became even more hyper-arid during the period 1970–2002.

3.4 Temperature and rainfall relationships

The relationship between the temperature and precipitation in this study showed a negative correlation in all cases except for Eilat (Table 5). In the coastal plain only Negba showed a statistical significant negative correlation (Table 5), indicating that the increase of 1°C in the average annual temperature is associated with a decrease of 147 mm in average annual precipitation for the period 1970–2002. The average annual precipitation for the above mentioned period of Negba is 517 mm.

Kefar Blum and Har Kena'an showed significant negative correlations within the inland eastern part of the country. The relationships between a 1°C increase in annual temperature and the decline in precipitation are 120 and 126 mm for Kefar Blum and Har Kena'an, respectively. The average annual precipitation during the studied period for Kefar Blum is 507 mm and for Har Kena'an 681 mm.

In the northern Negev, Beer Sheva and Sedom Pans showed significant negative correlations, with a 40 and 13 mm decrease of annual precipitation, respectively, in relation to a 1°C increase in annual temperature for the studied period. The average annual precipitation of Beer Sheva and Sedom Pans is 204 and 42 mm, respectively. Striem (1979) found a relationship of 5.9 mm increase of precipitation per 1°C decrease in temperature for the main rainy periods November to April. Also the study carried out by Hulme (1996) for the world's drylands showed significant negative relationships between temperature and precipitation in the dryland regions of North Africa, the Sahel and Southern Africa. The warmer years tended also to be the drier years. However, Jones and Reid (2001) showed that regions affected by desertification are not always warming.

Table 5 The correlation values between temperature and precipitation during the period 1970–1971 to 2001–2002 at selected meteorological stations in three different spatial transects in Israel (coastal plain from north to south, eastern inland part from north to south, northern Negev from west to east)

Area	Correlation between temperature and precipitation
Coastal plain	
Ein HaHoresh	−0.11 (NS)
Tel Aviv	−0.26 (NS)
Hazor-Ashdod	−0.33 (NS)
Negba	−0.48[a]
Inland eastward	
Kefar Blum	−0.51[a]
Har Kena'an	−0.46[a]
Sede Boqer	−0.32 (NS)
Eilat	0.01 (NS)
Northern Negev	
Besor farm	−0.34 (NS)
Beer Sheva	−0.45[a]
Arad	−0.34 (NS)
Sedom Pans	−0.36[b]

[a]Significant at 99%
[b]Significant at 95% level
NS not significant

4 Conclusions

A significant warming trend is evident in all 12 evaluated meteorological stations, located in different parts of Israel, as presented in this study. Tel Aviv-Sede Dov and Eilat showed the rise in annual temperature of 1°C for some years during the period 1970–2002; 1998–1999 and 1991–1992 were the warmest and coolest years respectively for all the meteorological stations in this study.

Precipitation was found to increase along or near the Mediterranean coast, with the exception of Negba. The other meteorological stations in the more inland and eastern part of Israel as well as in the northern Negev all showed a decline in precipitation. The precipitation trends are not statistically significant, except for the Sedom Pans, in an individual sense, but the *collective* downward trend in precipitation of most meteorological stations inland gives an undeniable statistical weight of significance that should not be underestimated.

The relationship between changes in temperature and precipitation showed a negative correlation in all cases, except for Eilat (Table 5). The negative correlation between temperature and precipitation of Negba (Coastal plain), Kefar Blum, Har Kena'an (Inland eastward), Beer Sheva and Sedom Pans (northern Negev) are statistically significant among the 12 meteorological stations studied.

The trend analysis of the P/PET index in the Mediterranean coastal plain of Israel showed mixed results. PET was not sufficiently affected by the warming trend in three stations along or near the coast, while precipitation values (P) increased slightly throughout the studied period 1970–2002. Only in Tel Aviv-Sede Dov increased aridity is noticed despite the increase in precipitation. P/PET trends are not statistically significant in any of the stations along the coastal plain.

All other stations situated more inland and in the eastern part of the country, showed a decrease in precipitation and also a decrease in the P/PET values, clearly reflecting increased aridity. The aridity index trends of Eilat, Beer Sheva and Sedom Pans are statistically significant. This shows that the climate has became more arid during the period 1970–2002 in the desert areas of Israel.

Sedom Pans is the only station showing a significant statistical trend in all the three studied parameters (temperature, precipitation and aridity index) among the 12 studied meteorological stations. However, evaluating our results in collective terms, considering the trends of all meteorological stations, it is clear that the climate has become more arid in most parts of Israel, except for the coastal plain and the coastal north-western Negev area.

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