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Full Length Research Paper

Biological and bioclimatic basis to optimize plant production: Increased economic areas of Palestine

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Abstract

This article analyses plant production such as olives, grapes and figs in several Palestinian Territories, and studies the correlation between productions and climatic, bioclimate features in the territory. Olive production is of particular significance variables Io, It/Itc and R. This work examines the following climate factors: average temperature, potential evapotranspiration, precipitation, soil water reserves, real evapotranspiration, water deficit; and bioclimatic parameters such as thermicity index, ombrothermic index, continentally index. The data used were from five meteorological stations in the Palestinian Meteorological Department. Based on the correlation analyses between olive, grape and fig production in five plots: H (Hebron), Ra (Ramallah), N (Nablus), J (Jenin) and T (Tulkarem) over five years, the multiple regression analysis (ANOVA) revealed a significant influence of the variables climate Io, Ic and It/Itc on the production of olives and figs, and a low influence on grape production. When we applied Canonical Correlation Analysis (CCA), the J and T plots were most affected by the climate and bioclimate factors Re, Pe, T, Df, It/Itc, whereas the Nablus and Ramallah plots showed the influence of Io, Ic, P and R. It is thus demonstrated that the production in plots Jenin and Tulkarem were conditioned by thermicity index and by water deficit, whereas the production of Nablus and Ramallah depends on precipitation and soil water reserves.

Key words: Palestine, evapotranspiration, bioclimate, indices, production.

INTRODUCTION

Palestine has a Mediterranean type climate, characterized by mild rainy winters and hot dry summers, with a subtropical tendency in the far south. Rainfall decreases from north to south, while the temperature increases

The winter rain regime has been extensively studied (Alpert and Reisin, 1986; Alpert et al., 1990; Samuels R. et al., 2009, 2010; Halfon N. et al., 2009) and long-term changes in annual rainfall patterns (Ben-Gai, T. et al., 1994; Bitan and Saaroni, 1990). The scenario analyses that have been prepared for the Israeli–Palestinian region using such models have suggested that precipitation levels may decrease and that extreme events may rise (Alpert et al., 2008; Black E,, 2009; Sowers Jeannie. et al., 2011). On the other hand, Mediterranean climate is characterized by mild rainy winters and warm to hot dry summers, with high solar radiation and high rates of evaporation (Boydak and Dogru, 1997; Le Houerou, 2005), the climate may be broadly defined as Mediterranean and one in which winter rainfall is more than three times summer rainfall (Aschmann, 1973; Wigley, 1992). However, due to climate change (Beaulant et al., 2008), cultivation is being affected in areas of climatic instability, as there is a close relationship between the biological characteristics of the species grown (olive, grape, fig), and climate. Olea europea L. (olive) is a Mediterranean species with a very specific biology, as its root system is extremely disperse and does not penetrate deeply into the soil, making it thus considerably susceptible to climate change (Cano et al., 2008a, b); whereas the biology of Ficus carica L. allows its root system to penetrate deeply into the soil in search

Table 1. Coordinates of meteorological stations Palestinian.

	Station Latitude (North)	Longitude (East)	Elevation m
Jenin	32º28 N´	35º18 E	178 m
Tulkarem	32º19 N´	35º01 E	83 m
Nablus	32º13 N´	35º15 E	570m
Ramallah	31º89 N´	35º21 E	856m
Hebron	31º32 N´	35º06 E	1005 m

Figure 1. Location of the meteorological stations (Palestinian Meteorological Department, 2013).

of the lower levels of the water table. These territories are clearly differentiated due to their geomorphological, climate, soil and vegetation characteristics, whereas the Gaza strip is represented by the coastal plain (Shmida A., 1995).

In the last decades there is an increasing interest in crop production systems that optimize yields while conserving soil, water, energy, and protecting the environment (Stamatiadis et al., 1996). This interest for sustainable agriculture is garnering support and acceptance within mainstream agriculture.

We determined the relationship between the different parameters and production in order to establish the optimization of the crop. The aim is to achieve the maximum production in economic terms with the minimum environmental cost, in view of the scarcity of water resources in Palestine due to the above-mentioned political conflicts, and to the effects of climate change on crops, something similar occurs in the rice fields in Côte D´Ivoire (Kouame et al., 1013), which leads to reduced production if the crop is not within its optimum area for growth (Pretty et al., 2011).

MATERIALS AND METHODS

Study area

Palestine is located between longitudes 34º15´ and 35º40´ east and between latitudes 29º 30´ and 33º15´ north. The geographic location of Palestine plays a major role in affecting the features of its climate and the climate diversity between the southern and northern parts.

Data were used from the meteorological stations in Palestine in the (Table 1), (Figure 1) for the years 2004,

Table 2: Log 10 of the independent and dependent variables.

R. Y.	T	Pe	P	R	Re	Df	Io	Ic	Itc	Po	Pg	Pf
H1	1,22	2.924	2.757	2.702	2.344	2.791	0.462	1.22	2.507	2.2672	2.897	2.786
H2	1.223	2.924	2.669	2.625	2.423	2.757	0.38	1.212	2.52	1.7404	3.019	2.795
H3	1.217	2.923	2.775	2.696	2.439	2.75	0.505	1.193	2.509	1.8261	3.022	2.699
H4	1.223	2.941	2.775	2.689	2.449	2.757	0.491	1.272	2.455	1.8388	2.996	2.699
H5	1.223	2.931	2.775	2.689	2.449	2.757	0.477	1.274	2.547	2.1239	2.985	2.716
Ra1	1.225	2.921	2.719	2.683	2.371	2.777	0.415	1.158	2.544	2.7168	2.713	2.477
Ra2	1.217	2.914	2.852	2.667	2.447	2.733	0.556	1.179	2.535	1.8451	2.713	2.544
Ra3	1.207	2.906	2.789	2.624	2.446	2.707	0.491	1.173	2.547	1.699	2.79	2.086
Ra4	1.228	2.927	2.79	2.671	2.479	2.735	0.477	1.253	2.504	2	2.79	2.544
Ra5	1.228	2.927	2.789	2.671	2.479	2.735	0.477	1.25	2.558	1.8808	2.755	2.447
N1	1.26	2.959	2.806	2.697	2.38	2.826	0.462	1.188	2.584	2.1139	2.699	2.903
N2	1.255	2.956	2.898	2.666	2.428	2.803	0.568	1.19	2.583	1.5441	2.563	2.903
N3	1.228	2.927	2.82	2.671	2.486	2.732	0.519	1.253	2.577	1.6021	2.728	2.845
N4	1.262	2.966	2.82	2.675	2.494	2.787	0.477	1.26	2.519	2.0792	2.885	2.777
N5	1.262	2.966	2.82	2.675	2.494	2.787	0.476	1.26	2.574	2.415	2.736	2.93
J1	1.301	3.022	2.628	2.572	2.362	2.915	0.255	1.207	2.658	2.316	3.176	2.476
J2	1.307	3.023	2.634	2.513	2.428	2.896	0.246	1.21	2.68	2.316	3.101	2.903
J3	1.312	3.036	2.67	2.651	2.453	2.905	0.301	1.21	2.665	1.4914	3.012	2.777
J4	1.316	3.043	2.67	2.621	2.479	2.905	0.274	1.276	2.615	1.5052	3.029	2.778
J5	1.316	3.039	2.67	2.657	2.455	2.908	0.27	1.17	2.693	1.8325	3.085	2.744
T1	1.358	3.098	2.739	2.618	2.43	2.993	0.301	1.201	2.702	2.3979	2.699	2.613
T2	1.364	3.102	2.768	2.563	2.433	2.997	0.324	1.196	2.693	1.4771	3.224	2.489
T3	1.367	3.108	2.779	2.667	2.555	2.965	0.332	1.17	2.701	1.301	3.209	2.602
T4	1.373	3.123	2.779	2.609	2.585	2.975	0.326	1.23	2.671	2.1761	3.061	2.622
T5	1.328	3.046	2.779	2.688	2.528	2.889	0.371	1.114	2.718	2.1673	3.106	2,62

2005, 2007, 2008 and 2009, and for the same years in the production of plants. The bioclimatology of the aforementioned stations was studied, and the value of the bioclimatic indices (Io, Ic, It/Itc, Ios1, Ios2, Ios3, Ios4) were obtained according to Rivas-Martinez (1996) and Rivas-Martinez , 2008), (Rivas-Martínez et al., 2011).

However, we analyzed the relationship between the dependent variables (Olive production (Po), Grape production (Pg), and fig production (Pf); the independent physical variables (climate factors) such as average temperature (T), potential evapotranspiration (Pe), precipitation (P), soil water reserves (R), real evapotranspiration (Re), and water deficit (Df); and the bioclimatic variables as ombrothermic index (Io), continentally index (Ic), and thermicity index (It/Itc), in order to establish the variables that had the greatest influence on agricultural production in the regions of Ramallah, Hebron, Jenin, Nablus and Tulkarem.

In order to avoid the effect of different measurement scales between the values of the different variables and to reduce the influence of high values, the original Excel table was transformed into a table of log 10 values (Tables 2). The Shapiro-Wilk and Jarque-Bera normality tests were applied, and the p-valor was obtained for the 12 variables. We applied an ANOVA regression analysis to each of the nine independent variables, the three bioclimatic variables and the six remaining physical variables, and each of the dependent variables olive, grape and fig production, in order to obtain the coefficient of regression R2 and the multiple regression line. Canonical correlation analysis (CCA) was subsequently applied in order to determine the influence of independent variables on production. These statistical analyses were done using the XLSTAT software.

In the (Table 2): Po: Olive production, Pg: Grape production and Pf: Fig production. R. Y. (regions and years).

RESULTS AND DISCUSSION

We used the bioclimatic classification of earth to Salvador Rivas-Martinez to analyses of the climate factors and bioclimatic parameters (independent variables).

After application of the Shapiro-Wilk normality test, the p-value obtained from the variables studied tended to be below 0.05, a conventionally accepted value.

The (ANOVA), with a 95% confidence interval, applied to each of the three production variables olive, grape and fig, with the nine independent variables factors T, Pe, P, R, Re, Df, Io, Ic and It/Itc, reveals significant differences in the case of olive, grape, and fig production , implying the influence of the nine factors in the production of olive, grape and fig, may be that changes in climatic and

Table 3. Values for the correlation coefficient R2

	P. olive	P. grape	P. fig
	R^2	R^2	R^2
Nine factors	0.7643	0.3504	0.324
Three factors	0.9464	0.5274	0.8809
Six factors	0.8629	0.3985	0.6469

Table 4: Table of index with the compensation values of Ios1, Ios2, Ios3 and Ios4. Ios1: Monthly festival ombrothermic index, Ios2: Bimonthly festival ombrothermic index, Ios3: Three monthlyfestival ombrothermic index and Ios4: Four monthlyfestival ombrothermic index. H1 (Hebron 2004, H2 (Hebron 2005), H3 (Hebron 2007), H4 (Hebron 2008), H5 (2009) and the rest of regions as the same.

District	Ios1	Ios2	Ios3	Ios4
H1	0	0	0	0
H2	0	0	0	0
H3	0	0	0.01	0.06
H4	0	0	0.01	0.06
H5	0	0	0.01	0.06
Ra1	0	0	0	0.04
Ra2	0	0	0	0.01
Ra3	0	0	0	0.04
Ra4	0	0	0	0.04
Ra5	0	0	0	0.04
N1	0	0	0	0.01
N2	0	0	0	0.02
N3	0	0	0	0.09
N4	0	0	0	0.08
N5	0	0	0	0.08
J1	0	0	0	0.01
J2	0	0	0	0.01
J3	0	0	0.01	0.03
J4	0	0	0.01	0.03
J5	0	0	0	0.03
T1	0	0	0	0
T2	0	0	0	0
T3	0	0	0	0.03
T4	0	0	0	0.03
T5	0	0	0	0.04

bioclimate factors have an impact on the sustainability plant production, it's have significant impacts on conditions affecting agriculture, food and water security and loss of biodiversity. In the multiple regression lines, only the case of olive production shows a better linear correlation with the values of R2 = 0.7643 (Figure 2), close to 1, although the correlations of grape and fig production are small, as R2 is low. The correlation analyses between each of the three dependent variables, olive, grape and fig production and the three independent bioclimatic variables have a different level of significance from the previous case. There are no significant differences in the case of olive and grape production, but there is a statistically significant difference for fig production, as the histogram is positive (Figure 3). Moreover, the high linear correlation between the bioclimatic factors and olive and fig production with values of R2 = 0.9464 and 0.8809 respectively, and the

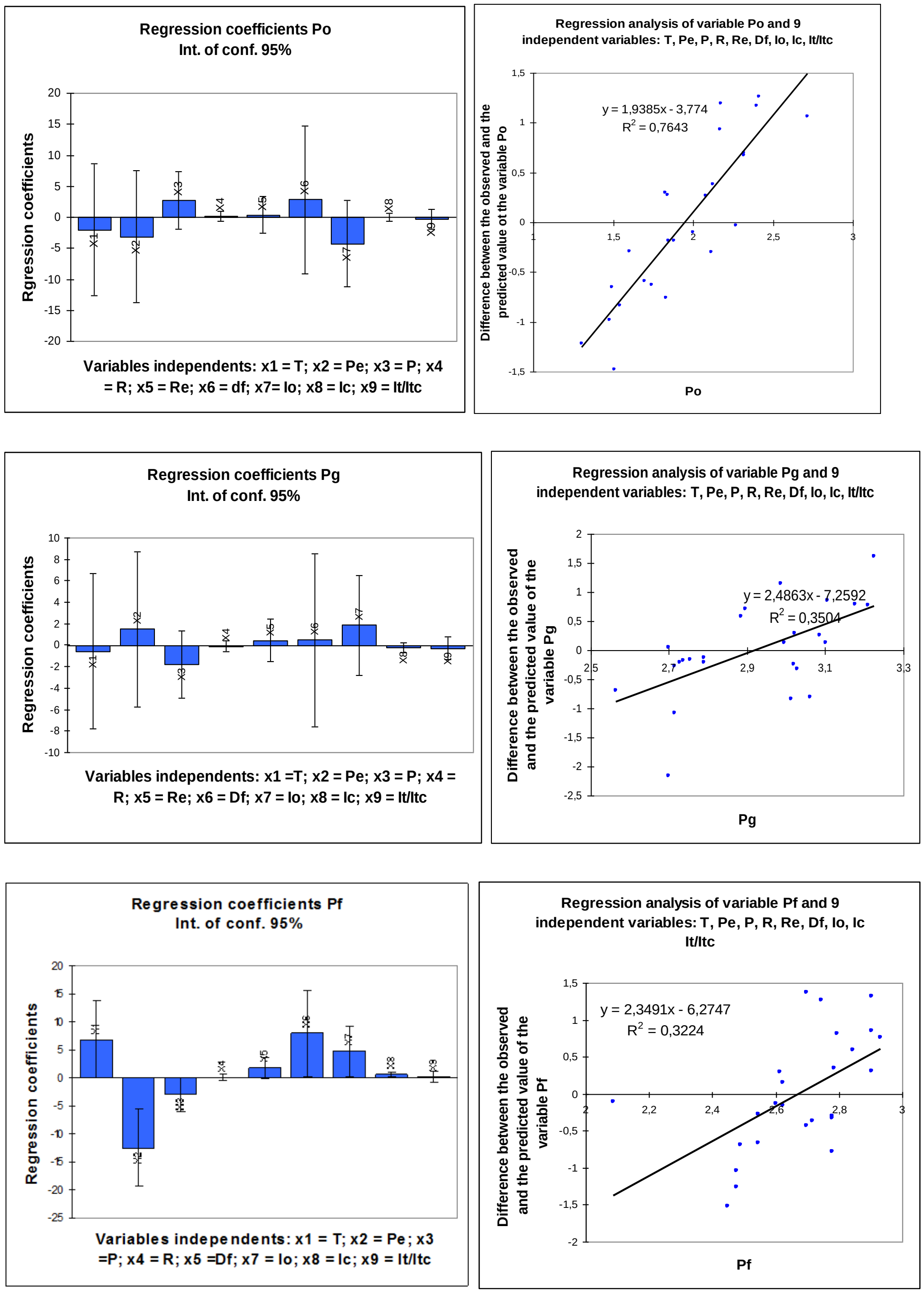

Figure 2. Regression analysis for the dependent and independent variables.

value of R2 = 0.5274 for grape production, shows the high influence of the independents variables of bioclimate Io, Ic and It/Itc on the olive and fig production, but low in the case of grape production.

Bioclimatic variables that were not taken into account in the model published by Galán et al. (2008) for the Andalusian olive grove.

When the multiple correlation analysis is applied to each of the dependent variables and the six physical parameters (independent variables), significant differences ($p< 0.05$) can once again be observed in all cases. These differences are lower in the case of olive production; again in this case the value of R2 obtained in the multiple regression line is 0.8629 (Figure 4), thus highlighting the high correlation between olive production and physical parameters (Table 3).

In view of the linear correlation obtained, we applied a canonical correlation analysis (CCA). This was done by comparing the dependent variables olive, grape and fig production with the total independent variables and the

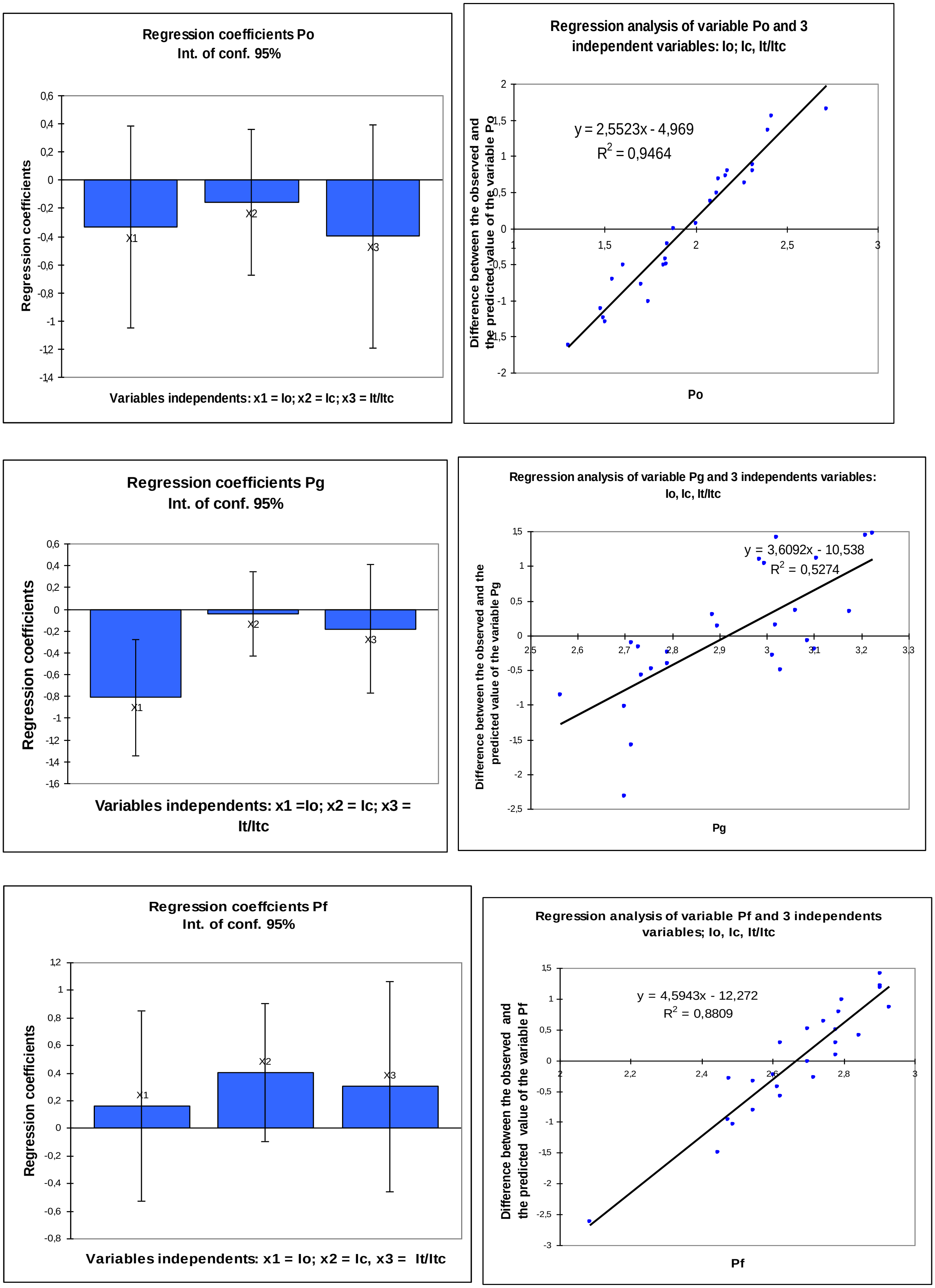

Figure 3: Regression analysis for the dependent and nine independent variables

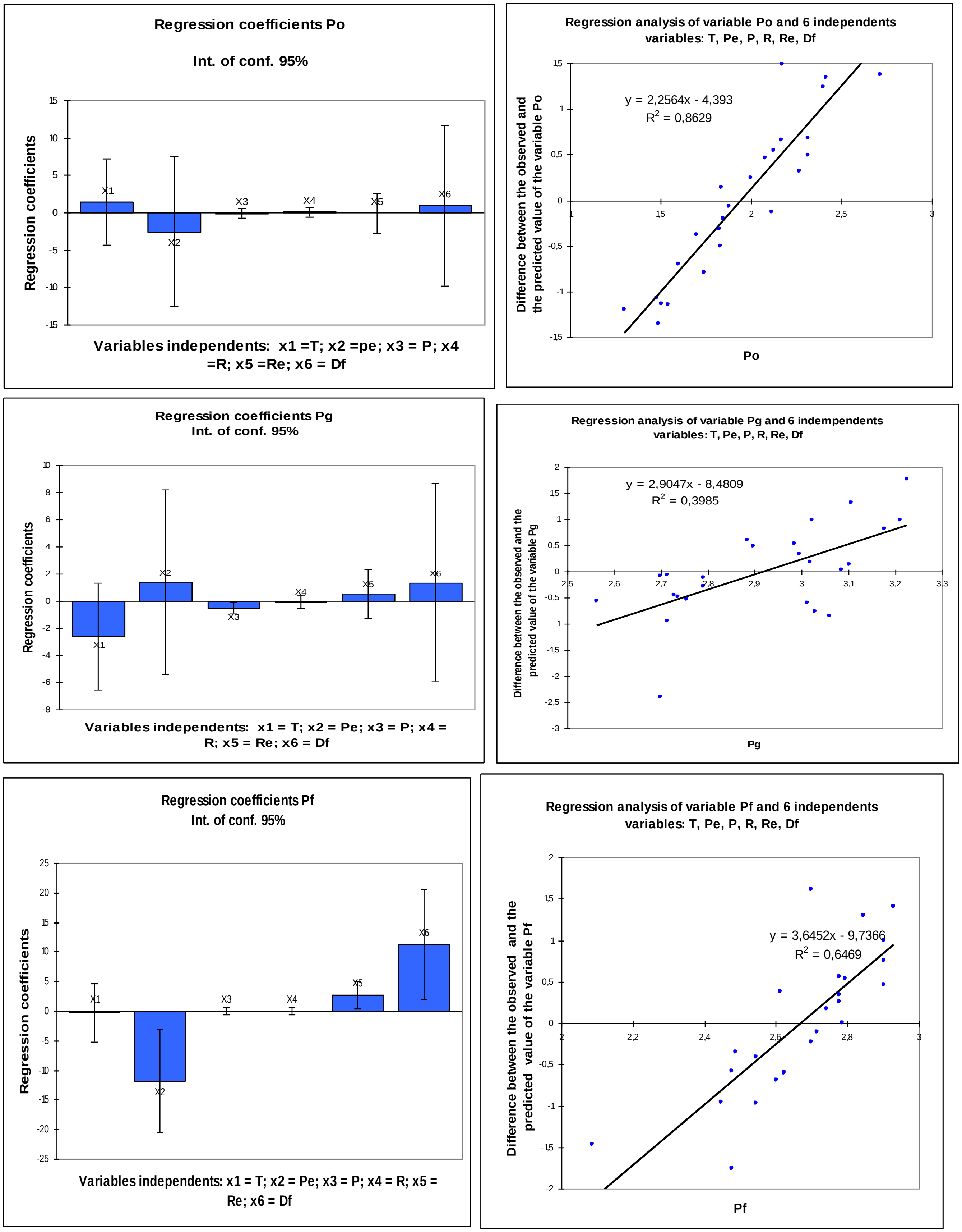

Figure 4. Regression analysis for the independent and dependent variables.

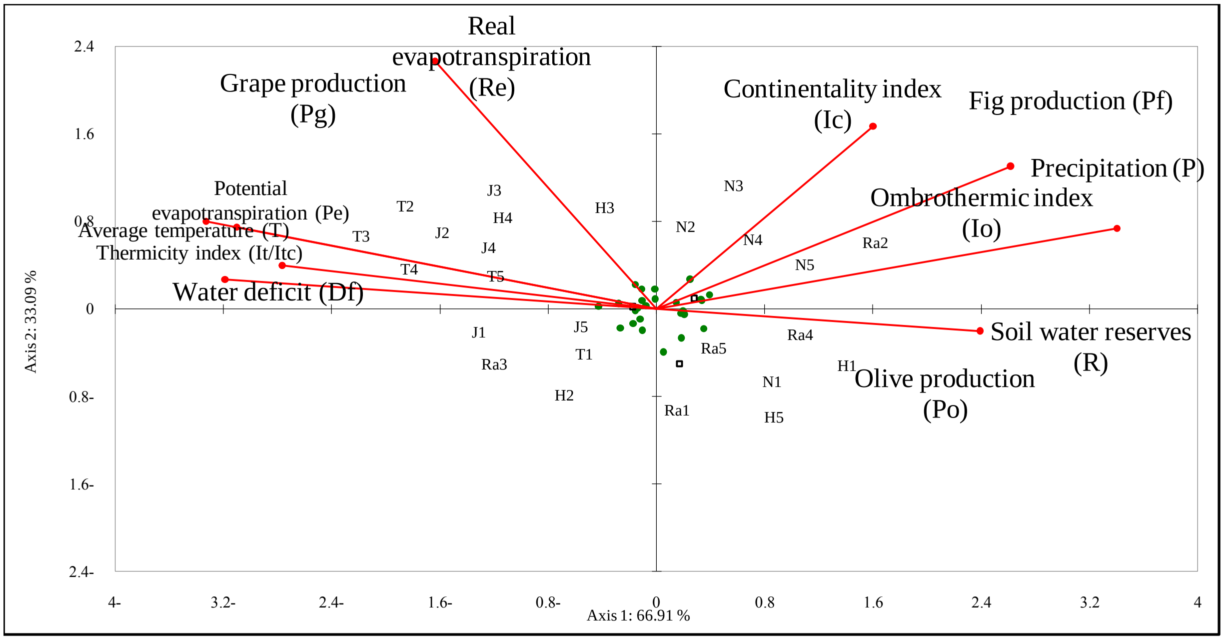

Figure 5. Canonical correlation analysis (CCA). Independent variables (climate and bioclimate factors) and variables dependents

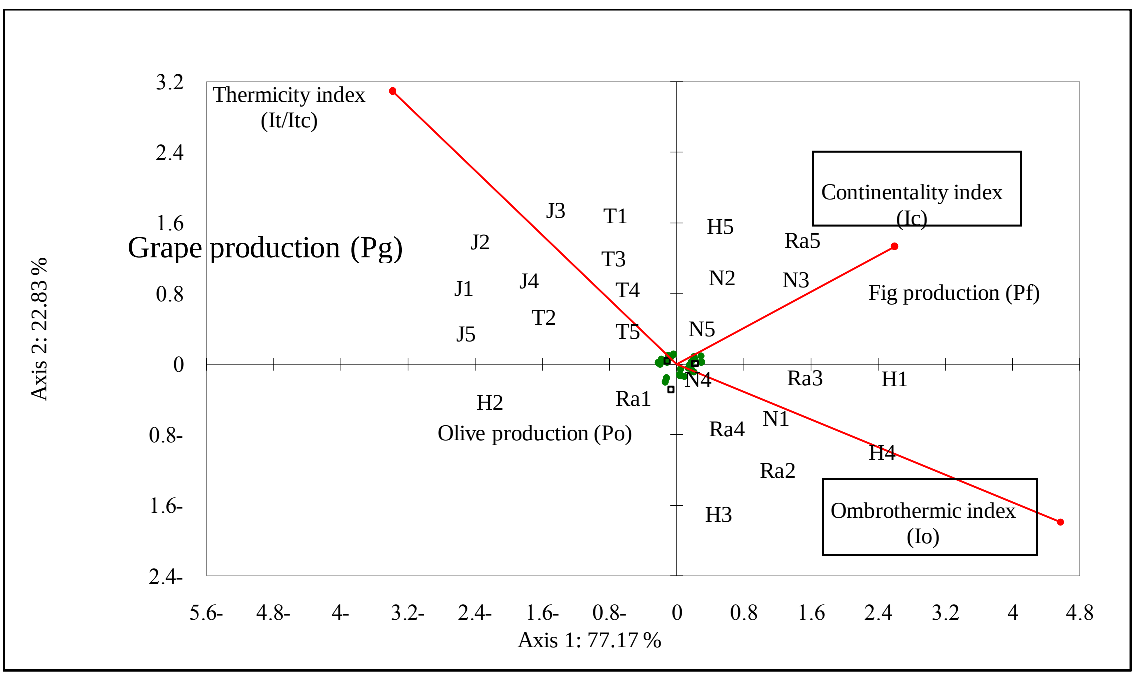

Figure 6: Canonical correlation analysis (CCA). Independents variables (bioclimate factors) and dependents variables.

three bioclimatic parameters Io, Ic and It/Itc, and with the six physical parameters, from 25 sampling plots. In the first place it was observed that the Jenin and Tulkarem type plots are located at the left of axis 2, while all the Nablus and Ramallah type plots –except Ramallah (Ra3) are at the right. Jenin and Tulkarem plots are more affected by the bioclimate factors Re, Pe, T, Df and It/Itc, thus highlighting the water deficit and the thermicity of the territory, this is probably also due to the amount of rain and the effect of climatic and bioclimate factors.

Generally, climate change is expected to have a negative effect on water resources and freshwater

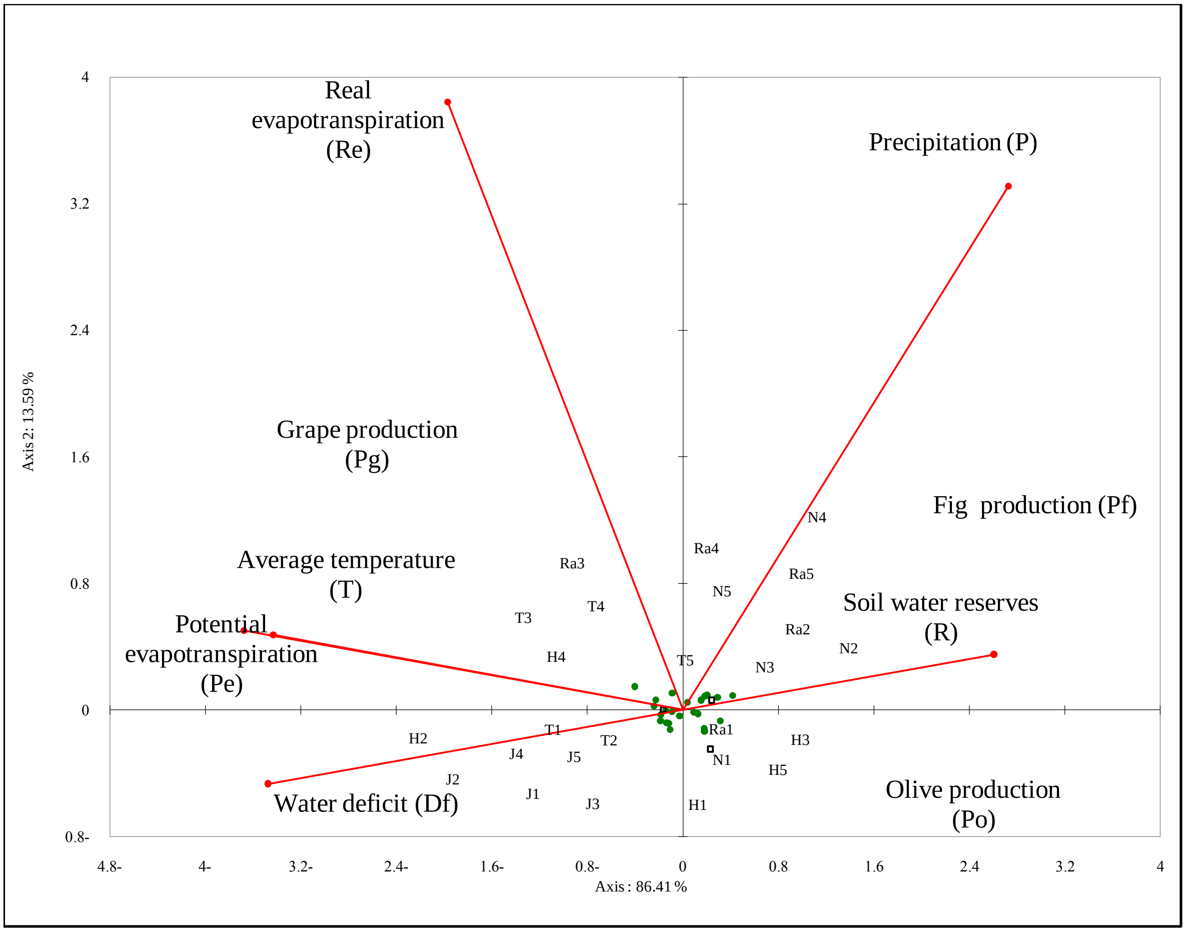

Figure 7: Canonical correlation analysis (CCA). Independent and dependent variables.

ecosystems in all regions of the world (Parry et al., 2007). Otherwise, some of areas and the Palestinian territories fall within the arid and semi-arid, therefore the importance of water shortage cannot be overemphasized for the rain-fed production systems in the semi-arid tropical regions (Pathak et al., 2009). In the other side, the effect of reduced precipitation could result in reducing annual groundwater recharge in the West Bank by 30% of existing value (Numan Mizyed, 2009). Nablus and Ramallah type plots reveal the influence of ombrothermic index, Continentally index, Precipitation and water reserve, and are barely affected by the previous parameters, with a large proportion of the variance explained by axis 1 (66.91%), as opposed to axis 2 (33.09%) (Figure 5). In the case of (Figure 6) the variance in axis 1 increases to 77.17%, while that of axis 2 is 22.83%. There is confirmation that the Jenin and Tulkarem type plots are maintained at the left of axis 2, and are conditioned by the thermicity index (It/Itc), underlining the fact that p grape production in these plots depends on It/Itc, whereas fig production is less influenced by the thermicity index and more by the continentally index. Olive production in the Hebron, Nablus and Ramallah type plots are conditioned by ombrothermic index. Nevertheless, it is worth noting that there was very low olive production in all the plots studied due to low values in the ombrothermic index and high evapotranspiration rates, which in all cases give rise to a water deficit (Df) far in excess of the water reserves (R). As in the upper thermo-Mediterranean and lower mesomediterranean environments, the optimum for the production of olives is achieved with values of Io = 3.6-4.0 (Cano et al., 1997; 2004). In the (CCA), with a variance of 86.41% (Figure 7) between production and environmental factors (Re, Pe, T, Df, P and R) explained by axis 1, plots type Jenin and Tulkarem are also conditioned by water deficit, whereas in plots type Nablus and Ramallah, production depends on precipitation and soil water reserves. However, this is probably also due to the lack of rainfall in general for these areas and the type of soil, therefore, storm water runoff are affected by soil types and local variations (Yair, 1994; Yair&Kossovsky, 2002).

CONCLUSION

Palestine's particular geographic location, in conjunction with a series of environmental factors makes this a very fertile land. The highest production of grapes is found in the south of Hebron, with olive production in the north and grape production in the central areas.

The knowledge of environmental and bioclimatic factors is essential for creating predictive models which serve to enhance the agricultural production of Palestine, in spite of its political uncertainties and the negative influence of the surrounding countries.

The multiple regression analysis reveals that bioclimatic variables have a greater influence on olive and fig production than on grape. The (CCA) in all cases separates two types of plot: Jenin and Tulkarem, whose production depends on the water deficit, which is the result of Io < 2.5, a high It/Itc and a high evapotranspiration (Pe, Re). These conditions favor the production of grape but not of fig and olive, as these crops need values of Io > 2.5. However, production is favorable in cases where Ios3 and Ios4 are between 0.01 and 0.09, as this offers compensation, although this does not occur when the values of Ios1, Ios2, Ios3, and Ios4 are zero (Table 4). This study demonstrates for each crop the bioclimatic optimum in which maximum production occurs, and in these situations the use of water from the soil is not required for irrigation.

Results also indicate that in some cases there is effect and antagonism between environmental factors, economic and productivity sustainability.

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