The Effect of Temperature and Rainfall Changes on Biophysical and Socio-Economic Status of People in Northern Jordan Valley Drylands, Palestine

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Abstract Drylands, particularly in the developing countries are highly affected by climate change. Major devastating changes are expected to happen in dryland areas, ecosystem structures, productivity and socio-economic characteristics of inhabitants. This study aimed at investigating drylands' socio-economic and biophysical characteristics and assesses its vulnerability to changes in temperature and rainfall. The Northern Jordan Valley region, Palestine was selected as a pilot study area. Direct meetings and a questionnaire were used to collect socio-economic and agricultural data over the period February–July 2019. Soil samples were collected from representative fields in the study area to test the major soil chemical properties. A large climatic dataset (1970–2019) was analyzed to investigate changes in rainfall and temperature. Results show that the average households' monthly income in the study area was in the range US $440–900. A significant portion of households' monthly income was spent on water for domestic and agricultural purposes. Water harvesting was a predominant activity due to water scarcity in the study area. The chemical analysis of the soil samples revealed that the salinity in the irrigated area was more likely a result of the farmers' agricultural practices. Analysis of climatic data of the Northern Jordan Valley revealed a reduction in annual rainfall by 4.5 mm/decade during the period 1970–2019. In addition, the average monthly values of maximum and minimum temperatures of the same period have exceeded the long-term monthly

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average of maximum and minimum temperatures in the study area. These changes in rainfall and temperature has exaggerated water scarcity in the study area and provided strong evidence on climate change in the region. The high vulnerability of Northern Jordan Valley region to climate change has strongly impacted the livelihoods' of its inhabitants and forced many people to immigrate.

Introduction

Drylands are characterized by low unpredictable precipitation (annual average rainfall <200 mm (Gaur and Squires 2018), scarcity of water, large difference in temperature between day and night-time, low organic content in soil and relatively high evapotranspiration due to abundant solar radiation, low humidity and high temperature (Ji et al. 2015; Feng and Fu 2013). The main feature of drylands is water scarcity where negative water balance (the amount of water evaporates during one year is more than that precipitates) is predominant (Huang et al. 2016).

There are different definitions of drylands; the United Nations Environment Programme (UNEP) defines drylands according to the aridity index (ratio between average annual precipitation and potential evapotranspiration, AI) (Huang et al. 2016) where drylands are those lands with AI < 0.65, whereas the Food and Agriculture Organization (FAO) defines drylands according to the length of growing period (LGP), where drylands are areas with LGP of 1–179 day per year. Further, based on either AI or LGP, drylands are classified into hyper-arid, arid, semi-arid and dry sub-humid lands (see Table 1) (Yukie and Otto 2011; UNCCD 1994).

Drylands accounted for 44% of the Word's agricultural land, 41.3% of the planets land surface and 50% of the Earth's livestock (Schlaepfer et al. 2017; Reed et al. 2012). Drylands are considered the largest terrestrial biome on Earth; 38% of the world's population is supported by drylands (Huang et al. 2017a, b). The vast majority of drylands' population lives in the developing countries (Yukie and Otto 2011).

Table 1 Classification of drylands based on the United Nations Environment Programme (UNEP) aridity index (AI), and length of growing Period (LGP) according to Food and Agriculture Organization (FAO)

Classifications of drylands	Aridity index (AI) according to UNEP	Length of growing period in days (LGP) according to FAO—(Day/year)
Hyper-arid	AI < 0.05	–
Arid	0.05 < AI < 0.20	1–59
Semi-arid	0.20 < AI < 0.50	60–119
Dry sub-humid	0.50 < AI < 0.65	120–179
Total drylands	0.05 < AI < 0.65	1–179

Incredible diversity of specialized species is found in drylands due to the special climate conditions in these areas (Yukie and Otto 2011).

Drylands are highly vulnerable to human activities and climate change (Huang et al. 2017b; Zhou et al. 2015). The response of drylands to climate change is reflected by changes in the structure and function of their ecosystem and changes in their area and distribution (Huang et al. 2016). Many studies have investigated climate changes and its effects over drylands (Ryan and Elsner 2016; Ji et al. 2015; Feng and Fu 2013).

Due to climate change, the global drylands have shown a surface warming of 1.2–1.3 °C over the past century, indicating 20–40% more surface warming over drylands than humid-lands (Huang et al. 2017a; IPCC 2013). The semi-arid regions have shown the largest expansion of global drylands (more than 50% of the total expansion of drylands over the World (Huang et al. 2017b). Climate change and human activities (such as—over cultivation, inadequate irrigation system and overgrazing) have led to desertification in many drylands around the World (Delgado-Baquerizo et al. 2013; Yukie and Otto 2011). Desertification is a major threat to the ecosystem of drylands and its inhabitants (Huang et al. 2017b; Gornish and Tylianakis 2013). It could lead to reduction in the carbon sinks and increase the emissions of greenhouse gases to the atmosphere, loss of livelihoods, salinity of soil and reservoirs, diminishing food production and increased flooding (Yukie and Otto 2011).

Many models predicted an increase in the aridity with climate change during the twenty-first century, particularly in the World's drylands. Any increase in aridity is predicted to negatively affect the soil content of total nitrogen (N) and organic carbon (C), and positively affect the soil inorganic content of phosphorus (P). This indicates that aridity may favor the dominance of physical processes (such as weathering of rocks) over biological processes (such as decomposition of litter). In turn, the key services that are provided by drylands' ecosystems will be negatively affected (Delgado-Baquerizo et al. 2013).

The scarcity of water in drylands have exacerbated as a result of changing in rainfall patterns, increasing surface air temperatures and weather extremes (e.g. droughts) (Ryan and Elsner 2016). These changes can damage vegetation and cause loss in livestock (Dawson et al. 2016; Ravi et al. 2010). In turn, this will add an additional stress on the availability and stability of food resources in drylands, leading to severe imbalances in natural production systems and consequently lower income of drylands' inhabitants and higher poverty rate (Schlaepfer et al. 2017). Under the stress of poverty and low income per capita, inhabitants of drylands particularly males are forced into either internal or external (cross boarder) migration to support their families (Yukie and Otto 2011).

Without agricultural innovations and adaptation for the rapidly growing population and changes in the land use around the world, 31% of the World's population will be food insecure (Dawson et al. 2016). When climate change is taken into the scenario, this percentage increases by 21% putting 4.2 billion people at the risk of undernourishment by the year 2050 with the vast majority of these in the developing countries (Dawson et al. 2016). All in all, climate change in drylands threatens food security, regional economics, energy production, public health (Yukie and Otto 2011) and may cause social and political conflicts leading to a global crisis (Markkanen and Anger-Kraavi 2019; Gaur and Squires 2018).

This study aims at investigating the effect of climate change on the biophysical and socio-economic characteristics of the drylands in Palestine; a developing country in the Middle East region.

Palestine is under the threat of desertification due to unsustainable management of resources (such as—urbanization, over grazing of land, excessive use of agro-chemicals and over pumping of ground water), Socio-economic factors (including poverty and food insecurity, land tenure and fragmentation), Institutional and legal factors (e.g. Weak institutional capacities), natural factors (like—climate change and population growth), Israeli occupation related factors (e.g. Israeli settlements, separation wall, control over natural resources and uprooting of trees) (UNDP 2011). The major consequences of desertification and land degradation include decrease in soil productivity and fertility, increase negative impacts of climate change, increased rain water runoff, less food production and increased food insecurity, increased financial and security burdens, and increased soil erosion and loss (UNDP 2011).

As part of the Middle East region, Palestine has been and will be subjected to many serious climate changes that include increases in temperature and sea level rise, reduction in the annual rainfall, shifts in rainfall patterns as well as hydro-meteorological dangers such as heat waves, droughts, floods, and storms.

Materials and Methods

Study Area

Palestine consists of two separated land masses; the West Bank and Gaza Strip (Fig. 1) with total area of 6257 km^2 of which 5840 km^2 the area of the West Bank including East Jerusalem and the rest is the area of Gaza Strip.

The total population of Palestine is 4.8 million; 2.9 million live in the West Bank and 1.9 million live in Gaza Strip. The Palestinian population is considered young as 69% of the population is below the age of 29 (PCBS 2018). Around 26.9% of the Palestinian population is unemployed of which 44% of the Palestinian women (UN Country Team 2016). According to the statistics of International Labour Office in 2014, around 34% of Palestinian households were classified as food insecure; this percentage jumped to 57% in Gaza Strip due to humanitarian and socio-economic conditions (International Labour Office 2014).

The main water resources in the West Bank are the western basin, eastern basin, north-eastern basin, springs and mekorot (national water company of Israel), whereas the major source of water in Gaza strip is the coastal aquifer; in fact, 85% of these resources is under the control of the Israeli occupation (UN Country Team 2016). The annual water share of Palestinians is less than 200 m^3/capita which is 300 m^3/capita

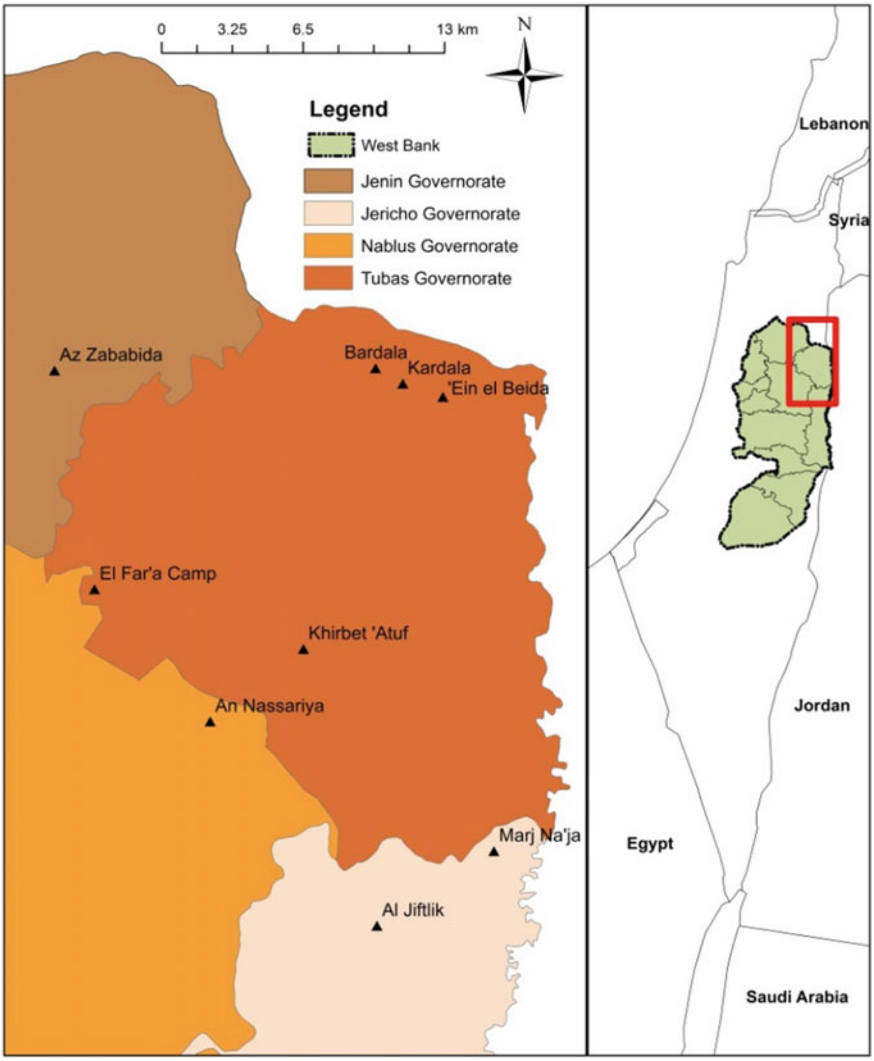

Fig. 1 Map of the study area

below the water scarcity limit of the World Health Organization (WHO) (MoFA Netherlands 2018).

Palestine is one of the most vulnerable drylands in the Middle East region due its political situation, limited water resources and bio-physical and socio-economic vulnerability to climate change (ARIJ 2013). The number of droughts has increased in the last few years (200–2010); consequently, the rate of vegetation has decreased in 42.7% of the West Bank area, especially in the Jordan Valley region (which is the most impacted area of land degradation in Palestine). Approximately 22.3% of the Jordan Valley area is under the effect of active degradation (ARIJ 2013).

Nine Locations in the Northern Jordan Valley region were selected as a pilot study area. These locations are: 'Ein el Beida, BradalaKardala, MarjNa'jeh, Al Zubaidat, AlJeftlik, An Nasariya, Alfara'a and Atoof as illustrated in Fig. 1. The Northern Jordan Valley region is considered historically as the food basket for the Palestinians. Although of its aridity, the region is known for its massive production of agricultural products due to fertility of its lands, availability of ground and drainage water, and elevated temperature all year around in comparison to the rest of Palestine and all Middle East countries, also due to its topographic settings, as most of the area is located around 350–370 below sea level (ARIJ 1995).

This study was conducted to assess the biophysical and socio-economic characteristics of the Northern Jordan valley due to the importance of this region on all levels. Geographically, this area is an International boundary among different neighboring countries; Culturally known for its importance to the three main faiths in the region; Economically as introduced to be a food basket in addition to its touristic attractive value; and Politically is an area of conflict, wherein current Palestinian citizens face deportation and annexation due to the dominant political conflict in the region.

Based on the UNEP AI; 44.4% of the West Banks' area is semi-arid, 30% is arid, 21.6% is dry-subhumid, and 4.0% is hyper-arid. Figure 2 shows that all of the study locations except for Al Fara'a are located in the arid zone where $0.05 < AI < 0.20$. As could be seen in Fig. 3 the dominant land use in the area is rough grazing/subsistence farming. The major economic activity in the Northern Jordan Valley region is agriculture. The average annual rainfall at the Jordan Valley region is only 100–200 mm (MoFA Netherlands 2018). The main water supply is Palestinian Water Authority through the West Bank Water Department that purchase bulk water from the Israeli Mekorot Company; other sources include groundwater and springs which are mainly used for agricultural uses (ARIJ 2012a, b, c). The Israeli occupation adds an additional stress to the problem of water scarcity in the area; inhabitants are neither allowed to construct or develop groundwater wells nor maintain old ones (ARIJ 2012a, b). Additionally, the water supply is not stable and is totally controlled by Israel.

The study was implemented over the period February to July 2019. Direct meetings were conducted to collect data regarding crops, irrigation intervals and quantities from farmers in the pilot study area. Soil samples were collected from representative fields in the study area to test the major soil chemical properties: salinity, pH, total nitrogen content (TN), calcium content (Ca), magnesium content (Mg), chlorine content (Cl), sodium content (Mg), Potassium content (K), phosphorus content (P), soil organic matter (OM) and sodium adsorption rate (SAR). The samples were composite samples where, each sample was composed of 10 samples in the field. Official methods of analysis of AOAC international and ICARDA referenced methods were used or soil analysis (Ryan et al. 2001; AOAC 1998). Parameters mean values were used to perform principal component analyses (PCA) along with the correlation analyses to test whether the variables are correlated or not was used. Level

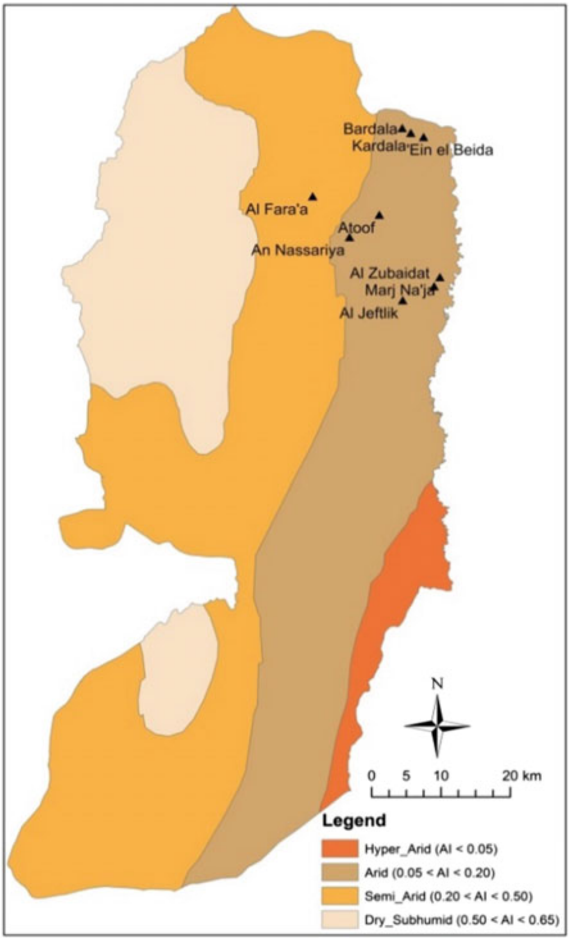

Fig. 2 Aridity map of the West Bank

of significant ($p < 0.05$) was estimated for all of the tested variables using crosstab (Chi-square).

For socio-economic data, a questionnaire was developed and tested to collect the data from a representative sample consisting of 180 rural households. The questionnaire covered various socio-economic topics such as household monthly expenditure, livestock holdings, land tenure and women contribution to agricultural work.

ArcMap (GIS 10.1) was used to create all the maps presented in this study, the shape files were provided by An-Najah National University (ANU). While the statistical analysis of socio-economic and climatological data was carried out using Microsoft Excel 2016. The dataset of annual mean temperature in Palestine over the period 1843–2013 was downloaded from (https://stat.world/en). The dataset is limited for this period (1843–2013), whereas the meteorological data for the study area was provided by the Palestinian Meteorological Department. The census data

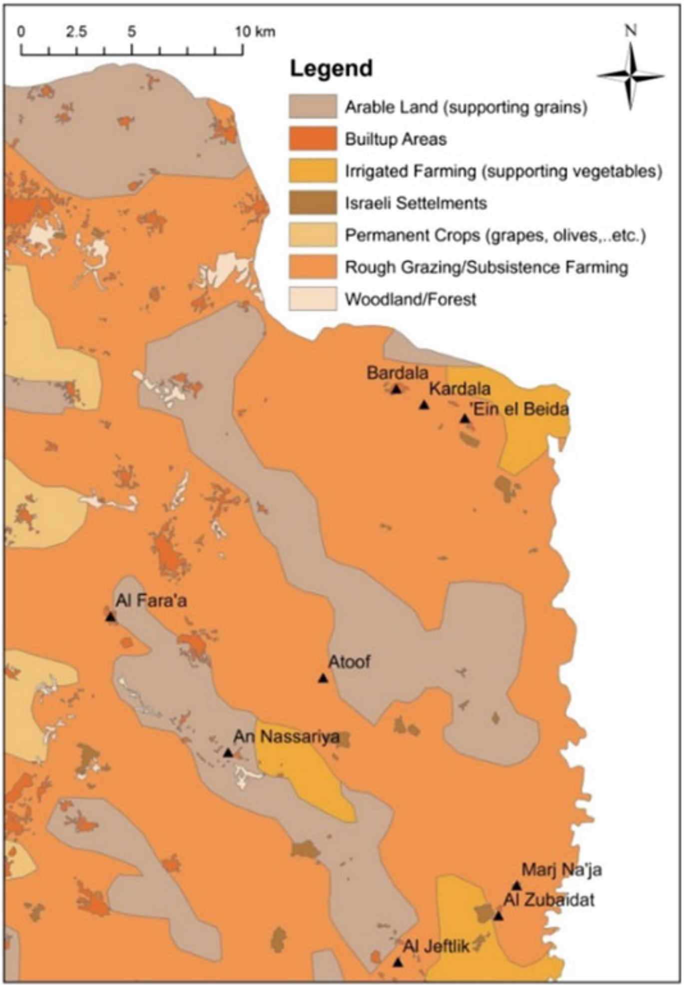

Fig. 3 Land use map

for the population in the study locations were drawn from The Palestinian Central Bureau of Statistics (PCBS) reports (PCBS 2018, 2008, 1999a, b, c). The forecasted population for the year 2017 was predicted using Equation (1):

$$P_p = Pe^{rt} \quad (1)$$

where, P_p is the predicted population, P is the present/past population in a specific year, r is the rate of natural increase and t is the time period between the P_p and P. According to the PCBS, the natural growth rate in Palestine is 2.8% (PCBS 2016).

Results and Discussion

Socio-Economic Characteristics

Climate change is seen as the consequence of complex social, economic and environmental interactions.

Climate change and geological processes contribute in reducing soil fertility and degradation, and have particularly serious consequences in the developing World, where millions of people are undernourished (Fischer et al. 2005).

The study findings revealed that, the average households' monthly income in the study area was US $440–1000 with animal production, labour farming wages and plant production as main sources of agricultural income. This agreed with (Kanafani 2016) where he found that the poverty line in Palestine for a family of 5 members was estimated at US $668 per month, and the deep poverty line at US $534 per month.

Furthermore, the survey showed a significant portion of households' monthly income was spent on water for domestic and agricultural purposes. Another major contributor to household monthly expenditure was animal feeds. Rubhara et al. (2020) found that the animal feed is a major contributor to household monthly expenditure. A strong presence was found for women contribution to agricultural income particularly in animal production sector. Women make essential contributions to agriculture in all developing countries. Rural women often manage complex households and pursue multiple livelihood strategies (SOFA Team and Doss 2011). The study also revealed that the majority of vegetable farmers (80%) and livestock farmers (77%) reported that agricultural inputs are most of the time accessible in terms of quality, quantity and prices. The results revealed that (65%) of the farmers receive extension services from the ministry of agriculture (MOA), (10%) from nongovernmental organizations (NGOs), (15%) from private companies, and 10% from other sources. More than 58% of farmers sell their agricultural products to wholesale market, 22% to traders, 5% to other farmers, 7% directly to consumers and 8% to others.

Moreover, water harvesting was a predominant activity in the area due to water scarcity in Palestine in general and the study area in particular, where the average annual rainfall is less than 200 mm. Rain is the cheapest source of water for agricultural purposes. In many dry regions of the World, there is no alternative but a better and more effective use of rain to increase and secure food production (Koohafkan and Stewart 2008).

Biophysical Characteristics

pH and Salinity, the pH level in the soil ranged from 7.9 to 8.6. In such type of soil (alkaline soil), phosphorus and most micro-nutrients become less available (Alvey et al. 2001). The salinity level of the soil in the root zone ranges from 1.5 dS/m up to 2.5 dS/m. According to the soil salinity classification it indicates that salinity is not an expected problem in the root zone in this area. This is due to the leaching of excess salts from the root zone. In many countries, the land is destroyed by salt accumulation each year. This rate can be accelerated by climate change and excessive use of groundwater (Machado and Serralheiro 2017) (Fig. 4).

Macronutrients, Potassium (K) ranged from 30 to 450 ppm. Bardala sample show very high level of K whereas Aljeftlik is very low and all other samples is within the normal range. Phosphorous (P) content in all sites is very high. Total Nitrogen (TN) percentage in all sites is very low (0.2 to 0.7 ppm), Magnesium (Mg) level from 20 to 170 ppm. In Aljeftlik and Alzubaidat Mg level is low and the level is high for Atoof (Fig. 5). Normally farmers apply excessive fertilizers and the soil environmental problems caused by these methods are substantial (Zhang et al. 2016). In the process

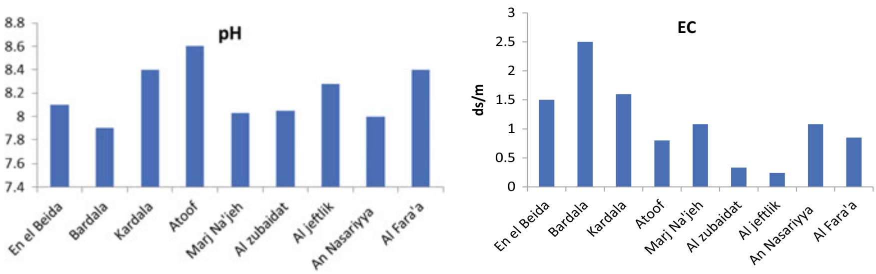

Fig. 4 pH and salinity of the tested soil samples

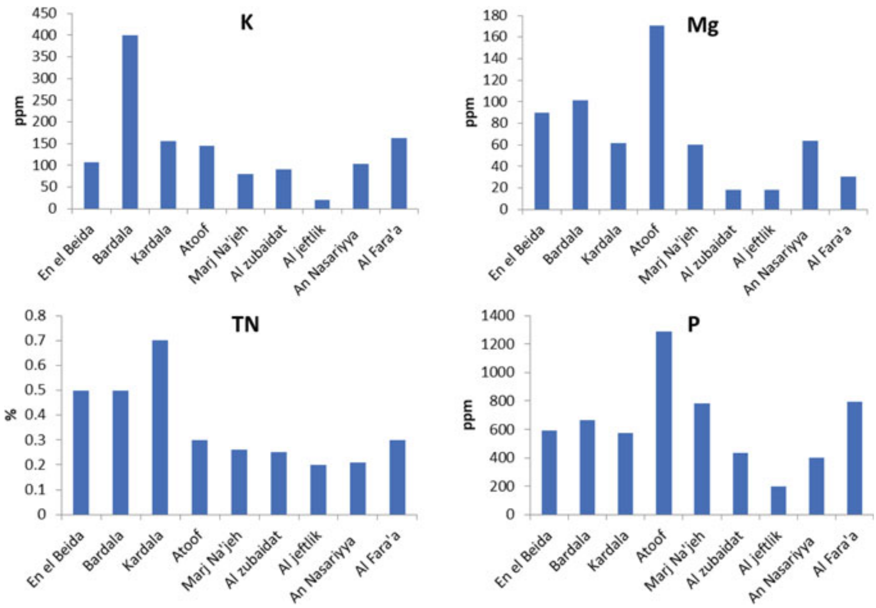

Fig. 5 Macronutrients level in the tested soil samples

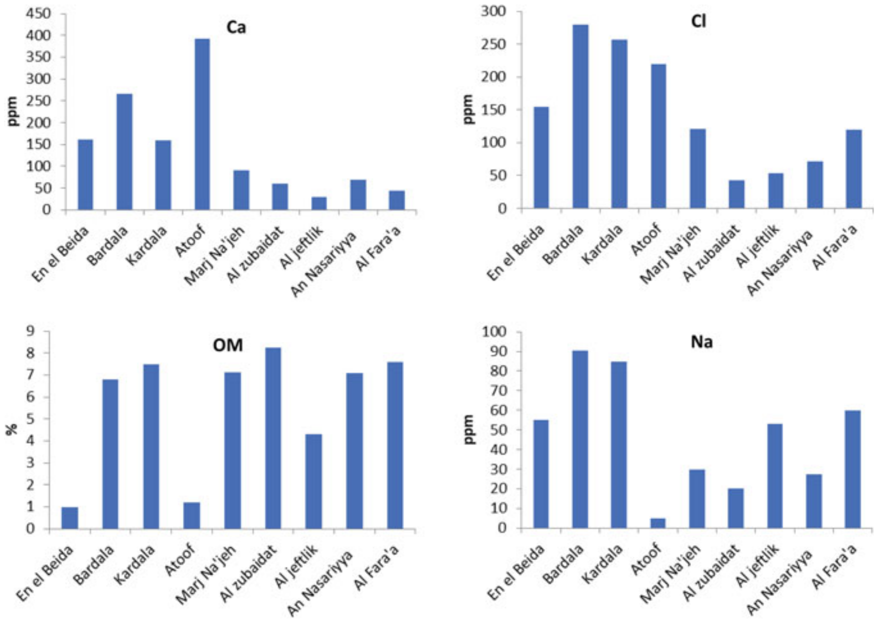

Fig. 6 Ca, Cl, Na and OM in the tested soil samples

of the growth and development of crops, the absorption and utilization of the nutrients are limited. Excessive nutrient application can inhibit the quality and yield of fruits and vegetables, leading to soil degradation (Dong et al. 2014).

Calcium (Ca), Chloride (Cl), Sodium (Na) and Organic matter (OM), Ca level in soil is low in all of the samples (ranged from 25 to 390 ppm). Calcium-deficiency is an economic problem for commercial vegetable growers due to the use of more intensive production practices (Olle and Bender 2009). The concentrations of Cl and Na in the soil samples were normal. The percentage of OM in the soil samples is normal and it ranged from 4 to 8%. OM affects crop yield by supplying nutrients and by modification of the soil physical properties for stimulating plant growth (Chang et al. 2007) (Fig. 6).

Principle Component Analysis (PCA)

The results of PCA matrix analysis showed that the first three axes, accounted for 90% of the total cumulative variation. This indicated a wide spectrum of the variation between the locations. As illustrated in Table 2, Cl, Ca and Na have a strong loading on the first principal component. While OM and TN have the strongest loading on the second principal component and pH has the strongest loading on the third component (Table 3).

Table 2 PCA matrix for the nutrients in the soil samples

Nutrients	Component		
	1	2	3
p	0.355	0.788	0.004
pH	−0.089	−0.017	0.985
EC	0.930	0.184	−0.275
OM	−0.230	0.913	−0.031
Ca	0.930	0.063	−0.302
Mg	0.825	0.330	−0.444
Cl	0.960	0.188	0.087
TN	0.882	0.960	0.345
NA	0.907	0.346	0.184
K	0.756	0.328	−0.301

Table 3 Correlation matrix for the nutrients in the soil samples

	P	OM	Ca	Mg	Cl	TN	Na
OM	−0.155						
Ca	0.555	−0.320					
Mg	0.646*	−0.382	0.946**				
Cl	0.662*	−0.098	0.642	0.676*			
TN	0.056	0.198	0.369	0.251	0.676*		
Na	−0.252	0.452	0.121	−0.015	0.368	0.778**	
K	0.212	0.221	0.530	0.401	0.643*	0.491	0.676*

* Correlation is significant at the 0.05 level (P<0.05)
** Correlation is significant at the 0.01 level (P<0.01)

Correlation

Different soil parameters were significantly correlated with each other. Strong positive correlation was found between Mg and Ca, Na and TN, K and Cl, K and Na, Cl and Ca. Other parameters showed weak negative correlation such as in the case of OM and P, Na and P, Cl and OM, and Mg and Na.

Variation Between the Sites

Significant variations ($p < 0.05$) were found between the sites for OM and for macro and micro nutrients (Table 4). The variation in the nutrients revealed the differences in agricultural input use by the farmers.

Table 4 Analysis of variance for tested sites for macro and micro nutrients

		Sum of Squares	df	Mean Square	F
Ca	Between groups	226,259.061	9	25,139.896	948.872
	Within groups	264.945	10	26.494	
	Total	226,524.006	19		
Mg	Between groups	36,965.368	9	4107.263	512.000
	Within groups	80.220	10	8.022	
	Total	37,045.588	19		
Cl	Between groups	148,008.347	9	16,445.372	49.135
	Within groups	3346.981	10	334.698	
	Total	151,355.327	19		
TN	Between Groups	0.434	9	0.048	123.755
	Within groups	0.004	10	0.000	
	Total	0.438	19		
Na	Between groups	17,536.745	9	1948.527	861.227
	Within groups	22.625	10	2.263	
	Total	17,559.370	19		
K	Between groups	172,581.138	9	19,175.682	852.253
	Within groups	225.000	10	22.500	
	Total	172,806.138	19		
P	Between groups	2,260,597.016	9	251,177.446	211.912
	Within groups	11,852.895	10	1185.290	
	Total	2,272,449.911	19		
OM	Between groups	21.286	9	2.365	29.703
	Within groups	0.796	10	0.080	
	Total	22.082	19		

Vulnerability to Climate Change

The analysis for the long-term annual average temperature of Palestine over the period 1900–2013 shows a clear increasing trend in the annual average temperature in Palestine as indicated in Fig. 7.

Focusing on the past century (1900–2000), the mean annual temperature in Palestine has increased at a rate of 0.082 °C/decade (Fig. 7a). While over the period (1984–2013) the mean annual temperature has increased at a rate of 0.27 °C/decade (Fig. 7b), this result is in line with the findings of UNDP (2010) and El-Kadi (2005) where both of the studies indicated an increasing trend in the mean temperature in Palestine and Gaza Strip, respectively.

Concerning the Northern Jordan Valley area, the monthly average maximum and minimum temperature in the study area has increased over the period 1975–2019

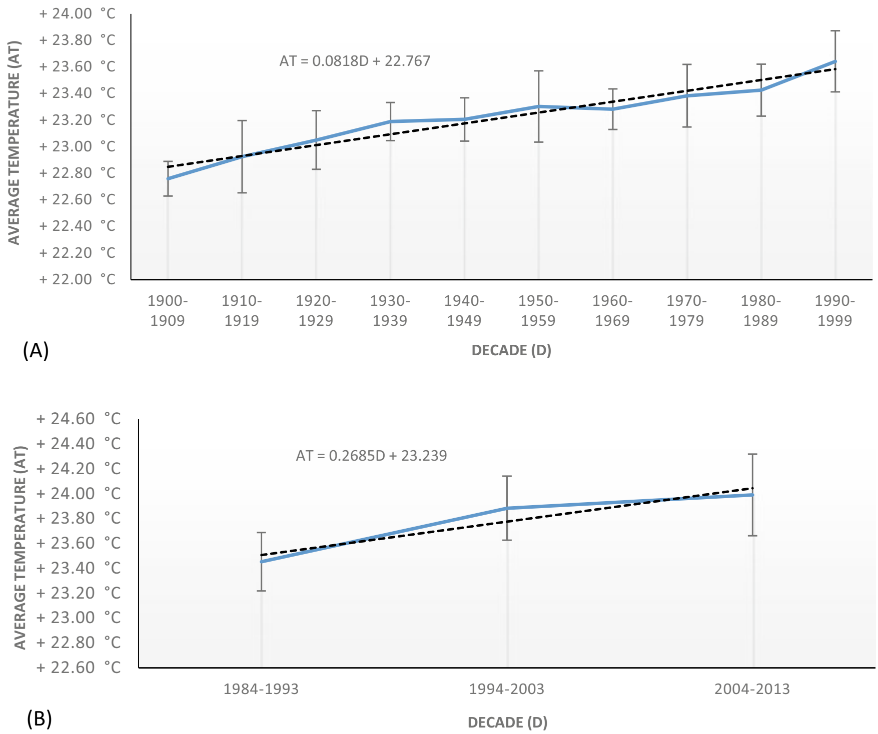

Fig. 7 Trends in mean annual temperature in Palestine: **a** over the twentieth century, **b** over the period 1984–2013

(Fig. 8). Moreover, the average monthly values of maximum and minimum temperatures of the period 1976–2019 in the study area have exceeded the long-term monthly average of maximum and minimum temperatures as illustrated in Fig. 9.

Concurrent with the increasing trend in temperature, more frequent heat waves have been observed in the last few years, especially in the Northern Jordan Valley region (ARIJ 2013). This region in particular is under risk because it usually has elevated temperature all year around in comparison to the rest of Palestine and all Middle East countries, due to its topographic settings, as most of the area is located around 350–370 below sea level (ARIJ 1995).

The average annual rainfall of the Northern Jordan Valley region showed a decreasing trend over the period 1970–2019 (Fig. 10). The ten-year moving average of rainfall revealed a reduction in annual rainfall by 4.5 mm/ decade for the same period (Fig. 11). The risk of droughts and aridity in the region will increase due to the predicted reduction in annual precipitation rates (MoFA Netherlands 2018).

Besides other political and natural factors affecting water resources in the study area, climate change has exaggerated water scarcity because of changing in the amount and patterns of precipitation (Fig. 10). Rainfall season in Palestine lasts

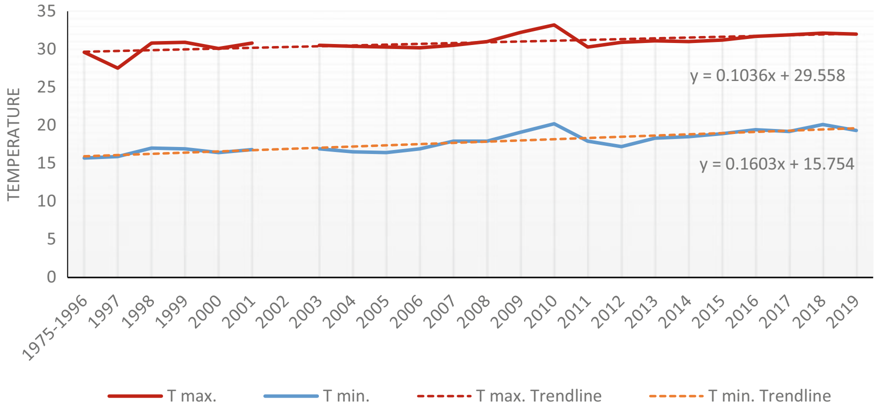

Fig. 8 Monthly average maximum and minimum temperature in the study area over the period 1975–2019

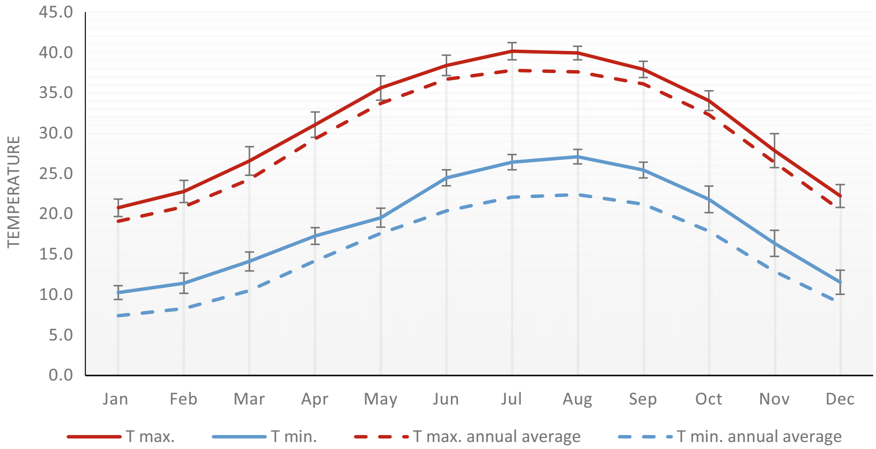

Fig. 9 Monthly average maximum and minimum temperature over the period 1976–2019 in the study area

from September to May, and usually reaches its peak in the period from December to March each year. However, due to climate change the rainfall season has been shifted to later summer months with dominant higher temperatures, which in turn has led to increase in the evapotranspiration rate and has reduced surface and groundwater supply in the Northern Jordan Valley region. Consequently, this has exacerbated the water crisis in the study area.

As a result of the combined effect of climate change (increased temperature, change in rainfall patterns and amount, heat waves and droughts) and human activities (e.g. intensive agriculture and rough grazing) the rate of vegetation has decreased in

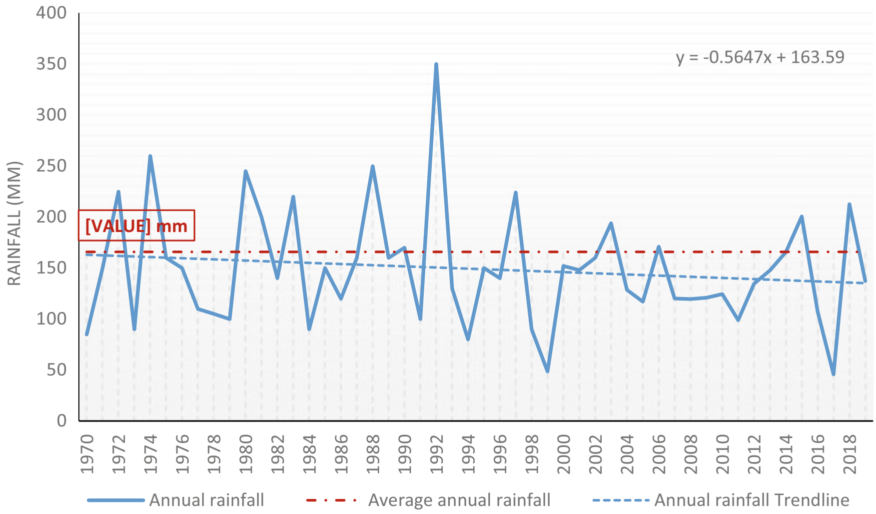

Fig. 10 Annual average rainfall over the period 1970–2019 in the study area

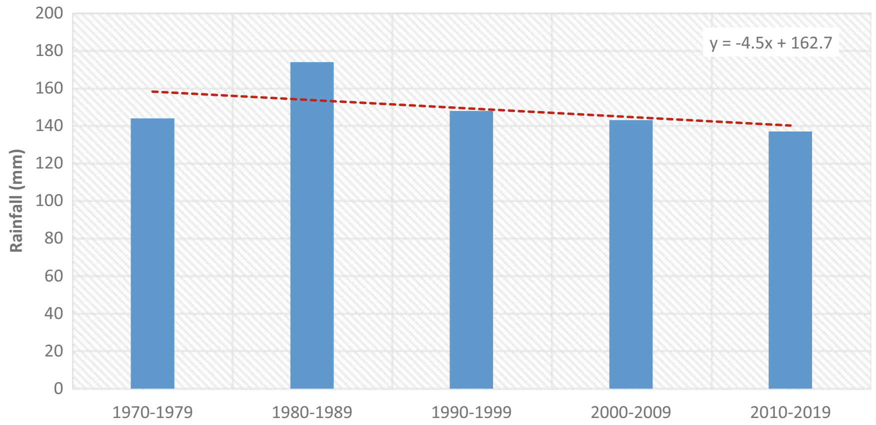

Fig. 11 Ten-year moving average of rainfall over the period 1970–2019 in the study area

42.7% of the West Bank area, especially in the Jordan Valley region (which is the most impacted area of land degradation in Palestine).

Approximately 22.3% of the Jordan Valley area is under the effect of active degradation (ARIJ 2013). Agriculture has been badly affected by climate change; the growing season has become shorter, water requirements for crops have increased and stocks and grazing range has declined, consequently the food prices has become higher (UNDP 2011; MoFA Netherlands 2018).

Compared to the past years, in recent years, salinity of groundwater has increased due to over-pumping, and reduction in groundwater recharge due to periodic shifting

Table 5 Population of the study locations in 1997, 2007 and 2017

Site	Population in 1997	Population in 2007	Population in 2017	Predicted Population in 2017 using Eq. (1)
Bardala	1154	1637	1607	**2166**
Kardala	121	307	203	**406**
Ein el Beida	791	1163	1138	**1539**
Al Fara'a	1713	2730	3998	3612
Atoof	76	171	216	226
An Nassariya	1010	1585	1889	2097
Al Jeftlik	3177	3714	3100	**4914**
Al Zubaidat	968	1421	1679	1880
MarjNa'ja	554	715	828	946

of rainfall resulted from climate change. This has led to another shift in cropping patterns, where farmers replaced historical cultivated species with more salinity tolerant ones. Quality and quantity of this shifting in crops is still not satisfactorily measured.

The high vulnerability of Northern Jordan Valley region to climate change has strongly impacted the livelihoods of its inhabitants as they are suffering from high production cost as they need to pay for animal feeds, fertilizers to meet the crops requirements of nutrients and increase their production, and water requirements due to water scarcity in the area. Furthermore, the lower production means lower income for inhabitants as agriculture supports most of the households in the area (e.g. 97% of Al Zubaidat's inhabitants are working in agriculture (ARIJ 2012b). All of this besides other political factors has forced many people to migrate causing a decline in the population of the Northern Jordan Valley region (Table 5). This could be clearly seen from the decreasing trend of population in certain locations of the study area during the period 2007–2017 (Fig. 12).

The impacts of climate change are expected to exacerbate threats to public health where many people will be food insecure and suffer from nutritional deficiencies, waterborne diseases due to low quality of drinkable water, and be at risk of other diseases related to lack of water such as dehydration, diarrhea and cholera (UNDP 2010; MoFA Netherlands 2018). This could be very dangerous in a population feeling insecure by all means.

Conclusions

The study findings revealed that the average households' monthly income in the study area was in the range (US $440–1000) with animal production, labour farming wages and plant production as main sources of agricultural income. Furthermore,

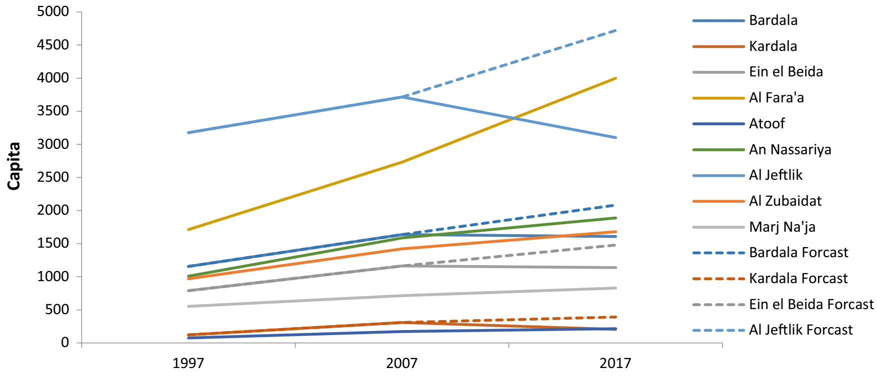

Fig. 12 The population of the study area by location

the survey showed a strong presence of women contributing to agricultural income particularly in animal production sector. A significant portion of households' monthly income was spent on water for domestic and agricultural purposes. Another major contributor to household monthly expenditure was animal feeds. Water harvesting was a predominant activity in the area due to water scarcity in Palestine in general and the study area in particular.

The chemical analysis of the soil sample revealed that the salinity problems in the irrigated area are not permanent problem, in fact, the problem is coming from the farmer practices and the irrigation management. Furthermore, the analysis results revealed that the fertilization efficiency was low and fertilizers losses were high.

Analysis of climatic data showed an increasing trend in the mean temperature in Palestine as a result of climate change where the mean annual temperature has increased at a rate of 0.27 °C/decade over the period 1994–2013. Analysis of climatic data of the Northern Jordan Valley announced a reduction in annual rainfall by 4.5 mm/ decade during the period 1970–2019. In addition, the average monthly values of maximum and minimum temperatures of the same period have exceeded the long-term monthly average of maximum and minimum temperatures in the study area.

Without appropriate adaptation strategies to climate change the existing problems at the northern Jordan Valley region are expected to increase. The significant warming, decreased rainfall amount, heat waves and droughts will cause environmental and social crisis, threaten food security and make water resources scarcer. Species and people won't be able to cope with climate extremes. The population in the arid area will decrease at an accelerated rate as more people will move to other places away from the vulnerable area. To avoid this, the Palestinian authority should adopt a clear strategy to combat and adapt to climate change, empower local communities, and attract agricultural investments in the region, and have a policy and strategy for management of drylands with clear development and investment plan. Strong collaboration between all stakeholders in the society is required for building resilience to climate change.

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